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ORINS TELETHERAPY MINUTES AND RELATED DOCUMENTS

FILE 3 OF 3

1136111

Teletherapy Minutes
1952 & 1953
Anderson Files

1136111 A

LIST OF UNIVERSITY REPRESENTATIVES ATTENDING THE
TELETHERAPY EVALUATION MEETING AT ORINS MEDICAL DIVISION

May 14-15-16, 1952

J. Robert Andrews, M.D.
Department of Radiology
Bowman-Gray School of Medicine
Winston-Salem, North Carolina

Joseph Bell, M.D.
President of the Radiological Society
Louisville, Kentucky

Stephen W. Brown, M.D.
Department of Roentgenology
Georgia School of Medicine
Augusta, Georgia

Noland M. Canter, Jr., M.D.
Instructor of Radiology
Medical College of Virginia
Richmond, Virginia

George Cooper, Jr., M.D.
Associate Professor of Radiology
University of Virginia
Charlottesville, Virginia

W. C. Davison, M.D.
Dean of the Medical School
Duke University
Durham, North Carolina

John Dennis, M.D.
Associate Professor of Radiology
University of Maryland
Baltimore, Maryland

Gilbert H. Fletcher, M.D.
Department of Radiology
M.D. Anderson Hospital
Houston, Texas

Manuel Garcia, M.D.
Associate Professor of Radiology
Tulane University
New Orleans, Louisiana

Frank E. Hoecker, M.D.
Physics Professor
University of Kansas
Lawrence, Kansas

R. K. Loeffler, M.D.
Baylor University
Houston, Texas

C. C. McClure, M.D.
Professor of Radiology
Vanderbilt University
Nashville, Tennessee

Renee Mastrovito
Physicist
Baylor University
Houston, Texas

George R. Meneely, M.D.
Associate Professor of Medicine
Vanderbilt University
Nashville, Tennessee

I. Meschan, M.D.
Professor and Head of the Department of Radiology
University of Arkansas
Little Rock, Arkansas

Bailey Moore
Department of Radiology
M.D. Anderson Hospital
Houston, Texas

P. A. Morgan, Jr., M.D.
Associate Professor of Radiology
Medical College of Alabama
Birmingham, Alabama

Carl E. Nurnberger, M.D.
Radio Physicist
University of Tennessee
Medical School
Memphis, Tennessee

H. S. Owens, M.D.
Professor of Radiology
Emory University
Atlanta, Georgia

E. L. Pirkey, M.D.
Professor of Radiology
University of Louisville
Louisville, Kentucky

Mrs. C. H. Purdy
Physicist
Baptist Hospital
Winston-Salem, North Carolina

R. J. Reeves, M.D.
Professor of Radiology
Duke University
Durham, North Carolina

Robert Swain
Consultant Physicist
University of Maryland
Baltimore, Maryland

G. M. Tice, M.D.
Professor of Radiology
University of Kansas
Kansas City, Kansas

John Tolan
Consulting Physicist
Emory University
Atlanta, Georgia

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COLLECTION Medical Division
BOX No. Teletherapy Meeting
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Program for Organizational Meeting of Teletherapy
Evaluation Board, May 14-15-16, 1952

Wednesday Night

8 p.m. to 10 p.m.	Open House Medical Division.....Drs. Andrews, Root Bruner, Perkinson, Hays, Kniseley

Thursday

9 a.m. to 10 a.m.	Transportation Arrangements and Tour of Medical Division Facilities.
10:00 a.m.	Introduction.....Dean Davison
10:15 a.m.	General Problem of Isotope Sources for Teletherapy.....M. Brucer
11:00 a.m.	Introduction to the Possible Uses of Cesium137.....M. Brucer
12:00 noon	Recess for Lunch
1:30 p.m.	Presentation of Data on Cesium137.....M. Brucer
2:00 p.m.	Production of Cesium137.....A. Rupp
2:30 p.m.	Procurement Problems.....P. Aebersold
3:00 p.m.	Problems for Discussion
	Single vs. Multiple Sources.....H. Kerman
	Cones and Diaphragms.....J. Richardson
	Penumbra.....M. Brucer
	Size of Source.....M. Brucer
	Construction of Head.....J. Wilde
	Rotational Machinery.....M. Brucer
8:00 p.m.	Informal Discussion and Reception at Museum of Atomic Energy.....Staff

Friday

9:00 a.m.	The Radiation Interaction Spectrum from Cesium137.....P. R. Bell
9:30 a.m.	General Discussion-Opened by.....M. Garcia
11:00 a.m.	Organizational Discussion-Opened by.....W. Gregorieff
12:00 noon	Recess for Lunch
1:30 p.m.	Organizational Meeting Continued
5 p.m. to 7 p.m.	Cocktails at the Home of Dr. H. Kerman, 102 Pickwick Lane.

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TELETHERAPY EVALUATION BOARD

SPECIFIC PROBLEMS FOR DISCUSSION DURING ORGANIZATIONAL SESSION

1. The Organization of the Board
2. Letter of Agreement
3. Invitation to Other Schools to Build up Required Number of Units
4. Committee to Approach A.E.C.
5. Committee to Design Source
6. Committee to Design Head
7. Committee to Design Rotational Mechanism
8. Committee to Design Radiobiological Experiment
9. Committee to Design Clinical Evaluation Experiments
10. Committee on Joint Construction of Units

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Minutes of the Teletherapy Evaluation Conferance

The Medical Division
Oak Ridge Institute of Nuclear Studies
Oak Ridge, Tennessee
May 15, 16, 1952

On May 15, 1952, twenty-five representatives from sixteen of twenty medical schools associated with the sponsoring universities of the Oak Ridge Institute of Nuclear Studies met in Oak Ridge to discuss the organization of a teletherapy evaluation board. A summary which includes a list of persons attending the meeting is attached. The program of the meeting is attached but should be amended to read, Friday 11:00 a.m., Organizational Discussion opened by Dr. Brucer since Dr. Grigorieff was unable to attend. The substance of the Thursday discussions is contained in the printed booklet on teletherapy problems.

Following considerable discussion on various methods of organizing a teletherapy evaluation board, the group felt that, since none of them had been appointed as the official representative of a university to the teletherapy evaluation board, they should not make any binding commitment to the Institute or to their universities. A number of actions, however, were taken as recommendations to the Board of Directors.

1. It was moved by Dr. Meschan of the University of Arkansas, seconded by Dr. McClure of Vanderbilt, and passed by unanimous vote that the assembled university representatives go on record as being in favor of the further development, construction, and testing of a cesium teletherapy unit.

2. The motion was made by Dr. Bell of Louisville, seconded by Dr. Hoecker of Kansas, and given unanimous approval by the entire group that the Executive Director of the Institute be asked to invite all interested four-year medical schools to join the Southern schools in a teletherapy evaluation program and to appoint an official representative to the board. In connection with the discussion on the appointment of a representative, it was brought out that it is not proper for the Institute to suggest to the universities the type of person to be appointed. To insure the participation of the radiotherapists and physicists from each school, the Medical Division of the Institute already has a consultant contract system which could be used to allow a large group to take an active part in the development of the program.

3. It was moved by Dr. Brown of Georgia and seconded by Dr. Dennis of Maryland that the recommendation for a general organizational plan be that each university or medical school appoint one official representative to the teletherapy evaluation board; that this board should meet once each year and committees appointed by the board to discuss various phases of the problem should meet at the call of the chairman of the board. The motion was passed unanimously.

4. It was the general feeling of the entire group that, since none of them had official standing, further consideration on organization of a steering committee and special committees be deferred until the official representatives of the universities are formally appointed. It was suggested that the universities who had not yet been invited be asked to send down representatives from their radiotherapy departments any time during the months of June or July to be

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briefed on the problems that were presented to the group on May 15. After all of them had had an opportunity to be briefed on these problems it was further suggested that some time during August a meeting be called of the official representatives of all interested universities to formally set up the group as a consultative and advisory group of the Medical Division of the Oak Ridge Institute of Nuclear Studies.

A summary of the meeting was prepared by Mr. Dixon Johnson of ORINS and will be printed in the ORINS News Letter.

Marshall Brucer, M.D.
Chairman
The Medical Division

Attachments: Program of the Meeting
Summary by Mr. Dixon Johnson and
List of Persons attending Meeting

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THE EVALUATION OF TELETHERAPY

All body cells can be killed with radiation. Some tumor cells are, and some are not, more radiosensitive than normal cells. Therefore, the degree of palliation possible with an external beam of radiation ranges from none (the idiosyncrasy of extreme total body sensitivity) to cure (the destruction of tumor with insignificant normal tissue damage). Within this range there are a large number of tumors in which the problem is to develop a geometrical pattern of canceracidal dosage.

Tumors are eccentrically placed within irregular bodies and have irregular shapes. Information on the actual shape of the tumor is always, of necessity, incomplete. The primary job of the radiophysicist is to build a maximum and uniform dosage in this irregular mass with a minimum dosage elsewhere. The minimization of dosage elsewhere is complicated by interference of critical and extra-sensitive tissues, i.e. mucosae and bone marrow. There is also the limiting hazard of a variable allowance of integral dose.

Any three dimensional pattern of dosage can be developed with a beam of radiation from an external source. The machinery for such a source is called a Teletherapy Unit. All such external therapy may be called rotational therapy since single or multiple stationary beams are special cases wherein the rotational movement is zero or the beam is intermittant in a rotational path.

A uniform dosage in any three dimensional pattern can be developed if there is complete freedom of rotation of the unit, the body, or both. But tumors are often in non-rigid suspension, the body can be maintained only partially rigid for short periods of time and its limits of rotation are narrow. Therefore, most of the rotating must be done by the unit and there is a premium on small unit size.

The uniformity of dosage within a perfect geometrical pattern is modified by attenuation of the beam in traversing tissues of varying density. The affect of

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inhomogeneity of tissue is minimized at gamma energies between 0.2 and 7.0 mev. but there is a dilemma in choosing an ideal energy.

The energy from the source should be high in order to get maximum penetration of tissue and should be low to get minimum penetration through the source shield. Since tissue has a low Z and the shield has a high Z the divergent effects of energy and Z on photoelectric absorption and Compton scatter helps resolve the problem.

At any Z high energy photons interact largely by the Compton process. Below one million volt energies the photoelectric process increases absorption in the higher Z shielding materials. The ideal energy from these physical considerations would appear to be below 1.0 mev. but above 0.2 mev.

Various Radioisotopes decay by gamma emission within the range desired. Other requirements are: high gamma dose in small source volume, long useful life and availability. At the present time practical methods of production are by thermal neutron reaction and Fission product separation. Depending upon the definition of "high", "small", "long" and "practical" about 6 to 10 radioisotopes are better than radium. Only three appear "practical" for large teletherapy units: $Eu^{152-154}$, Co^{60} and Cs^{137}. The medical profession has given insufficient thought to the problem of smaller restricted usage machines such as intravaginal and intraoral applicators where the very low energies have greater usefulness.

About 83% of the gamma energy from $Eu^{152-154}$ is about 1 mev. radiation. The remainder is a mixture of low energies averaging 0.28 mev. and is easily filtered out of the beam. (This data is extrapolated from a narrow beam absorption in lead and may be inaccurate). This is essentially the same quality of radiation as that from Co^{60} at 1.2 mev. $Europium^{152-154}$ will have a specific activity from 10 to 30 times higher than Co^{60} depending upon the conditions of source design and irradiation. The "cold" material is available in both cases and the cost difference is insignificant. Therefore it would appear that $Europium^{152-154}$ is

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a better teletherapy source than Co^{60}.

Cs^{137} yields gamma radiation at 0.66 mev. Its linear absorption coefficient in carbon is 0.18 and compares with 0.14 for $Eu^{152-154}$. Therefore the Cs^{137} radiation is absorbed and scattered only slightly different than $Eu^{152-154}$ radiation in low Z tissue-like materials, Cs^{137} should be a few per cent less effective than $Eu^{152-154}$ in depth dose. However in high Z shielding material the photoelectric component becomes effective. The linear absorption coefficients in lead for Cs^{137} is 1.2 and for $Eu^{152-154}$ is 0.6. A teletherapy unit with a Cs^{137} source will be about one fourth the mass of an $Eu^{152-154}$ unit. In a rotating unit under automatic control such a mass difference is almost decisive. Further, the 33-year half-life of Cs^{137} makes the 5.3 year half-life of $Eu^{152-154}$ seem inadequate. It would appear that Cs^{137} is the logical choice for a teletherapy source.

There is a sufficient number of "imponderables" and "overlookeds" to demand experimental verification. The final decision rests with the clinician who assesses the results in patients. Medical statistics being what they are, and since the unit of measurement (degree of palliation) is more a matter of opinion than of fact, the results will be in the form of an opinion poll. One qualified observer's opinion is worth little compared to that of a large group of qualified observers.

To get such a group together all medical schools have been invited and 25 have accepted the invitation to participate in a long range evaluation of all teletherapy sources. Because many of the problems can be solved only in AEC facilities a portion of the support is from AEC funds. But this will not be a government controlled project. The Teletherapy Evaluation Board has been organized by the medical schools, the major portion of the evaluation will be done at the schools, and most important in the historical trend of the peacetime use of Atomic Energy, a large portion of the cost will come from the limited budgets of the medical schools.

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3. This article is not classified and may be released to any other interested person.

GENERAL SPECIFICATIONS FOR PROTOTYPE TELETHERAPY MACHINE

Marshall Brucer
Oak Ridge Institute of Nuclear Studies

L. J. Bulliet
W. F. and John Barnes Company

Paul Elza
Oak Ridge Institute of Nuclear Studies

These general specifications are tentative and subject to revision. They were jointly arrived at as an engineering estimate of a feasible goal and not as a binding contractual agreement.

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The head of the unit is to be an internal rotating wheel type design similar to that in the Oak Ridge and Saskatoon units. The head is to be mounted on a horizontal shaft close to the center of gravity and this shaft is to be supported in the fork at the lower end of a vertical telescope column. The fork or cantilever supporting the head should be an interchangeable unit to fit either cesium, with a 500 pound head, europium, with a 1500 pound head, or cobalt, with a 2000 pound head.

The telescopic column is to be supported from a carriage which moves on tracks supported from the ceiling. This column and carriage mechanism are to be designed for the maximum weight of the heaviest or the lightest head interchangeably. The motions of the unit are shown on the accompanying chart.

A. The Degrees of Freedom of Motion for the Source-Collimator Assembly.

1. All motions are to be on either spherical or cylindrical co-ordinates and are described from rest position. The first motion is rotation about a horizontal axis perpendicular to the axis of the beam of radiation. The beam may be swept in a vertical plane from vertically downward to an angle approximately 70 degrees above horizontal.

2. Vertical movement of the head. The vertical motion of the head should be such that there is permitted a miximum traverse of at least 4 feet in a room 9 1/2 feet high, with the focus of radiation at standard treatment table height.

3. Horizontal motion. The maximum horizontal motion will be the diameter of the cylindrical or spherical co-ordinate system and must be such that the machine can completely clear a standard 6 foot patient. By co-ordinating the movements of the head and the table, this rotary diameter can be modified to a smaller diameter but must be such that from

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any point of the body the source can be at one meter distance. It should be possible to modify the source skin distance from a radius of 50 cm to a radius of 90 cm.

B. Table Motions.

To a large extent the motions of the table are probably necessary only for set up and focusing purposes. The additional range of motion specified for the prototype model are for the purpose of investigating the complexity of controls necessary in single or double moving systems.

C. Controls.

The above described motions should provide complete flexibility for placing the head in any position in which it could possibly be used. The efficiency with which the device can be used will depend upon the type and degree of control that is provided for these motions.

Since the prototype machine is to be used for investigating various techniques of treatment, it is proposed that this machine be provided with controls which permit the widest possible variety of head movements while at the same time they will automatically maintain fixed source to target distance. Furthermore, the controls should be so designed that after a certain pattern of movement has been determined it can be repeated automatically and accurately by means of a simple "set-up" of the control mechanisms.

The maintenance of a fixed source to target distance demands that the source be constrained to follow a spherical surface with the locus centered at the target. The extent of the spherical locus is somewhat greater than a hemisphere since it is possible for the source to occupy positions somewhat below the level of the target.

Each of the spherical or cylindrical co-ordinate motions is to

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be effected by its own electric motor. Each of these motors are to be controlled in their speed and direction by means of a controlling force connected to a computer mechanism which can be automatically set to reproduce any pattern over the surface of the sphere. On spherical coordinates the following motions are to be controlled as shown on the chart.

Some of the motions will be by manual control only. Some of the motions must be automatic in pattern but must also be automatic to position only. A number of the motions are not to be put in the present mechanism but the present design should so arrange that on further development they could be put into an automatic control pattern. A number of motions may be made automatic but this depends upon the engineering possibilities. The period of cycling on these motions should vary anywhere from about 5 to 20 minutes. The central axis of the beam is to be focused on a point in space and must be maintained at this point as accurately as possible. A 1 mm accuracy is desirable, a 1 cm accuracy is necessary. It should be possible to interrupt the beam within the pattern at any point.

Some of the type patterns that will be used are as follows:

1. Meridian motion. In meridian motion the source travels along a great circle so that the beam cuts a perpendicular or oblique cross section through the body.

2. Conical motion. In conical motion the beam follows the surface of a right or oblique cone with the locus at the tumor. The cycle of motion should be able to start from any point on the sphere and the angle should be a continuous variable.

3. Eccentric pattern. In eccentric patterns either of the two motions previously described may be combined with a motion of the table to produce an eccentric pattern.

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CHART OF MOTIONS OF PROTOTYPE TELETHERAPY UNIT WITH CONTROL SYSTEMS PROPOSED

Motion of Head	Maximum Range of Motions	Automatic in Pattern	Automatic to Position only	Manual	Possible Further Development
Loading	Special	--	--	x	--
On-off	Intermittent	x	x	x	--
Vertical	1.5 M	x	x	--	--
Horizontal	2.0 M	x	x	--	--
Tilt angle	160°	x	?	--	x
Azimuth	360°	x	x	--	--
Radius	50 to 90 cm	?	?	x	x
Diaphragm	15 x 15 cm	?	?	x	x
Wedge filter	--	?	?	x	x
Automatic Filter	--	x	--	--	x
Motion of Table					
Rotation	360°	?	x	x	x
Vertical	0.5 M	?	x	x	x
Horizontal N-S	1.0 M	?	x	x	x
Horizontal E-W	1.0 M	?	x	x	x
Tilt N-S	90°	?	?	x	x
Tilt E-W	45°	?	?	x	x

Some of the motions will be by manual control only. Some of the motions must be automatic in pattern but must also be automatic to position only. A number of the motions are not to be put in the present mechanism but the present design should so arrange that on further development they could be put into an automatic control pattern.

1136124

PROBLEMS IN SEPARATION AND PRODUCTION OF CESIUM^{137} FOR TELETHERAPY SOURCES

In a September 1941 research report from the University of California, Melhase showed that there was a long-lived cesium isotope in fission, distinct from the already well known cesium^{134}. In 1942, absorption curves were run which indicated two beta energies and a gamma energy of about 0.7 mev.*

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*Glendenin, L. E., and Metcalf, R. P. Paper 152, Radiochemical Studies: The Fission Products, National Nuclear Energy Series - IV - 9, Book 2, McGraw-Hill, New York, 1951. Most of the material used hereinafter is from this source. Further reference will be made to the Paper Number of series 4-9.

This long-lived isotope of cesium was first assigned in 1943 to the mass 135 chain (Paper 153). Some of the published fission yield charts retain this error. From the decay of intense sources of Iodine^{135} and Xenon^{135} studied to verify the 135 mass assignment, there was revealed a 10^6 year half-life material for mass 135 and thus the 33-year material was assigned to mass 137. Further work in 1945 confirmed this assignment. In 1948, the barium^{137} daughter of cesium^{137} was identified by Townsend, Cleland and Hughes.**

**Townsend, J., Cleland, M. and Hughes, A. L., Physical Reviews 74: 499 (1948)

In Paper 152, the basis of much of the published data on yields of cesium^{137} in fission and the determination of half-life is described. The half-life, yield, fission rate, and the radiation time are shown to be interrelated. Fission yield is usually based upon the saturation activity of a fission monitor of known yield. In the case of 137, a barium 140 monitor of 6.1 per cent known yield is assumed. Many experiments and changes in calculated values between 1944 and 1950 have led to various yield values, all close to 6 per cent, and a half-life of about 33 (plus or minus 3) years for the cesium^{137}

isotope.

However, cesium^{137} is not the only isotope of cesium present in fission products. Starting with mass number 133, and extending up to mass number 145, most decay chains pass to or through atomic number 55.

The mass 133 chain decays from 10 minute antimony through 66 minute tellurium, 22 hour iodine, 5 day xenon, to stable cesium^{133}. The mass 134 chain stops at stable xenon. The mass 135 chain passes in hours to a 10^6 year cesium to end as stable barium^{135}.

The mass 136 chain stops at stable xenon 136 but there is also a cesium^{136} in fission which has a 13.7 day half-life and decays to stable barium.

The mass 137 chain may start with a very short lived iodine, about 6 per cent may decay to a stable xenon, but most passes through 33 year cesium to stable barium. All of the others, masses 138 through 145, have very short lives and pass through cesium in seconds to minutes.

Therefore, there are two other isotopes of cesium besides 137 which must be considered in any separation process. Cesium^{133} is stable. Cesium^{135} has a two million year half-life, hence, a very low specific activity. It is a pure beta emitter and will not affect the radiation characteristics of cesium^{137}, but will help dilute its specific activity.

Both of these contaminating cesium isotopes have a neutron capture cross section, which in long term irradiation might affect the 137 isotope. Cesium^{133} has a large cross section of 26 barns. It is converted to cesium^{134}, which has a half-life of 2.3 years. A year's irradiation of a third of a gram of cesium^{133} in a 10^{13} flux of neutrons can produce about 10 curies of activity. Since the 134 isotope has radiation characteristics similar to cesium^{137} (0.5 to 0.7 mev gamma radiation), it is not a serious contaminant, but it can distort the half-life calibration of a supposedly pure cesium^{137} sample.

1136126

The neutron capture of the other isotopes leads to very short half-life isotopes which decay to barium and are separated out chemically. (The absorption studies with our present 2-curie source of cesium^{137} may be distorted in very thin and very thick samples by the cesium^{134} contamination. Hence, we should use only that portion of the curve between 10 and 25 grams/ cm^2.)

The best estimates of the yields of the four isotopes are:

Isotope	Yield	Selected Value
Cesium^{134}	4.6% to 6.1%	5.0%
Cesium^{134} (?) may be appreciable, hence, fresh material should be used.		
Cesium^{135}	5.2% to 5.9%	5.5%
Cesium^{137}	6.1% to 6.6%	6.0%

Inspection of the smoothed fission yield curves from either uranium or plutonium show that the yield of all three should be around 6 per cent. Mass 137 should probably be a little bit higher than the other two and, hence, for the sake of calculations, the selected values shown above are tentatively accepted.

Calculation of Specific Activities

The specific activity is defined as the fraction of atoms decaying per unit time multiplied by the number of atoms available in a unit mass. The decay constant for cesium^{137}, if we accept 33 years of 1.04×10^9 seconds as the half life, is: $0.693/1.04 \times 10^9 = 6.7 \times 10^{-10}$ sec^{-1}. Therefore, 1 in every 1.5×10^9 atoms of cesium^{137} decays per second.

The number of atoms in a unit mass is Avogadro's number divided by the atomic weight.

$$\frac{6.02 \times 10^{23}}{137} = 4.4 \times 10^{21} \text{ atoms}$$

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The specific activity of pure cesium^{137} is, therefore:

$$(6.7 \times 10^{-10}) \times (4.4 \times 10^{21}) = 3 \times 10^{12} \text{ d/sec.}$$

The definition of the curie is 3.7×10^{10} d/sec. Therefore, 3×10^{12} d/sec. is equivalent to 81 curies/gram. This is the maximum obtainable specific activity of cesium^{137}.

However, cesium is at the head of the electromotive series. Because of its ease of reaction, cesium cannot be produced in metallic form. It must be produced as a salt. A stable salt is desired which does not complicate the separation process, does not degenerate under high gamma activity, is non-deliquescent, and has a high crystalline density. The sulfate has been chosen by Mr. Rupp of ORNL as best fitting these criteria.

Cesium sulfate has the following weight proportions:

Cesium	=	135	or 270	or	74%
Sulphur	=	32	or 32	or	9%
Oxygen	=	16	or 64	or	17%
Cs_2SO_4	=		366	or	100%

Therefore, only 74% of the atoms by weight will be cesium in a gram atomic weight of cesium sulfate, and the specific activity we should use is not 81 curies/gram cesium but 60 curies/gram of cesium sulfate. However, only 37% of the cesium is cesium^{137}; 63% is cesium^{133} and cesium^{135}. Therefore, the true specific activity is about 22 curies/gram of cesium^{137}.

Mr. Rupp of ORNL, using more recent yield data, estimates that 23.4 curies/gram is the best that can be done in separating pure samples from fission products.

The important specific activity, from the standpoint of teletherapy, is not one given by weight but is a specific activity by volume. Cesium sulfate is a white crystalline powder which can be compressed to a theoretical crystalline density of 4.24 grams/cm^3.

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Using a simple laboratory Carver press, we have compressed cesium sulfate to 95% of maximum density without the use of heat. The density used in Brucer's report on "Teletherapy Design Problems: Cesium 137" was 3.3 grams per cc. The effect of increasing density on the volume specific activity is shown in the following table.

Density	Volume Specific Activity (Curves/cm^3)		
gms/cm^3	at 18 curies/gm	at 21 curies/gm	at 23.4 curies/gm
3.3	59	69	77
3.5	63	74	82
3.7	67	78	87
3.9	70	82	91
4.1	74	86	96
4.24	76	89	99

The figure of 77 curies/cm^3 used in the report gives about the lowest specific activity that can be made useful in a 100 cm treatment distance machine. The treatment distance can be decreased to a minimum of about 70 cm, in which case a specific activity of about 67 curies/cm^3 could be used. However, this is an unnecessary restriction and decreases the relative value of the isotope in external therapy.

Even using the poorest yields of cesium^{137}, it should be possible, by paying attention to compression techniques, to get a sufficiently intense source. It would appear to be relatively more economical to pay some attention to the problem of compression. There will be an added expense of a few thousand dollars in setting up a large hydraulic hot press to give a pressure of about 20,000 psi, over a 4.5 cm diameter. Schwarzkopf describes a significant increase in density of compressed disks, with increasing tem-

1136129

perature during the dwell time of the compression.* By using both increased

*Schwarzkopf, P. Powder Metallurgy, MacMillan Company, 1947.

temperature and increased pressure, it should be possible to achieve specific activities approaching 100 curies/cm^3. The figures on radiation intensity quoted in the cesium teletherapy design report can thus be increased by 10 to 20%, in which case cesium^{137} should make an ideal source for teletherapy which cannot be matched by any other isotope.

Marshall Brucer, M.D.
Chairman
The Medical Division

1136130

August 15, 1952

TO: Participants in the 8 August 1952 Meeting of the Teletherapy Evaluation Board

Deans of Medical Schools which have not yet Taken Action on the Teletherapy Evaluation Board Proposal

SUBJECT: MINUTES OF THE 8 AUGUST 1952 MEETING OF THE TELETHERAPY EVALUATION BOARD

Enclosed is your copy of the minutes of the first official meeting of the Teletherapy Evaluation Board. Since definite membership requirements have been set up, which will affect the decisions of those medical schools which have not yet taken definite action, a copy of these minutes is being distributed to the Deans of those schools. Information copies are being distributed to various officials of the Oak Ridge Institute of Nuclear Studies, and the Atomic Energy Commission.

Marshall Brucer, M.D.
Chairman, Medical Division
Oak Ridge Institute of
Nuclear Studies

1136131

MINUTES OF AUGUST 8 MEETING OF TELETHERAPY EVALUATION BOARD
1952

The first official meeting of the Teletherapy Evaluation Board met in the Conference Room of the Medical Division, Oak Ridge Institute of Nuclear Studies, at 9:00 a.m., August 8, 1952, with the following persons attending.

Dr. George Cooper, Department of Radiology, University of Virginia, Charlottesville, Virginia.

Dr. J. Robert Andrews, Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, North Carolina.

Dr. Gilbert H. Fletcher, Department of Radiology, M.D. Anderson Hospital, Houston, Texas.

Dr. Arthur C. Guyton, Department of Physics and Biophysics, University of Mississippi, University, Mississippi.

Dr. Harold W. Jacox, Department of Radiology, Columbia University, New York, New York.

Dr. Frederick B. Mandeville, Department of Radiology, Medical College of Virginia, Richmond, Virginia.

Dr. I. Meschan, Department of Radiology, University of Arkansas, Little Rock, Arkansas.

Dr. Robert Nieset, Director, Biophysics Laboratory, Tulane University, New Orleans, Louisiana.

Dr. E. S. Pederson, Department of Radiology, University of Nebraska, Omaha, Nebraska.

Mrs. C. H. Purdy, Physicist, Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, North Carolina.

Dr. D. S. Pankratz, Dean, School of Medicine, University of Mississippi, University, Mississippi.

Dr. Robert J. Reeves, Department of Radiology, Duke University, Durham, North Carolina.

Dr. Paul Riemenschneider, Department of Radiology, State University of New York at Syracuse, Syracuse, New York.

Dr. Sidney Rubenfeld, Department of Radiology, New York University, Bellevue Center, New York.

Dr. Joe C. Rude, Department of Radiology, University of Texas - Medical Branch, Galveston, Texas.

Dr. G. M. Tice, Department of Radiology, University of Kansas, Kansas City, Kansas.

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Dr. H. Stephen Weens, Department of Radiology, Emory University, Atlanta, Georgia.

Dr. C. C. McClure, Department of Radiology, Vanderbilt University, Nashville, Tennessee.

Dr. Carl E. Nurnberger, Consulting Physicist, Medical College, University of Tennessee, Memphis, Tennessee.

Dr. H. D. Kerman, Radiologist, ORINS - representing University of Louisville Medical School, Louisville, Kentucky.

Dr. Marshall Brucer, Chairman, The Medical Division, ORINS.

GENERAL INTRODUCTION

Following an introduction of the various members of the Board, Dr. Brucer stated that the purpose of the first meeting was to set up the organizational framework and to appoint the major committees of the Board. It was not the intention of this meeting to present any new data, or to make any formal declaration of policy, other than that concerned with organization.

1. Review of Correspondence.

Following the introduction and statement of purpose, Dr. Brucer reviewed the history of the proposals up to August 7th, and discussed all of the correspondence concerning the Teletherapy Board. A detailed reading of the official invitation and an explanation of the reasons for various portions of the official invitation was given. A copy of the official invitation letter is appended to this report. Dr. Brucer explained to the group that it was his intention that within the framework of the contract of the Oak Ridge Institute of Nuclear Studies with the Atomic Energy Commission, and except for those decisions which must legally be made by the Board of Directors of the Institute, the Teletherapy Evaluation Board should have considerable autonomy and as complete a freedom as possible in directing the Medical Division's program of investigation of the teletherapy problem. The Teletherapy Board is actually an advisory body to the Medical Division and the recommendations of the Board will be followed, with the one proviso that all actions of the Medical Division are subject to the approval of the Board of Directors of the Oak Ridge Institute of Nuclear Studies.

2. Official Name for the Group.

There was considerable discussion of the problem for an official name for the group. The following five names were suggested. a. Teletherapy Evaluation Board. b. Teletherapy Board. c. Oak Ridge Teletherapy Board. d. Radioisotope Teletherapy Evaluation Board. e. Oak Ridge Radioisotope Teletherapy Board. The first vote eliminated all except "a" and "d". On the second vote, results were 11 votes for "a" and 7 votes for "d".

Recommendations:

Dr. Kerman moved that the name "Teletherapy Evaluation Board" be accepted as the official name for the group. This was seconded by Dr. Jacox. The motion carried.

3. Purpose of Group.

After some discussion on the purposes for the group, it was the feeling of the Board that a short, single sentence statement be drawn up to serve as the official stated purpose of the group.

Recommendations:

Dr. Kerman made the motion that the purposes of the Teletherapy Evaluation Board be stated as follows. "To investigate, develop, and evaluate radioisotopes for teletherapy". Dr. Jacox seconded the motion. The motion carried.

4. Membership Requirements.

There followed a discussion on the requirements for membership on the Teletherapy Evaluation Board. It was pointed out that representation on the Teletherapy Evaluation Board is both a privilege and an obligation. It cannot be the intention of the Institute, or of the Atomic Energy Commission by contract with the Institute, to withhold membership from any section of the country or from any qualified person or institution. There can be no intention or suggestion that any design, development or construction data or records be in any sense secret, or restricted to a small group. A large portion of the funds for this program, including in many cases the money contributed by the State Universities, is from public funds and it is necessary that all data from this project should be considered public property.

Even though it is not the intention to make the Teletherapy Evaluation Board a small restricted group, it is impossible for the Medical Division of the Institute to maintain correspondence with a very large group of individuals. If the membership were opened up to anyone who cared to join, there would undoubtedly be from 100 to 500 members requesting admission from various private organizations. The only fair method of handling such a problem is to invite all interested parties to join, or to make a restriction which is equally fair to all sections of the country. Since the Institute is already working with medical schools and is an organization of universities, the original invitations for participation were sent out to medical schools. In recognition of the fact that the Board should be a non-restrictive one and yet must be a relatively small organization, the following motion was carried.

Recommendations:

Dr. Cooper moved that membership on this Board be limited to four year medical schools or sponsoring universities of the Institute. This was seconded by Dr. Tice. The motion carried.

It was recognized in the discussion that some final date for membership should be set up so that the business of the Board can be handled

with a relatively stable group. Dr. Nieset of Tulane, and others, pointed out that the formation of the Teletherapy Evaluation Board has been accomplished very rapidly and much of the time for final decisions was during the summer months when many of the schools were not at full working capacity. The past few months have been during a period when many of the senior administrative personnel have been on vacation, and it was pointed out that many of the state schools are working under very tight budgets and an expenditure of $2500 must be made with the approval of directors, trustees, and higher administrative officials. Such administrative matters take time. It was suggested that the closing of the membership list on August 8th might be unfair to certain institutions, and that additional time should be allowed. After considerable discussion, the following motion was passed.

Recommendations:

Dr. Mandeville made the motion that membership for the Board should be closed on November 15th. After this date, any additional requests for membership must be referred to the existing members. Additional members will be admitted by a majority vote of the Board. Dr. McClure seconded the motion. The motion carried.

An additional problem was brought up concerning the new school that has just been formed in Florida. If our intentions to keep the group from being restricted are carried out, it was felt by the group that this new school also should be invited to join.

Recommendations:

Dr. Mandeville made the motion that when new four year medical schools are formed, they should be sent an invitation to join the Board and given three months to make their decision. Dr. Kerman seconded the motion. The motion carried.

5. Official Representatives, Consultants, Etc.,

The problem of official representation, consultantships, and the participation of other members of radiotherapy departments was then brought up for discussion. Dr. Brucer stated that he would like each official representative to suggest 2 or 3 people from each school who are interested, and who would like to take an active part as consultants. It was brought out that no matter who had been appointed by the medical school administration as the official representative, it was desirable that at least the radiotherapist and the physicist from each school be included as active members on the teletherapy program. It was suggested that at least one of these consultants be named as an alternate for the official member so that each medical school can keep an active voice in all of the meetings. These additional consultants can be made regular consultants to the Medical Division. It was pointed out that for official meetings of the Teletherapy Evaluation Board, the expenses could be paid only for the official representative or his alternate. At committee meetings the expenses would be paid only for those who had been appointed to the committees by the executive committee of the Teletherapy Evaluation Board. Under the terms of the consultant contract, a request for consultation must be completed by the Chairman of the Medical Division. The

consultation contract can be used for having expenses paid to meetings in Oak Ridge. The experience of the Medical Division, with a large number of consultant contracts, is that the privileges of operating under the consultant contract method have not been abused, and that it is actually a relatively inexpensive way of conducting business.

There was discussion as to consultants who are not members of four year medical schools, or of sponsoring institutions of the Institute. Dr. Brucer stated that it is possible to put on a consultant contract any person who qualifies as an expert in some phase of the Medical Division program. Dr. Andrews stated that he felt that non-member consultants should be left to the discretion of the various committees of the Board.

6. Industrial Organization Participation.

Several questions were brought up regarding the participation of industrial organizations who had no connections with medical schools but might be interested in joining the Teletherapy Evaluation Board.

A. Shall industrial organizations be allowed to have a formal connection?

After considerable discussion it was stated that the answer to the question would have to be in the negative, in view of the previous decision regarding membership.

B. Shall industrial organizations be allowed to contribute money?

The group as a whole has had considerable experience in dealing with industrial organizations and were unanimous in their opinion that it would be improper for the Institute to accept donations in the name of the Teletherapy Evaluation Board. However, it was felt that the reply to any organization who should suggest the contribution of funds, should be so worded as to express the sincere opinion of the members of the Teletherapy Evaluation Board that the spirit behind such donations is appreciated, and that the Board would welcome the assistance and skills of such organizations. It was emphasized that every attempt should be made to give interested industrial organizations any and all information they may wish to have on the progress of the program.

C. Can specialists from industrial organizations be called in consultation from time to time?

It was the feeling of the group that we should take every advantage of the technical assistance of any qualified personnel, especially those belonging to industrial organizations. Dr. Meschan recommended that industrial consultants be handled by committees on a consultant basis.

Recommendations:

Dr. McClure made the motion that industrial organizations shall not be given membership on the Board, and that no donations be accepted from them. However, any information regarding the Board's work should be made freely available to any industrial organization. Dr. Reeves seconded the motion. The motion carried.

A question was brought up by Dr. Rubenfeld about foreign consultants.

Dr. Brucer stated that he did not think it was possible to pay the expenses of foreign consultants with U. S. Government funds. He was not certain about the expenditure of funds from the contributions of the universities.* The expenses for consultants from overseas are considerable and it appears that much of the consultation on matters of mutual interest, especially with interested persons in England, has already been and can continue to be carried on by mail.

7. Problems of Formal Organization of the Board.

Dr. Brucer suggested an outline regarding the organizational set up and pointed out that it was the purpose of most of those present to keep the organizational pattern as simple as possible. It was suggested that an executive committee of from 5 to 7 people be set up as an over-all policy making and steering committee. Under this, there should be set up a number of subcommittees.

(1. Source Evaluation Subcommittee.
(2. Shield Design Subcommittee.
(3. Small Source Design Subcommittee.
(4. Rotational Methods Subcommittee.
(5. Housing Design Subcommittee.
(6. Clinical Program Subcommittee.

Recommendations:

Dr. Rubenfeld nominated Dr. Brucer as Chairman of the Executive Committee. Dr. Guyton seconded the motion. Dr. Rubenfeld moved that nominations be closed for Chairman of the Executive Committee. Motion seconded by Dr. Keens. The motion carried.

Dr. Rubenfeld moved that, in view of the fact that the group consisted of individuals who were not familiar with each other, or with the total problem, Dr. Brucer act as Chairman pro tem, and appoint the committee members. Dr. Cooper seconded the motion. Dr. Brucer stated that he would like to have help on the appointment of the executive committee. Dr. Nieset suggested that as an amendment to the motion, the executive committee be nominated by a small group of those present, to be called the nominating committee, and that the recommendations of this nominating committee be voted on by the entire group. The subcommittees should be appointed by Dr. Brucer, in consultation with the executive committee. Dr. Cooper and Dr. Rubenfeld accepted the amendment to the motion. The motion carried.

Drs. Kerman, Jacox, reeves, Fletcher and McClure were selected for the nominating committee. It was requested that the nominating committee meet during the lunch recess and report their recommendations after lunch.

The meeting adjourned for lunch at 12:30 p.m.

* Upon checking this point we have found that foreign consultants may be brought to this country with Government funds but, because of the large amount of money involved, a request for such a consultation would have to be backed up with considerable evidence for its necessity.

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AFTERNOON SESSION:

8. Election of Executive Committee.

The group reconvened at 2:00 p.m. following a half hour meeting of the subcommittee to nominate the executive committee. Dr. Brucer explained that the nominating subcommittee had attempted to select an executive committee so as to represent all parts of the country. Drs. Jacox, Reeves, Tice, McClure, Guyton, and Kerman were nominated by the nominating committee.

Recommendations:

Dr. Mandeville moved that nominations be closed, and the nominees be unanimously elected to the executive committee. Dr. Andrews seconded the motion. The motion carried.

9. Subcommittee Preferences.

Dr. Brucer stated that he would like to know which subcommittee held the greatest interest of each of the members of the group so that he could prepare recommendations for the executive committee. The results of the poll were as follows:

(1. 1. Source Evaluation Subcommittee, and (2. Shield Design Subcommittee: Drs. Meschan, Kerman, Nieset and Weens.

(3. 2. Small Source Design Subcommittee: Drs. McClure, Reeves, and Riemenschneider.

(4. 3. Rotational Methods Subcommittee: Drs. Rubenfeld, Jacox, Guyton, and Nurnberger.

(5. 4. Housing Design Subcommittee: Drs. Andrews, Cooper, Mandeville, and Tice.

(6. 5. Clinical Program Subcommittee: Drs. Cooper, Rude, Hunt and Fletcher.

It was decided to combine Nos. 1 and 2, Source Evaluation and Shield Design, using one committee for both problems.

10. Duties of Executive Committee.

Dr. Andrews brought up the problems of the authority of the executive committee. After considerable discussion, the following range of duties was specifically assigned to the executive committee, in addition to such duties as may arise in the future.

1. To appoint subcommittees.
2. Financial advisors to the Board of Directors of ORINS, on the university contribution to the program.
3. To call meetings of the Teletherapy Evaluation Board.
4. To determine publication policies.
5. To prepare the AEC project proposal.
6. To prepare the agenda for board meetings.

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Recommendations:

Dr. Andrews moved that the committees be requested to act on the items listed above. Dr. Riemenschneider seconded the motion. The motion carried.

11. General Discussion of Problems.

The question was brought up as to how members of the Board should go about submitting travel expenses for trips to Oak Ridge. Dr. Brucer explained that for the universities who have officially joined the project, the consultant contracts of the official representatives would be processed. It was pointed out that in view of the fact that many of the schools are on vacation schedules, and that since formal actions could not be taken before the August 8th meeting, even though the decision had been made to join the Teletherapy Evaluation Program, that an attempt should be made to pre-date the contract for the individuals attending the present meeting. Dr. Brucer did not know whether he could do this but he stated that he would make an attempt to have contracts processed for all the participating members. It was pointed out that expense forms and instructions for preparing expense statements would be sent to the members, together with the minutes of the meeting.

Dr. Brucer stated that a copy of these minutes of the first official meeting would be sent to the members of the Teletherapy Evaluation Board. A correspondence will be started with the members of the executive committee, in order to get the committees set up as soon as possible. An attempt will be made to get all subcommittees together within the next six months. The subcommittee meetings should probably start sometime next November or December.

Dr. Rubenfeld brought up the question of giving information on this meeting to newspapers and the method of universities dealing with their own public relations data. Dr. Brucer stated that Mr. Dixon Johnson would prepare a statement for the ORINS Newsletter, and would probably prepare a statement for the press very shortly. He stated that it would be unlikely for the Institute to attempt to influence public relations policy of any of the universities. He was sure, however, that Mr. Dixon Johnson would be happy to cooperate in the preparation of any material for any one of the universities. Mr. Johnson usually prepares a newspaper statement following each of the various meetings that are held at the Institute. A number of members of the group expressed a desire to have the statement on the meeting before it goes out in general circulation.

The statement by Mr. Johnson, for the August 8th meeting, is appended to the minutes of this meeting.

The meeting adjourned at approximately 3:30 p.m.

APPENDED TO THIS REPORT:

1. Copy of official letter of invitation from Dr. Pollard, to Deans of Medical Schools which indicated an interest in the Teletherapy Evaluation Board.
2. Dixon Johnson's Newsletter statement.

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July 29, 1952

Dr. John W. Doe
Dean, College of Medicine
Blank University

Dear Dr. Doe:

The proposal for a cooperative effort in research on a teletherapy radiation unit by a group of interested medical schools and the Oak Ridge Institute of Nuclear Studies was described in Dr. Marshall Brucer's letter to you of May 29, 1952. This letter transmitted preliminary information regarding the formation of a Teletherapy Evaluation Board and the nature of the program to be carried out under its guidance.

An exploratory meeting of representatives of institutions interested in participating in such a joint research program was held in Oak Ridge on May 15 and 16 and further discussions were held through July 13 for those individuals who could not attend the May meeting. As a result of this meeting and subsequent discussion with other interested parties, the Institute is now prepared to proceed with the formal establishment of the proposed Teletherapy Evaluation Board and the initiation of the research program to be carried out under its guidance. The purpose of this letter is to invite your institution to participate in this program by naming a representative to serve on this Board and to contribute to the cost of the program to the extent recommended initially by the Council Committee.

It is expected that the project will cover a period of about three years. The Institute proposes to undertake it under its operating contract with the Atomic Energy Commission in the government-owned facilities at Oak Ridge which the Commission has made available to the Institute for its medical program. Within the limitations of funds allocable to this program which are made available to the Institute from year to year by the Atomic Energy Commission, together with the contributions of the participating medical schools, the Institute will endeavor under the guidance of the Teletherapy Evaluation Board to design, construct, and test a prototype unit at Oak Ridge. Any such unit together with other equipment and materials related to this program will be wholly the property of the United States Government in the custody of the Institute irrespective of the extent to which the fund made up of contributions from the medical schools is employed in defraying a portion of the cost of acquisition of such materials and equipment. If this initial phase of the program is successfully completed, it is hoped that each of the participating medical schools will wish to procure a teletherapy unit of its own of the type developed by the Board, although no

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expressed or implied commitment to do so is involved in acceptance of this invitation. Those who do so would then participate in a joint clinical evaluation of the unit under the direction of the Teletherapy Evaluation Board. Within the limits of necessary security regulations, if any should be applicable, all data and other information related to this project will, of course, be available to all members of the Board at all times. Finally, the Institute will use its good offices to assist the participating medical schools in developing their own teletherapy programs and facilities in any appropriate ways open to it.

If your institution decides to accept this invitation, it will be expected to contribute to the support of the complete project the total sum of Twenty-Five Hundred Dollars ($2,500.00). This may either be paid in full at the time of acceptance of this invitation by check made out to the order of the Oak Ridge Institute of Nuclear Studies, or it can be paid in three yearly installments of $1,200 now; $800.00 in July 1953; and $500.00 in July 1954. All contributions so received will be placed in a special fund which will be used by the Institute only for defraying costs incurred in carrying out the teletherapy research program. Institutions contributing the total amount of $2,500.00 now will be entitled to representation on the Teletherapy Evaluation Board throughout the life of the project. Those contributing in accordance with the above schedule of annual contributions will be entitled to representation on the Board only during the year for which the contribution is made until the full amount has been paid, at which time representation will be for the life of the project.

In accepting this invitation you should also inform me officially of your appointment of a representative to sit on the Teletherapy Evaluation Board. The first meeting of this Board is being called for Friday, August 8, 1952, at 9:00 A.M. in the Conference Room of the Medical Division of the Institute in Oak Ridge. Travel expenses of representatives attending this and other meetings of the Board will be paid by the Institute in accordance with the terms of a standard contract, a copy of which is attached, which will be executed with each member of this Board. The Chairman of the Medical Division, Dr. Marshall Brucer, will serve as secretary of the Teletherapy Evaluation Board. Upon request, his office will make travel and transportation arrangements and hotel reservations for the members.

The officers of the Institute hope that you will find it possible to accept this invitation and to join with us and with the other schools represented on the Board in carrying out this very promising project. I shall look forward to hearing from you in the near future.

Sincerely yours,

William G. Pollard
Executive Director

WGP:mc

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Note to Board Members: This is a suggested release only. Please make changes which may appear desirable to you. Since other board members have a copy of the same material, it should receive no more than a statewide release, or, if two cooperating medical schools are located in the same state, perhaps only a local release. The quotes particularly should be changed to suit your style.

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A new approach to the use of atomic energy products in cancer treatment will be undertaken by _____ _____ _____ and other medical
(Name of School)
schools in cooperation with the Oak Ridge Institute of Nuclear Studies.

_____ _____ _____ has just returned from Oak
(Name & title of person attending meeting)
Ridge, where he participated in the formation of a Teletherapy Evaluation Board which will test new multi-curie radiation sources, now becoming available for the first time through the nation's atomic energy program. (Teletherapy means treatment of cancer by externally-applied radiation). Dr. _____ will serve as a member of the Board and as a member of the subcommittee on _____.

The three radiation sources which the Board may test are cesium, a sodium-like material which is one of the products produced when uranium atoms split; cobalt, a metal of the iron family, and europium, one of the so-called rare earths. Cobalt and europium are made radioactive by neutron bombardment in uranium reactors.

Dr. _____ predicted that the appearance of new radiation sources would be a powerful stimulus to cancer research and treatment. "While they offer no radically new type of treatment", he said, "new radiation sources could make super-voltage therapy widely available. Super-voltage therapy is necessary to treat many types of deep-seated cancers by radiation.

In discussing the program, Dr. _____ pointed out that radiation and surgery are still the two principal treatments for cancer with early diagnosis a major element in either case. Refinements in either type treatment would be of great value.

(more)

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As presently planned, the Board will authorize the building of a single teletherapy unit at Oak Ridge which will undergo comprehensive tests. As the bugs are worked out of this unit, certain of the participating medical schools will purchase units for a complete testing program. At the end of this phase, the unit would be ready for production and general use in cancer therapy.

The principal advantage the new radiation sources may have over x-ray or radium therapy were listed as:

1. Cesium, europium and cobalt have powerful radiation beams of very high energy and of essentially a single wave length which penetrate to deep cancers with a minimum of damage to intervening tissue. (Super-voltage x-rays have varying wave length, resulting in excessive radiation to normal tissues).

2. Sources many times as powerful as radium can be used in treatment. (Cobalt and cesium are about 25 times as powerful as like amounts of radium, while europium is several hundred times as powerful).

3. Unlimited sources will become available within a few years compared to presently scarce radium and super-voltage x-rays. (Only a few super-voltage x-ray machines are in use).

4. When development problems are licked (the _____ _____ and other medical schools are meeting development costs cooperatively) the cost of units should be far less than either x-ray or radium machines of comparable power.

5. The relatively large amount of radioactive source material to become available will permit entirely new types of radiation therapy machines to be devised.

The Teletherapy Evaluation Board is studying one type which may have as much as 7500 curies of cesium as the radiation source.

(more)

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Many ways of using the various sources of energy are being discussed. The engineering problems must be solved to make best use of the advantages of each isotope. One type of unit discussed utilizes a rotating beam to give a greater dose of radiation to the tumor than to other body tissues.

It will be several years before these new teletherapy units are generally available for therapy because of developmental problems, Dr. _____ _____ said. A cesium source is expected to be available by next spring, and cobalt sources will become available in 1954. Since cesium is a fission product, it is produced by separating cesium from other fission products in the reactor. Both cobalt and europium are produced by neutron bombardment in a reactor. Since cesium is essentially a waste product of atomic energy, its long-term prospects appear very bright, although cobalt sources in quantity are expected within the next few years and its short-term prospects are better. The production of cobalt and europium sources is dependent on much uranium reactor time becoming available for this purpose.

The following medical schools are participating in the teletherapy program:

Bowman Gray School of Medicine, Wake Forest College
Medical College of Virginia
University of Mississippi
Columbia University
University of Arkansas
University of Nebraska
Duke University
Emory University
Medical College of the State University of New York, Syracuse
New York University - Bellevue Medical Center
University of Texas
University of Kansas
Vanderbilt University
University of Tennessee
University of Louisville
M. D. Anderson Cancer Hospital
Medical College of Alabama

Minutes of the Meeting of the Executive Committee
of the Teletherapy Evaluation Board
Held at the Oak Ridge Institute of Nuclear Studies
Medical Division Library, Oak Ridge, Tennessee
25 January 1953

TO: ALL MEMBERS OF THE TELETHERAPY EVALUATION BOARD

The Executive Committee of the Teletherapy Evaluation Board convened at 10:00 a.m. Sunday, 25 January 1953 with the following members in attendance:

Marshall Brucer, M.D. (Chairman)
Oak Ridge Institute of Nuclear Studies, Inc.
Medical Division
Oak Ridge, Tennessee

Herbert D. Kerman, M.D.
Department of Radiology
University of Louisville
Louisville, Kentucky

C. C. McClure, M.D.
School of Medicine
Vanderbilt University
Nashville, Tennessee

Robert Reeves, M.D.
Professor of Radiology
Duke University
Durham, North Carolina

Sidney Rubenfeld, M.D.
Associate Clinical Professor of Radiology
New York University Post Graduate Medical School
New York, New York

Galen M. Tice, M.D.
Department of Radiology
School of Medicine
University of Kansas
Kansas City, Kansas

Arthur C. Guyton, M.D. (absent due to illness)
School of Medicine
University of Mississippi
University, Mississippi

1) The first item on the agenda was a review by Dr. Kerman of his observations that there was some confusion concerning the aims and plans of the Teletherapy Evaluation Board. He suggested that a statement from the Board be published in one of the Radiology journals. Dr. Kerman then read a statement which he had been asked to prepare as a suggestion for the Executive Committee. There was some discussion of the statement and a number of minor revisions were made. Dr. Rubenfeld moved that Dr. Kerman's statement be accepted as revised. The motion

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was seconded by Dr. McClure and passed by the Committee.

2) There was some discussion concerning the method of publication and under whose name it should be published. Dr. Kerman moved that the statement be submitted to Dr. Doub, the editor of Radiology, as an editorial statement preferably without signature. If a signature on the editorial was desired by the editorial committee of the journal, then it be signed by Dr. Brucer as Chairman of the Executive Committee. The motion was seconded by Dr. Reeves and passed by the entire committee.

3) Prior to the meeting a "standard proposal for an AEC contract" had been sent to each member of the Committee. The second item on the agenda was a discussion of this standard proposal. There was considerable discussion, which is summarized as follows: The committee suggested that the proposal should be revised to remove all statements which would legally bind any university to a specific cost. For example, statements where the university is directly bound to a cost should be stated as a cost to be borne from sources other than AEC. It was suggested that the title of the proposal be changed to fit the stated purpose of the TEB. This was approved.

Dr. McClure presented a proposal written to fit Vanderbilt University and gave his permission to use his proposal as a type example of a format to be followed by all participating universities. It was suggested that this type example be submitted to AEC unofficially for comment, and following the suggestions of the Commission a reworded statement should be mineographed and submitted to every member of the TEB for their criticisms. Each member should be given approximately one month to return the proposal with any suggested amendments or changes. Following the return of all of the proposals a revised proposal should be resubmitted to the Executive Committee at the June meeting. Approval of the form for the proposal was tabled until the June meeting.

4) A review of the development of the Barnes Contract and the progress to date on the construction of the prototype machine was then brought up for discussion. Following a discussion of the problems concerned in negotiating a contract and carrying it through to completion, Dr. Tice made a motion that the Chariman of the Executive Committee be given full authority to proceed with the construction of the prototype model, without further referral to the Committee except for information purposes. The motion was seconded by Dr. Reeves and was approved by the entire Committee.

5) Dr. Brucer brought up for discussion a number of letters that had been written by members of the TEB and other interested individuals concerning individual problems in the construction of the prototype model. A number of persons have made very thorough analyses on the problems of rotational control and other desirable features which may or may not be added to the prototype design. Although it was felt that it was already implicit in the instructions already given to the Chairman of the Executive Committee, in order to clarify any misunderstanding, Dr. Reeves made a motion that the Chairman be allowed to ask any exceptionally interested persons to go to Rockford with him whether or not they are members of the Teletherapy Board to consult on individual problems of design and construction and to see the progress of the construction of the machine. Dr. McClure seconded the motion and it was passed by the Committee.

6) The Executive Committee then went through a discussion of the recommendation for membership on the subcommittees. The membership list, as stated in the 29 December 1952 letter to the Executive Committee, was approved as it stands with the exception of the subcommittee on the Clinical Program. Dr. Reeves moved that the subcommittee membership, as stated in the December 29th letter to the Executive Committee, be approved as written with the exception of the Clinical Program Subcommittee. He further moved that Dr. Brucer be made Chairman of each of these committees and be impowered to call such meetings of these groups as he saw fit. The motion was seconded and passed unanimously.

7) The problem of the fifth subcommittee on the Clinical Programs was then brought up for discussion. It was suggested by Dr. Rubenfeld that this Clinical Program Subcommittee be set up as a central steering committee which would eventually expand to a committee of the entire TEB. It was emphasized that the duties of this subcommittee should be primarily to organize the scope and early phases of the clinical program. During the next year the Clinical Program Subcommittee should organize an agenda and make recommendations to the entire membership. It was suggested that the final decisions in the Clinical Program should probably be voted on by the entire membership of the Board. Because of the importance of the duties of the Clinical Program Subcommittee it was suggested that its membership be somewhat larger than that of the other committees. Dr. Rubenfled made the motion that the Executive Committee be members of the Clinical Program Subcommittee ex officio. This was seconded by Dr. Reeves. Following considerable discussion the motion and second was withdrawn and amended by Dr. Rubenfeld to read "the members of the Executive Committee be members of the Clinical Program Subcommittee". The motion as amended was seconded by Dr. Reeves and passed by the entire Executive Committee. Following considerably discussion on further subcommittee membership, the following members were suggested as members of the Clinical Program Subcommittee in addition to the Executive Committee:

Robert J. Andrews, M.D.
Bowman Gray School of Medicine

Gilbert H. Fletcher, M.D.
M. D. Anderson Hospital

H. B. Hunt, M.D.
University of Nebraska

Isadore Meschan, M.D.
University of Arkansas

Martin Schneider, M.D.
University of Texas - Medical Branch

Stephen H. Weems, M.D.
Emory University

Dr. Rubenfeld made a motion to approve this additional list which was seconded by Dr. Reeves and passed by the Executive Committee.

8) After considerable discussion the Board decided to appoint a Chairman of the Clinical Program Subcommittee. Dr. Kerman moved, Dr.

Reeves seconded, and the Board voted to appoint Dr. Rubenfeld Chairman of the Clinical Subcommittee.

9) Dr. Brucer was asked by the Executive Committee to send out a statement of the approved memberships on subcommittees.

The question of dates for these subcommittee meetings was then brought up. It was pointed out that we should attempt to have one subcommittee meeting toward the end of each month from now until June so that the entire membership can participate in the program before the next meeting of the entire membership of the Teletherapy Evaluation Board. For the lack of time, it may be necessary to skip the February meeting and have two meetings in one month. Dr. Brucer was given authority to set the meeting toward the end of each month for all of the subcommittees except the Clinical Program Subcommittee.

The date for the second annual meeting of the Teletherapy Evaluation Board is set for the 11th of October, 1953. This should be a one day meeting, and on the 10th of October there should be a half day meeting of the Executive Committee. If it appears desirable, later on in the year, a scientific session may be set for the 12th of October. These dates are set as a tentative schedule for consideration during the next two months. If there are no serious objections by the end of March the schedule will automatically become the official dates for the annual meeting of the Teletherapy Evaluation Board.

10) There was some discussion on the dates for the next meeting of the Executive Committee and for the meeting of the Clinical Program Subcommittee. Since the Executive Committee must attend both of these meetings it was decided to hold the two meetings on succeeding days in June. Dr. Rubenfeld suggested that he may be able to arrange for a meeting place in New York in conjunction with the AMA meeting. It was pointed out that in order to hold a meeting of this Board away from Oak Ridge it might be necessary to get permission from the Executive Director of the Institute. Dr. Brucer was asked to inquire whether it would be possible to hold the meetings of the two committees at New York University School of Medicine at the time of the AMA meetings in New York City, and to report the decision by mail.

The meeting was adjourned at 12:15 p.m. for lunch. The meeting reconvened at 1:45 p.m.

11) The first problem brought up during the afternoon session was the question of the writing of a set of bylaws for the membership as a whole. It was felt that this would be a desirable feature to clarify the relationships of all parties and the Institute. Dr. Kerman made a motion that Dr. Brucer prepare a set of bylaws for the approval of the Executive Committee at the June meeting. Dr. Rubenfeld seconded the motion and it was passed by the entire Committee.

12) Some new data on the characteristics of europium, as communicated by Dr. W. S. Eastwood, the Atomic Energy Research Establishment, Harwell, England, was presented to the Executive Committee. Some of the recent discussions with Dr. Aebersold of the U.S. Atomic Energy Commission, Isotopes Division were mentioned. Following a discussion of the various

sources which could be used in the prototype model, Dr. Reeves made a motion that the Institute be encouraged to authorize the Barnes Company to start on the construction of the europium or cobalt shield to fit the prototype machine as soon as possible. This was seconded by Dr. Tice and passed by the Committee

The meeting adjourned at 3:30 p.m.

Marshall Brucer, M.D.
Chairman
Executive Committee

1136150

MINUTES, MARCH 29, 1953 MEETING
TELETHERAPY EVALUATION BOARD - SUBCOMMITTEE NO. 1,
SOURCE EVALUATION AND SHIELD DESIGN

Members present: Dr. Isadore Meschan
Dr. Herbert D. Kerman
Dr. David S. Carroll
Dr. Stephen H. Weems
Dr. John Tolan
Dr. Carl E. Nurnburger
Dr. Marshall Brucer

Members absent: Dr. Frank Hoecker

Dr. Marshall Brucer opened the meeting with a discussion on the desirability and availability of sources. It was estimated that cobalt^{60}, with a five year half-life and a specific activity of approximately 240 curies per cubic centimeter, would be available for a few persons within the coming year. There appears to be a possibility of ten sources per year available thereafter. The early calculations on the cross section of europium$^{152-154}$ by Dr. Brucer and others at the Oak Ridge National Laboratory were reviewed and compared with calculations by Dr. Eastwood of Harwell, England. Dr. Brucer reviewed the neutron capture and decay characteristics of europium while in the reactor flux and pointed out that the calculations did not agree with observed data. It was pointed out that lastest calculations show that the europium isotope has an approximate half-life of 12.4 years. Dr. Brucer stated that the procurement and radiation of many sources of europium is now at a standstill pending further studies. Cesium^{137} with approximate specific activity of 95 curies per cubic centimeter was reviewed. Dr. Brucer pointed out that cesium is probably the one isotope that eventually will be readily available in very large quantities, due to fission products soon to be available from power and research reactors. In summarizing the desirability and availability of each isotope, it was recommended that each university's proposed contract with the Commission specify Co^{60}, $Eu^{152-154}$, or Cs^{137} whichever is available. Also, it was stated that the Executive Committee should decide immediately on the submission of formal applications for sources.

The second item on the agenda was the design of the experimental prototype unit. Dr. Brucer opened the discussion on the design of the unit by reviewing the functional requirements of the unit which necessitated a 9½ or 10 feet ceiling height. Also, it was pointed out that certain limiting factors existed in the current design, one of which was that a table limited the field of motion to less than a full 360 degrees, whereas, a chair used during rotational therapy would not limit the field of movement. Also, it was pointed out that a single support for the unit, such as the GE support, would not be stable enough for rotational therapy. The design of the W. F. and John Barnes Company permits a movement to within fourteen inches of the floor. Dr. Nurnburger questioned the necessity for the maximum motion and utilization provided for in the design and it was pointed out that the present unit is an experimental unit, therefore, should be designed with maximum possible movements; and once the preliminary studies have been completed, it would be a simple matter to omit some of the operational characteristics. It was felt desirable to include as much of the engineering cost as possible in the prototype unit.

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The committee discussed the desirability of design permitting top versus side loading of sources. The W. F. and John Barnes Company engineers had expressed definite opinions as to the desirability of top loading which would permit much better weight distribution over bearing surfaces. Dr. Kerman insisted on designing the head for Co^{60}, but not for Cs^{137}, so as to provide for a loading technique that could be accomplished in the field. Following a detailed discussion, the committee requested a design to permit loading and unloading of sources by medical school personnel.

The committee next studied the design of the shutter mechanism. It was pointed out that the first factor in the design of a shutter mechanism was the total time required in the "on" position. It was agreed that for therapy ten minutes probably would be the maximum time, whereas, for physical measurement or experimental purposes the time might occasionally reach as high as four or five hours. Also, it was agreed that one second opening and closing time for shutter mechanism was adequate for contemplated research techniques. There was then reviewed a number of designs for a shutter mechanism using centrifugal force to operate the shutters. It was agreed that the design principles were good except that the mechanism is impractical in bulk and costly to maintain. The committee considered gravity mechanisms but it was pointed out that the principle is impractical because of the many operational positions of the machine.

There was then discussed a number of other designs by the W. F. and John Barnes Company such as the magnetic clutch, Borg-Warner overdrive, magnetic oils, etc. Due to safety factors and bulk, these were discarded as inefficient and impractical. A pneumatic tube system was described which provides for alternating forces to a double rack and pinion for operating the shutter mechanism without back lash. It was pointed out that this design had many good safety factors in that loss of air pressure would automatically close the shutter mechanism. Also, utilization of simple regulating pneumatic valves would prevent variable air pressure being a serious problem. The design of the pneumatic control is such as to start the opening movement with a fast motion but would be considerably slowed by springs as unit moves towards the open position. Dr. Meschan and other members of the committee pointed out that the simplified pneumatic system was completely removable for maintenance, thereby eliminating any exposure problems. Dr. Brucer also mentioned that the W. F. and John Barnes Company had been using this system in many industrial applications and that it had proved completely satisfactory. Dr. Tolan suggested a solinoid system for operating a similar rack and pinion device and Dr. Brucer informed the committee that such a system had been discussed and discarded by the Barnes Company on the basis of cost and size of solinoids required for moving the source wheel.

Dr. Brucer next opened the discussion on a variable aperture diaphragm designed as a twelve-sided unit giving a zero to fifteen inch opening at the skin surface. Dr. Carroll discussed the sizes of variable cones, irregular, and rectangular portals. It was pointed out that the Barnes design does not provide for irregular or rectangular patterns. Dr. Brucer pointed out that this mechanism could be used for two functions. One as a variable circular aperture and two as a mechanism for inserting irregular and rectangular portals. If the variable diaphragm is to be used as a variable circular portal then the mechanism would have to be constructed of lead plates four centimeters thick. If used as a supporting mechanism it would be desirable to fabricate the mechanism of steel plates two centimeters thick. Dr. Nurnburger brought up some questions

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regarding the characteristics of the present design and its relationship to the bearing surfaces of the twelve-piece unit. The committee discussed the fabrication of the mechanism of such metals as lead, brass, steel, tungston, etc. Dr. Brucer pointed out, as an example of the costs of materials, to fabricate a small source unit of tungston, cast about two mill tolerance, would cost approximately $5,000 for raw material alone; whereas, the materials for a similar unit fabricated of lead would probably cost around $600. Discussion brought out that the thickness of the shutter mechanism was not critical and in line with this, Dr. Meschan suggested that a medium Z metal could be used. However, this in turn would give a higher transmitted penumbra.

Dr. Brucer outlined studies by the Barnes Company to provide an automatic wedge filter. The committee discussed the many problems of moving a doughnut wedge filter into the field from any direction, to maintain homogenous tissue dosage under rapidly changing conditions. The filter must move in three directions and under control of the "computor", and must be fully automatic to be satisfactory. Dr. Brucer stated that it might be necessary to eliminate the filter as no satisfactory control had been devised as yet.

Dr. Richardson outlined a procedure for using the Co^{60} light localizer in the delineation of penumbra. The design of the cobalt unit light localizer was discussed and Dr. Brucer stated that a similar design would be used on the cesium unit, unless a more desirable design is suggested.

Dr. Brucer reported on table design problems, and the possible utilization of a sectional table approximately 20 inches wide and 9 feet long, with a center section cut to a narrow width to permit greater rotational freedom. Only preliminary discussions have so far been completed on the table design.

The committee discussed the most desirable position for the rest position of the machine. It was shown that the control mechanism must always return to, and start operating from, one given rest position. The committee agreed that a rest position directly above the table would simplify design of unit and provide a safety factor..

During a discussion of automatic and mechanical controls of the machine, Drs. Meschan, Tolan, and Weems pointed out the need of a surface body contact plate to operate a micro switch for immediate stopping of the unit if it should come in contact with the table or patient while under treatment. The committee unanimously requested such a safety device and recommended a simple design for the unit.

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SUMMARY OF DISCUSSION OF CHARACTERISTICS OF PROTOTYPE UNIT

	Cs^{137}	Co^{60} or Eu^{152}
SSD	(90, 70, 50)	(100, 80, 60)
Variable Diaphragm	Use	Questionable
Portal Sizes	12.5 x 12.5, 10 x 15, 10 x 10, 6 x 12, 4 x 6	
Fork Height	54"	54"
Ceiling Height	9½' if possible	9½' if possible
Table Height	36" max., rest 30", min. 24"	
Light Localizer	Use	Use
Wedge Filter	May be impractical	
Loading Device (field)	No	Yes
Shutter Device Time	1 sec.	1 sec.
Table Size	9 feet length, 20 inch width	
Rest Position	Center of table	
Max. Size of Patient Phantom	30 x 40 c.m. x 100	
Telescoping Cone	Yes	Questionable

Marshall Brucer

Marshall Brucer,
Chairman,
Subcommittee No. 1

1136154

MINUTES, APRIL 12, 1953 MEETING
TELETHERAPY EVALUATION BOARD - SUBCOMMITTEE NO. 2
SMALL SOURCE DESIGN

Members present: Dr. Henry Jaffe -- University of Southern California
Dr. Robert Reeves -- Duke University
Dr. Paul Riemenschneider -- University of Syracuse
Mr. John Tolan -- Emory University
Dr. Marshall Brucer -- ORINS

Visitors: Dr. Robert P. Ball, Radiologist, Oak Ridge General Hospital
Mr. J. W. Wilde, Instrument Engineer, ORINS
Mr. H. E. Kimble, Instrument Maker, ORINS

Members absent: Dr. C. C. McClure -- Vanderbilt University
(Absent due to illness. Came in to Oak Ridge on 19-20 April 1953 to review Subcommittee #2 proceedings.)
Dr. J. F. Kelly, Jr. -- University of Nebraska
(Absent due to illness.)

Dr. Marshall Brucer opened the meeting with a review of previous discussions on the design principles of teletherapy units, outlining the problems encountered to date in designing a small "head and neck" therapy unit, and sketched, for purpose of discussion, a suggested design which would solve most of these problems. Because of the anatomical conformation of the head and neck region, the primary principle to be followed in any small unit is to remove as much mass as possible away from the cone of the machine in two planes. This can be done by placing the source at a 45° angle to the normal angle of rotation of the shutter mechanism.

There followed a discussion of the sizes and specific activities of Co^{60} sources currently available, or expected to be available in the near future. The sources presently available are 1 cm in diameter by 0.2 cm, 1 cm, 2 cm, or 4 cm in length and have activities of 85 to 140 curies per inch of length. There are also available 1/8 inch diameter rods 1/8, 1/4, 1/2, and 5/8 inches in length. These smaller rods have activities of from 10 to 15 curies per inch of length. Several design patterns were discussed which would allow the build up of about 300 curies in a 2 cm diameter source. A double overlapping clover leaf design is considered to be the most economical in space and curiage. Based on this information the committee agreed that the small therapy unit should be designed for an approximate maximum of 45 r/min, at 30 cm Source-Skin Distance.

Dr. Jaffe suggested that the committee review advantages and limitations of a small therapy unit of this size and design. Dr. Riemenschneider discussed the flexibility of the small Co^{60} therapy unit versus 250 kV x-ray unit. Also, he pointed out that a 250 kV x-ray unit would cost approximately $15,000 as against an estimated cost of $10,000 (or less) for the small "head and neck" unit. The committee reviewed the following factors both for and against the small unit.

1. Possibility of a high tumor-skin dose ratio in tumors approximately 5 cm below the surface of the skin.

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2. Since the unit must be used in contact with the skin at 30 cm, the inverse square reduction in exposure rate is considerable. It probably will not be suitable for any form of deep therapy.

3. With correct cone designs it is possible to use the unit in intravaginal and intraoral therapy.

4. It can be designed with extraordinary flexibility in manipulation but this will depend directly upon the amount of money allowed for the suspension mechanism.

5. Because of the short source-skin distance, the unit is not practical for any form of rotational therapy.

6. It has many of the advantages of the radium pack but will be superior in its depth dose and output.

7. It requires a very small space for the machine itself; however, with each increased degree of freedom in motion, there will be an additional requirement for shielding of the room.

8. It is competitive with a million volt unit at short distances in all respects except exposure rate.

Dr. Jaffe brought up a number of questions relative to initial cost, replacement of sources, and routine maintenance. As listed, the cost of multicurie sources is $100 per 2 curies plus $5 per curie or fraction thereof above 2 curies. There will be a loading charge of anywhere from $500 to $1500, however, this depends upon the difficulty of loading sources and whether the sources are just incapsulated or are loaded into the shield. In addition, there is of necessity a shipping charge for the shield or isotope carrier which would differ for each university, depending upon the distance from Oak Ridge and the mode of transportation. The replacement cost would occur at approximately eight year intervals. Mr. Tolan, in summarizing the discussion, expressed an opinion that these costs are comparable to replacement cost for X-ray tubes. The committee then discussed the service or maintenance costs of custom built units versus service costs for commercial x-ray units. Dr. Riemenschneider pointed out that the type of maintenance required on the small source unit under discussion was not of a specialized nature and was well within the scope of any mechanical shop, except for the maintenance of a source wheel. It was agree that any proposed engineering design, if of a simple nature, could provide trouble free operation for several years.

The committee then held an informal discussion of the various factors involved in the design of any unit. Mr. Wilde demonstrated a simple design shown in Figure 1. Mr. Wilde's estimates are that a prototype unit some similar to the design demonstrated would cost approximately $12,000 to engineer and build, whereas on a second unit the cost might be reduced to approximately $8,000. It was emphasized that these estimates are independent of source costs and installation costs. The ORINS design was tentatively accepted in principle to facilitate the discussion of various specific factors which would influence any particular design.

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A. Size of Fields at Skin Distance

Dr. Brucer pointed out limiting factors affecting the portal size at the skin surface, such as the relative weight of various size cones, types of material used in fabricating cones, visual and transmitted penumbra problems, the source-skin distance, the problems of cone contact with irregular surfaces, etc. Dr. Jaffe lead a discussion on the desirability of using maximum size portal versus multiple fields. The committee discussed the probability of a continuously variable diaphragm arrangement. The variable diaphragm being developed for the cesium machine was outlined, however, the committee agreed that the size and cost of such a mechanism made it impracticable for the small therapy unit. A motion by Dr. Reeves, seconded by Dr. Riemenschneider, and approved by the committee, recommended a minimum 2 cm diameter, and a maximum 10 cm diameter field at skin surface. This is to be considered a minimum requirement. If an engineering study shows it to be practical, the maximum size should be increased to a 12 cm diameter field. Following this motion the committee agreed on the fabrication of a number of experimental cones to be at 4 x 6, 6 x 8, 8 x 10 rectangles; 2, 3.5, and 6.5 cm circles. The committee requested that the cones and holding devices be designed to permit rotation of the cones.

B. Treatment Distance

It was brought out that the source-skin distance intimately affects such other factors as field size, penumbra, dose distribution, source curiage, and in addition affects such mechanical items as the balance of the unit. Discussion around these factors brought out other possible uses of a small therapy unit in addition to tumors in the head and neck areas. It was the unanimous opinion of the committee that in spite of the design restrictions imposed by the small curiage source, many uses were possible with the suggested design. Dr. Jaffe moved that the committee adopt a 45 r/min output at 30 cm source-skin distance as a goal to be reached. The motion was seconded by Dr. Reeves and carried without objection.

C. Size of Co^{60} Sources

Dr. Brucer outlined the number and specific activity of Co^{60} sources expected to be available for the next five years. The committee was informed that cobalt sources are available in the following sizes, as listed in the radioisotopes catalog.

Diameter	Activity per inch of length	Lengths available
0.5 mm	0.2 mc - 25 mc	2 mm to 6 cm
1.0 mm	1 mc - 100 mc	2 mm to 6 cm
1/8 inch	10 mc - 15 curies	1/8", 1/4", 1/2", 5/8"
10 mm	84 mc - 140 curies	2 mm, 1 cm, 2 cm, 4 cm

The committee discussed the desirability of various source sizes and shapes which could be made from the materials now available. On motion by Dr. Reeves, seconded by Dr. Riemenschneider, the committee voted for a source container slightly greater than 2 cm diameter with the sources arranged in a double clover leaf design. With this arrangement, approximately six 1 x 1 cm rods plus one 1/8 x 1/2 inch rod would be used. This allows for the minimum self shielding and depending upon the specific activity of the material should yield greater than

250 and less than 350 curies. Such a source would cost about $1800 and should approach a 45 r/min output at 30 cm. There is some question on the flatness and symmetry of the isodose curves with such a source design, however, this can be determined only by experiment.

D. Allowable Penumbra

The committee discussed isodose curves and the penumbra problems which might be produced with the source design recommended. A report was given on Dr. Richardson's work measuring the isodose curves around the Canadian Source as used in the ORINS - M.D. Anderson Co^{60} Unit. For comparison Dr. Robert Ball discussed the isodose curves around the Oak Ridge General Hospital's 250 kV x-ray therapy unit. The penumbra on even these small curiage sources can be expected to be better than that shown for the 250 kV x-ray therapy unit and much better than those shown for the various radium packs throughout the country. However, it is not expected that, with such a large source and small collimating distance, the penumbra will be anyway near as sharp as that shown for the large Co^{60} machine. To a certain extent the large penumbra can be overcome by bringing treatment cones up to contact with the skin. The recent work on electron build up with the large cobalt machine was discussed and it was shown that the excessive electron contamination in the first few millimeters of skin can be markedly minimized provided proper precautions are taken in the design of electron filters over the end of the cone.

E. Light Localizer

The committee was of the opinion that in a small curiage source machine it was probably advantageous to bring the cones up to contact with the skin, in which case there was no necessity for a light localizer. Dr. Reeves moved and Dr. Riemenschneider seconded the motion that with the short source-skin distance machine no light localizer was required. Other committee members concurred.

F. Timing Mechanism

The committee discussed the design of the source wheel and the expected operating speeds with the source wheel moving into the "on" and "off" position. Without voting the committee agreed that much of this depends upon what can be engineered and agreed on an estimated one second build up of dosage, (less than 1% of total dose) during the "on" and "off" movements.

G. The Shutter Mechanism

Dr. Brucer outlined a shutter mechanism consisting of a doughnut wheel operated from the control panel, complete with timer switch, signal lights, and master key lock switch. Mr. Tolan questioned the ability of the cogwheel and worm gear mechanism to be as efficient as an axle drive. It was explained that the original design feature was the result of an attempt to locate the drive mechanism in the most advantageous position with respect to the center of gravity of the unit so that the shutter drive could float inside of the fork suspension. This would avoid bulky projections at the treatment end of the machine. Mr. Wilde discussed other possible shutter drive arrangements which would locate the driving mechanism in the desired position, however, these alternate arrangements placed gears within the shielding head and the committee expressed a desire to eliminate

any machinery which could be repaired only on dismantling and exposing the source. Dr. Tolan pointed out that the cogwheel would have to be built of high alloy metal to withstand eight years wear of the high speed on the worm gear design suggested and asked for further discussion on possible use of an axle drive. It was pointed out that the arrangement of a wheel at an angle puts any axle drive in such a position so as to locate an exterior obstacle in a forbidden area, however, it was felt that some arrangement must be made which will place all gears and bearings on the outside of the unit. The committee expressed agreement on the general design ideas, although they disagreed with the specific design suggested. The discussion was closed with a consideration of the recommendations of the new NBS Handbook on Protection from Incapsulated Sources which will demand some extention for manually shutting off the beam.

H. Shielding Materials

The committee reviewed the cost factors in various shielding materials which could be used. It was immediately agreed that the cost factor alone made it necessary to use lead as the prime shielding material. There is still a possibility of using small pieces of more dense materials in strategic locations within the design.

I. Suspension Mechanism

The committee agreed, after much discussion, that no matter what the design of the shielding unit, the problem of suspension depends to a large extent on the individual needs and specifications available to each user. Whereas, it might be possible for one university to use a wall mount, another university may find it more economical to use a ceiling mount. It was agreed that the prototype unit should be designed with a specific suspension mechanism but that this suspension might have to be modified for each university. For the prototype unit it was agreed that the suspension mechanism must provide for a vertical motion of the yoke between two feet and five and a half feet above the floor, a 360° rotation of the yoke, and tilting of the head through an arc of 180°. It was agreed not to attempt to put in a horizontal movement of the yoke. It was suggested that an investigation be made immediately of the commercially available suspension mechanisms, and to compare their design and cost with a specially constructed model. The one criticism of most commercially available suspension mechanisms is that few are designed to carry the load required of even a small curiage unit. Mr. Tolan showed the committee descriptive literature on one typical commercial X-ray suspension unit which might be adaptable to a small Co^{60} unit.

J. Loading of Replacement Sources

The committee discussed the desirability and the advantages and disadvantages of field loading of replacement radioactive sources. There remains considerable disagreement on the necessity for field loading versus loading by a vendor such as the Oak Ridge National Laboratory. In the case of universities located within a short distance from Oak Ridge, it is probably far more economical not to attempt the field loading device within the design, however, in the case of organizations a long distance from Oak Ridge, a lack of field loading equipment would be a serious handicap. Mr. Wilde is of the opinion that any design can easily be adaptable to any field loading device, however, some central organizations would have to have and be responsible for such a piece of equipment. The committee did not vote for either arrangement, however, the members did express a definite

desire for a field loading design provided it is practicable.

K. Automatic Versus Manual Controls of the Suspension Mechanism

Dr. Jaffe discussed the desirability of motor controls versus manual controls for at least the fine adjustments on any therapy machine. It was his opinion that radiologists in general were currently in favor of manual controls. The committee agreed that fully automatic operations of all movements was too costly, but that it was necessary to have motor operation of the shutter device and any motion which covers a considerable distance. In the case of the present design this would be only the vertical movements of the yoke. All members expressed an opinion that manual operation of vertical motions were necessary for fine adjustments. At this point Dr. Jaffe and Mr. Tolan expressed the desire for the prototype unit at least have a maximum possible freedom of movement as specified in Item I. Excepted from this statement are the horizontal "in" and "out" motions which are easily obtainable by positioning the patient in a chair or on a treatment table.

Dr. Jaffe made a motion that Subcommittee No. 2 approve the preliminary design as detailed above and authorize ORINS to proceed with fabrication of the pilot model. The motion was seconded by Dr. Riemenschneider and unanimously voted by the committee. Dr. Brucer expressed a desire that the committee review the progress and development of the pilot model prior to the October meeting of the full TEB board. A tentative date sometime in September was agreed upon for the committee's second meeting.

Dr. Jaffe questioned the feasibility of the Institute or some industry building other units simultaneously with the pilot model. It was suggested that the fabrication of a number of units might lower the per unit cost. Dr. Brucer informed the committee that the Institute could not undertake the manufacture of teletherapy units for sale, and explained that the ORINS procedure of building the prototype unit of necessity would be one of simultaneous fabrication and design. It is expected that complete engineering plans will not be available before completion of the pilot model. The committee was informed that "as-constructed-prints" will become public property upon completion of the pilot model and that patent rights will all be, by the terms of our contract, in the hands of AEC.

Although Dr. McClure was unable to attend the April 12 meeting of the subcommittee due to illness, he was able to come into Oak Ridge on the 18th of April. During his visit Dr. McClure went over the discussions and deliberations of the April 12th meeting of the Subcommittee No. 2 and adds his concurrence to the deliberations.

Marshall Brucer, Chairman

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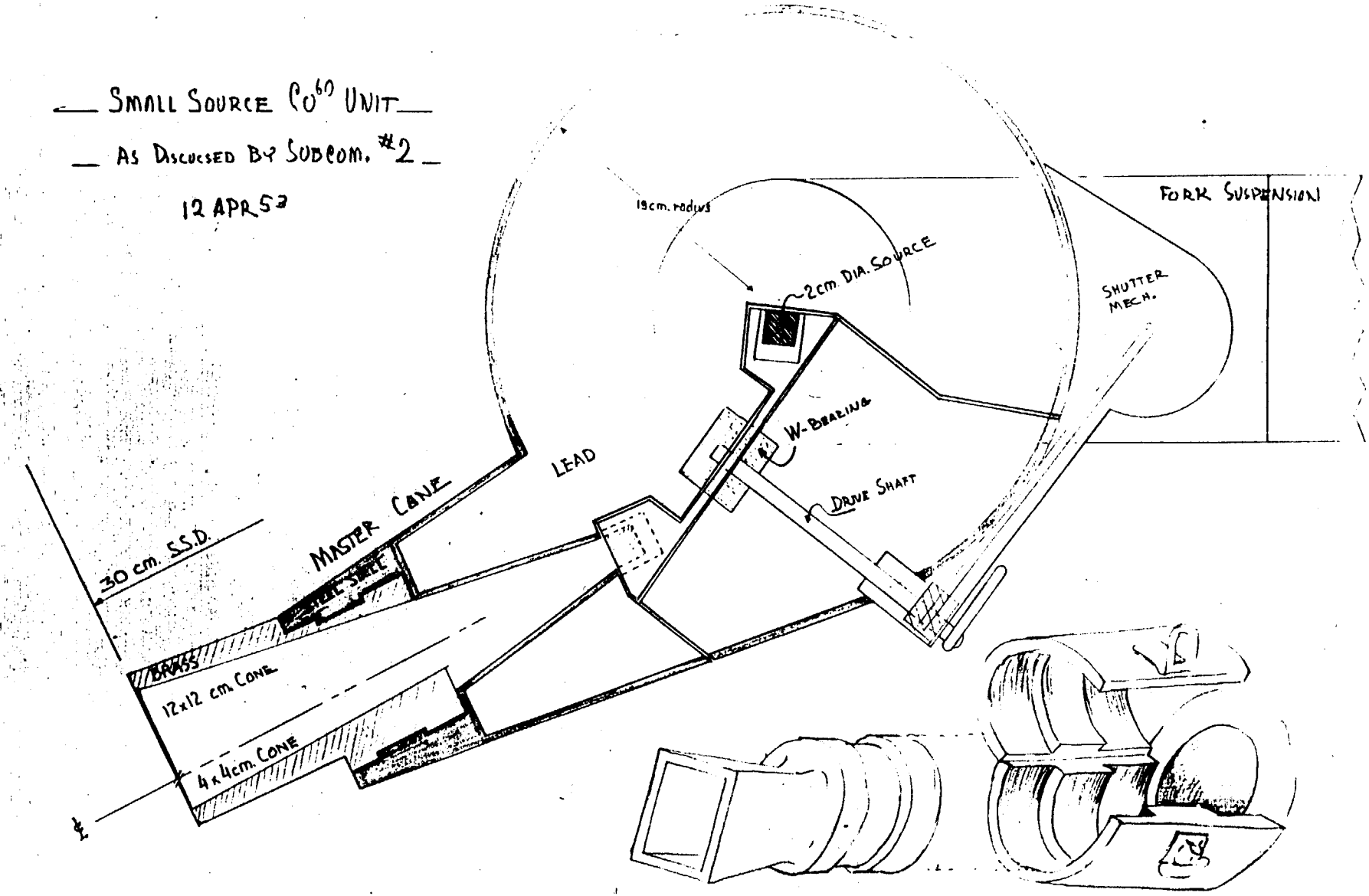
1136160

1136161

SMALL SOURCE Co^{60} UNIT

AS DISCUSSED BY SUBCOM. #2

12 APR 53



1136162

MINUTES, MAY 3, 1953 MEETING
TELETHERAPY EVALUATION BOARD - SUBCOMMITTEE NO. 3
ROTATIONAL METHODS AND PROCEDURES

Members Present: Dr. Sidney Rubenfeld -- New York University School of Medicine
Dr. Arthur C. Guyton -- University of Mississippi
Dr. William H. Riser -- Medical College of Alabama
Dr. Carl E. Nurnburger -- University of Tennessee
Dr. George Cooper -- University of Virginia
Dr. Marshall Brucer -- Oak Ridge Institute of Nuclear Studies

1. Current Status of the Construction of High Curiage Machine:

The present status of designing and building the high curiage machine by the W. F. & John Barnes Company was outlined and the subcommittee discussed in detail the design features which permit automatic operation with the central axis of the beam always focused at a central point of a spherical orbit circumscribed by rotation. The subcommitee studied engineering prints and expressed approval of specific features for obtaining tilt, vertical, horizontal, and azimuth motions for rotational therapy procedures as visualized by subcommittee members.

The subcommittee was informed that original design specifications did not call for field loading of replacement radioactive sources; however, at this stage of design it was believed that the most desirable design of the shielding head provides for field loading.

Dr. Riser asked if the design provided for rotation on a continuously variable radius up to a given maximum. The subcommittee was informed that the original design had specified such operational features; but, because complicated control machinery made such a motion impractical, the Subcommittees on Source Evaluation and Shield Design approved a change in design and accepted the following source-skin distances for rotational therapy:

Cesium^{137} ---------- 90, 70, and 50 cm

Cobalt^{60} or Europium^{152}---------- 100, 80, and 60 cm.

Members of Subcommittee No. 3 expressed approval of these changes in design specifications.

Dr. Brucer outlined studies showing the necessity for an automatic wedge filter. The subcommittee discussed the many problems of moving a wedge filter into the field, from any direction, to maintain homogenous tissue dosage under rapidly changing conditions. The filter

must move in three directions, under control of the "computor", and must be fully automatic to be satisfactory. Dr. Nurnburger discussed the necessity of a filter completely covering the beam and its relationship to the shape of the isodose lines. Dr. Guyton questioned the necessity of locating a filter close to the source; and, offered for discussion an opinion that inasmuch as the unit would not contain a point source it would be practicable to use a filter at the far end of the collimator.

The wedge filter is designed so that the thickest edge is always close to the central axis of the angle of suspension. If the angle of rotation is identical with the angle of suspension, control of the wedge filter is simple; but, as the angle of rotation moves away from the angle of suspension, the wedge position becomes related to the position of the rotating head and the position of suspension mechanism, therefore, making automatic control more complicated.

Dr. Cooper summarized and questioned the necessity for all automatic motions designed into the experimental unit. Also, Dr. Rubenfeld asked if head motions could be simplified by designing the treatment table with some movements. It was pointed out that Subcommittee No.1 had raised the same questions and after full discussion had voted to have maximum freedom of movements designed into the experimental. It will be a simple matter to omit unnecessary movements once the preliminary studies have been completed. The subcommittee agreed with the actions of the Subcommittee on Shield Design.

The subcommittee discussed the design of the variable aperture diaphragm which was approved by the March 29th Meeting of Subcommittee No. 1. The mechanism consists of 12 triangular units forming an iris diaphragm closing to less than 3 cm diameter and opening to a maximum 15 cm diameter. It was explained that this mechanism would not give irregular or rectangular portals; however, these patterns are obtainable by using the diaphragm as a holding device for cones. The subcommittee was informed of design problems in providing a supporting device and shielding between the head and variable diaphragm. The present status of design visualizes a series of telescoping steel cylinders providing adequate shielding when the diaphragm is extended to maximum distance from the head. The subcommittee did not find any design features objectionable for rotational therapy technicues.

The subcommittee approved in principal the present design status of the light localizer which cannot be greater than 2 cm in diameter. The system consists of an external light source with a collecting lens focusing the light beam through a lucite channel to an expanding lens which transmits the beam to a reflecter, thereby simulating a beam equal to the radioactive source and appearing to be coming from the surface of the source. Dr. Guyton suggested using a slight concave reflecter to better collect and collimate the light beam received from the expanding lens.

The subcommittee studied Dr. Richardson's work on the design of cones most suitable for reducing the build-up of secondary electrons. It was pointed out that lead, with its desirable shielding properties, also contributed to the build-up of undesirable secondary electrons. It was suggested that brass or brass-lined cones would greatly reduce these electrons and that brass filters at the portal would further reduce the electrons. Dr. Rubenfeld requested information regarding the suspension of the filter which would permit indication of penumbra by visible light. The subcommittee was informed that an adequate holder has been constructed of lucite and brass which emits a rectangular light beam around the edge of the brass shim simulating the penumbra. The inside edge of the light beam is an indication of the 100% isodose line with the outer edge dropping off to the approximate 12% to 20% isodose line depending upon the size of the field.

Dr. Brucer discussed the design engineer's study of shutter mechanisms and informed the subcommittee that cost and space requirements made impracticable such devices as a continuous rotating motor utilizing centrifical force to rotate the source wheel 180°, various slip clutches such as the magnetic clutch, magnetic oils, Borg-Warner overdrives. Dr. Brucer then described the pneumatic system currently under study by the Barnes company.

2. Present Status of the Construction of the Small Curiage Machine:

The small source unit is not designed for rotational therapy; however, Dr. Brucer informed the subcommittee of the current design status of a prototype unit. The subcommittee discussed the design features as outlined in the Minutes of the April 12th Meeting of Subcommittee No. 2. The subcommittee was informed that the original cost estimates were approximately $12,000 for construction of the small therapy unit, but simplification in design had reduced the cost estimate to less than $10,000 including supporting mechanism. The subcommittee discussed installation requirements likely to be encountered at different medical schools.

A. Installation of a unit on a top floor corner room, with beam directed toward the outside corner, would require shielding on two sides and floor.

B. Installation of a unit in a basement, with four sides of the room surrounded by earth, would require shielding only for the ceiling. The subcommittee was informed of a ceiling shielding design, by Dr. C. C. McClure, Vanderbilt University, whereby maximum shielding directly above a unit is carried on a suspension track and moves with the unit.

C. A third possible mount is indicated by Dr. Carl Braestrup, Francis Delafield Hospital, New York. This design has a

source mounted on one end of an arc circumscribed by an angle of 180° and a heavy shielding surface mounted on the other end of the arc in such a manner that the shield always remains directly in the path of the beam.

Dr. Cooper, Dr. Rubenfeld, and Dr. Nurnburger discussed the adequacy of the shielding provided in the design of the small therapy unit. Dr. Brucer listed the approved standards of radiation exposures (.3 r/48 hours, total body; 1.5 r/48 hours, hands and arms; 1.5 r/48 hours, feet) and informed the subcommittee that calculations and tests indicate that exposure can be within these limits at reasonable cost.

3. Control Panel of High Curiage Machine:

The subcommittee was informed of the preliminary design studies of the automatic control panel consisting of a double magnetic amplifier on a thyroton system providing equal opposing forces on each electric motor. An increase or decrease in bias, applied to opposing forces, permits movement in the desired direction and at a rate of speed maintainable with a high degree of accuracy. Patterns of motions are controlled by a multiple cam system; shape and eccentricity of each cam determines functional patterns of the therapy unit.

The teletherapy unit should be designed with two control systems: fully automatic controls on the panel in the control room, and semi-automatic controls on the yoke of the suspension mechanism for the mechanical positioning of the unit. The switch for mechanical operation breaks the automatic control circuits from the control room and the closing switch permits automatic operation with the unit returning to rest position directly over the table before starting therapy cycle. The manual control system permits single portal therapy.

Existing regulations for an x-ray therapy unit suggest an indicator for showing which filter is in position. This regulation was established to inform the operator of the half value equivalent of the x-ray beam. The factor is constant on a teletherapy unit utilizing radioactive isotopes; therefore, such a device was omitted on the prototype unit. Also, existing regulations suggest indicators showing the position of an x-ray head. Dr. Brucer informed the subcommittee that the control panel might possibly have indicators for degree of tilt, lateral motion, and azimuth motion, but the necessity for this has been questioned.

4. Photographic Isodose Curves of Co^{60} Rotations:

Dr. Brucer outlined preliminary studies of isodose curves from a rotating beam in an attempt to point out some of the factors involved. Simulated conditions were established by keeping the O.R.I.N.S.-M.D. Anderson Co^{60} therapy unit in a fixed position and rotating a phantom

in the beam of radiation. The phantom consisted of a molded cylinder of paraffin of approximate torso dimensions. This phantom had been cut crosswise and lengthwise, and two pieces of Type M Industrial X-Ray Film placed at 90° with respect to each other. Films were obtained with the Co^{60} beam striking the film in increments of 10° angles from angle of suspension.

It was emphasized that photographic dosemitry was very unrealiable; however, the following factors were demonstrated by the studies. (See attached figures.) Some angles of suspension and rotation give an acceptable pattern of major dose. The tumor dose will not be uniform throughout the tumor area unless a wedge filter is positioned within the beam. This wedge must be of dimensions maximized at approximately 45° and minimized at 0° and 90° angle of insidence to the tumor. Not shown on the attached figures but demonstrated on other studies were figures showing the infinite possibilities of distorting the shape of the focal area by changing the cross section of the cone.

Following this detailed discussion of the design characteristics and capabilities of the large teletherapy unit, the subcommittee held an exploratory discussion of possible rotational therapy patterns. The subcommittee was in unanimous agreement that an infinite number of patterns were possible and that rotational therapy patterns should not be attempted until the unit is in operation and isodose curves accurately determined. The subcommittee discussed such factors as three dimensional dosage pattern, integral tumor dose, critical dose in and around normal body organs, etc. The subcommittee members suggested that another meeting be held late this lear for a more detailed discussion and formulation of therapy procedure.

Marshall Brucer, M.D.
Chairman, Executive Committee

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0° ANGLE
14 cm

1136168

10° ANGLE
14 CM

1136169

20° ANGLE
14 cm

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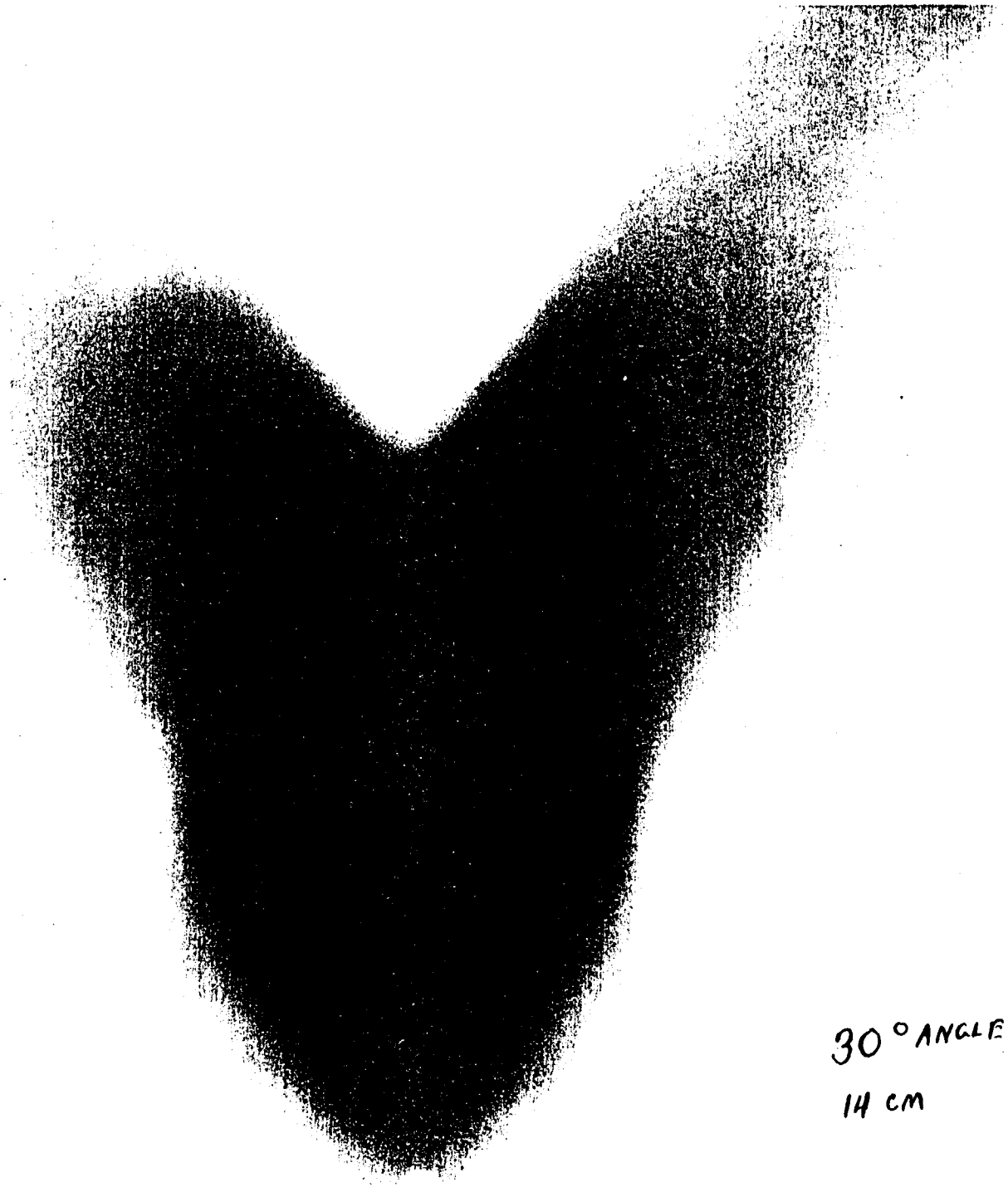
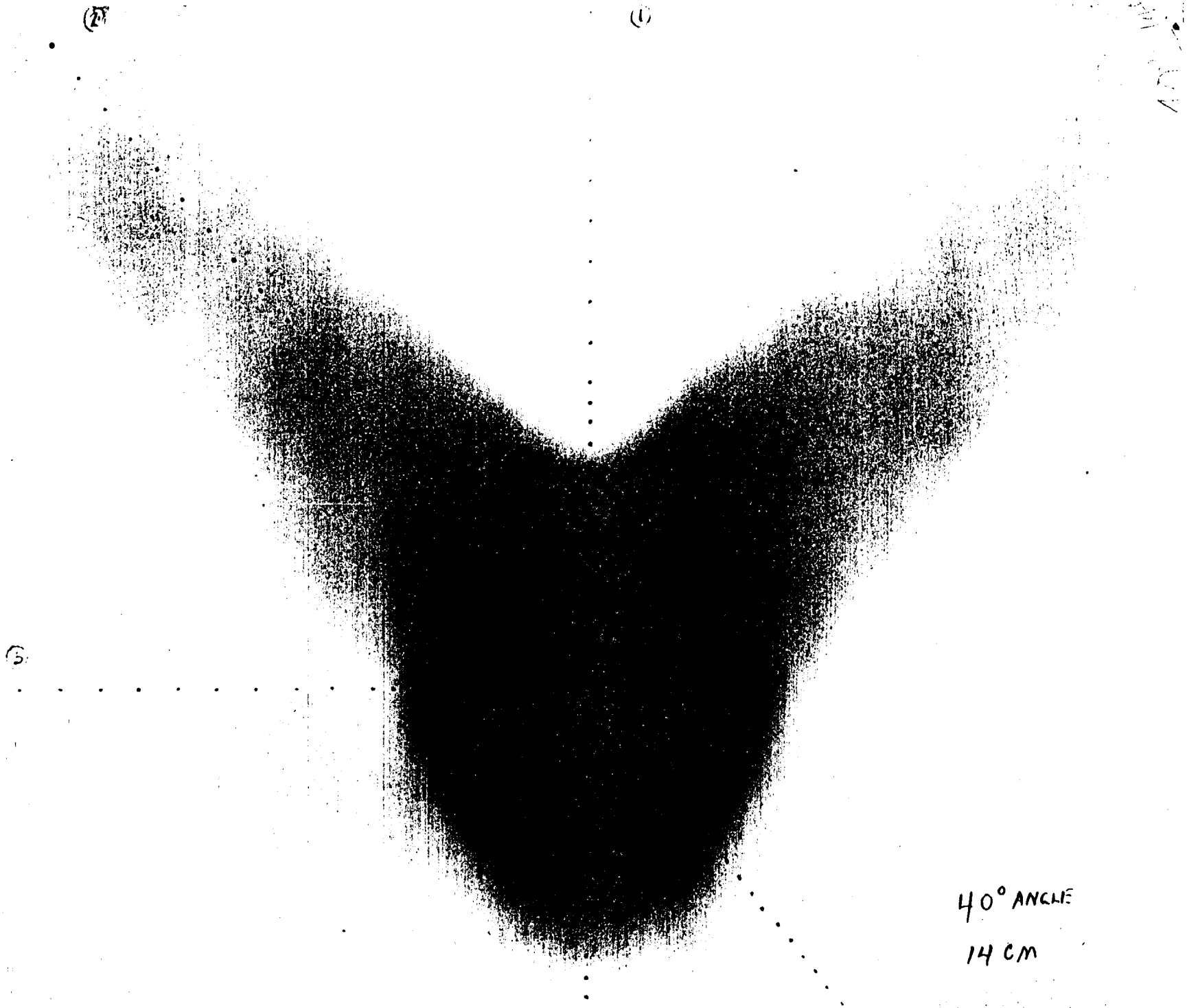


30° ANGLE

14 cm

1136171



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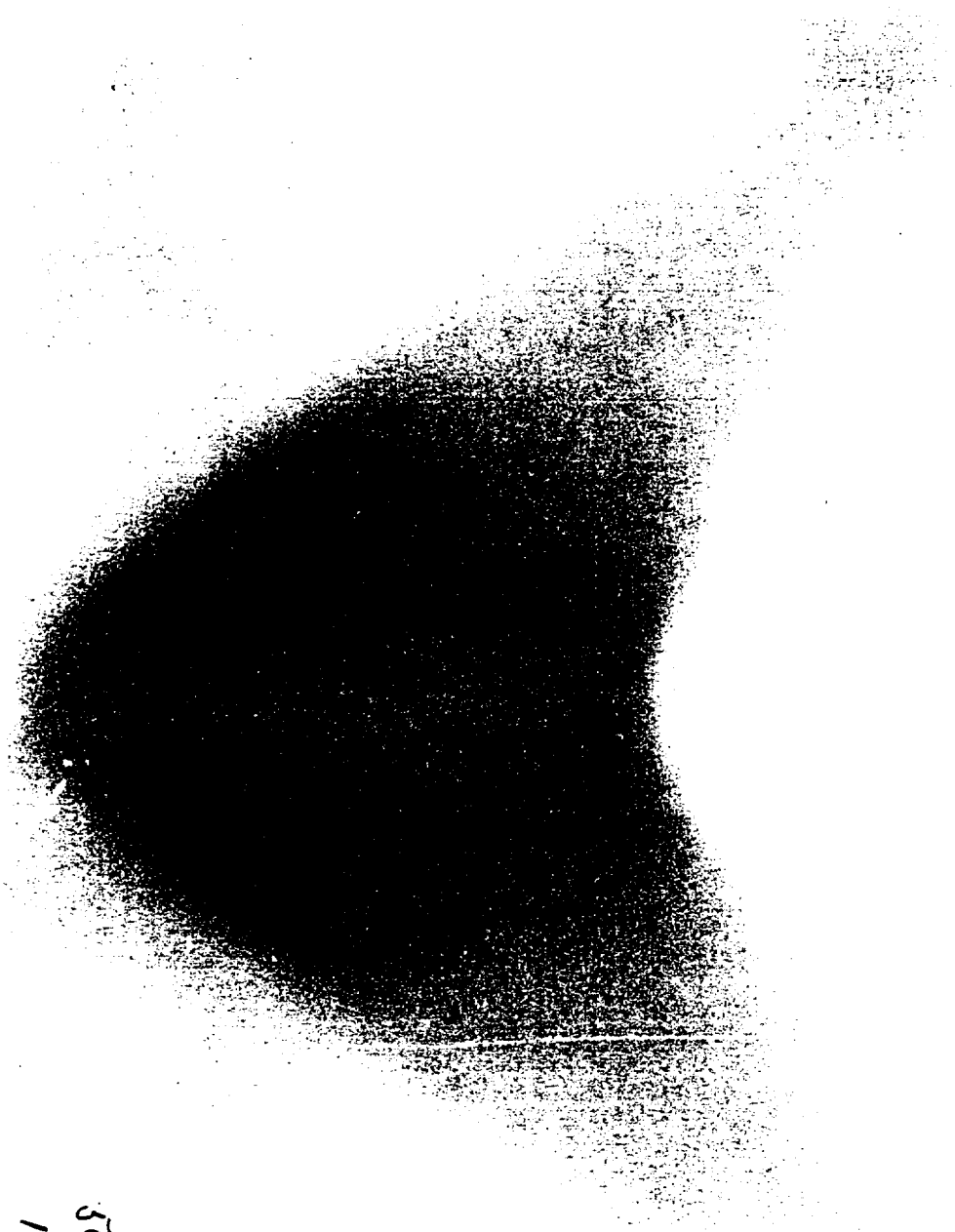

50° ANGLE
14 CM

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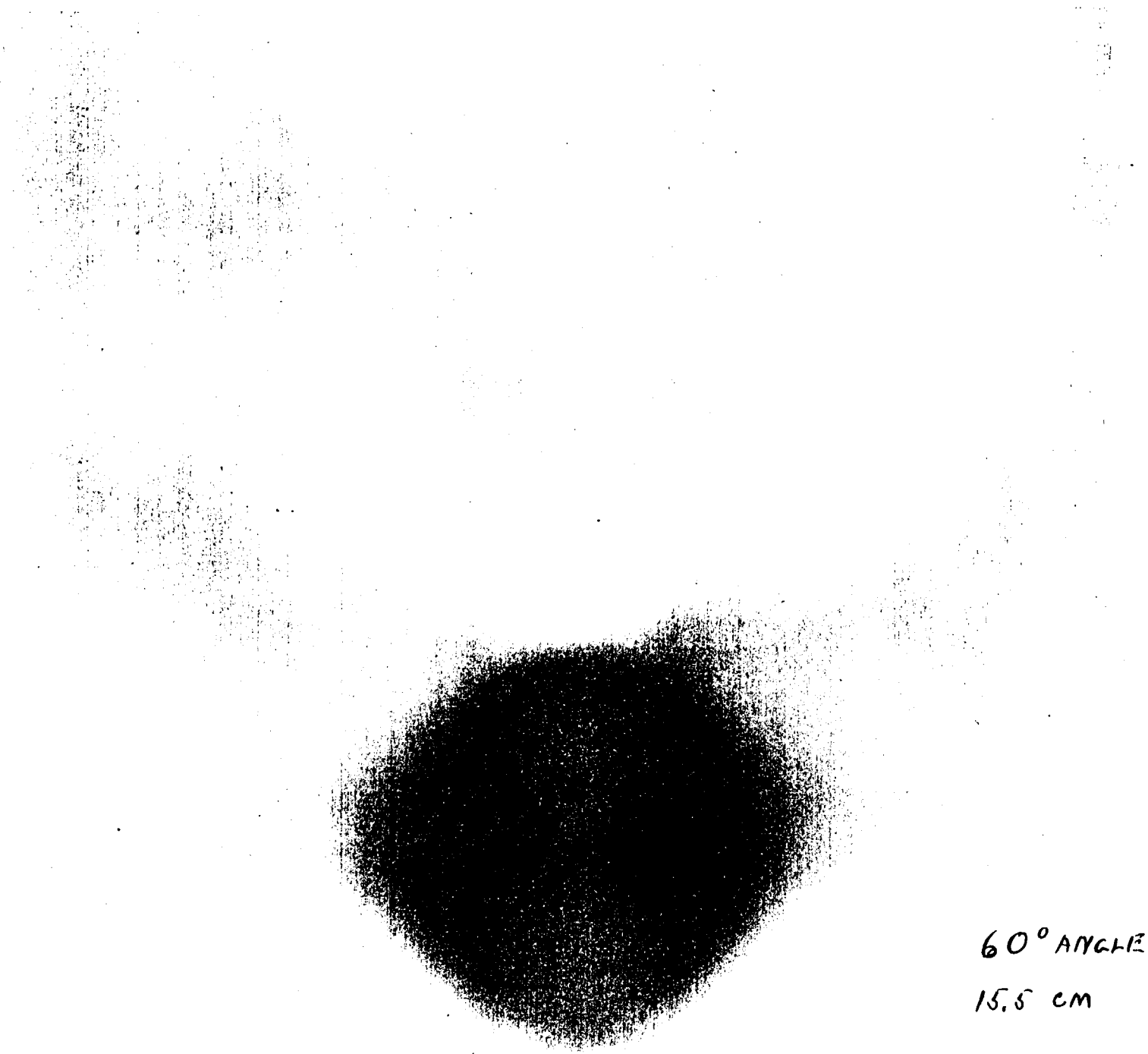
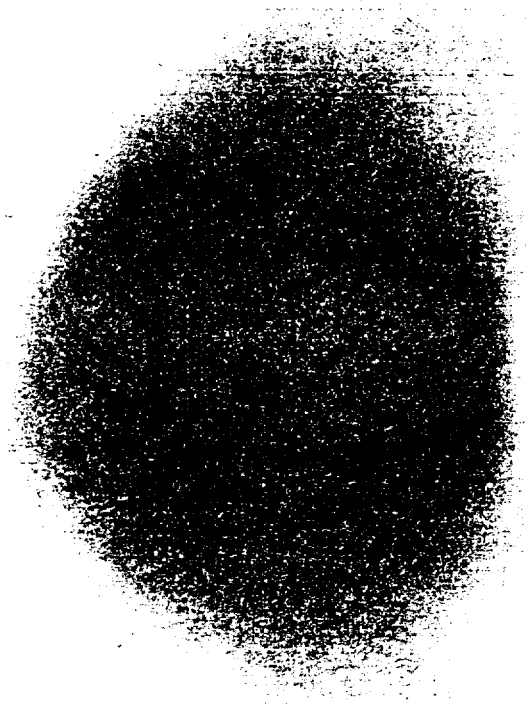


60° ANGLE

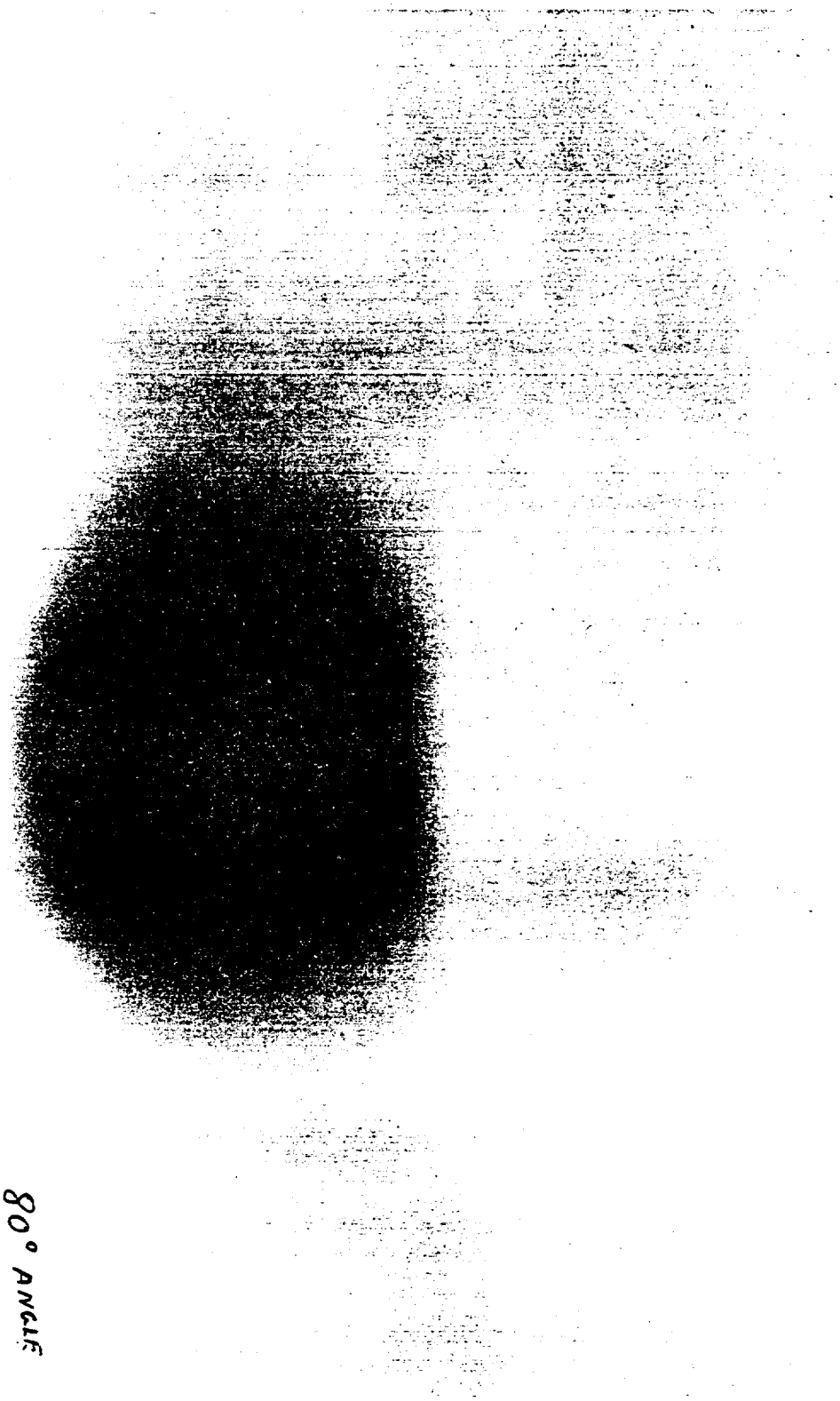
15.5 cm

1136174



70° ANGLE
16 CM

1136175



80° ANGLE
16 CM

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AEC, Oak Ridge, Tenn. 5-13-53-75-W-2158

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MINUTES, MAY 24, 1953 MEETING
TELETHERAPY EVALUATION BOARD - SUBCOMMITTEE NO. 4
HOUSING DESIGN

Members Present: Dr. Frank E. Hoecker, - University of Kansas
Dr. James E. Lofstrom, - Wayne University
Dr. Frederick B. Mandeville, - Medical College of Virginia
Dr. Walter J. Burdette, - Louisiana State University
Dr. Marshall Brucer - ORINS
Carol Purdy, - Representing Dr. J. Robert Andrews, Bowman Gray School of Medicine

Members Absent: Dr. Galen M. Tice, - University of Kansas Medical Center
Dr. J. Robert Andrews, - Bowman Gray School of Medicine

Visitors: Dr. Robert P. Ball, Radiologist, Oak Ridge General Hospital

The subcommittee was informed of the current status of the design and construction of the high curiage Cs^{137} teletherapy unit. The subcommittee members discussed in detail the specific design features such as: Constant variable diaphragm, the shutter mechanism and its operation by a pneumatic control device; automatic wedge filter; and the design and control features which permit unlimited rotational patterns.

The subcommittee then reviewed in detail the action of Subcommittee No. 2 in establishing design criteria for the small curiage Co^{60} therapy unit and its requirements for housing design facilities.

The subcommittee studied the current status of rotational problems as outlined in the minutes of subcommittee meeting on rotation methods and procedures. Also, in connection with rotational problems, the members reviewed photographic isodose curves obtained from the ORINS - M. D. Anderson Co^{60} unit.

The subcommittee then entered into a lengthy discussion of a number of factors presented earlier. This discussion was for the purpose of clarifying the current status of therapy problems involved in high curiage rotational therapy units and a low curiage unit designed for head, neck, oral, and vaginal cavities. These discussions outlined the operational characteristics of the two units as they effect housing design problems. Following this discussion, the subcommittee then reviewed in detail the attached elementary design criteria for housing facilities of therapy units. Also attached from Minutes of Subcommittee No. 2 are the isodose curves of the present Co^{60} unit.

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2. DATA FOR HOUSING DESIGN PROBLEMS*

The problem of radiation shielding can be a complex one and is not easily calculated on the basis of simplified tables and charts; however, many different systems of tables and charts have been prepared which allow for the reasonable estimate of the order of magnitude of shielding necessary under certain conditions. In most cases the shielding requirements as determined from such tables have an excessive safety factor. A primary problem in shielding is the judgment required to balance good architectural practice and good radiation protection. The simplified system shown below is taken from a method devised by the National Bureau of Standards.

The first factor that should be considered in the reduction of dosage from a large source is the factor of distance from the source. To a certain extent the inverse square law is followed but the distance factor must include absorption and scatter by air. Air interaction will not be inappreciable at long distances and there will be some variation with energy. Table 1 presents a reduction factor as produced by distance in air. Notice that at long distances, for example 100 meters from a source, where the inverse square reduction would be 10,000, the actual reduction is 27,000. At short distances up to 10 meters an inverse square calculation can be used without excessive waste.

If the exposure rate is given in roentgens per hour of primary radiation one meter from the source (rhm), the standard shielding requirements are such that the dose rate must be reduced to at least 6.25 mr/hr at all occupied regions. In Figs. 1 and 2 are presented the fractional transmission through lead and concrete of radiation from cesium^{137} and cobalt^{60}. To use these curves it is necessary to calculate a barrier thickness value (B) for the primary radiation. Let B (barrier thickness factor) be a function of the thickness of the barrier necessary. U is the exposure rate in rhm from the source in operational position, D is the distance factor as shown in Table 1. T (time) is the fraction of full 48 hour occupancy that must be expected at distance D. Then the method of calculating B is as follows:

$$B = \frac{0.00625\ (D)}{UT}$$

Fig. 1 shows the transmission factor (B) at various thicknesses of lead and concrete for both cesium^{137} and cobalt^{60} energies.

For radiation scattered at a 90° angle from an irradiated object, there will be a lower exposure rate and a lower energy than from the incident beam. The scattered exposure rate, when measured

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* Much of this material is taken from data prepared by Dr. Wyckoff for the National Committee on Radiation Protection, Subcommittee No. 9. It will be published in more complete form as a part of a handbook on radiation protection.

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at 1 meter from the scattering object, does not vary much with the angle of scattering but the energy of the beam is a strong function of this angle. For the usual treatment field sizes, it has been found that the scattered exposure rate is of the order of 0.1 per cent of the incident rate. Where the distances (d) from the source to the scattering object are so small that air attenuation is not important, the scattered exposure rate becomes 0.001 U divided by distance squared. When there is no barrier the exposure rate at a position of occupied space would then depend upon a factor (S) which is the distance in meters between the scattering object and the position of occupied space. Thus, the scattered dose rate is equal to 0.001 U divided by the distance squared (S^2). This exposure rate must be reduced to the maximum permissible exposure by some barrier for a particular time, and for the scattered radiation the factor (B) becomes a new factor (B_s). This new factor is defined as:

$$B_s = \frac{6.25\ (d^2)\ (S^2)}{UT}$$

Fig. 2 shows curves of B_s for 90° scattering of cobalt^{60} and cesium^{137} energies through lead and concrete.

Table II gives the relative thickness of the three main shielding materials used in large construction areas: Lead, marble, and concrete. Under a set of standard radiation conditions the thickness is shown for the energies of radium, cobalt^{60}, and cesium^{137}.

The relative thickness of sheidling required is strongly influenced by the energy of the radiation. This is especially true for low energy radiations through high Z materials. In Table III the relative lead equivalence of marble and concrete is given at various radiation energies. At low energies (less than 500 kev) concrete and marble are far less efficient than lead; but at the energies of most isotopes which can be used in teletherapy, marble and concrete are very efficient.

The situation does not completely cancel the use of concrete or marble at diagnostic voltages since usually only very thin lead shielding is required. Table IV gives the required thicknesses of marble and concrete at diagnostic energies.

In designing shielding barriers it should be remembered that if shielding is adequate for the primary radiation, it must also be sufficient for leakage and scattered radiation. All openings in barriers such as for doors, windows, pipes, etc. must adhere to the same radiation protection requirements as the surrounding barrier. Joints between the same or different kinds of protection material must have an overlap at least equal to the thickness.

In a new construction concrete generally provides the most economical barrier. Under certain circumstances marble may actually be more economical and generally the concrete figures can be used for marble by assuming that the marble thickness would be .88 of the concrete thickness. Where space is valuable lead is the preferred material.

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Examples of How the Tables are Used in Barrier Calculations:

Example: A cobalt source with a dose rate of 100 rhm is placed in a room with workers located continuously 48 hours per week in the path of the useful beam at a distance of 30 feet from the source.

U = 100 rhm
T = 48 hrs = 1
D = 30 ft = 89 (from Table 1)

therefore:

$$B = \frac{.00625\ D}{UT} = .0056$$

From the curves on Fig. 1 it is apparent that directly in the path of the beam 21 inches of concrete or 10 cm of lead are the required thicknesses to reduce the exposure rate to 6.25 mr/hr.

Definitions:

U = the exposure rate of the source in air of the primary radiation in rhm.

T = the largest fraction of 48 hours per week a person is expected to be in the location for which the barrier thickness is being calculated. (See note on time factor later in discussion.)

D = a modified distance factor based upon the inverse square reduction of exposure rate and the absorption in air. These figures are taken from water measurements and corrected to a low value for air density. (Kennedy and Wyckoff unpublished.)

0.00625 rh = maximum permissible exposure.

d = distance in meters between the source and an object which will scatter the radiation. This figure is always used as a squared function (d^2).

S. = distance in meters between the scattering object and the position in space to be occupied by a person for which a barrier thickness is being calculated. This figure is always used as a squared function (S^2).

For moderate fields the scattered exposure rate is of the order of 0.1 per cent of the incident rate. This scattering exposure rate is based upon a 90° angle of scatter and should be a safe approximation for walls exposed to a variable angle of scatter from 180° to 90° off the useful beam. In all of the following examples

the data will set up conditions to calculate a barrier factor (B) for the direct useful beam and a barrier scatter factor (B_s) where the angle is always greater than 90° from the useful beam. From the calculated factors (B) and (B_s) the thickness of lead or concrete required for a safe barrier can be found in Figs. 1 and 2.

Example 1:

Given a small source with an exposure rate of 100 rhm. The beam is directed at an office 30 feet from the source which must be fully protected. Another office is at 90° to the beam 20 feet away. Animals to be irradiated are placed 50 cm from the source.

$$U = 100 \text{ rhm}$$
$$T = 1 \text{ (48 hrs)}$$
$$D = 89 \text{ (30 ft from Table 1)}$$
$$d = .5 \text{ meters from source}$$
$$S = 6 \text{ meters}$$
$$B = \frac{.00625\ D}{UT} = \frac{.00625\ (89)}{100\ (1)} = 0.0056$$
$$B_s = \frac{6.25\ d^2\ S^2}{UT} = \frac{6.25\ (.25)\ (36)}{100\ (1)} = 0.56$$

Therefore, the barrier requirements for either a cobalt or a cesium source are obtained from Figs. 1 and 2.

	Direct Beam		Scattered Radiation	
	Lead (cm)	Concrete (cm)	Lead (cm)	Concrete (cm)
$Cobalt^{60}$	10	53	0.1	4.6
$Cesium^{137}$	4.75	41	0.05	3.0

Example 2:

Given a large source with an exposure rate of 30 rmm or 1800 rhm, the beam is directed at an office 5 meters away which must have full protection. A corridor is located at 90° to the beam 5 meters away. It is considered necessary to have protection for 50 per cent usage. Treatments are at 90 cm.

$$U = 1800 \text{ rhm}$$
$$T = 1.0 \text{ for the office, } 0.5 \text{ for the corridor}$$
$$D = 26 \text{ (from Table 1)}$$
$$d = .9 \text{ meters}$$
$$S = 5 \text{ meters}$$
$$B = \frac{.00625\ D}{UT} = .00009$$
$$B_s = \frac{6.25\ d^2\ S^2}{UT} = .14$$

Therefore, the barrier requirements for a cobalt and a cesium source from Figs. 1 and 2 are:

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	Direct Beam		Scattered Radiation	
	Lead (cm)	Concrete (cm)	Lead (cm)	Concrete (cm)
$Cobalt^{60}$	17.5	89	0.60	12
$Cesium^{137}$	8.5	71	0.25	10

Example 3:

Given a cobalt source similar to the small curiage unit with an exposure rate of 45 rm at 30 cm or 243 rhm. The machine is in a small room and the beam is directed at an office 4 meters away. The 90° scatter is directed towards an office 2 meters away. Complete protection is required in both places. On the other side there is a closet at 3 meters with a calculated minimum 10 per cent time occupancy. Treatments are at 30 cm.

U = 243 rhm
T_1 = 1 (front office)
T_2 = 1 (side office)
T_3 = .1 (closet)
D = 17 ft (from Table 1)
d = .3 meters
S = 2 meters to office, 3 meters to closet

Office $$B = \frac{.00625\ D}{UT_1} = .00043$$

Side Office $$B_s = \frac{6.25\ d^2\ S^2}{UT_2} = .00925$$

To Closet $$B_s = \frac{6.25\ d^2\ S^2}{UT_3} = .208$$

Therefore, the barrier requirements for both offices and the closet are as follows: (cesium is shown for comparison).

	Direct Beam to Office		Scatter to Side Office		Scatter to Closet	
	Lead(cm)	Concrete(cm)	Lead(cm)	Concrete(cm)	Lead(cm)	Concrete(cm)
Co^{60}	14.7	76.2	0.73	14.7	0.42	10.1
Cs^{137}	7.2	59.7	0.32	12.6	0.18	8.1

Each of the various factors entering into the modification of radiation exposure has a different effect on the barrier thickness requirement. In Fig. 3 the effect of the exposure rate U is shown for both concrete and lead for the front wall and a side wall. The standard conditions that were set up for Fig. 3 through Fig. 8 are as follows:

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$U = 243$ rhm
$T = 1$ (48 hrs)
$D = 10$ (3 meters)
$d^2 = .1$ (30 cm)
$S^2 = 10$ (3 meters)

Note in Fig. 3 that a change in exposure rate is very rapid from 0 exposure to the exposure expected from a low output machine. At 243 rhm the barrier thickness is 80 cm of concrete for a cobalt^{60} machine. For a very large curiage machine, one giving a 100 r/min, the barrier is approximately 100 cm. Thus, there is little saving to be expected from changing the exposure rate of the machine and it is probably just as cheap to design a room for a large machine as it is for a small machine.

In Fig. 4 there is shown the effect of the factor T on barrier thickness. For all practical purposes, if there is any doubt as to the usefulness of an adjoiring room one might just as well assume that there will be full usage and design accordingly. It is only when the expected occupancy of an adjoining room falls less than 10 per cent of full time occupancy does there appear to be any saving in barrier thickness.

Dr. Hoecker of Kansas has brought up a serious objection to the definition of the factor T as given. Factor T assumes that the beam of radiation is on during the entire 48-hour period. It was the impression of the members of Subcommittee No. 4 that under optium use, it would not be expected that the beam would be in the "on" position more than about 50% of the working week. An attempt is being made to gather data on the actual daily exposure hours of present-day radiation machines.

Another factor in determining the time factor for a specific wall is especially important in the case of the machine where rotational therapy or high maneuverability is possible so that the beam can be pointed in various directions. The useful beam for most present-day supervoltage installations is usually directed toward the floor; however, such factors may not be true for rotational machines.

In Fig. 5 the effect of distance (D) on barrier thickness is shown. Curves are drawn out to a distance of 90 meters and have a strong effect on barrier thickness. This is especially true within the practical limits of ordinary room sizes. Even a small increase in the size of the room has a marked effect on the thickness of the barrier required to give protection. For this reason the use of outside rooms where the nearest occupied space is many meters away can make a big saving in the cost of the shielding necessary for a teletherapy machine.

In Fig. 6 there is shown the effect of treatment distance (d) on barrier thickness. Although the curves appear to show a marked effect the scale on the curve is larger. Also, the treatment distances are relatively fixed between 30 and 100 cm and any shielding would have to be calculated for the minimum (d) possible with the machine in question.

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In Fig. 7 is shown the effect of S on barrier thickness. For all practical purposes this factor S is an indication of room width. As in the case of the D factor even a small increase in room size allows a marked decrease in wall thickness.

In Fig. 8 all of the factors affecting wall thickness are put together on one chart for comparative purposes. The distances from the source to the nearest occupied space are shown to be the most influential factors in determining wall thickness. The next figure (see Fig. 9) shows a possible design of a teletherapy room. Given constants for this room are shown in the following table:

Given Constants	Small Co^{60} Machine	Large Co^{60} Machine	Large Cs^{137} Machine
U	243 rhm	2700 rhm	1800 rhm
T	1 for occupied space or 0.1 for unoccupied space		
D	Variable		
d	0.30 meters	0.7 to 1.0 meters	0.5 to 0.9 meters
S	Variable		

Small Cobalt ^{60} Unit
(Corner room entered through maze 3rd floor)

A Wall	Outside Wall	30 meters to nearest occupancy
B Wall	Outside Wall	10 meters to nearest occupancy
C Wall	Inside Wall	90° scatter 1 meter to nearest occupancy
D & E Walls	Inside Wall	90° scatter 3 meters to nearest occupancy
Floor		4 meters to nearest occupancy
Ceiling		3 meters to nearest occupancy

A Wall	$B = \frac{.00625\ (1250)}{243\ (1)} = 0.032$	15 inches of concrete, 13 inches of marble, 2.8 inches of lead
B Wall	$B = \frac{.00625\ (110)}{243\ (1)} = 0.0028$	24 inches of concrete, 21 inches of marble, 4.5 inches of lead
C Wall	$B_s = \frac{6.25\ (.09)(1)}{243\ (1)} = 0.0023$	14 inches of concrete, 12 inches of marble, 1 inch of lead
D & E Walls	$B_s = \frac{6.25\ (.09)(9)}{243\ (1)} = 0.021$	9 inches of concrete, 8 inches of marble, 0.5 inches of lead
Floor	$B = \frac{.00625\ (18)}{243\ (1)} = 0.00046$	30 inches of concrete, 26 inches of marble, 5.3 inches of lead
Ceiling	$B = \frac{.00625\ (10)}{243\ (1)} = .00026$	32 inches of concrete, 28 inches of marble, 6.1 inches of lead

If, instead of using the small machine as the type example, a 2700 rhm cobalt machine were used, the thickness of the A wall would be 23 inches rather than 15 inches of concrete. If a large cesium source were used, the thickness of the wall would be 18 inches rather than 15 inches. In the case of the B wall for a large cobalt^{60} machine,

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the thickness of B wall would be 32 inches rather than 24 inches; and for the large cesium machine, the thickness would be 24 inches of concrete as in the case of the small cobalt machine.

The window in C wall could be made of a standard 2 inch Corning or Penberthy Hi-Density Glass, and could be as large as the budget permits. The doors would have to have a barrier efficiency equal to that of the E wall. Since this would make for a very cumbersome and expensive door, it would be less expensive to insert a strip of extra shielding on the D wall to shadow the area so that ordinary wooden doors could be used. Experience has shown that there is no danger of scattered radiation leaking around the entrance maze. It would be possible to decrease the thickness of the floor and the ceiling by placing the required thickness only directly over and under the machine and scaling down to thickness as one extended at an angle from the position of the machine.

There is soon to be a report of the National Committee on Radiation Protection Subcommittee on "Maximum Permissible Exposure from External Sources of Radiation". This handbook is being prepared under the chairmanship of Dr. Failla and will contain an extensive set of recommendations on the problems of the definition of an occupied area and the maximum permissible exposure. Dr. Carl Braestrup has an excellent discussion of Structural X-ray Protection in Progressive Architecture, June 1951, pages 98-101. There is an AEC report on the "Construction of Cheap Shields: A Survey" by Theodore Rockwell, III, AECD-3352, published January 16, 1950, Technical Information Service, United States Atomic Energy Commission, Oak Ridge, Tennessee. This summary reviews techniques of monolithic concrete construction using various kinds of high density ores in the concrete mix. For example, a steel aggregate can be used to obtain densities three times the normal density of concrete. A table is given of the characteristics of hematite, barytes, galena, iron dust, iron shot, mud shot, and various other cheap aggregates. The construction problems which come up in using such aggregates are discussed in detail. G. W. Morgan of the Isotopes Division, AEC, has published an article which gives some simple derivations of the basic formulas which are used in determining dosage rates and shielding values for both beta and gamma radiation. A considerable amount of data is given in tabular and graphic form on the shielding values of the most commonly used shielding materials. This is published as Isotopes Division Bulletin-4, November 1948, under the title, "Some Practical Considerations in Radiation Shielding". Balderston, J. L., Taylor, J. J., and Baucker, G. J. have published "Nomograms for the Calculation of Gamma Shielding", November 15, 1948, AECD-2934. Nomograms were given in this paper for the calculation of shielding required for gamma ray sources at various geometries and for sources subtending small angles. The advantages and errors involved in using these nomograms are discussed and the basic equations used in drawing the graphs are described in detail. M. H. Hull discusses the "Penetration of Gamma Rays Through Thick Layers" in Physical Reviews, Vol. 73, pp. 852-62, 1948. Hull discusses the degradation of energy of photons by scatter as they pass through a medium. The basic principles of shielding nuclear radiations primarily as they apply to nuclear reactors of including the shielding for gamma rays is given in "The

Shielding of Nuclear Reactors", M. L. Goldberger in the Science and Engineering of Nuclear Power, Vol. 2, pp. 196-206, 1947-8, March 18, 1947, AEC File No. NP-159. The very interesting problem of divergents on the simple exponential absorption law of gamma rays in air, water, iron shot, and lead shot are given in a report on Nuclear Shielding Studies: II Gamma Ray Ionization in Spherical Geometry; Technical Report 22 by Jules S. Levin, John W. Weil, and Clark Goodman. AEC File No. NP-875, June 15, 1949. The problem of the attenuation of gamma rays in dust, voids, and various wide-angle offset bends in concrete shields are discussed in AEC File No. NP-3370 by Clark Goodman and T. S. Gray, December 31, 1950. A detailed study of the gamma ray transmission through both finite slabs and large thicknesses of heavy materials is given by Glenn H. Teedles in "Gamma Ray Transmission Through Finite Slabs", AECD-3239, July 23, 1951 and T-155 (Rand, June 8, 1950).

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TABLE I

DOSE RATE REDUCTION PRODUCED BY DISTANCE

Distance Meters	Distance Ft.	Distance Factor (D)	Distance Meters	Distance Ft.	Distance Factor (D)
3		9.3	10		110
	10	9.6		35	125
4		17	15		260
	15	22		50	270
5		26	20		480
	20	40	25		790
7		52		100	1250
	25	62	50		4100
8		68		200	6600
	30	89	100		27000
				400	56000

1136188

TABLE II

Thickness of Protective Barrier for High Energy Gamma Radiation

When the exposure rate is 25 r/min at one meter from the source this table shows the thickness of lead, marble or concrete required to reduce the radiation to the maximum permissible level (0.3 r/week) so that a person could work 48 hours per week directly in the path of the beam ten to thirty feet from the source.

Distance from Source to Person	Gamma Rays From a Source of								
	Inches of Lead Barrier			Inches of Marble Barrier			Inches of Concrete Barrier		
	Radium	Cobalt^{60}	Cesium^{137}	Radium	Cobalt^{60}	Cesium^{137}	Radium	Cobalt^{60}	Cesium^{137}
10 feet	9	7 3/4	3 3/4	36 1/2	33 3/4	26 1/2	42	38 1/4	30 1/4
15 feet	8 1/4	7	3 1/2	34 1/2	30 3/4	24 1/2	39	35 1/4	28 1/4
20 feet	7 1/2	6 3/4	3 1/4	32	29 1/4	23	36 1/2	33 1/4	26 1/4
30 feet	6 3/4	6 1/4	3	29 1/2	26 3/4	21	33 1/2	30 3/4	24 1/4

1136189

TABLE III

Relative Lead Equivalence of Marble and Concrete at Various Radiation Energies

Where the required barrier is 1 inch thickness of lead the table shows the required thickness of marble and concrete. At higher energies marble and concrete become increasingly more effective but at lower energies they are less effective in stopping radiation.

	Energy in kev						
			Cesium			Cobalt	
	200	500	661	800	1000	1200	2000
Inches of Marble	36 1/2	8 3/4	7	5 1/2	5	4 1/2	4 1/2
Inches of Concrete	41 1/2	10	8	6 1/4	5 1/2	5	5

The thickness of marble required is roughly 0.88 that of concrete.

1136190

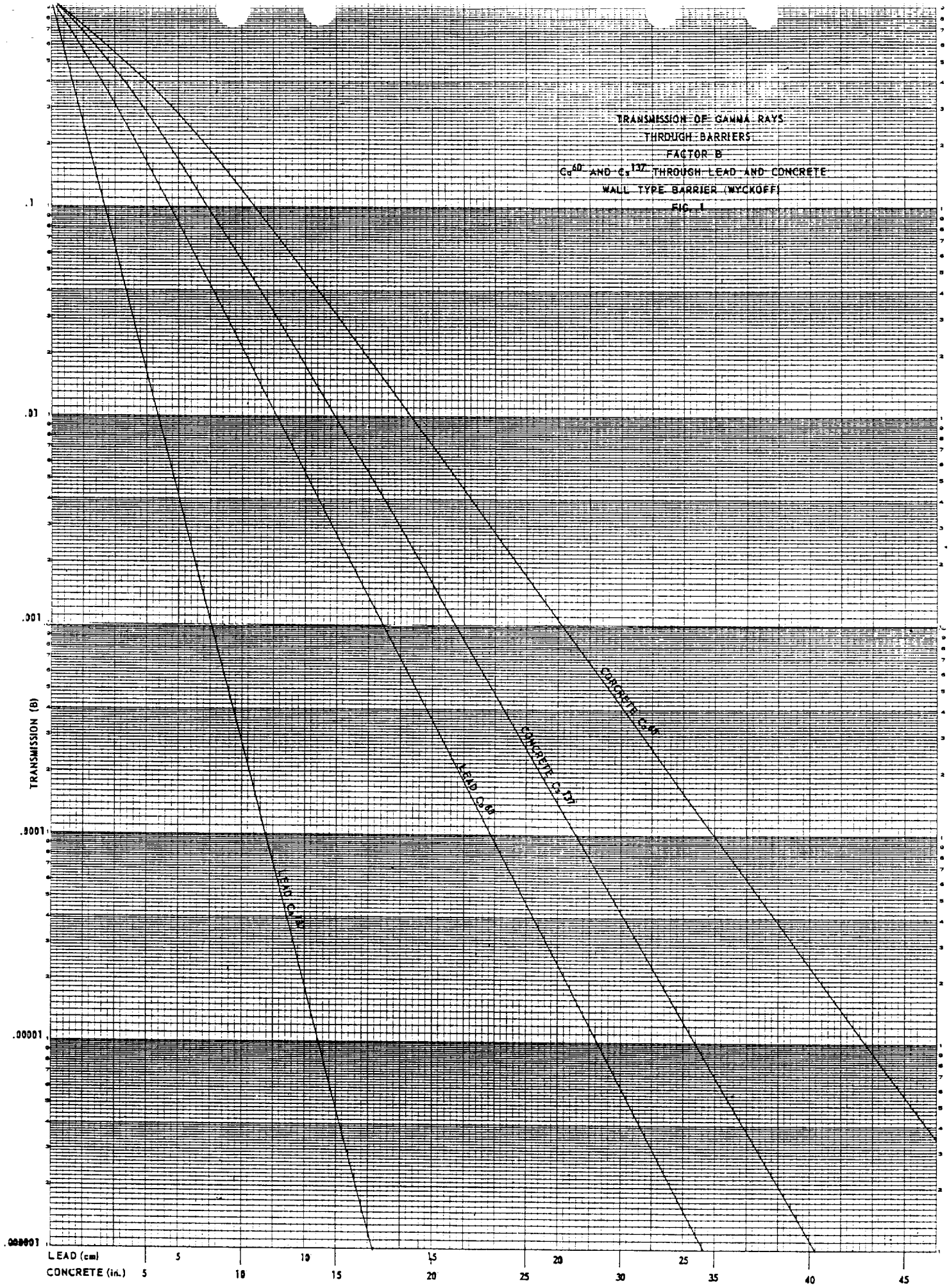
TABLE IV

Relative Lead Equivalence of Marble and Concrete at Diagnostic X-ray Tube Potentials

If a thickness of 1/64 inch of lead is required for protection from an x-ray machine operating at 150 kvp then 1.29 inches of marble will give the same degree of protection. At these very low radiation energies marble and concrete are much less efficient in stopping radiation than they are at higher energies.

Thickness of Lead Inches	Tube Potential 150 kvp		200 kvp	
	Marble Inches	Concrete Inches	Marble Inches	Concrete Inches
1/64	1.29	1.50	1.22	1.38
1/32	2.28	2.60	2.13	2.44
3/64	3.39	3.86	3.15	3.58
1/16	4.21	4.80	3.94	4.49
5/64	5.20	5.91	4.84	5.51
3/32	6.02	6.81	5.55	6.34
7/64	7.13	8.03	6.54	7.44
1/8	7.99	9.06	7.32	8.35
9/64	8.82	10.00	8.11	9.25
5/32	9.69	11.02	9.02	10.24

1136191


TRANSMISSION OF GAMMA RAYS
THROUGH BARRIERS
FACTOR B
Co^{60} AND Cs^{137} THROUGH LEAD AND CONCRETE
WALL TYPE BARRIER (WYCKOFF)
FIG. 1
TRANSMISSION (B)
.1
.01
.001
.0001
.00001
.000001
CONCRETE Co 60
CONCRETE Cs 137
LEAD Co 60
LEAD Cs 137
LEAD (cm)
5
10
15
20
25
CONCRETE (in.)
5
10
15
20
25
30
35
40
45

1136192

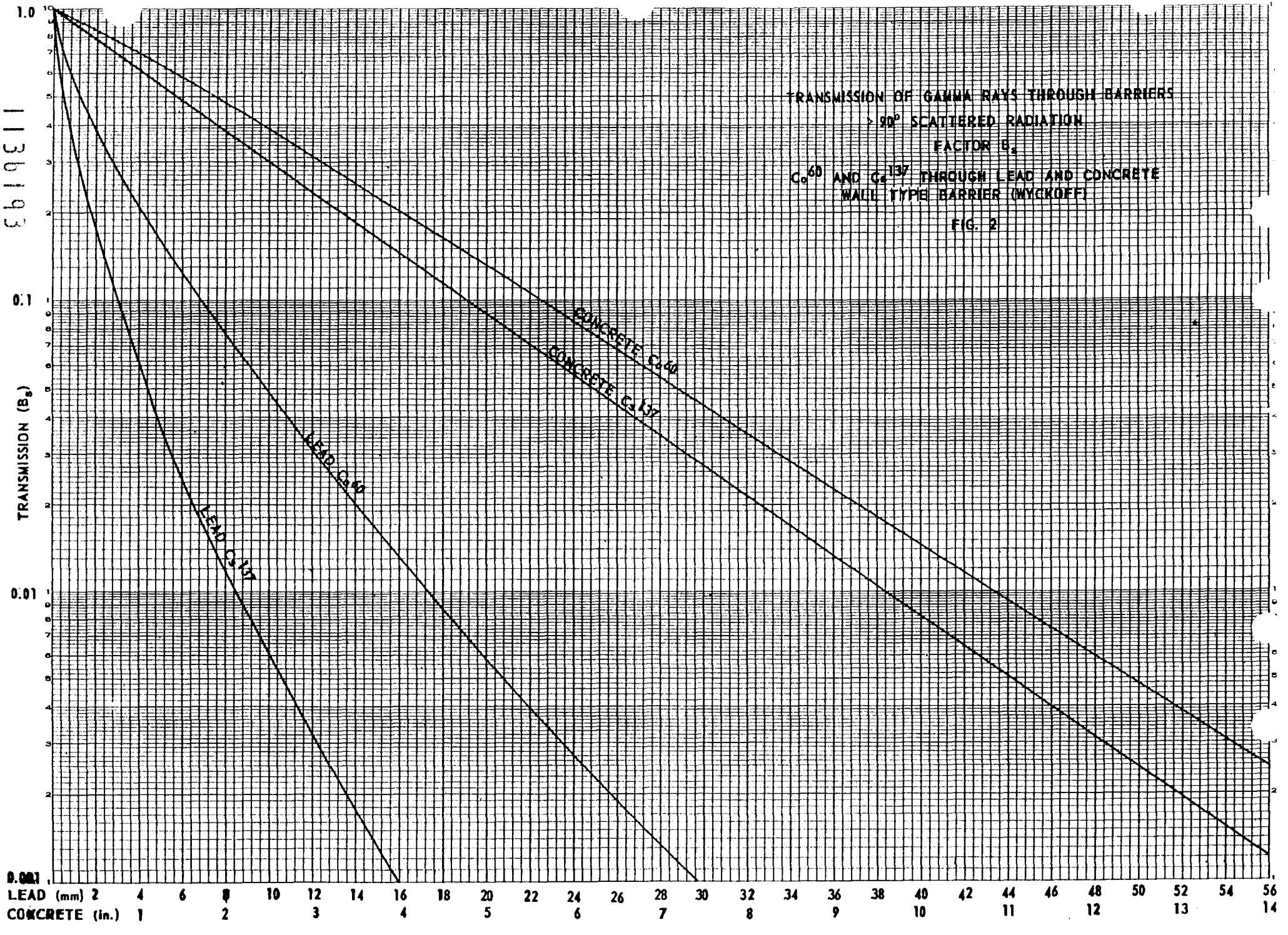

TRANSMISSION OF GAMMA RAYS THROUGH BARRIERS
> 90° SCATTERED RADIATION
FACTOR B_s
Co^{60} AND Cs^{137} THROUGH LEAD AND CONCRETE
WALL TYPE BARRIER (WYCKOFF)
FIG. 2
CONCRETE Co60
CONCRETE Cs137
LEAD Co60
LEAD Cs137
TRANSMISSION (B_s)
1.0
0.1
0.01
0.001
LEAD (mm) 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56
CONCRETE (in.) 1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIG. 3 EFFECT OF EXPOSURE RATE (U) ON BARRIER THICKNESS

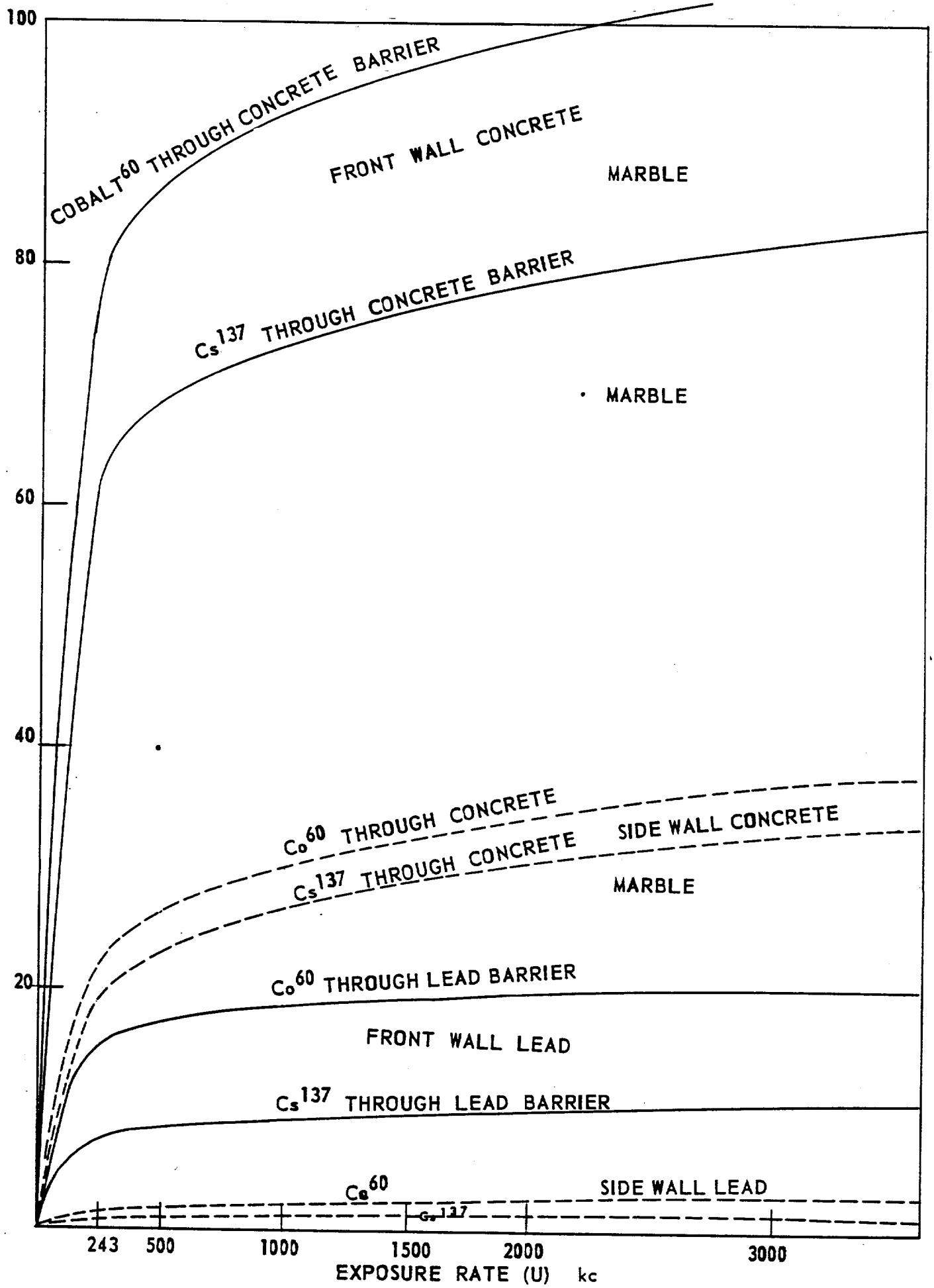


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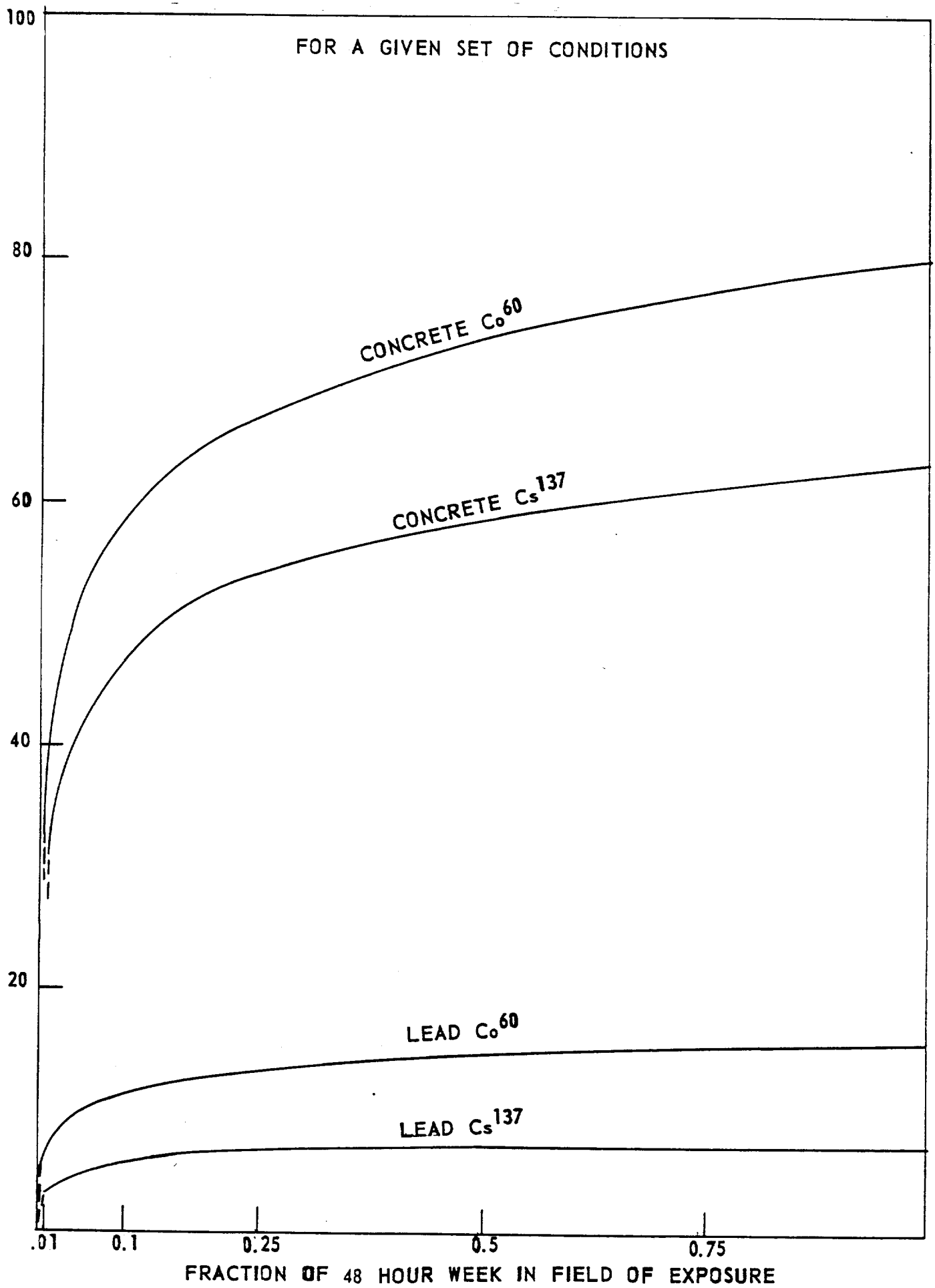
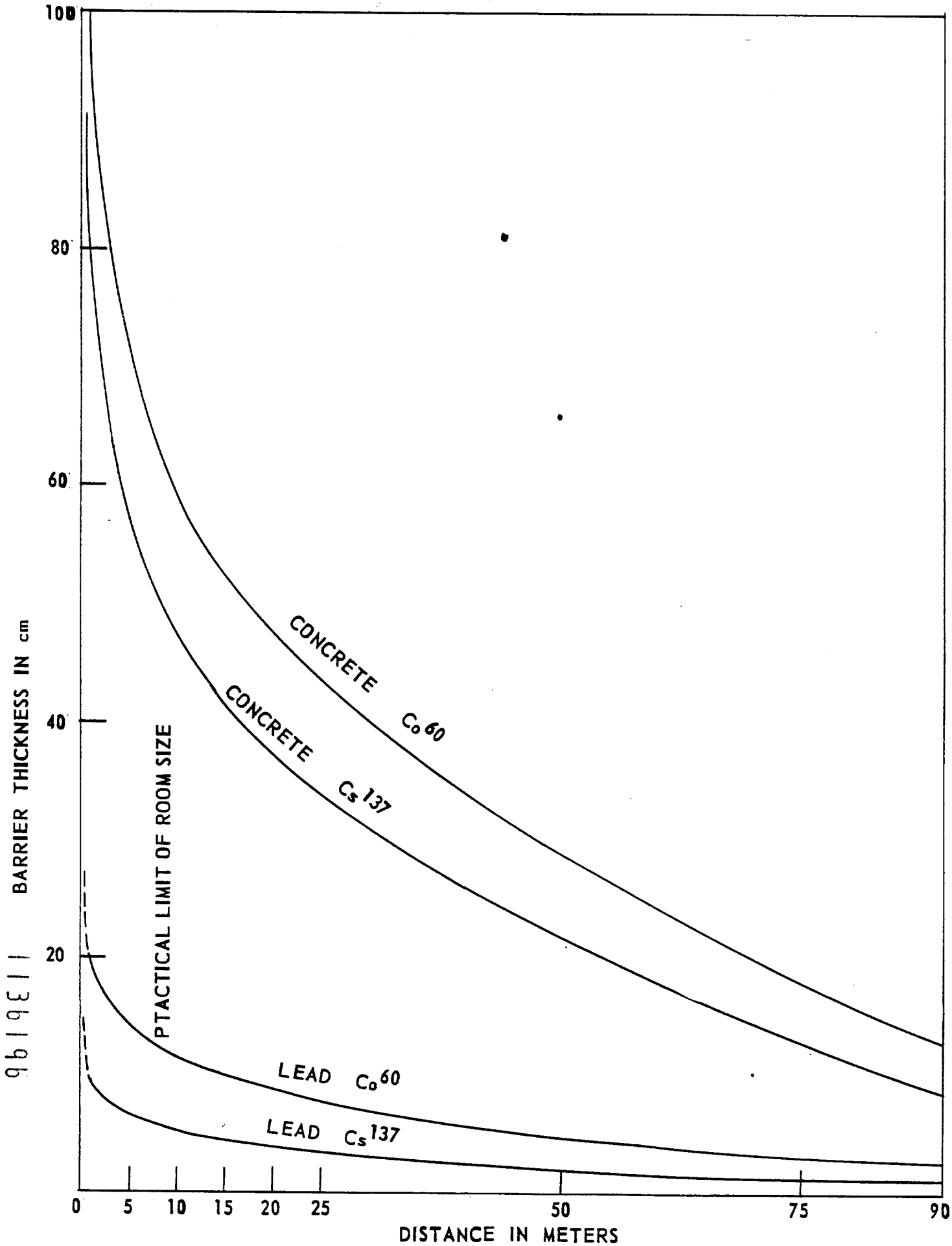
FIG. 4 THE EFFECT OF THE FRACTION OF TIME IN FIELD OF EXPOSURE (T) ON BARRIER THICKNESS



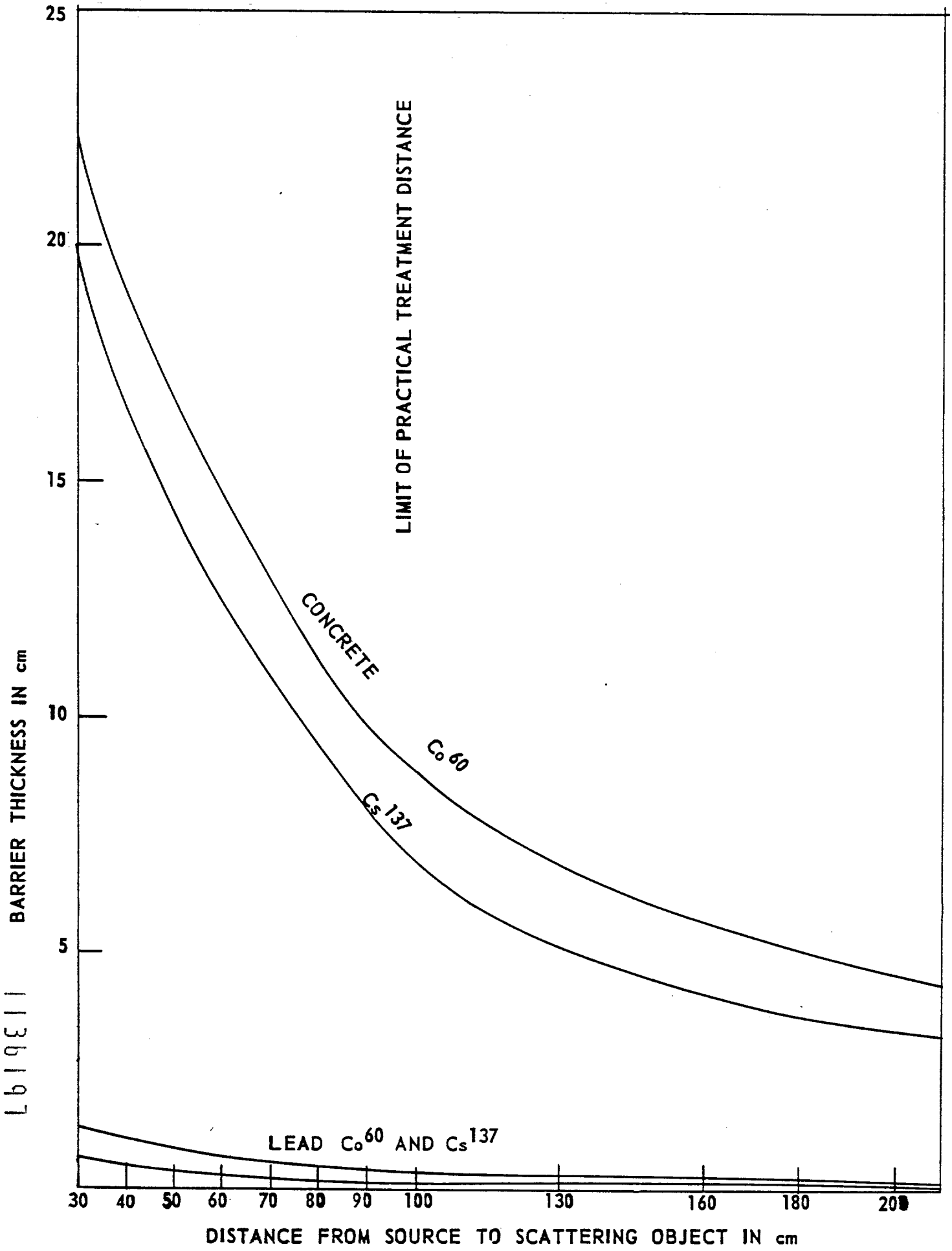
1136195

FIG. 5 THE EFFECT OF DISTANCE (D) ON BARRIER THICKNESS FOR A GIVEN SET OF STANDARD CONDITIONS



1136196

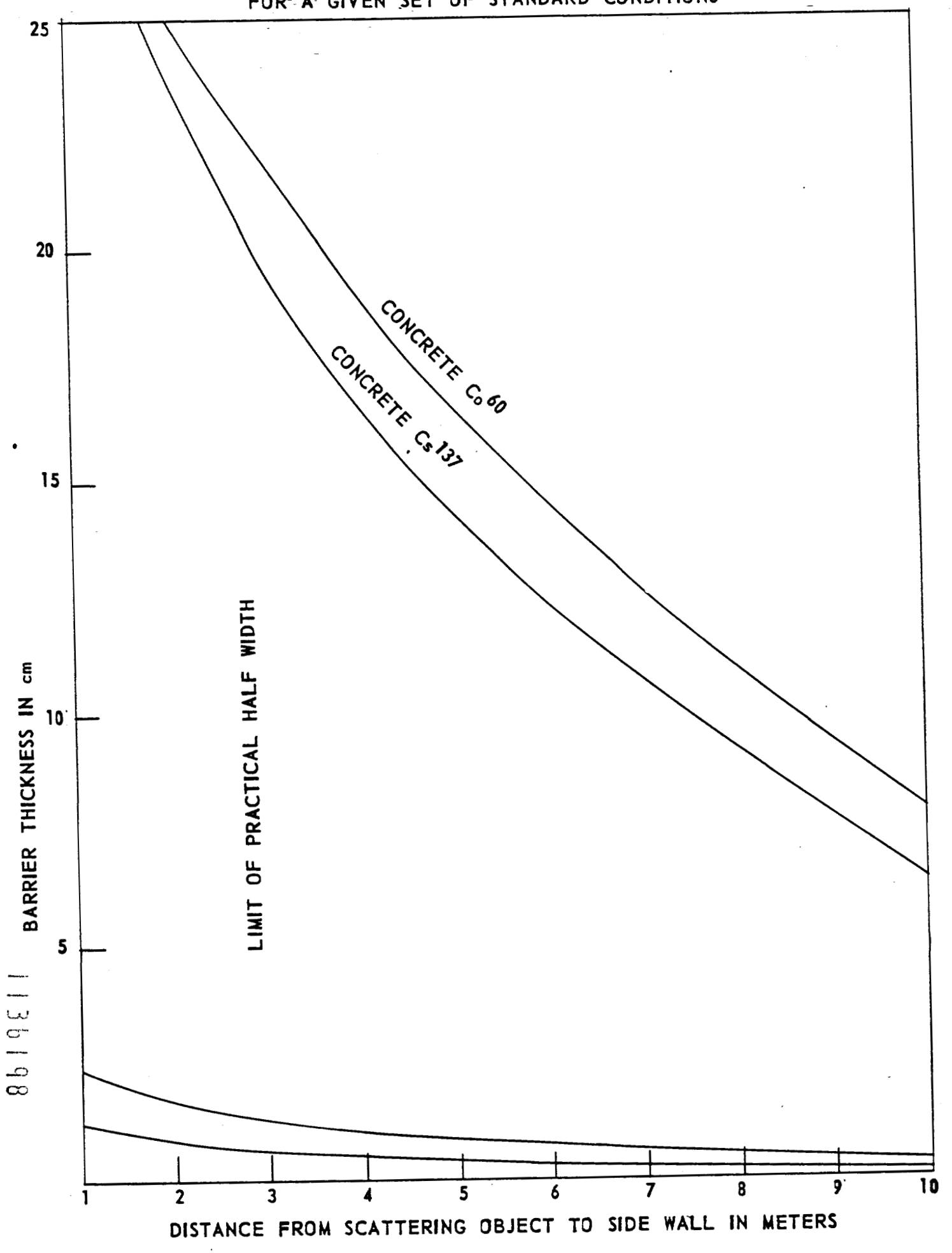
FIG. 6 THE EFFECT OF TREATMENT DISTANCE (d) ON BARRIER THICKNESS FOR A GIVEN SET OF STANDARD CONDITIONS



1136197

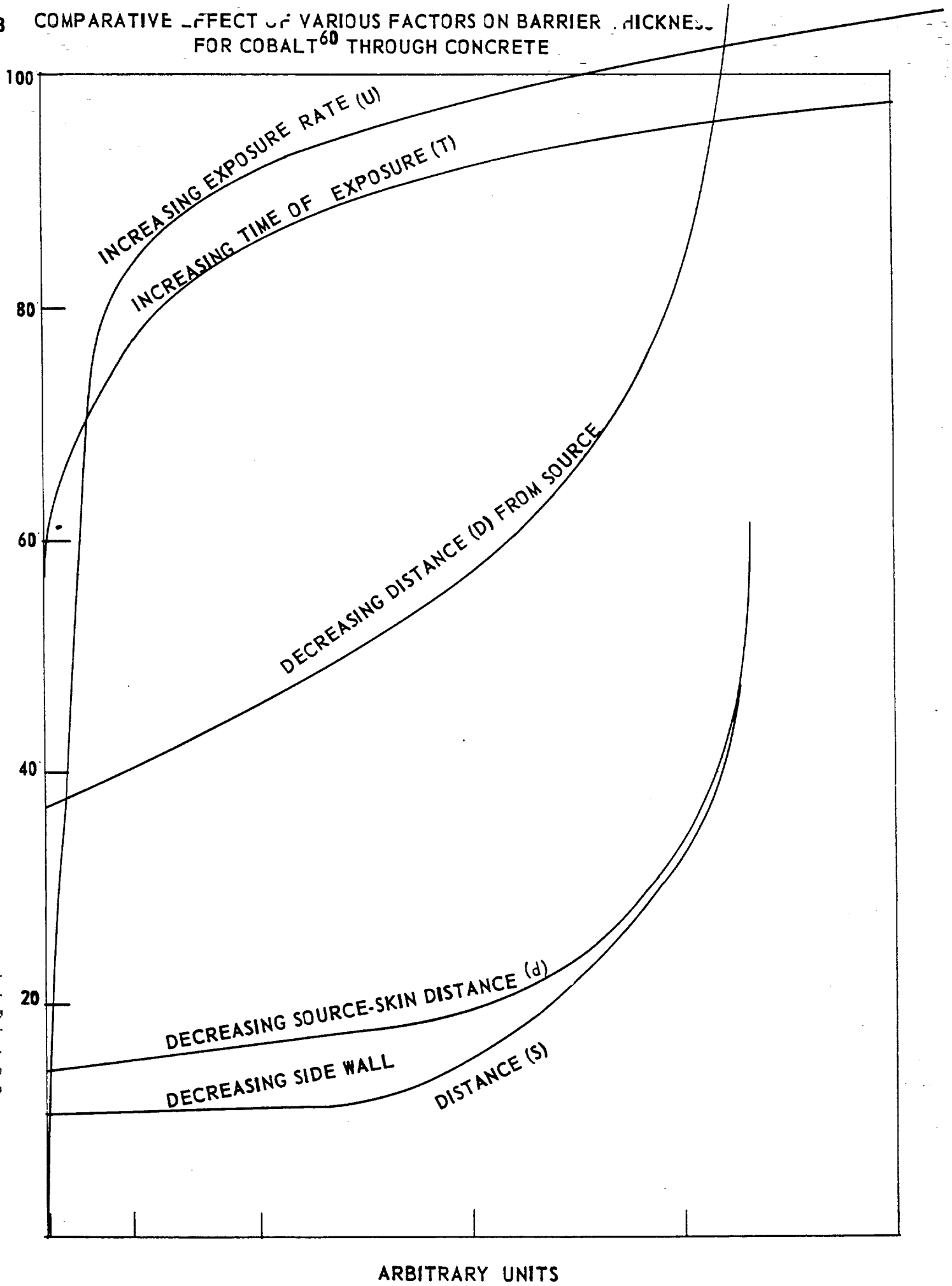
FIG. 7

THE EFFECT OF ROOM WIDTH (S) ON BARRIER THICKNESS
FOR A GIVEN SET OF STANDARD CONDITIONS



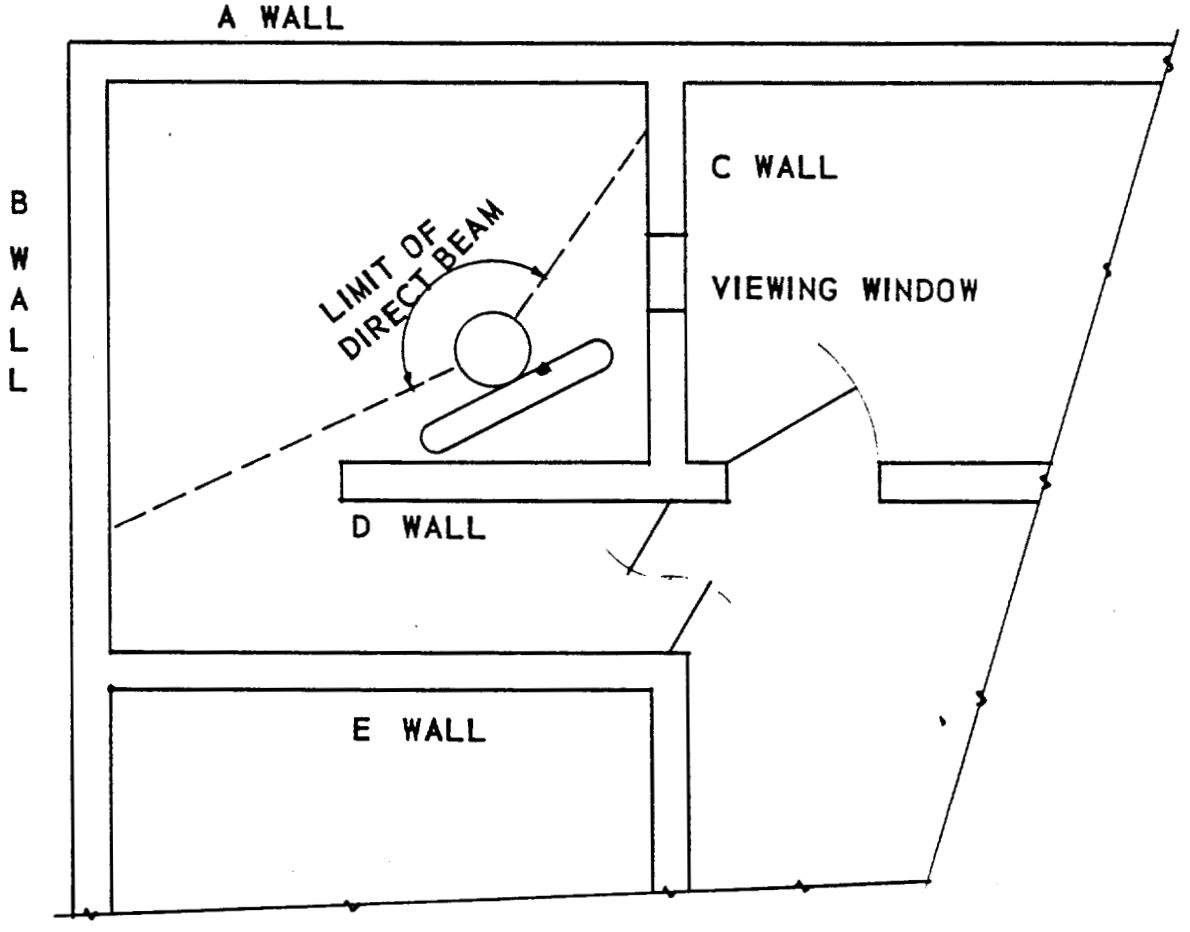
1136198

FIG. 8 COMPARATIVE EFFECT OF VARIOUS FACTORS ON BARRIER THICKNESS FOR COBALT^{60} THROUGH CONCRETE



1136199

FIG. 9



1136200

DESIGN OF TELETHERAPY ROOM
USED FOR EXAMPLE
IN TEXT

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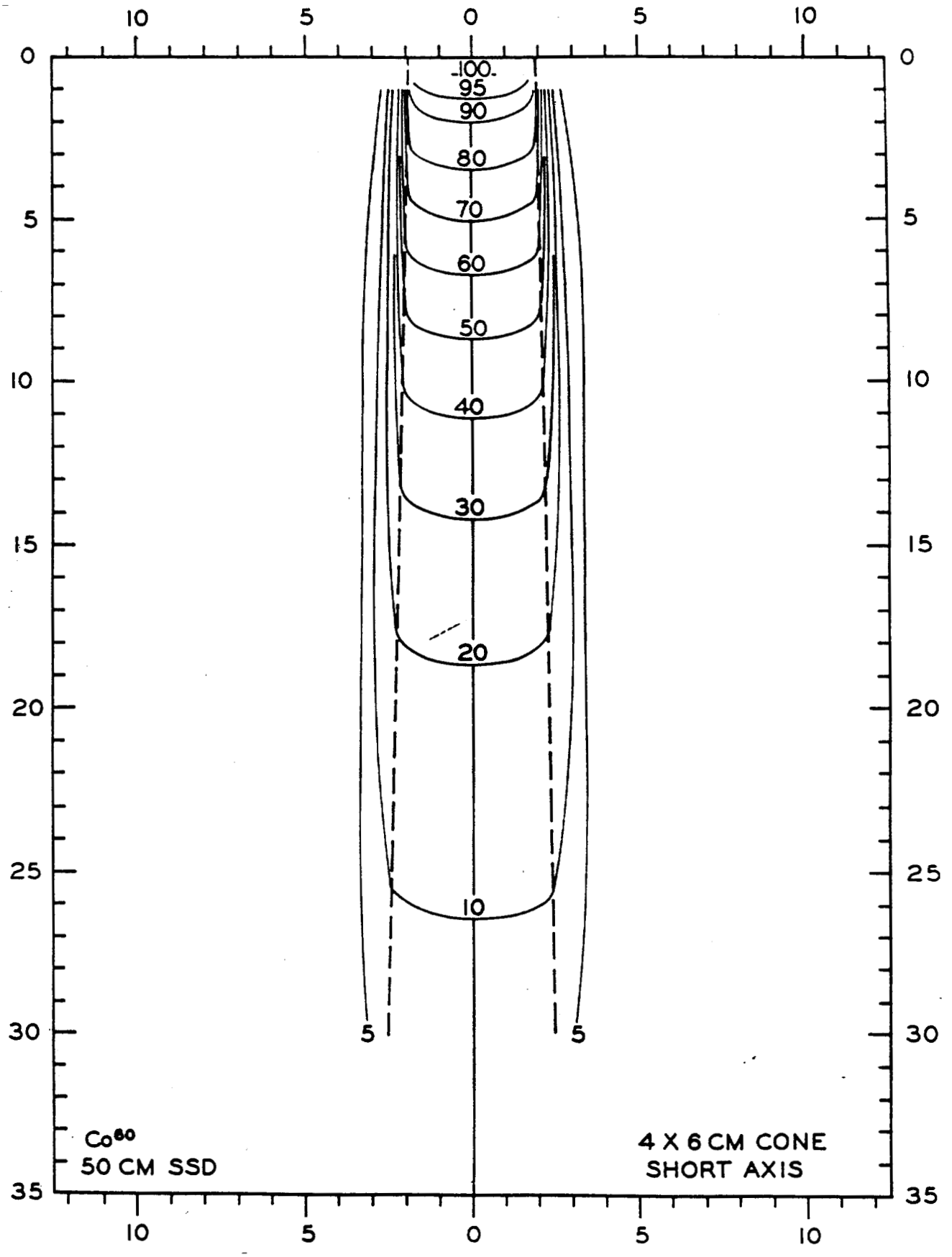
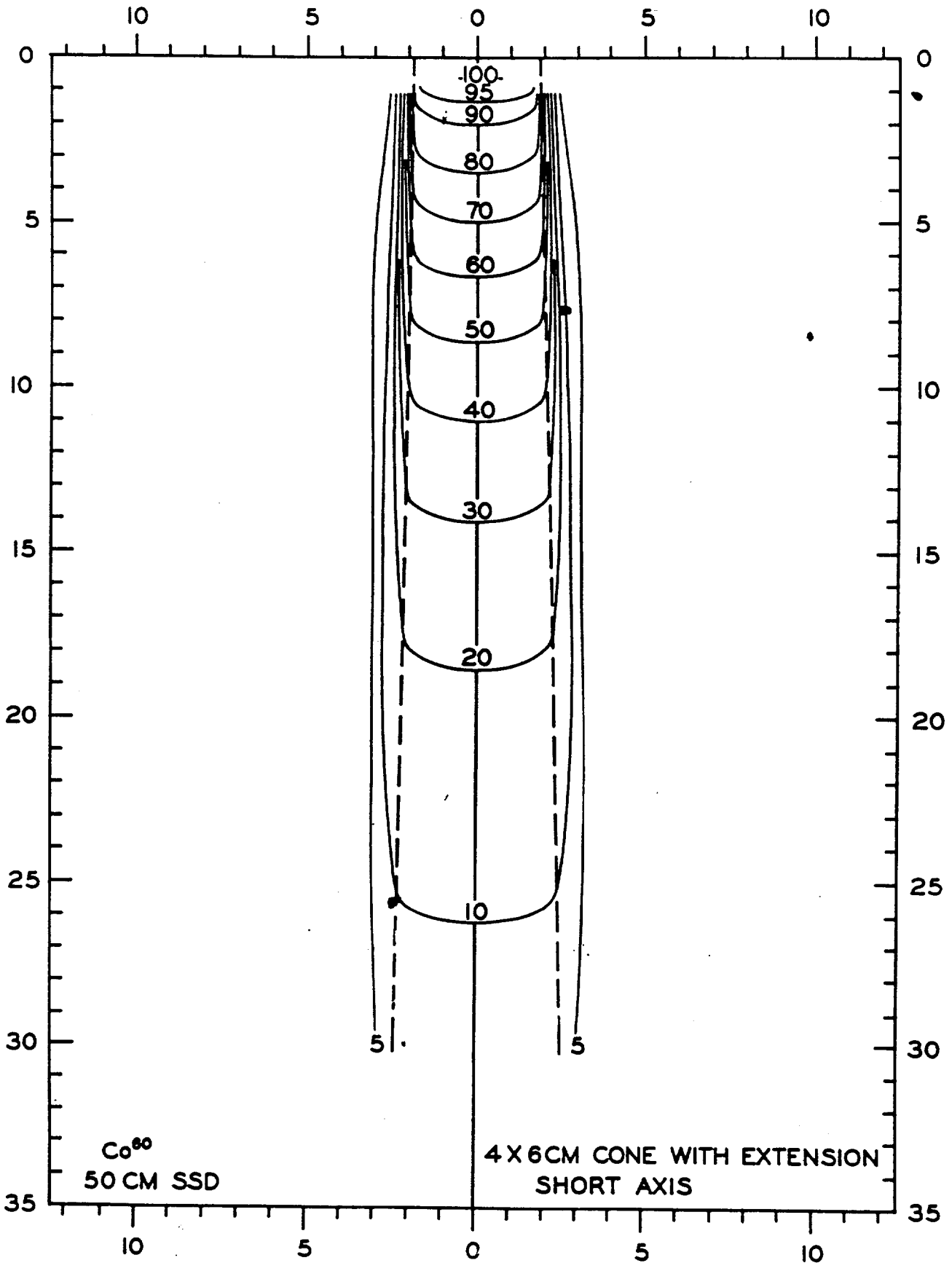
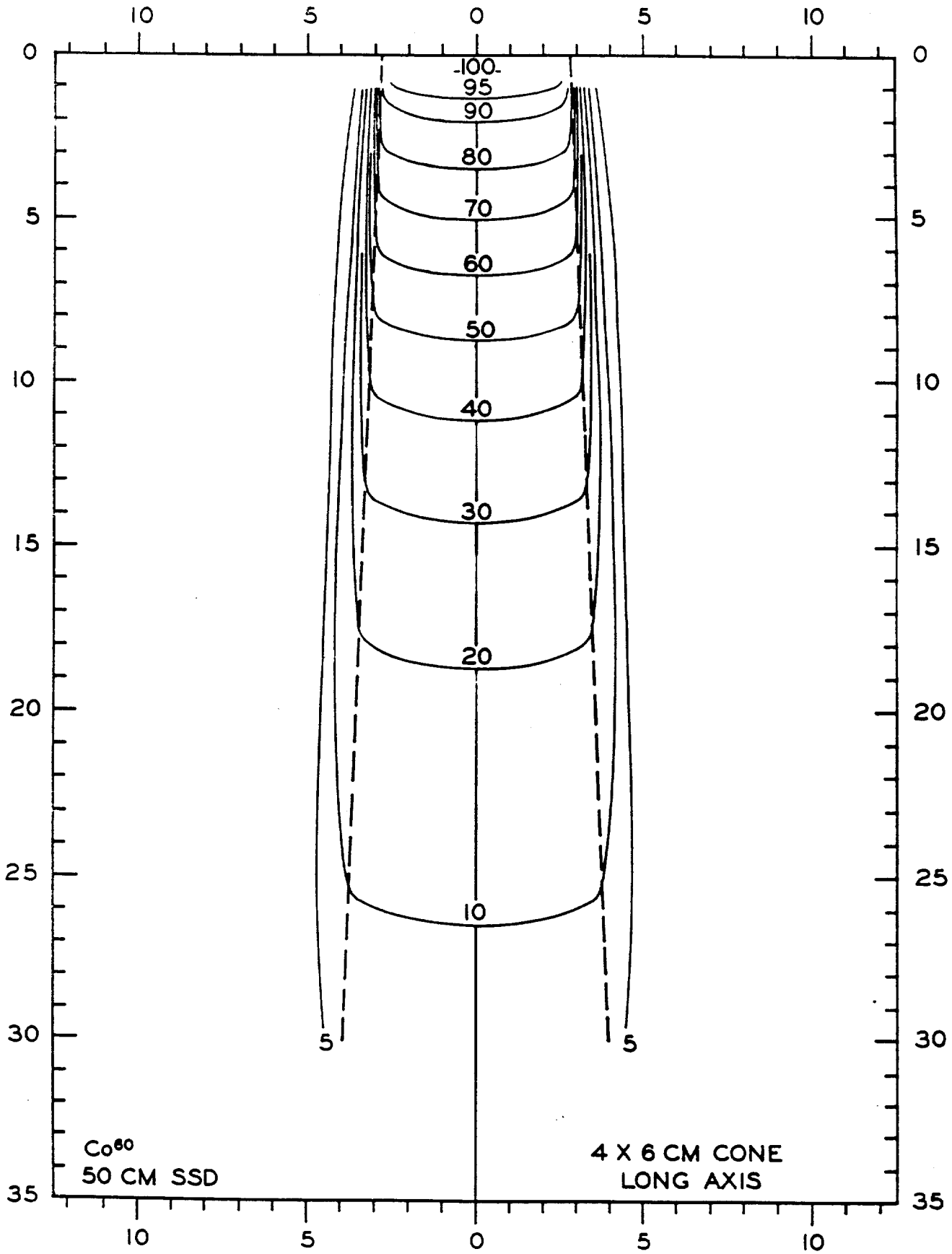


AEC, Oak Ridge, Tenn. 5-28-53-100-W-21637

1136201


100
95
90
80
70
60
50
40
30
20
10
5
5
Co60
50 CM SSD
4 X 6 CM CONE WITH EXTENSION
SHORT AXIS

1136202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5
10
15
20
25
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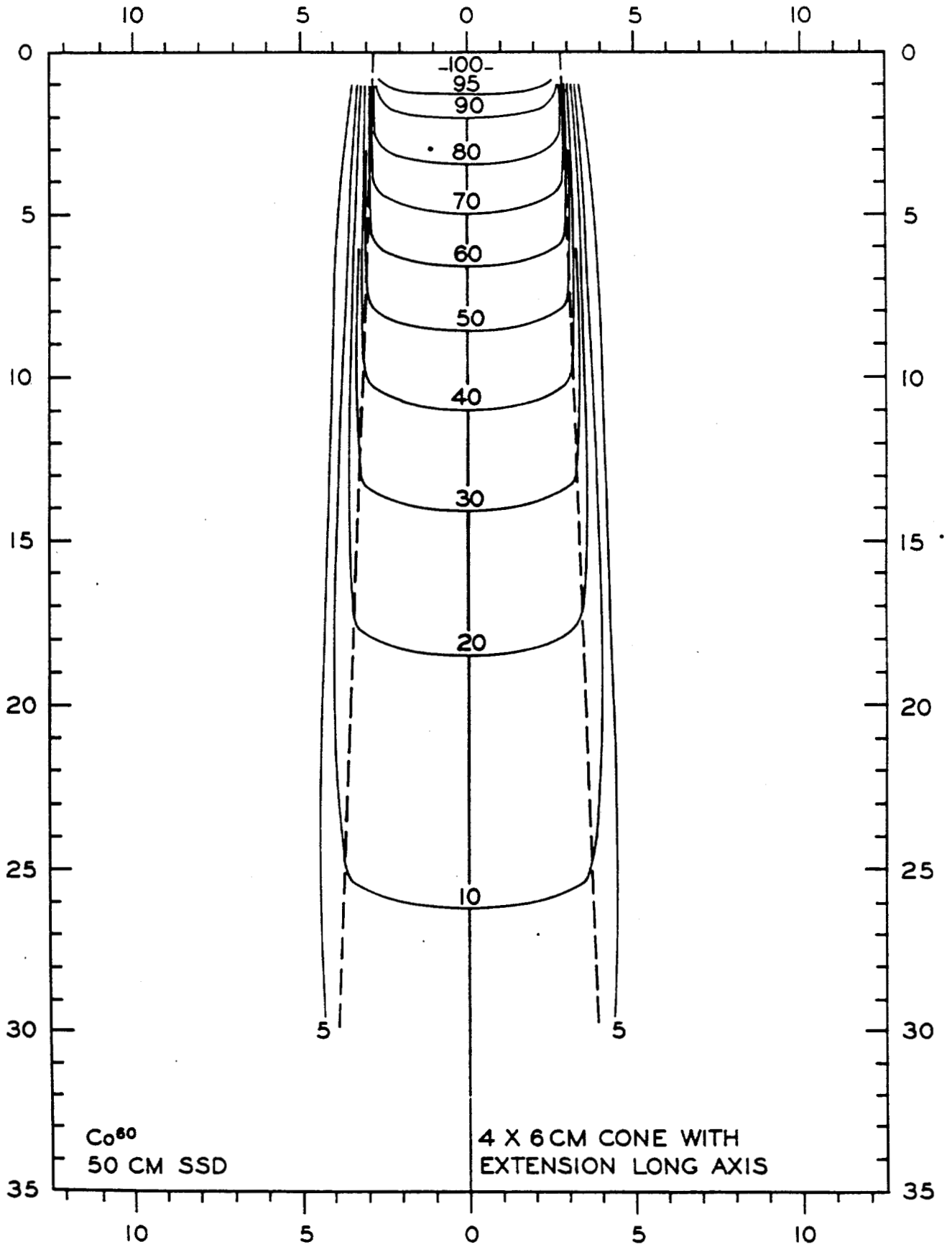
35
-100-
95
90
80
70
60
50
40
30
20
10
5
5
Co60
50 CM SSD
4 X 6 CM CONE
LONG AXIS

1136203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20
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-100-
95
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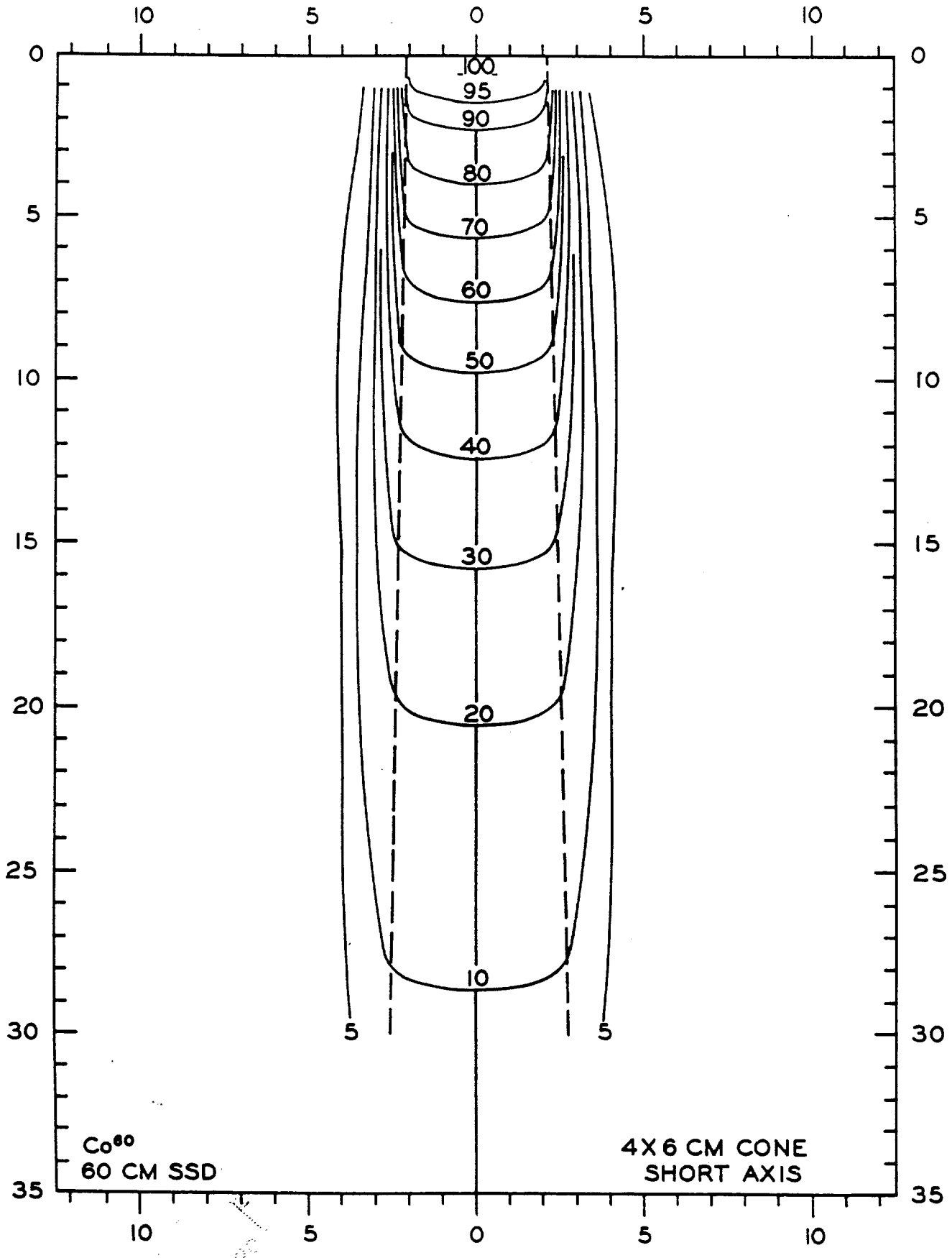
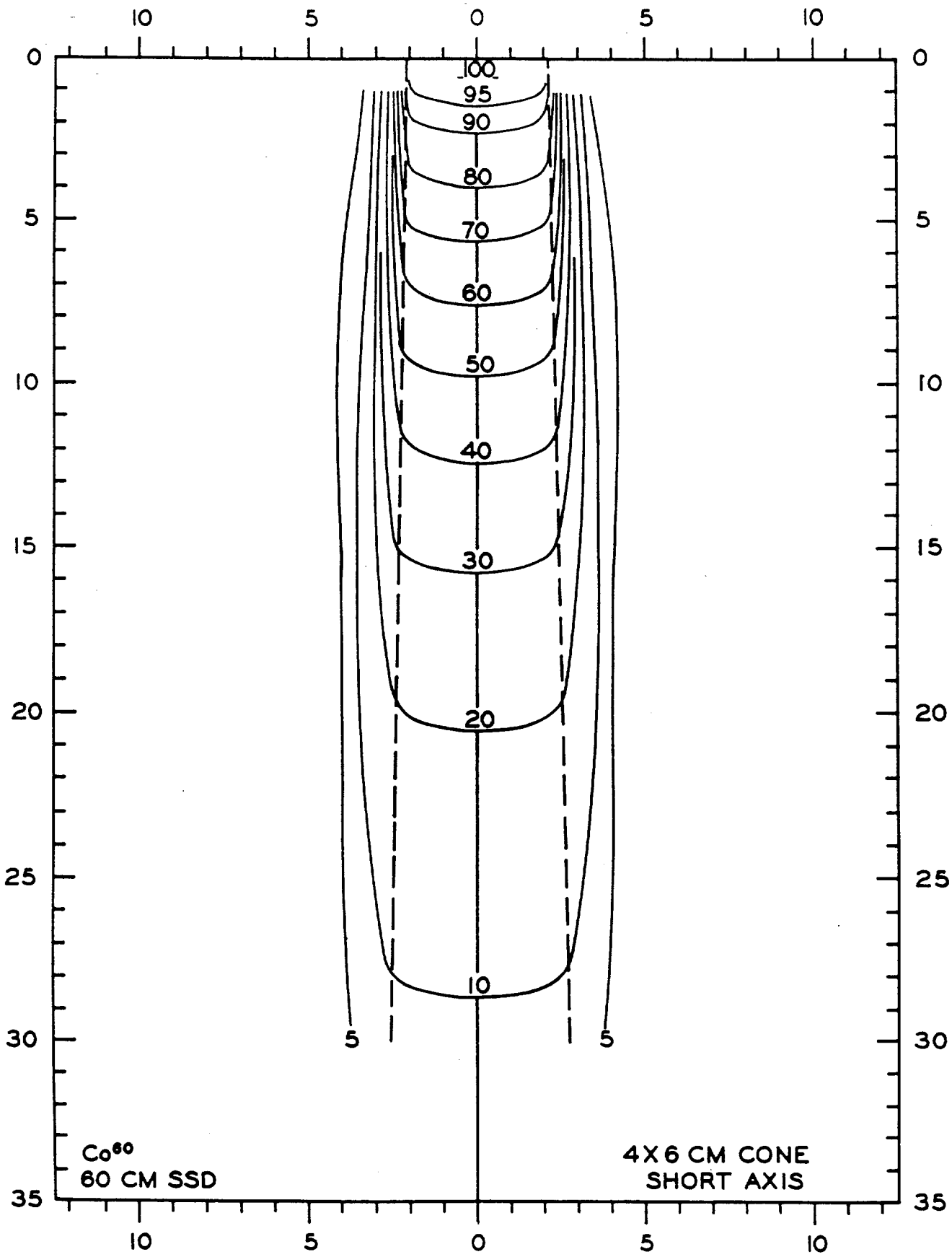
60
50
40
30
20
10
5
5
Co60
50 CM SSD
4 X 6 CM CONE WITH
EXTENSION LONG AXIS

1136204


100
95
90
80
70
60
50
40
30
20
10
5
5
Co60
60 CM SSD
4X6 CM CONE
SHORT AXIS

1136205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95
90
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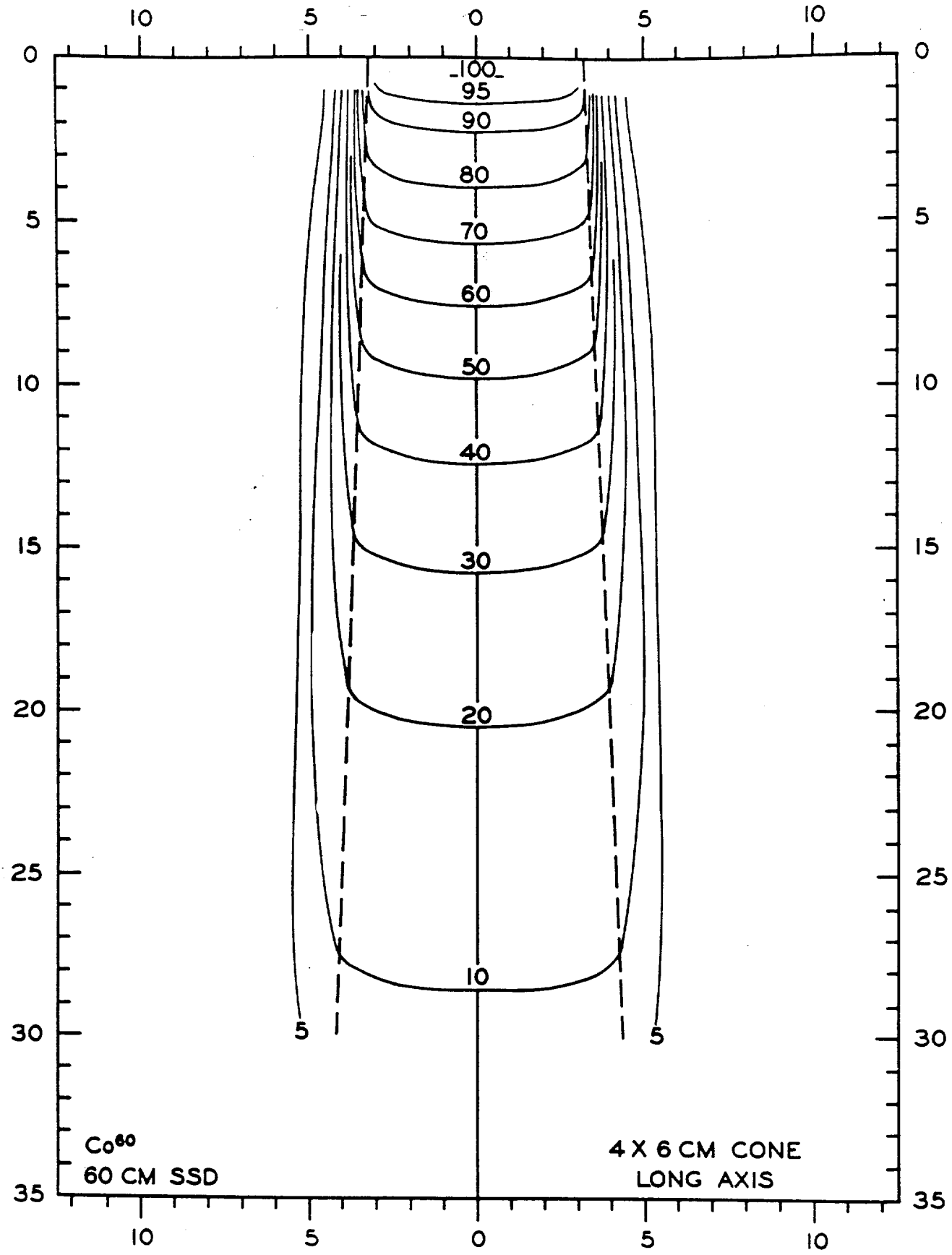
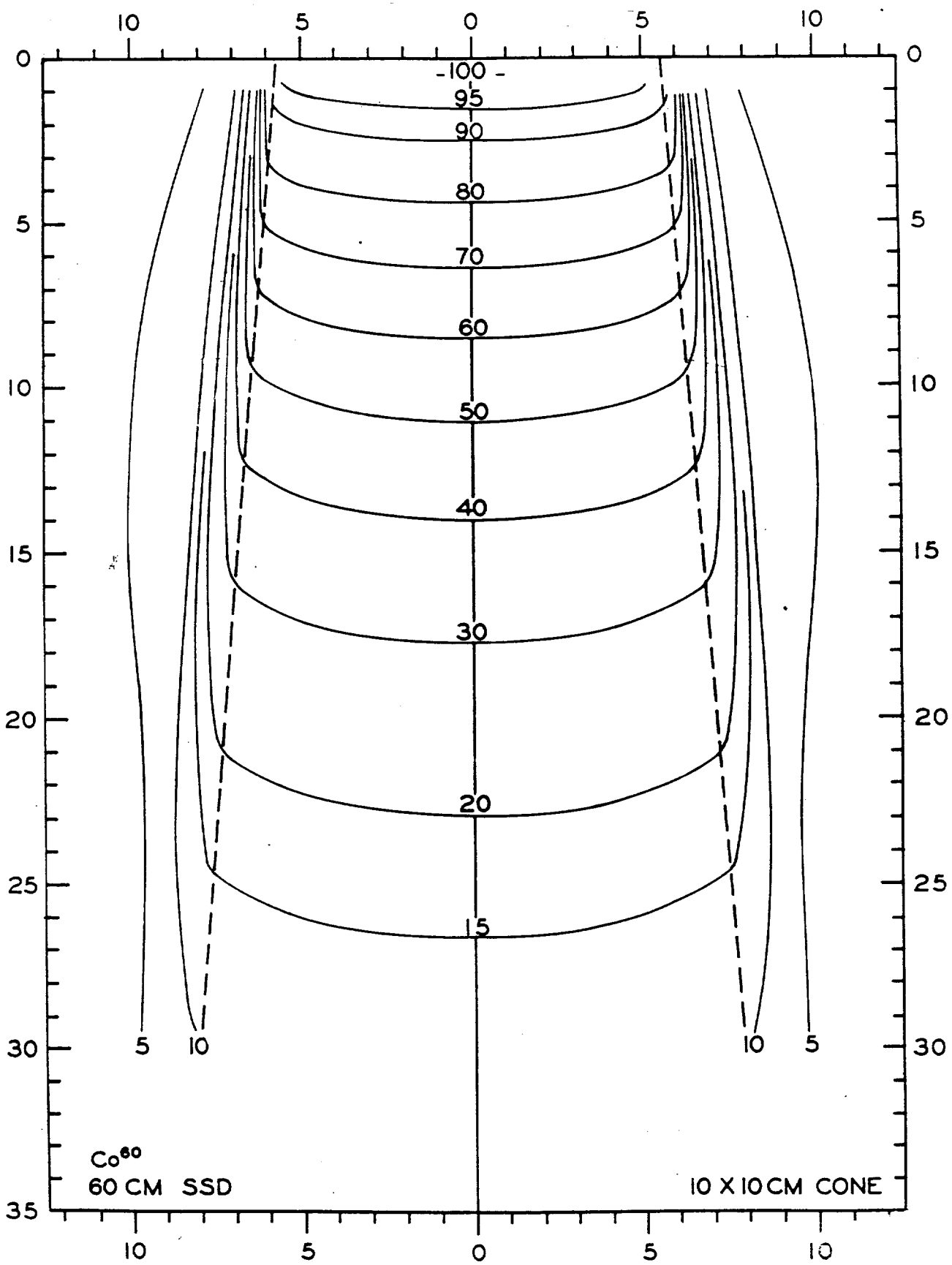
70
60
50
40
30
20
10
5
5
Co60
60 CM SSD
4X6 CM CONE
SHORT AXIS

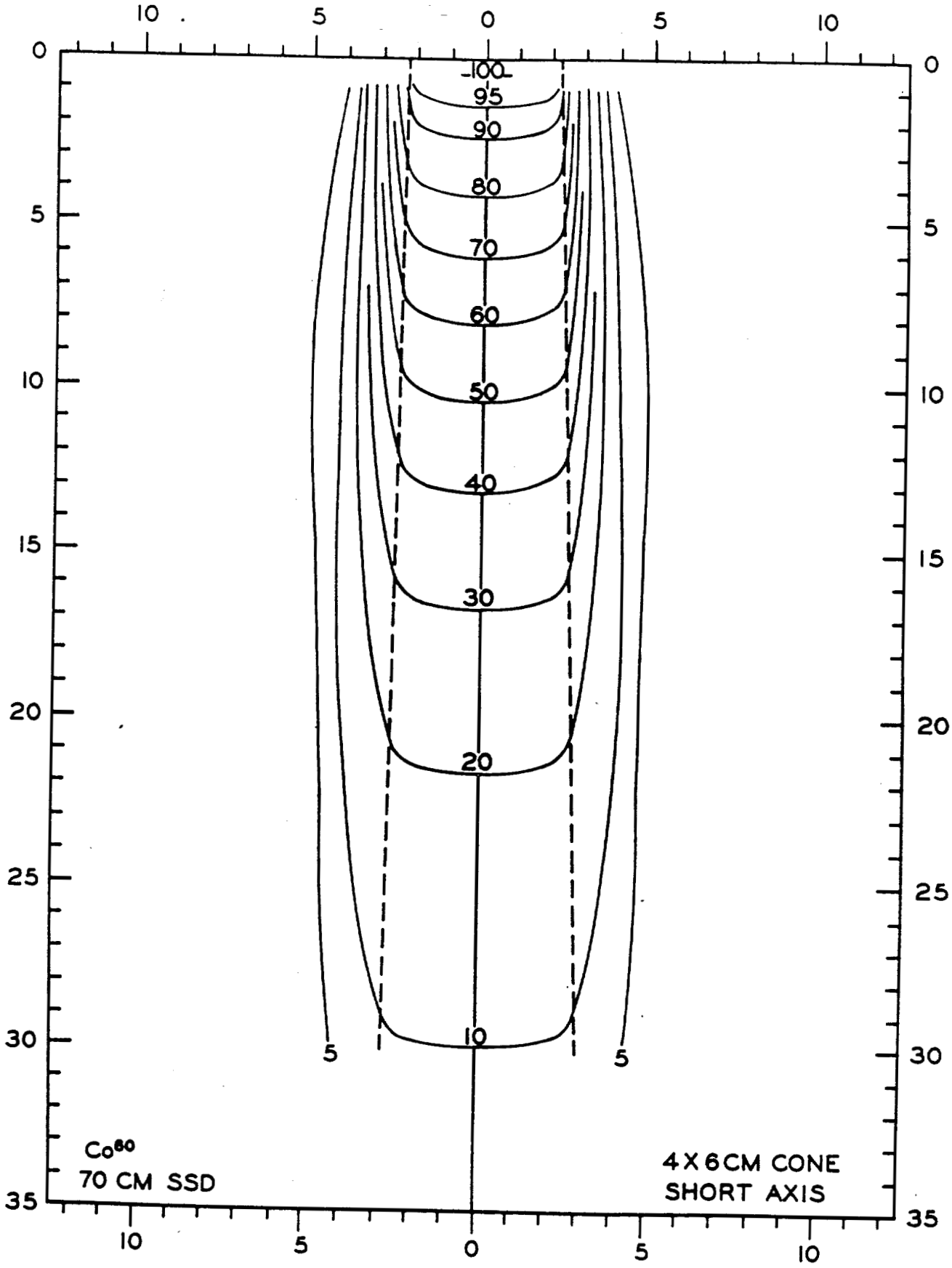
113620b


100
95
90
80
70
60
50
40
30
20
10
5
5
Co60
60 CM SSD
4 X 6 CM CONE
LONG AXIS

1136207



1136208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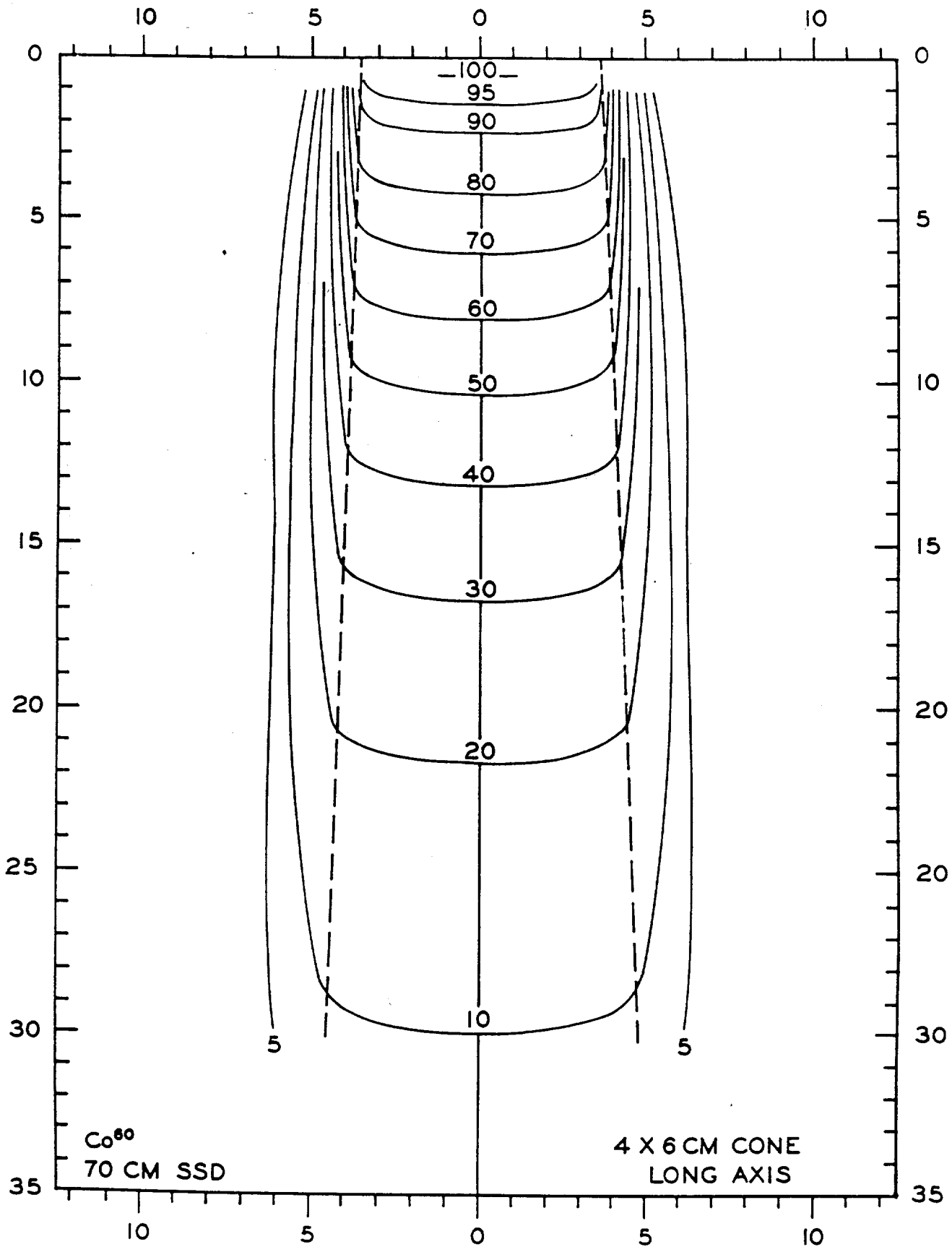
5
Co60
70 CM SSD
4X6CM CONE
SHORT AXIS

1136209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95
90
80
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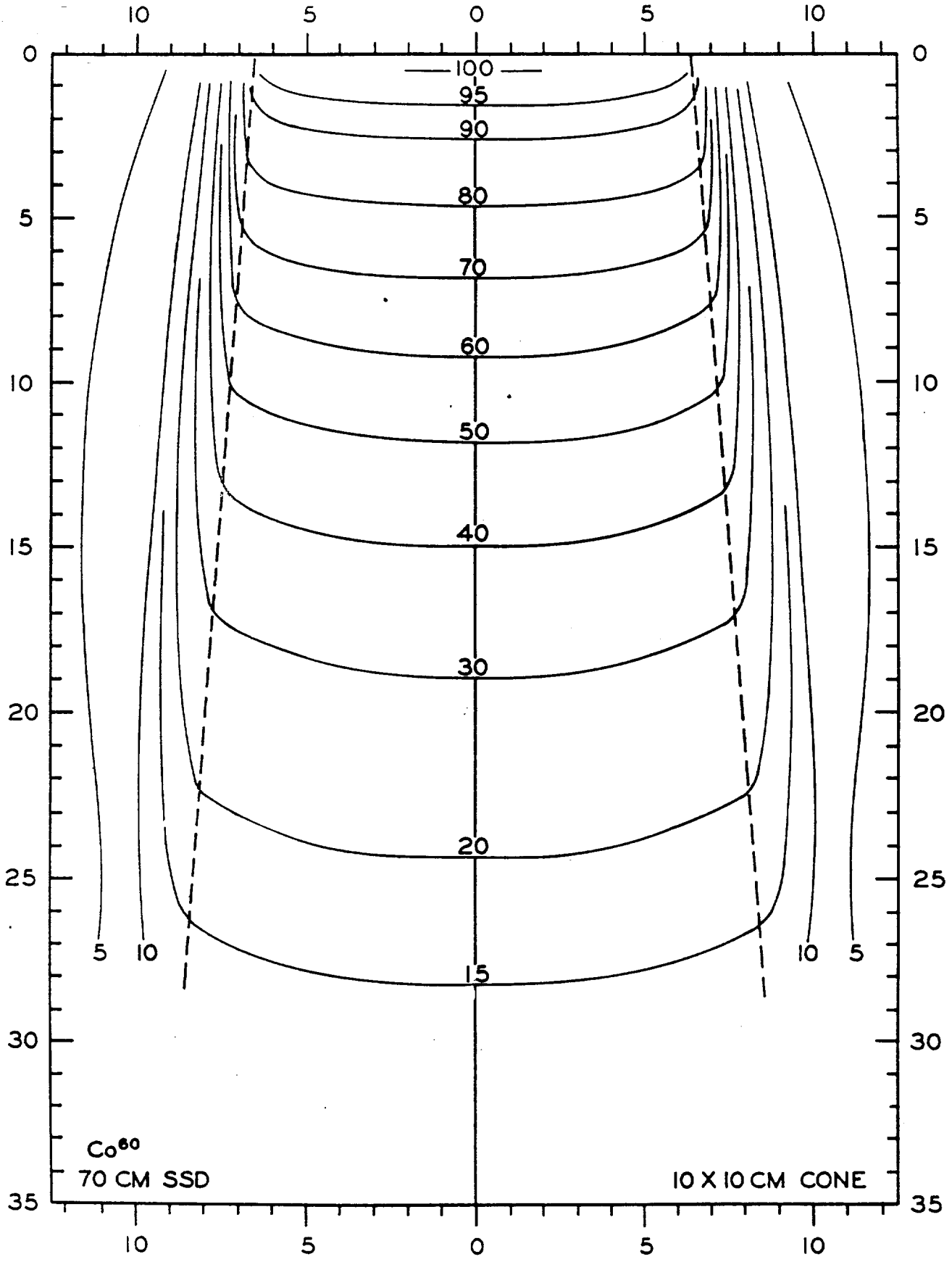
60
50
40
30
20
10
5
5
Co60
70 CM SSD
4 X 6 CM CONE
LONG AXIS

1136210



1136211

MINUTES OF THE JUNE 2ND MEETING OF SUBCOMMITTEE NO. 5
CLINICAL PROGRAM SUBCOMMITTEE

MEMBERS PRESENT: Dr. C. C. McClure, Vanderbilt University
Dr. Robert Andrews, Bowman Gray School of Medicine
Dr. Gilbert H. Fletcher, M.D. Anderson Hospital
Dr. H. B. Hunt, University of Nebraska
Dr. H. Stephen Weems, Emory University
Dr. Isadore Meschan, University of Arkansas
Dr. Sidney Rubenfeld, New York University Bellevue Medical Center
Dr. Herbert D. Kerman, University of Louisville
Dr. Marshall Brucer, ORINS Medical Division

The June 2nd Meeting of Subcommittee No. 5, Clinical Program Committee, met at the New York University, New York City. The meeting was conducted by Dr. Sidney Rubenfeld, Chairman.

Dr. Rubenfeld opened the meeting with a question to clarify whether this subcommittee is to be concerned with the therapy program for both the high curiage and low curiage therapy units. Dr. Brucer stated that it was his opinion that this was the original thinking of the Teletherapy Evaluation Board at the August 8th Meeting 1952, and that this opinion was shared with Subcommittee No. 2, Small Source Design, which met on April 12, 1953. During the ensuing discussion, Dr. Fletcher wanted to know whether the cost of the small therapy unit could be kept low enough to make the unit competitive with the 250 kv X-ray unit. The Clinical Program Subcommittee was informed that Subcommittee No. 2 agreed that the unit could be competitive with a 250 kv X-ray unit providing the cost of construction of the shielding head could be maintained at $10,000 or less. Also, the subcommittee was informed that this criterion had been given to two or three commercial companies interested in designing a low curiage therapy unit.

Dr. Andrews asked if the production and availability of radioactive sources for the large teletherapy unit had changed appreciably since the last meeting of the Executive Committee. The subcommittee was informed that the availability of radioactive sources had not changed appreciably and that cobalt is available to the extent announced by the Isotopes Division for some requirements within the next year or two. Unlimited large cobalt^{60} sources will probably not be available in the near future. However, it is estimated that it will be approximately three years before cesium^{137} sources will be available for high curiage therapy machines. Dr. Andrews then asked about the production of europium sources. Data were presented to the Executive Committee showing the early work of Dr. Eastwood and his colleagues in England showing the longer half-life of europium and the later interpretation of some reactor build-up calculations by personnel at the Oak Ridge National Laboratory. The problem of europium irradiation has turned out to be an excessively complex one because of the build-up of daughter activities. ORINS has a number of sources ready for irradiation but will not send them to the reactor until the current Oak Ridge National Laboratory calculations are completed. Because of the complexity of the problem, a more detailed report will be made to the subcommittee at a later date.

1136212

Following the presentation of the data on europium, Dr. Fletcher suggested that this isotope be disregarded as a radioactive source in the current thinking of teletherapy units. The subcommittee unanimously concurred.

Dr. Fletcher requested additional information regarding the minutes of Subcommittee No. 4, Housing Design, which met on May 24th. Attention was called to the fact that the shielding design factors which were presented in the minutes of the May 24th meeting were based on the specifications in the National Bureau of Standards Handbook on Radiation Protection. Attention was called particularly to the definition of the time factor. Dr. Weems stated that the assumptions in the handbook did not always agree with the experiences of practicing radiologists. Also, Dr. Andrews stated that if these requirements had to be geared to the small therapy unit, it appeared to be impractical. The subcommittee was informed that there seemed to be considerable general disagreement with the results of handbook type calculations and that Dr. Hoecker and Dr. Lofstrom of Subcommittee No. 4 are now collecting data on the actual time of exposure of X-ray units and that these data will be presented to the subcommittee on preparation of the National Bureau of Standards handbook by Dr. Marshall Brucer, who is a member of that subcommittee. Since the Executive Committee meeting, it has been learned that some changes are being made and that such changes will be available for the next meeting of the subcommittee. Also, Dr. Lofstrom of Wayne University has prepared a brief summary of his current experiences.

MAXIMAR 250

Date	Exposure reading	(hrs)
12-12-52	09021	
2-11-53	09137	116
5-13-53	09422	401
6-6-53	09489	468

Total of 25 weeks - average actual hours per week - 18.7

Department operates approximately 44 hours per week.

Monday 5/25	3 hrs	39 mins & 39 secs
Tuesday 5/26	3 hrs	37 mins & 30 secs
Wednesday	3 hrs	21 mins & 42 secs
Thursday	3 hrs	19 mins & 21 secs
Friday	2 hrs	30 mins & 30 secs

From the foregoing data, it appears that the time factor could easily be reduced to 0.5 and that when the data on the position of the beam during various therapeutic maneuvers are available, the time factor may be reduced to less than 0.1 except in the direct downward position.

In order to clarify the scope of a therapy program to be developed by this subcommittee for use with a large teletherapy unit,

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Dr. Andrews raised the question as to why the large therapy unit should have unlimited movements as now designed and offered for consideration a cheaper unit that could be designed to use an upright rotating chair, or some other method for moving the patient. A lengthy discussion followed Dr. Andrews' question. The subcommittee, without a vote, expressed a general opinion that greater advantages might be obtained by rotating the teletherapy head instead of depending upon a rotating chair. The subcommittee also was informed that Subcommittee No. 3, Rotational Methods and Procedures, were in unanimous agreement that maximum movements should be designed into the prototype unit as was stated in the original meetings of the Teletherapy Evaluation Board. Furthermore, following experiences gained in experiments with the prototype unit, it would be an easy matter for each university to eliminate the features that seemed unnecessary for the clinical program to be undertaken by that school.

Dr. Kerman pointed out that all medical schools will not agree on therapy procedures; therefore the Teletherapy Evaluation Board should work out a flexible program in which those cases that are to be treated by rotational methods could be given to medical schools who purchase a unit with complete rotational features, and those cases that are not suitable for rotational therapy could be given to schools that do not have such a unit. Dr. Hunt pointed out that some schools cannot provide adequate housing for a rotational therapy unit and he questioned whether the prepared unit is suitable for stationary installation and to be used with a rotating chair. It was pointed out that the prototype unit is designed to provide maximum freedom,or if necessary restriction of movement, for experimental purposes, and that from this prototype unit, each medical school could decide on a unit with the maximum movements designed for their specific purposes; and it was agreed that this subcommittee should not try to influence any medical school in its decision to buy a unit with any specific rotational features.

Dr. Hunt wanted to know whether the small source machine was suitable for rotational therapy. The subcommittee was informed that the Subcommittee on Small Source Design had agreed that they did not want rotational therapy with the small unit. It was pointed out that to obtain such characteristics in the small unit would increase the cost to far beyond $10,000.

Dr. Fletcher pointed out that it was not the purpose of this subcommittee to design the therapy units, but to develop a teletherapy program for using the machines that are to be available; and for the purpose of clarifying the discussion, he pointed out that the following units would be available by the end of the current calendar year: (1) a small source unit of a fixed type which will not have rotational properties; (2) a large rotational therapy unit with maximum rotational properties, but in a modified design usable with a rotating chair. Dr. Fletcher stated that the initial units will use cobalt^{60} radioactive sources.

Dr. Andrews wanted to know what clinical work remained to be done with the small unit in a fixed position which had not already been done by Scandinavian or English radiologists. Dr. Fletcher

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was of the opinion that even though the work has been done with other units, this need not prevent the Teletherapy Evaluation Board from proceeding with plans for using small source units. Dr. Andrews reiterated his statement that the motivating force of the subcommittee was the evaluation of teletherapy units and pointed out that a unit such as the small source could be made and marketed by anyone; therefore, he again questioned the advisability of proceeding with such a unit. Dr. Meschan stated that here was a unit of approximately 250 kv equivalent which could be desirable for short distance therapy at approximately 50 cm using gamma rays. He also stated that a patient treated under such conditions might be better off than a patient treated with a 250 kv unit. He felt that this subcommittee should determine whether or not this is true.

Dr. Kerman stated that the Teletherapy Evaluation Board had the unusual opportunity of developing a well defined clinical experiment and suggested that this was the primary aim of the Teletherapy Evaluation Board as stated in the Radiology Editorial published by the Executive Committee. As an example of how this could be accomplished, he suggested that each participating medical school be responsible for treating a small number of cases and add their data to the pool of data to be collected from other participating schools. Dr. Kerman then made a motion that 75% of the time of a therapy unit be devoted to an experimental program under the direction of the therapist at the medical school and that the remaining 25% be devoted to a well defined program of this subcommittee. The motion was seconded by Dr. Meschan and unanimously carried. Dr. Meschan than made a motion that the body be divided into regions with selected tumors and that the subcommittee develop a detailed program for each region using the large and small teletherapy units and other existing equipment and that each medical school utilize 25% of the time of their teletherapy machine in following this program. The motion was seconded by Dr. McClure. In the discussion period prior to voting on the resolution, Dr. Meschan pointed out that the subcommittee membership should be subdivided and that one or two members take a section or a region of the body and develop a therapy program using the small source unit in a fixed position, and the large rotational unit, with immediate emphasis devoted to the small therapy unit inasmuch as it is immediately ava ilable. He further suggested that the subcommittee report back at a further meeting. For the purpose of clarifying the 25% time usage of a unit under the Board supervised program, Dr. Fletcher asked whether he must select one out of every four patients, for example, cancer of the cervix, or could he assume that during the course of a days' work, he would take the diseases in the order in which he normally receives them in his department and devote approximately two hours a day in treating various cases. It was agreed that the latter method is the most desirable and that the 25% time of a Board supervised program need not necessarily be rigid but may be flexible. The subcommittee agreed with Dr. Fletcher's suggestion that only a well defined group of cancers be chosen for the 25% time usage of the machine. These should include those cancers which are potentially curable but seldom are and that the experiment be build around this group. Dr. Meschan pointed out that, in effect, this would be writing a manual on radiotherapy for those diseases and the subcommittee agreed that this would be a desirable thing for the subcommittee to do. Dr. Meschan suggested that there be a definite procedure for the selection

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of patients with a specific disease to be treated in order to eliminate the element of human error in the selection. At this point the committee unanimously approved Dr. Meschan's motion. The subcommittee then selected the body regions and tumors in each region and assigned them to committee members as follows:

Region No.	Body Region	Subcommittee
1	Brain	Dr. Hunt
2	Head and Neck	Dr. Fletcher
3	Breast	Dr. McClure
4	Uterus	Drs. Meschan and Andrews
5	Esophagus and Lungs	Dr. Weems
6	Testes, Bladder, Pituitary and Urinary Systems	Drs. Tice and Kerman
7	Ovaries	Dr. Rubenfeld
8	Lymphoma	Dr. Reeves

These assignments were made to allow each member to devote his entire effort to developing a recommended manual of procedure in selecting specific cases within the assigned area and to recommend a method of therapy for the approval of the Teletherapy Evaluation Board.

The subcommittee then discussed a procedure for establishing a form for recording the therapy procedure and clinical data. It was agreed that the form would essentially contain the clinical history of the patient and that the clinical history itself would determine the regime to be followed. For example, the clinical history might indicate one of three possible suggested procedures of therapy. Dr. Rubenfeld asked if there was to be a central file for the clinical history of all patients treated under the 25% cooperative therapy program. The subcommittee unanimously agreed that there should be such a central file and agreed that this file should be adequately supervised. They also agreed that in order to maintain a central liaison and uniformity of procedure the subcommittee member in charge of the file should periodically visit the various medical schools which are participating. Dr. Weems pointed out that there cannot be a uniform clinical protocol for widely varying diseases. Each disease would have to have a specialized form. Dr. Rubenfeld expressed an opinion that the arrangement of the protocol should be suitable for IBM tabulation and that narrative or descriptive summaries should be avoided as much as possible. Dr. Fletcher made a motion that there should be an individual protocol for each disease in a given region and that the member assigned the disease should design such a protocol. At the next meeting of the subcommittee, these protocols should be presented for revision. They should also be arranged for presentation to the entire Teletherapy Evaluation Board at its next a annual meeting. The motion was seconded by Dr. Kerman and approved by the subcommittee. Dr. Meschan made a motion that an administrative secretary be obtained for the administrative details of record keeping and that the secretary be under the guidance and direction of the Teletherapy Evaluation Board. The motion was seconded by Dr. Kerman and unanimously carried. Dr. Kerman made a motion that there be an evaluation of the program records at stated intervals by the entire membership of the

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Teletherapy Evaluation Board. The motion was seconded by Dr. Fletcher and unanimously carried.

The subcommittee voted to recommend that the next meeting of the subcommittee be held in Oak Ridge at the time of the Roentgen Ray Society meeting, in the week of September 29 to October 6. This would allow members to attend both meetings on one trip. The Motion was seconded by Dr. Weems and carried. During the discussion that followed, it was pointed out that a meeting in late September, for the purpose of approval of therapy data forms, would not leave enough time for redrafting the forms for submission to the Teletherapy Evaluation Board currently scheduled to meet on the 10th of October. Dr. Meschan suggested that the date of the Teletherapy Evaluation Board be delayed. Dr. Kerman made a motion that the subcommittee recommend to the Executive Committee that they postpone the next meeting date of the Teletherapy Evaluation Board to late in December or early January and that Subcommittee No. 5 meet again on a date preceeding the meeting of the Teletherapy Evaluation Board. The motion was seconded by Dr. Hunt and carried.

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June 3, 1958

MINUTES OF THE JUNE 3RD MEETING OF THE EXECUTIVE COMMITTEE OF THE TELETHERAPY EVALUATION BOARD

MEMBERS PRESENT: Dr. Robert J. Reeves, Duke University
Dr. H. D. Kerman, University of Louisville
Dr. C. C. McClure, Vanderbilt University
Dr. Sidney Rubenfeld, Bellevue Medical Center
Dr. Galen M. Tice, University of Kansas
Dr. Marshall Brucer, ORINS Medical Division

The Executive Committee of the Teletherapy Evaluation Board met on June 3 at the New York University College of Medicine Building, New York City. The meeting was opened with a review of the minutes of the January 25 Executive Committee meeting. Dr. Brucer summarized various directives of the January 25 meeting, all of which have been completed except the writing of a set of by-laws. It was agreed that the Chairman should prepare a set of by-laws, possibly patterned after those of the Oak Ridge Institute of Nuclear Studies, and present them for approval at the next meeting of the Executive Committee. Dr. Kerman made a motion that the minutes of the January 25 meeting be approved as written. The motion was seconded by Dr. McClure and unanimously carried.

The Subcommittee was asked if they desired a detailed review of the minutes of Subcommittees No. 1 through No. 4. It was agreed that a review was unnecessary and a motion by Dr. Rubenfeld, seconded by Dr. Tice, expressed approval of the minutes of these Subcommittees.

REVIEW OF THE CURRENT STATUS AND DEVELOPMENT OF THE LOW CURIAGE MACHINE.

The Subcommittee reviewed the design of the small teletherapy unit as now planned by the engineers of the W. F. and John Barnes Company, consisting of a spherical casting in two sections, the outer segment slightly distorted with a pneumatic device for operating the source wheel. It was stated that the Barnes and other interested companies have been informed that this unit could not be practical, and competitive with standard X-ray equipment, unless the cost could be maintained at $10,000 or less. This estimate does not include the cost of the radioactive source and that of loading.

Then followed a discussion of the sizes and the specific activities of cobalt^{60} sources currently available or expected to be available in the near future. Several design patterns were discussed which would allow the build-up of about 300 curies in a 2 cm diameter source. A double overlapping cloverleaf design is considered to be the most economical in space and curiage. The Executive Committee was informed that the Commission hopes to have high specific activity cobalt sources available in the future and that the present design of the machine could utilize a source of 30 r/min at 50 cm. Dr. McClure asked if Hevimet was to be used as a shielding material in the construction of the head and the committee was informed that the source wheel itself would be constructed of Hevimet and that this construction would result in a

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considerable saving in the shielding required by lead. Also, Dr. McClure asked if the moving parts of the unit would be lined with a material such as brass or steel, and the committee was informed that various designs under consideration were such that all moving parts would be lined with steel or brass depending upon various design considerations. Therefore, there will be no lead surfaces working against lead surfaces except in non-moving parts. The Subcommittee was informed of a design visualized by the ORINS Technical Shop consisting of a prefabricated spherical shield into which lead would be poured. However, it was feared that this method of construction would create a degree of warping in the shielding and the housing around the rotating wheel. It is the expressed opinion of the engineers from two different companies that such a fabrication method could be used if allowed a tolerance of 1/8 inch around the source wheel. This degree of freedom around the source wheel would lower the shielding properties of the head an appreciable amount. Therefore, this method of construction is considered undesirable.

The Subcommittee was shown detailed design prints as drawn by the W. F. and John Barnes Company. It was unanimously agreed that the unit need not have a light localizer, inasmuch as the unit is to be used with the cone in contact with skin surface. Also, the Subcommittee discussed the advantages and disadvantages of cones constructed of brass or lead. In view of the cost of lead, it was agreed that the initial unit should be constructed with cones fabricated from brass in order to maintain a low unit cost. It was agreed that most medical schools would have shop time and facilities available for constructing additional cones. Following a detailed discussion, a motion was made by Dr. Reeves and seconded by Dr. Rubenfeld that the Subcommittee approve the present status of the design and development of the small teletherapy unit. The motion was unanimously carried.

Dr. Brucer pointed out that a low curiage teletherapy unit of the foregoing design probably would be commercially available in the next six months. Dr. Kerman stated that if this is true, it would require early action by the Teletherapy Evaluation Board in developing a program of clinical investigation using the low curiage machine, and made a motion that the Executive Committee recommend to the Teletherapy Evaluation Board that a clinical investigation program be designed to incorporate the use of the small head and neck unit, and that a teletherapy program be geared to the development of the small head and neck unit. The motion was seconded by Dr. McClure and unanimously approved.

DEVELOPMENTS OF HIGH CURIAGE MACHINE

The Subcommittee was shown full size detailed plans of the high curiage machine as currently designed by the W. F. and John Barnes Company and were informed that the Institute would make final approval of these plans on June 12, and construction of the prototype unit would start immediately. The Subcommittee examined in detail the design of the Barnes unit and were well pleased with the current status of the design and development of the unit.

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SHIELDING REQUIREMENTS FOR HOUSING A HIGH CURIAGE OR LOW CURIAGE TELETHERAPY UNIT.

The Subcommittee discussed the problem of shielding in a room for housing high curiage and low curiage teletherapy machines, and it was feared that this might be a limiting factor in the use of small curiage therapy units. Dr. Brucer reviewed the preliminery standards as set forth in the National Bureau of Standards Handbook on Radiation Protection. It was pointed out that the formula for calculating the room shielding requirements defined a time factor which assumed that the therapy unit would be on a total of 48 hours per week. It was the unanimous opinion of Subcommittee members that this was an erroneous factor. The Subcommittee was informed that members of the Subcommittee on Housing Designs concurred in this belief and that Drs. Hoecker, Lofstrom, and others were obtaining data from old records to verify the actual average "time-on" of their machines during a working day or working week.

Since the Executive Committee meeting, it has been learned that the National Bureau of Standards handbook definitions are being changed and that such changes will be available for the next meeting. Also, Dr. Lofstrom of Wayne University has prepared this brief summary of his current experience.

MAXIMAR 250

Date	Exposure reading	(hrs.)
12-12-52	09021	
2-11-53	09137	116
5-13-53	09422	401
6-6-53	09489	468

Total of 25 weeks - average actual hours per week - 18.7

Department operates approximately 44 hours per week.

Monday 5/25	3 hrs	39 min & 39 secs
Tuesday 5/26	3 hrs	37 min & 30 secs
Wednesday	3 hrs	21 min & 42 secs
Thursday	3 hrs	19 min & 21 secs
Friday	2 hrs	30 min & 30 secs

It appears that the time factor could easily be reduced to 0.5 and that when the data on the position of the beam during various therapeutic maneuvers is available, the time factor may be reduced to less than 0.1 except in the direct downward position.

Instead of an overall shielding of walls, floor, and ceiling as specified by the National Bureau of Standards handbook, Dr. Kerman suggested consideration of a simplified shielding arrangement utilizing a mobile shield in critical areas for shielding the primary beam during therapy. Dr. Braestrup's mobile shield was discussed since it follows a similar pattern. During the discussion which followed Dr. Kerman's suggestion, it was pointed out that

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additional shielding might be necessary for the floor and ceiling depending upon the location of the room and personnel working in adjoining areas.

Dr. Rubenfeld questioned the possibility of reducing the shielding requirements if the small therapy unit could be installed to operate in two fixed positions. In reply to this question the committee reviewed the minutes of the Subcommittee on design of small source unit. Dr. Brucer informed the committee of the discussions which developed a suspension mechanism from a simple saw horse to the present concept of a unit which would provide an up and down, in and out motion, rotation of the head, and tilting of the unit. Dr. Tice and Dr. Kerman brought up the question of shielding for the ceiling and both expressed the opinion that ceiling shielding was not critical as it first appeared. Dr. Brucer again reviewed the formula developed by Dr. Wyckoff of the National Bureau of Standards and pointed out that if these standards are to be followed the only practical variable in reducing shielding requirements was a direct function of the "time-on" factor. It was pointed out that the utilization of less shielding would place responsibility on the individual therapist to define his "time-on" factor as being less than one-tenth of the total assumed working week of 48 hours. Dr. Kerman and Dr. Rubenfeld made the statement that these standards seemed to be more rigid than those currently accepted by the X-ray manufacturers and might be excessively cautious. Dr. Brucer agreed that in general this was recognized but that some states were making these recommendations legal standards.

At this point Dr. Rubenfeld requested the Subcommittee to study the shielding required for a small source and a large source therapy unit. By keeping all factors constant in the National Bureau of Standards formula except the output of the teletherapy unit, it was demonstrated that there was a relatively small difference between the shielding required for a low curiage and high curiage teletherapy unit. For example, the difference in shielding required for a 240 rmm source and the shielding required for an 1800 rmm source amounted to only 20 cm of concrete.

REVIEW OF THE PROBLEM OF PRODUCTION OF EUROPIUM

Data was presented to the Executive Committee showing the early work of Dr. Eastwood in England using short-term irradiation of a small europium source and the later interpretations of the work by personnel at Oak Ridge National Laboratory. The problem of europium irradiation has turned out to be an excessively complex one because of the build-up of daughter activities. The Oak Ridge Institute of Nuclear Studies has a number of sources ready for irradiation, but will not send them to the reactor until the current calculations by the Oak Ridge National Laboratory are completed. A number of discussions are scheduled for next month with Dr. Eastwood. Because of the complexity of the problem, a more detailed report will be made to the Subcommittee at a later date.

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RESERVATION OF CESIUM SOURCES BY INDIVIDUAL UNIVERSITIES

The Subcommittee was informed that the United States Atomic Energy Commission now has 15 requests for various sources and that some of them are two years old. Also, it was pointed out that commercial organizations such as General Electric X-ray Division, Picker X-ray Company, Keleket, etc., have for some time been trying to make reservations for a large number of cesium sources. This may be an excellent way for distributing sources but might interfere with our problem of keeping costs of units at a minimum. Following the discussion, the committee recommended that all universities contemplating the purchase of a teletherapy unit make application with the United States Atomic Energy Commission immediately for a large source. The Subcommittee asked if the application (AEC Form-313) should be submitted to the Committee on Human Application and the members were informed that this would be the procedure. However, for external radiation sources the procedure could be simplified by a statement from the local Isotopes Committee that a qualified radiologist would supervise the use of the unit. Also, it was recommended that the universities ordering a source should specify approximately 2,000 curies of cobalt^{60} or 7,000 curies of cesium^{137}. Early action should be taken inasmuch as the Commission has an established policy that they will distribute sources on a "first come, first served" basis. Dr. McClure made a motion that Dr. Brucer write a letter informing each member university of the current Atomic Energy Commission policy on the distribution of radioactive sources and ask each university to file application immediately for purchase in the next two or three years.

EXECUTIVE COMMITTEE MEMBERSHIP

The Executive Committee was informed that Dr. Arthur C. Guyton, University of Mississippi had formally submitted his resignation from the Executive Committee of the Teletherapy Evaluation Board. Dr. Guyton had requested that his resignation be accepted for personal reasons and pressing demands of other assigned duties at the University of Mississippi. Also, he is of the opinion that the Executive Committee of the Board holds the responsibility for long range developments of the Board's program; therefore, inasmuch as he was originally appointed to represent the University of Mississippi only until such time as a radiologist is appointed at that medical school, it would be desirable that he not continue his membership on this committee. It was explained, however, that he would retain his membership on the Teletherapy Evaluation Board, until such time as the University of Mississippi obtains the services of a radiologist. Dr. McClure made a motion that the Executive Committee accept the resignation of Dr. Guyton with regret and with an expression of appreciation for valuable services rendered. The motion was seconded by Dr. Reeves and carried.

Dr. McClure made a motion that Dr. Carl E. Nurnberger, University of Tennessee at Memphis be appointed interium membership on the Executive Committee until the next meeting of the Teletherapy Evaluation Board. The motion was seconded by Dr. Kerman and approved.

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The Executive Committee was informed that many persons had strongly recommended that membership to the Teletherapy Evaluation Board be left open in order that any future application by medical schools could be accepted. Dr. Brucer also stated that the Board of Directors of the Oak Ridge Institute of Nuclear Studies concurred in this matter. Dr. McClure made a motion, seconded by Dr. Reeves, that membership to the Teletherapy Evaluation Board be open to any accredited or approved medical school. The motion was unanimously carried.

PREPARATION FOR FUTURE MEETINGS OF SUBCOMMITTEES AND EXECUTIVE COMMITTEE OF THE TELETHERAPY EVALUATION BOARD

The Executive Committee reviewed the expressed wishes of Subcommittees No. 2 and No. 5 for the postponement of the next meeting of the Teletherapy Evaluation Board previously scheduled to meet in October of this year. Subcommittee No. 5 has worked out tentative plans for evaluation programs and felt that another meeting for the purpose of final approval should be held before the next meeting of the Teletherapy Evaluation Board; Subcommittee No. 2 has asked for a meeting late in August. After discussing various meeting dates, Dr. Kerman made a motion that the following dates be approved: Subcommittee No. 2 on August 30 in Oak Ridge, Tenn.; Subcommittee No. 5 at the time of the Executive Committee Meeting September 27 in Oak Ridge; next meeting of Executive Committee in Oak Ridge on January 9, 1954; next Teletherapy Evaluation Board meeting January 9-10, 1954. It was recommended that the Executive Committee meeting be held on the morning of January 9 with the Teletherapy Evaluation Board meeting starting at noon of that day and continuing through January 10. The motion was seconded by Dr. Tice and carried. Following this motion, it was recommended that Subcommittee No. 2 invite representatives of medical schools who are definitely interested in obtaining a small unit.

PREPARATION OF A STANDARD PROPOSAL FOR AN ATOMIC ENERGY COMMISSION CONTRACT

The Subcommittee reviewed the tentative draft of a research contract between participating medical schools and the United States Atomic Energy Commission for the evaluation of radioactive isotopes gamma ray sources for medical teletherapy.

The members of the Subcommittee approved the contract with corrections to be made as suggested by various members of the Board The Chairman of the Committee was requested to make the changes and submit the revised draft to all members of the Teletherapy Evaluation Board for their action.

TRAINING OF CLINICAL PHYSICISTS

Dr. Kerman brought up for discussion the problem of supplying trained clinical physicists at approximately the master's degree level. He requested that a committee be formed to study possible methods in which the Teletherapy Evaluation Board might be able to assist in solving this critical problem. Following a lengthy discussion, Dr. Rubenfeld made a motion that a Subcommittee

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No. 6, Clinical Physicist Training Program be established and that the Subcommittee establish a well defined program setting forth the need for such personnel, suggest possible methods of supporting a training program, and make recommendations Teletherapy Evaluation Board on proposed courses of action for promoting this program. The motion was seconded by Dr. Tice and carried. By acclamation Dr. Kerman of the University of Louisville was appointed Chairman of this Subcommittee with instructions to select other Subcommittee members from medical schools interested in the program

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MINUTES, AUGUST 29, 1953 MEETING

TELETHERAPY EVALUATION BOARD - SUBCOMMITTEE NO. 6

CLINICAL PHYSICIST TRAINING PROGRAM

Members Present: Frank E. Hoecker - University of Kansas
James F. Kelly, Jr. - Creighton University
James E. Lofstrom - Wayne University
I. Meschan - University of Arkansas
John Tolan - Emory University
Carl E. Nurnberger - University of Tennessee
Frank Morgan - Emory University*
Paul Riemenschneider - Syracuse Memorial Hospital
William G. Pollard - ORINS
Marshall Brucer - ORINS Medical Division

Members Absent: Herbert D. Kerman - University of Louisiville
Robert J. Shalek - M. D. Anderson Hospital
H. Stephen Weems - Emory University

Subcommittee No. 6 on the Clinical Physicist Training Program was authorized by the Executive Committee at its June 3 meeting. All members of the Teletherapy Evaluation Board were invited to attend. The meeting opened at 9:00 a.m. in the Conference Room of the ORINS Medical Division at Oak Ridge.

In the absence of Dr. Kerman, Dr. Brucer acted as the temporary chairman of the committee. He opened the meeting with a discussion of the English system of training hospital physicists and the hospital physics situation in other European countries. (See page 15 of Brucer's report on European trip.) A discussion followed outlining some of the advantages and disadvantages of both the formal and informal methods of recruiting and training students in the field of hospital physics.

Dr. Meschan had discussed the problem with Dr. T. H. Oddie, now at the University of Arkansas, and had brought some notes by Dr. Oddie based upon his Australian experiences on the problems of training medical physicists. (A full copy of Dr. Oddie's notes are attached.)

Dr. Hoecker then outlined the new course of study with eight students in attendance, at the University of Kansas. (A full copy of Dr. Hoecker's curriculum is attached to this report.) The present course at Kansas leads to a Bachelor's Degree in science in the field of biophysics. Following the Bachelor's Degree the student may continue on to a Master's Degree in science in the field of biophysics. It is the intention of the University of Kansas to expand this program to include the Doctor of Philosophy Degree.

Mr. Tolan brought up the question of requirements for certification in radiological physics by the American Board of Radiology. So far as he is aware, this is the only certifying board within the field. The following requirements for certification are abstracted from the handbook published by the American Board of Radiology.

* Representing Dr. H. Stephen Weems who was unable to attend.

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The candidate for certification must be of good moral and ethical character; must hold himself out to be a specialist in radiological physics; must be a citizen of the United States or Canada; must have a Bachelor of Arts Degree, or its equivalent, with a major in physical science or engineering, and must have membership in the American Physical Society or a similar organization. Following these general requirements, all candidates must have one year of post graduate training in radiological physics or in a radiation laboratory. In addition, if the candidate has announced that he is to be certified in "X-ray and radium physics" he must have one year's additional experience with a department of radiology approved by the American Board of Radiology in the field of X ray and radium. If the candidate wishes qualification in the field of "medical and nuclear physics", he must have one year's additional experience with a department of radiology approved by the American Board of Radiology in the field of medical and nuclear physics. Although the handbook is somewhat ambiguous on the point, if the candidate announces that he requires certification in the entire field of radiological physics, presumably, he must have at least one year's experience in both fields.

Dr. Lofstrom discussed the training program at Wayne University. Their program is less definite than the Kansas program and has not been announced as a program leading to certification as such, but the training is available for anyone interested.

Dr. Meschan discussed the limited training at the University of Arkansas and feels that the physical separation of 200 miles between the undergraduate and medical schools makes a training program difficult. Dr. Riemenschneider and Dr. Nurnberger expressed similar difficulties at Syracuse and in Tennessee. Dr. Nurnberger mentioned briefly the programs at the University of Chicago, the University of Minnesota, and at Columbia. Mr. Tolan reported that there was no training program at Emory but felt that such a program was possible in cooperation with Georgia Tech. Dr. Kelly reported that there was no training program at Creighton or in Omaha. The program of Dr. Johns at Saskatoon was mentioned. Dr. Nurnberger brought out the fact that there are now about 50 radiological physicists certified by the American Board of Radiology. Most of these are well established men of considerable reputation.

Dr. Brucer outlined the AEC Fellowship Program of training in radiological physics (really health physics). This discussion was amplified by Dr. Pollard later in the meeting. Three schools are cooperating in the training program - Vanderbilt, Rochester, and the University of Washington. The program was set up to meet an urgent need for trained health physicists in AEC facilities. It consists of a one year fellowship at one of the three universities. Three months of this period is spent "on-the-job" at one of the AEC installations. Students at Vanderbilt come to the Health Physics Division of the Oak Ridge National Laboratory for three months; Rochester students go to Brookhaven; Washington students go to Hanford. A few of the students continue their training and some have already received a Master's Degree. However, to a large part, the fellows are selected from persons who really are not qualified to take a Master's Degree. At the present time, Dr. Pollard explained, there is such a shortage of health physicists that very tempting job offers are made immediately following the completion of the one year fellowship. Dr. Meschan asked what salaries health physicists command. Dr. Pollard replied that most of the students finishing the fellowship training program are hired at from $3600 to $4000 per year. Dr. Pollard discussed briefly

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the similar Industrial Hygiene Program. Dr. Riemenschneider asked how many fellowships had been granted in the Radiological Physicists Program. Dr. Pollard said that there are about 7 at the University of Washington, 21 at Vanderbilt, and 18 at Rochester for this year. Last year there were 130 applications but this year there are only 70. A discussion of some of the problems of administering the Radiological Physicists Program followed.

After a lengthy discussion of the kind of training program Subcommittee No. 6 should set up, the following outline was made for more concrete study:

I. Title
II. Job Specification
III. Educational Level and Certification
IV. Educational Requirements
V. Financial Support
VI. Job Availability and Salary Level

There was considerable discussion on each of the items with the general consensus of opinion as follows:

I. Name or Title

The committee felt that there was need for a definite title to distinguish a person attempting to qualify, as outlined in Dr. Oddie's notes, from the many other specific fields that have opened recently. What we are actually aiming for is a job specification similar to that of the "hospital physicist" in England. The name "hospital physicist", however, has not been well received in this country. Here the word "hospital" is usually connected with the housekeeping and administrative phases of hospitalization. The word "biophysicist" is far too broad a term and includes many subjects not included in the job specifications we are discussing. The same is true of the term "medical physicist". Both of these latter terms are considered as generic terms which may include "hospital physicist" among many other designations. It was felt that the term "clinical physicist", as proposed by the Executive Committee, would have a similar fault. Some of the members felt that the word "radiation" must be in the terminology. No one was completely satisfied with the term "clinical radiation physicist". Such a name, however, does include the fact that we are considering a person with physical training, working primarily in the field of radiation and applying the data to clinical problems. Hence, the term "clinical radiation physicist" was adopted as a recommended name. It was felt that the name radiological physicist, as adopted by the American Board of Radiology is too all-inclusive. Moreover, it has been pre-empted in another fellowship program to include only the health physics functions as now defined by the Atomic Energy Commission. The terms adopted by the American Board of Radiology, "X-ray and radium physicists" and "medical and nuclear physicists", were felt to be either too narrow or somewhat meaningless. The name "clinical radiation physicist" is recommended by the Subcommittee to the Teletherapy Evaluation Board.

II. Job Specification

After many attempts to define specifically the duties of a clinical radiation physicist, it was felt that the best system would be to define certain

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fields of performance and certain functions within each field.

A. Fields of performance.

1. Radiation machines.

a. X-ray diagnostic machines.
b. X-ray therapy machines (less than 400 kev).
c. X-ray supervoltage machines.
d. Teletherapy machines.
e. High energy accelerators.

2. Radioactive materials.

a. Small sources (A source is defined as a non-absorbable encapsulated volume of radioactive material.)

(1) Classical radium usage.
(2) Other small sources (Seeds, needles, beads, pearls, etc.)

b. Metabolically distributed radioactive material (Iodine, Phosphorus, etc.)
c. Semi-mechanically distributed radioactive material (Colloidal gold, etc.)

B. Functions in each field.

1. Dosimetry
This should include all phases of the dosimetry problem, especially as it relates to the clinical application of external beams of radiation under clinical conditions. A large portion of the routine work of a clinical radiation physicist will be the computations from isodose patterns of the dosimetry of X-ray therapy.

2. Calibration and standardization
The term calibration here is usually referred to as external emitters or machinery producing beams of radiation. The word standardization is usually referred to as the determination of doses of radioactive materials.

3. Instrumentation
The clinical radiation physicist should be able to operate and interpret the data from a wide variety of radiation instruments including ionization chambers, Geiger-Muller Counters, scintillation crystals, etc. He should understand both the electronic and mechanical operation of the instruments and be able to perform what the army would call first echelon maintenance. Such maintenance is a minimum for a clinical radiation physicist. Some members thought that since first echelon maintenance

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refers only to cleaning and care of an instrument; the clinical radiation physicist should go beyond to such things as minor repairs and adjustments. Along with the knowledge of calibration and standardization of radiation producing machinery, a clinical radiation physicist should be able to calibrate and standardize his instruments so they can serve, at a minimum, the purposes of tertiary standards.

4. Protection

The clinical radiation physicist should be able to do simple health physics surveys, understand the principles of radiation protection, be able to gather data, and determine the risks on the use of large volumes of radiation. Since both diagnosis and therapy always involve hazardous levels of operation, it was felt that this was an important service function of the clinical radiation physicist.

5. Assay and survey

Especially in the field of use of radiative isotopes semi-mechanically and metabolically distributed in the body, the clinical radiation physicist should understand and be able to perform assays of tissues, urine, blood, etc. He should also be able to survey the distribution of radioactivity within the body.

III. The Academic Training of the Clinical Radiation Physicist.

A. Objective

The objective of the program is to train the clinical radiation physicist who will work within the fields of performance described in Section II A and perform the functions described in Section II B.

B. Pre-requisites

There was considerable discussion concerning the extent of training desired of a clinical radiation physicist and the starting point of this training. Dr. Hoecker's basic argument for starting with high school graduates was amplified in later discussions on curriculum. It was emphasized that the type of training required of a clinical radiation physicist differs from the major academic fields of pure physics and chemistry which tend throughout the American schools to be intensive in training and to develop persons who will specialize in a single academic field. The clinical radiation physicist is bridging not only the double fields of physics and chemistry but must have a considerable knowledge of human physiology. Hence, the training must be extensive rather than intensive. Since the present curricula do not allow for such a field of "unspecialized specialist" training, Dr. Hoecker has devised a new Bachelor's Degree program in biophysics. Other members of the committee pointed out that although they agree on the desirability of the University of Kansas plan

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and admitted its superiority, it did not meet the immediency of the present situation.

The opposite extreme of Dr. Hoecker's thorough program would be the establishment of short courses for persons already partially trained within the field. In spite of the present insistant demand for well trained technicians, the entire committee felt that we are attempting to develop a class of persons who are beyond the technician stage and that short speed-up courses would be highly undesirable. The committee was of the opinion that it would be possible to adopt an intermediate ground and to select well qualified students with a Bachelor's Degree. If necessary, they could make up during advanced training some of the elementary courses they may have missed in their qualifications for a Bachelor's Degree. The committee recognized that this probably should be a temporary program and that they should work towards having other schools adopt a type of program outlined by the University of Kansas. It was also brought out that many pre-medical curricula meet all of the requirements with the exception of a weakness in mathematics. The physical science curricula usually meet the requirements but are weak in biology. Therefore the committee recommends that a fellowship program for the development and training of clinical radiation physicists select candidates with a Bachelor of Science Degree or its equivalent. The following are pre-requisites to further training.

1. Mathematics - through differential and integral calculus.
2. Biology - including a minimum of elementary physiology.
3. Physics - including a minimum of general physics.
4. Chemistry - including a minimum of general chemistry.

C. Course offered

The selected candidates should be offered an opportunity to pursue an academic course leading to the following:

1. A Master of Science Degree

   It matters little whether this is in physics, chemistry, biology or biophysics but would probably be better if it were eventually labelled as a Master of Science in biophysics.

2. Qualifications for certifying boards

   At the present time there is only one board, that of the American Board of Radiology, certifying candidates for qualification in the field of radiological physics.

3. Qualifications for candidacy for a Ph.D. Degree

   The subcommittee agreed with the opinions expressed by many persons prior to this meeting that there is a great need for qualified research people in the field of clinical radiation physics. It was felt that with the development of a fellowship program, a broad base of candidates for the Ph.D. Degree could be developed.

There should be a natural outgrowth of higher training once the field is clearly outlined.

IV. Requirements for Candidates

The committee felt that the academic requirements should include a full two year's course of training. Within these two years the emphasis should be on the development of a broad base of experience covering the entire field with no attempt at specialization on any single facet of training. It was recognized that the field is entirely too broad for any one man to be a complete expert. The subcommittee felt, however, that any specialization within the field should be built upon a broad academic base wherein the candidate had an opportunity to understand and appreciate at least the language and problems of the entire field.

A. First year

The first year should be academic, including didactic courses coupled with laboratory courses. In this first year there should be an opportunity for making up possible deficiencies. The candidate should have completed courses in all of the following fields, but it should be recognized that some of these courses should have been completed during the undergraduate years.

1. Mathematics

   a. Differential calculus
   b. Integral calculus
   c. Analytical geometry

2. Physics

   a. Atomic physics
   b. Electricity
   c. Electronics
   d. Nuclear physics

3. Biology

   a. Human physiology
   b. Biochemistry
   c. Microscopic anatomy

4. Chemistry

   a. Qualitative analysis
   b. Quantitative analysis
   c. Organic chemistry
   d. Physical chemistry

B. Second year

The committee felt that the second year should consist of a maximum of practical experience with a minimum of didactic teaching and that most of this work should be done in the school of medicine. It was felt that the second year should be

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considered, in a sense, an internship year with emphasis on immediate contact with the actual clinical work of a radiation physicist.

1. Didactic work and practical experience in the functions of the clinical radiation physicist listed in Section II B should be combined.

2. A three month section in some laboratory or hospital not immediately connected with the school in which the degree is given should be arranged. This "journeyman" period is in recognition of the fact that few departments can offer a complete experience with all types of instrumentation and methods of both diagnosis and therapy. The committee recognizes that the field of clinical radiation physics is a rapidly expanding one in which no one department can possibly be completely abreast of the field.

3. The Master's Degree should include a requirement for a thesis on a clinical problem.

V. Requirements for Schools Offering Training in Clinical Radiation Physics

The subcommittee felt that although many schools were well qualified to offer training as outlined above, some schools could not meet the requirements. They felt that the minimum institutional requirements were as follows:

A. The university must have a graduate school offering a Ph.D. Degree.

B. It must have a four year medical school.

C. It must have a suitably equipped hospital. Within the definition of the work suitable herein used there must be at least:

1. A qualified radiologist or equivalent.

2. A certified radiological physicist or equivalent.

3. A radioisotope laboratory with facilities for both diagnostic and therapeutic use of isotopes.

4. X-ray therapy equipment including at least X-ray therapy up to 200 KVP and radium or its equivalent.

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VI. Financial Support

A. Fellowship program

The subcommittee felt that a fellowship program should be developed with full financial support for the Fellows for a limited number of years. This program should start on a relatively small scale, 6 to 10 Fellows. Within a period of 5 years it should build up to 50 or 60 Fellows. Then as the field becomes defined and recognized, it should taper off to no support after 10 years. By this time the field should be sufficiently well defined to be carried on by its own momentum. The following requirements for a Fellowship Program were stated as minimum:

1. Students with a Bachelor's Degree should be selected by a Fellowship Board of the Donor Agency.

2. The fellowship should start with admission of the student to universities willing to participate in the program.

3. The fellowship should end with the granting of the Master of Science Degree, or after two years.

4. The fellowship should carry a tax-exempt stipend similar to that of the AEC Radiological Physics Fellowship which includes a $1600 basic stipend with $350 additional for dependents. It should also include the payment of tuition and regular fees.

B. Sources of funds

The subcommittee recommended that the AEC Division of Biology and Medicine be requested to undertake this fellowship program. At the same time they felt that it might be desirable to request additional support for schools from such organizations as the Damon Runyon Fund, Picker Foundation, American Cancer Society, National Science Foundation, and other organizations.

VII. Job Market

A discussion of the potential job market for clinical radiation physicists followed. It was felt that the therapy sections of radiological departments now in existence and the various isotope laboratories that have developed within the past 5 years could use at least 1000 clinical radiation physicists at the present time. The committee felt that we are aiming for a class of personnel who would be hired eventually at the $5000 - $6000 level.

The committee requested Dr. Brucer and the Chairman of the University Relations Division of ORINS to arrange for a meeting in Washington to present the problem to Drs. Bugher and Dunham of the Division of Biology and Medicine. The committee also requested that the minutes of this meeting be sent to the entire Teletherapy Evaluation Board. The entire board is requested to review the minutes and send their comments and suggestions to Dr. Brucer for transmittal to Subcommittee No. 6.

NOTES ON PROBLEMS OF TRAINING OF MEDICAL PHYSICISTS

Dr. T. H. Oddie
University of Arkansas

I. Reasons for shortage of physicists:

The number of physicists who take up work in medical physics could be limited at present by the following factors:

A. Lack of pure research "glamour" that attaches to some other fields, and routine nature of work.

B. Low pay compared with other types of employment.

C. Lack of status and amorphous nature of duties.

D. Lack of training facilities.

E. Small past demand for medical physicists due to custom, in this country, for most published work in this field to be produced by radiologists and medical specialists.

F. Possibility that advances in chemotherapy will render obsolete many phases of radiotherapy, drastically reducing the openings available for the physicist who has specialized too narrowly in this work.

G. Lack of good workshop facilities in many hospitals.

No doubt if good training facilities are provided some of the other difficulties will resolve themselves, particularly C and E. Moreover, much might be done to overcome A if the proposed full training course could be approved by the universities concerned as a Ph.D. program, whereas a short course could be provided for the suggested "calculators", who would undertake much of the routine work. Difficulty C, and F to some extent, also might be overcome by encouraging as wide a field of interest as possible for the trainee, and by a general recognition by all concerned of the need for the physicist to be given a fair degree of autonomy. The physics group in any particular hospital should operate as a unit, either independently or within the radiotherapy department, depending on the volume and type of work to be undertaken. Close collaboration with the radiotherapy department is, of course, essential.

Finally, there is no need to stress here that physical work requires laboratory space, preferably in one location, and auxiliary services in the form of laboratory equipment and skilled workshop assistance, usually both mechanical and electric.

II. Method of training

Assuming that relatively few people will apply for training there seems no good alternative to a combined effort by the various interested institutions, and

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therefore a moving around of the students amongst these institutions. The following points may be worth discussion:

A. Administrative means for approval of training institutions by the universities willing to grant degrees on the basis proposed, and for admission of new institutions from time to time.

B. Fees and the question of whether trainees will be paid for work in hospitals during the later stage of their course.

C. Pre-requisites for course - B.S. in physics, with mathematics, electronics, chemistry, biology, and statistics useful background subjects.

D. Duration of course - 3 years for Ph.D. - 1 year for diploma?

E. Number of moves and duration of each during the period of training.

III. Subjects for possible inclusion

A. General

1. Elements of Anatomy and Physiology.
2. Medical ethics so far as are applicable.
3. Statistics and planning of experiments.
4. Use of library, writing of reports and material for publication.
5. Principles of laboratory layout and design.

All of these could be covered by written notes and/or short formal courses.

B. X rays

1. Standardization and dose measurement.
2. Positioning and beam localization.
3. Dose computation.
4. Physical and practical aspects of radiography.

C. Gamma rays

1. Standardization and measurement of gamma sources.
2. Dose measurement.
3. Dose computation. Paterson-Parker and similar techniques.
4. Practical interstitial and intracavitary methods for Ra, Rn, Co^{60}, Au^{198} and so on.
5. Radon preparation and handling.

D. Teletherapy

1. Source design.
2. Dose measurement and computation.
3. Rotational methods.

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E. Radioisotopes

1. Fundamentals, preparation and processing.
2. Assay techniques.
3. Instruments.
4. Tracer methods - I^{131} studies, circulation time, blood volume and so on.
5. Therapy, external and internal - methods and dose computation.
6. Autoradiography.

F. Radiobiology

(No detailed suggestions)

G. Protection

1. Tolerance levels and general requirements.
2. X rays.
3. Gamma rays.
4. Isotope handling, decontamination, disposal of waste.
5. Instruments and photographic methods.

These could be a formal course.

IV. Staff training

Staff to carry out a physicist training program may not be readily available with experience in all aspects of the work. Gaps in their own training could perhaps be filled by arranging for them to work temporarily in other laboratories to gain experience, such as:

A. National Bureau of Standards.
B. Oak Ridge National Laboratories.
C. Various major medical physics laboratories in England.
D. John's set-up in Canada.

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MINUTES OF THE AUGUST 30 MEETING OF SUBCOMMITTEE NO. 2

Low Curiage Source Design

Members present:

Dr. Paul Riemenschneider - University of Syracuse
Dr. C. C. McClure - Vanderbilt University
Mr. John Tolan - Emory University
Dr. J. F. Kelly, Jr. - Creighton University
Dr. Marshall Brucer - ORINS Medical Division

Members absent:

Dr. Henry Jaffe - University of Southern California
Dr. Robert Reeves - Duke University

Present at the invitation of the Subcommittee:

Dr. Frank E. Hoecker - University of Kansas
Dr. I. Meschan - University of Arkansas
Dr. Carl E. Nurnberger - University of Tennessee
Dr. James E. Lofstrom - Wayne University
Dr. Frank Morgan - Emory University
Dr. George Cooper - University of Virginia
Dr. Gilbert Fletcher - M. D. Anderson Hospital
Dr. Norman Simon - Mt. Sinai Hospital
Dr. Robert P. Ball - Oak Ridge Consultant
Mr. L. J. Bulliet - W. F. and John Barnes Company
Mr. Emil Galvanoni - W. F. and John Barnes Company
Mr. Gene Stober - Keleket Corporation
Mr. Tom Carraher - Keleket Corporation
Mr. J. W. Wilde - Instrument Engineer, ORINS
Mr. H. E. Kimble - Instrument Maker, ORINS

Dr. Brucer opened the meeting at 9:00 a.m. with a brief discussion of the original objectives of Subcommittee No. 2.

1. To use the cobalt 60 now available.
2. To design a "limited use" machine.
3. To follow all NCRP Subcommittee No. 9 recommendations.
4. To keep "costs" consistent with "limited use".

The source container shown at the meeting is designed to use the cobalt sources now available, but sufficient shielding to take a 600 curie source has been built into the design. This was done in recognition of the fact that larger sources should be available within a few years. Mr. Bulliet of the W. F. and John Barnes Company, in a discussion of cost, said that their accounting department had not yet caught up with the engineering department and that he did not know the cost of the machine. These cost data will be made available as soon as possible. Dr. Brucer pointed out that the design was started in May, was approved in June, and that the machine was delivered in August. This achievement is remarkable in an age that glorifies administrative paralysis. Dr. Brucer said that the necessity for using Hevimet as shielding material on the source wheel had added about $1200 to the cost, but that he had approved it in order to maintain the Lederman idea of removing mass from the shoulder and head region.

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The industrial participants were reminded of the Subcommittee's insistence that the price of the machine be kept at the level of 250 KVP X-ray equipment. The Subcommittee in turn was told of a design meeting in June with McClure, Tolan, Brucer, and Barnes and Keleket representatives. At this meeting each item on the machine was considered for cost reduction or replacement with cheaper quality. We believe there is no further way to reduce cost through engineering. Any reduction of the costs must now come through administrative and production methods. The Subcommittee was asked to review the design and to look for unnecessary features particularly as they relate to cost.

The group then adjourned to the cobalt room to inspect the machine. Following the showing, the machine was taken apart to show construction details.

After much informal discussion the group returned to the conference room and discussed the following points in considerable detail:

I. The Design of the External Surface.
There were no criticisms of the general shape of the shield. It allows, as expected, ample room for the patient to be placed in all treatment positions. The final decision on this particular shape or external configuration will depend upon the health physics surveys after loading. Following the meeting, a preliminary test survey was done with a small source. Some of the immediate results are included in these minutes, although they were not a part of the Subcommittee deliberations. With a 2 curie source of cobalt 60 in place, a set of 96 hour exposures with "Kodak no-screen" type film completely surrounding the machine at contact distance revealed only a faint fogging which was too light to interpret. With the machine in "off" position, and without a cone in place, there was a narrow pencil leak on the cone as expected from the design. This appears to read about 1 mr/hr/curie. With the cone in place it cannot be measured. Since there is no significant leakage in the design the large source will be loaded within the next week.

II. Opening and Closing Mechanism.
The mechanism is excellent. The 3-way solonoid air valve heats up on prolonged use. This is a commercial item that can be replaced with a better valve. Only one piston is being used at 80 pounds pressure. The Barnes Company should consider activating both pistons, each one at 40 pounds pressure, if this will lessen maintenance problems on the piston washers and if it does not add substantially to the cost. The rotation period is about 3 seconds and is remarkably smooth. The timer should be adjusted to read with the beam light rather than with the activating push button. The mechanism for the control panel is excellent. The "on-off" light system is a positive indication of the position of the source and appears to be fool-proof. Some of the members felt that the air piston is a major advance over other methods of rotating the wheel.

III. The Internal Wheel Loading Plug.
The plug housing the internal rotating wheel was removed and demonstrated. With the present loading mechanism there is no conceivable need for ever again removing the plug. The manual opening and closing wheel is difficult to operate. It might be better to serrate the edges or to use an open spoke wheel. A hole and wedge pin has been put into this model to mechanically hold the source "on" for purposes of 8 hour measurements and 24 hour health physics surveys. Such a device is NOT recommended for any except experimental machines.

IV. Design of Cones.
The cone design is a special problem and cannot be discussed without isodose curves and build-up studies. Most members felt that the electron shield should be moved back into the cone. Some felt that a few centimeters should be cut off the cone extension and lucite positioning cones should be place outside the beam limits. When preliminary data are ready the Subcommittee will be recalled to consider cone design. Copies of the Richardson paper on build-up will be distributed when available and before recalling the committee.

V. Loading Device.
Following the recommendations of the Subcommittee and also the stated policy of Subcommittee No. 1, the machine was designed for field loading. During the assembly of this machine Mr. Bulliet and Mr. Kimble suggested that the loading mechanism could be improved by removing the snap ring and letting the source float in the race way as a free bearing. No one can think of any objections and it is so recommended to the Barnes Company. However, even with this snap ring device now in place, it is very simple to load and unload the machine. During the first loading of a 2 curie cobalt 60 source, every possible thing went wrong. In spite of the fiasco, Brucer got less than 10 mr exposure on one loading of 2 curies. This is with no special shielding. It appears that the large source could be loaded in the field with less than 1 r exposure. The only expense will be a $1.50 pair of pliers, some lead bricks, a vacuum cleaner, and a mirror.

VI. Suspension.
A Keleket wall stand was used in the present prototype model. The base plate on this wall stand was objected to and should be removed. A permanent flush floor plate should be used. The fork can then be shortened by about 6 inches. At the rear of the stand the air mechanism projects unnecessarily into the wall area. This mechanism should be repositioned to allow the stand to fit close to the wall. No motor box should be on the stand. The side arms should be moved back as far as possible. The shield should be suspended at the center of gravity to get rid of the pendulum effect in extreme positions. The position of the adjustment wheels was discussed. Following the meeting,

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the suggestion for changing the plane of the wheels was tried by some members. If the plane of the adjustment wheel is rotated 90° it becomes impossible to reach the wheels with a bed under the machine. Hence, the committee's recommendation to change the plane might be a serious error. It is recommended that the Barnes Company prepare a ceiling mount. The committee would like some cost estimates from the Barnes Company on ceiling and wall mounts.

The committee then made the following recommendations:

1. Source shield.
   The design is approved with some suggestions.

   a. There should be labels for the moving parts of the cone device.

      1) Rotate - remove
      2) Rotate - locked
      3) "On-off" lights should be placed on the machine as recommended by NCRP Subcommittee No. 9. (This suggestion has been added by Brucer. It was not discussed in committee.)

   b. If possible the two locking devices for the cones should be incorporated into one locking device. If this is not possible, the cone locking device should use a rotating handle with a fast screw thread similar in operation to the cone rotating device.

   c. Since the Subcommittee meeting, the health physics survey indicates that the following statement should be engraved around the master cone base plate: "Do Not Leave Machine Without A Cone Insert." If the Subcommittee disagrees with this suggestion, it will be withdrawn.

2. Fork design.
   The design was approved with some suggestions.

   a. The fork should be shortened in its forward extension as much as possible.

   b. The plane of the adjustment wheels should be rotated 90°. (Further study indicates that this might be a serious error.) With the machine in some positions it is possible to reach the wheel at all times. However, if the plane is rotated in some positions, it is impossible to reach the wheel. The Barnes Company is urged to study the problem before adopting the suggestion. (This statement is counter to the Subcommittee's recommendation, but has been agreed to by 2 members of the Subcommittee following the meeting. If there are any objections, we will reconvene the Subcommittee for reconsideration.)

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3. Motions of the machine.

   a. The Subcommittee recommended keeping the up and down motion. The cone should clear (at the highest position of the machine) the sitting height of a tall man. This places the cone at about 55 inches and the source at about 65 inches. The down motion should be extended as low as possible.

   b. The Subcommittee approved the shield tilt of 225°. A method is inherent in this shield tilt for stopping the tilt at any position in the arc.

   c. The Subcommittee recommended that the fork rotation question be delegated to the manufacturer after the manufacturer has checked on the cost significance of this motion and the cost of the mechanism. The Subcommittee could not reach agreement on whether a tilt of the fork was necessary. Some members felt that fork rotation was undesirable from the point of view of room shielding. Other members felt that it was necessary from the standpoint of the maneuverability in setting up patients.

   d. The Subcommittee recommended that a ceiling suspension be prepared by the manufacturer at his option. The ceiling suspension was highly recommended by some members of the Subcommittee.

4. The Subcommittee recommends that manufacturers make every effort to agree on a standard source container design.

5. Base Plate.

   The Subcommittee recommends that a base plate for pointing and positioning gadgets be attached close to the top, next to the cone device.

At the close of the meeting Dr. McClure suggested that the Subcommittee extend their appreciation and compliments to the Barnes Company for the excellence of design, their beautiful workmanship, and the remarkable speed of execution. This suggestion was passed as a motion of the Subcommittee. Mr. Bulliet complimented the Keleket people for their cooperation in getting a wall stand prepared and shipped in great haste. The meeting adjourned at 4:30 p.m.

Marshall Brucer, M.D.

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MINUTES* OF THE SECOND MEETING - SUBCOMMITTEE NO. 5 - CLINICAL PROGRAM - TELETHERAPY EVALUATION BOARD
SUNDAY, SEPTEMBER 27, 1953

Dr. Rubenfeld, Chairman of the Committee, presided at the meeting.

Members present:
J. R. Andrews, M.D. - Bowman Gray School of Medicine
M. Brucer, M.D. - ORINS Medical Division
H. D. Kerman, M.D. - University of Louisville
I. Meschan, M.D. - University of Arkansas
C. Nurnberger, Ph.D. - University of Tennessee
S. Rubenfeld, M.D. - New York University
G. M. Tice, M.D. - University of Kansas

Members absent:
G. H. Fletcher, M.D. - M. D. Anderson Hospital
H. B. Hunt, M.D. - University of Nebraska
C. C. McClure, M.D. - Vanderbilt University Hospital
R. Reeves, M.D. - Duke University
H. S. Weens, M.D. - Emory University

Dr. Rubenfeld opened the meeting by requesting that the subcommittee delay the consideration of the proposed therapy plans long enough to consider the commercial availability of the low curiage machine.

Dr. Rubenfeld expressed an opinion that the Board had lost the original concept of its objectives. He said that it was his understanding that the Board was to develop teletherapy units for use by Teletherapy Evaluation Board members. He expressed concern over the fact that a low curiage teletherapy unit is soon to be available from a commercial X-ray company. Also, Dr. Rubenfeld requested a discussion of how this occurred and how it affected the program of the Teletherapy Evaluation Board and member universities.

In the discussion that followed a letter from Dr. Fletcher was read which expressed an opinion that the results of the Board's efforts have gone to the benefit of private hospitals and private radiologists. It was pointed out that private persons can make immediate purchase of machines, whereas, most universities must delay action from six months to one year.

Dr. Rubenfeld stated that he felt that the small unit had progressed too rapidly and that the member universities had not been adequately informed of the progress.

Dr. Brucer's opinion was that the members had been informed very quickly after any action had been taken or decision had been made, and pointed out that the minutes of each meeting were distributed within approximately two weeks following each meeting. He also stated that the minutes had contained complete reports of all actions and that repeated requests for corrections of errors had not resulted in any request that any minutes be changed.

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* These minutes are distributed without revision by the participating members in the interest of speed. Corrections and additions will be included in the next meeting.

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October 5, 1953

Mr. L. J. Bulliet
W. F. and John Barnes Company
301 South Water Street
Rockford, Illinois

Dear Mr. Bulliet:

The Executive Committee of the Teletherapy Evaluation Board met Sunday, September 27 in connection with the study of the preliminary clinical research program for the high and low curiage teletherapy machines. The members of the committee reviewed the Teletherapy Evaluation Board's activities in the development of the low curiage head and neck therapy unit. They noted that a unit, based upon the design specifications developed by the Board, is now commercially available.

The rapid development of the low curiage therapy unit has found some of the members without adequate funds for immediate purchase of a unit inasmuch as they must develop their budgets well in advance. Therefore, the universities are in the position of seeing the results of their joint efforts going to organizations or individuals not associated with the teletherapy program.

In recognition of this fact, the Executive Committee passed a resolution stating that inasmuch as the W. F. and John Barnes Company has been stimulated, guided, and aided in the construction of the design approved by Subcommittee No. 2 of the Teletherapy Evaluation Board, the committee feels that just consideration should be given to the member universities for their contribution to this development and that member universities of the Board be granted, by the Barnes Company, a six month priority to purchase units before they are made available to the profession at large. The university members are requesting that this priority shall be in affect as soon as firm contract prices are given to the member universities, and shall include all units constructed by the W. F. and John Barnes Company, including the prototype unit now in Oak Ridge. This priority should include enough units to offer one of each type to the participating members of the Teletherapy Evaluation Board.

Your consideration of this request by the Executive Committee of the Teletherapy Evaluation Board would be greatly appreciated. I would like to transmit your reply to the Board members as soon as practicable.

Sincerely yours,

Marshall Brucer, M.D.
Chairman, The Medical Division

CC: Members of the
Executive Committee

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Dr. Brucer then read excerpts from the recorded minutes in order to review the original intent of the Teletherapy Evaluation Board. He read the following motion taken from the August 8, 1952 organizational meeting of the Teletherapy Evaluation Board:

> "Dr. Kerman made the motion that the purposes of the Teletherapy Evaluation Board be stated as follows: 'To investigate, develop, and evaluate radioisotopes for teletherapy.' Dr. Jacox seconded the motion. The motion carried."

Also from the August 8 minutes:

> "There can be no intention or suggestion that any design, development or construction data or records be in any sense secret, or restricted to a small group. A large portion of the funds for this program, including in many cases the money contributed by the State Universities, is from public funds and it is necessary that all data from this project should be considered public property."

He read the following motion, also passed during the August 8 meeting:

> "Dr. McClure made the motion that industrial organizations shall not be given membership on the Board, and that no donations be accepted from them. However, any information regarding the Board's work should be made freely available to any industrial organization. Dr. Reeves seconded the motion. The motion carried."

To show that advance notice had been given on the timing and availability of a low curiage teletherapy unit, Dr. Brucer quoted the following excerpt from the minutes of the April 12, 1953, meeting of Subcommittee No. 2, Small Source Design:

> "Dr. Jaffe made a motion that Subcommittee No. 2 approve the preliminary design as detailed above and authorize ORINS to proceed with fabrication of the pilot model. The motion was seconded by Dr. Riemenschneider and unanimously voted by the committee. Dr. Brucer expressed a desire that the committee review the progress and development of the pilot model prior to the October meeting of the full TEB board. A tentative date sometime in September was agreed upon for the committee's second meeting."

After reading the above from the minutes Dr. Brucer informed the committee that he had worked under the impression that this motion was an expression of a desire to obtain a prototype model as soon as possible and that a prototype model would be desirable for demonstration at the September meeting.

Dr. Brucer also pointed out that Subcommittee No. 3, Rotational Methods and Procedures, May 3, 1953, had discussed the design features as outlined in the minutes of the April 12 meeting of Subcommittee No. 2, and that he felt this was another indication to all members of the Board that the low curiage teletherapy unit was progressing. Also, he pointed out that Subcommittee No. 4, Housing Design, which met on May 24, 1953, had reviewed the action of Subcommittee No. 2 in establishing design criteria for the cobalt 60 therapy unit and its requirements for housing. Dr. Brucer then quoted the following statement from the minutes of Subcommittee No. 4:

"The subcommittee then entered into a lengthy discussion of a number of factors presented earlier. This discussion was for the purpose of clarifying the current status of therapy problems involved in high curiage rotational therapy units and a low curiage unit designed for head, neck, oral, and vaginal cavities."

Dr. Brucer pointed out that as late as the June 2 meeting of Subcommittee No. 5, definite indications were given that a low curiage unit would soon be available, and he quoted the following paragraph from the minutes of the June 2 meeting:

"Dr. Rubenfeld opened the meeting with a question to clarify whether this subcommittee is to be concerned with the therapy program for both the high curiage and low curiage therapy units. Dr. Brucer stated that it was his opinion that this was the original thinking of the Teletherapy Evaluation Board at the August 8, 1952 meeting and that this opinion was shared with Subcommittee No. 2. Small Source Design, which met on April 12, 1953. During the ensuing discussion, Dr. Fletcher wanted to know whether the cost of the small therapy unit could be kept low enough to make the unit competitive with the 250 kv X-ray unit. The Clinical Program Subcommittee was informed that Subcommittee No. 2 agreed that the unit could be competitive with a 250 kv X-ray unit providing the cost of construction of the shielding head could be maintained at $10,000 or less. Also, the subcommittee was informed that this criterion had been given to two or three commercial companies interested in designing a low curiage therapy unit."

Also, the following paragraph was quoted:

"Dr. Fletcher pointed out that it was not the purpose of this subcommittee to design the therapy units, but to develop a teletherapy program for using the machines that are to be available; and for the purpose of clarifying the discussion, he pointed out that the following units would be available by the end of the current calendar year: (1) a small source unit of a fixed type which will not have rotational properties; (2) a large rotational therapy unit with maximum rotational properties, but in a modified design usable with a rotating chair. Dr. Fletcher stated that the initial units will use radioactive cobalt 60 sources.

"Dr. Andrews wanted to know what clinical work remained to be done with the small unit in a fixed position which had not already been done by Scandinavian or English radiologists. Dr. Fletcher was of the opinion that even though the work has been done with other units, this need not prevent the Teletherapy Evaluation Board from proceeding with plans for using small source units. Dr. Andrews reiterated his statement that the motivating force of the subcommittee was the evaluation of teletherapy units and pointed out that a unit such as the small source could be made and marketed by anyone; therefore, he again questioned the advisability of proceeding with such a unit. Dr. Meschan stated that here was a unit of approximately 250 kv equivalent which could be desirable

for short distance therapy at approximately 50 cm using gamma rays. He also stated that a patient treated under such conditions might be better off than a patient treated with a 250 kv unit. He felt that this subcommittee should determine whether or not this is true.

".....Dr. Meschan than made a motion that the body be divided into regions with selected tumors and that the subcommittee develop a detailed program for each region using the large and small teletherapy units and other existing equipment....."

Dr. Brucer questioned the sudden concern over the commercial availability of the low curiage unit and pointed out that this factor was discussed at length at the June 3 meeting of the Executive Committee of the Teletherapy Evaluation Board. Dr. Brucer pointed out that not only had this been discussed in detail but that it was very explicitly stated in the minutes of the meeting which were distributed in approximately two weeks following the meeting. He then quoted the following from the minutes of the June 3 meeting.

"The Subcommittee reviewed the design of the small teletherapy unit as now planned by the engineers of the W. F. and John Barnes Company, consisting of a spherical casting in two sections, the outer segment slightly distorted with a pneumatic device for operating the source wheel. It was stated that the Barnes and other interested companies have been informed that this unit could not be practical, and competitive with standard X-ray equipment, unless the cost could be maintained at $10,000 or less. This estimate does not include the cost of the radioactive source and that of loading.....

"The Subcommittee was shown detailed design prints as drawn by the W. F. and John Barnes Company. It was unanimously agreed that the unit need not have a light localizer, inasmuch as the unit is to be used with the cone in contact with the skin surface. Also, the Subcommittee discussed the advantages and disadvantages of cones constructed of brass or lead. In view of the cost of lead, it was agreed that the initial unit should be constructed with cones fabricated from brass in order to maintain a low unit cost. It was agreed that most medical schools would have shop time and facilities available for constructing additional cones. Following a detailed discussion, a motion was made by Dr. Reeves and seconded by Dr. Rubenfeld that the Subcommittee approve the present status of the design and development of the small teletherapy unit. The motion was unanimously carried.

"Dr. Brucer pointed out that a low curiage teletherapy unit of the foregoing design probably would be commercially available in the next six months. Dr. Kerman stated that if this is true, it would require early action by the Teletherapy Evaluation Board in developing a program of clinical investigation using the low curiage machine, and he made a motion that the Executive Committee recommend to the Teletherapy Evaluation Board that a clinical investigation program be designed to incorporate the use of the small head and neck unit, and that a teletherapy program be geared to the development of the small head and neck unit. The motion was seconded by Dr. McClure and unanimously approved."

Dr. Rubenfeld again reviewed the notes of the August 8 meeting regarding admission of industrial organizations to the Teletherapy Evaluation Board, and asked how the Keleket Company had access to the manufacturing of units, and called for a review of how it affects the program of the Teletherapy Evaluation Board.

Dr. Meschan expressed an opinion that the Board should ask for an ethical consideration of the universities' position from the Barnes Company. He felt that his previous experience with the representatives of the company was such that the company would readily agree to cooperate with the Teletherapy Evaluation Board. He felt that a six month priority should be considered by the Barnes Company because it would take him at least that long to get his university to act. Dr. Kerman expressed an opinion that the W. F. and John Barnes Company has a definite obligation to the Teletherapy Evaluation Board and that he concurred with Dr. Meschan in the above statement. Dr. Kerman then read an excerpt from the W. F. and John Barnes Company advertising brochure in which recognition was given to the Oak Ridge Institute of Nuclear Studies and the Teletherapy Evaluation Board in designing the small teletherapy unit.

Dr. Andrews made a motion that Subcommittee No. 5 make a recommendation to the Executive Committee that the Teletherapy Evaluation Board request the Barnes Company to grant a 90 day priority on the first production models. Dr. Andrews then amended the motion to read six months and the motion was seconded by Dr. Meschan.

The committee then discussed the motion and Dr. Meschan stated that he felt this action was necessary because commercial availability of the unit had crept into the picture rather unexpectedly. Dr. Tice then raised the question of what control the Barnes Company would have in honoring the previous commitments to the Keleket Company for one unit, and the Barnes commitment of one unit to Dr. Jaffe, who is a member of the Teletherapy Evaluation Board. Dr. Meschan and Dr. Kerman pointed out that they could not go to their university administration authorities to request a unit because they have not as yet been able to get a firm price from the John Barnes Company, and this condition automatically gives private individuals a priority in procurement of units. Dr. Brucer pointed out that neither the Oak Rige Institute of Nuclear Studies nor the Teletherapy Evaluation Board has invested any money in the development of the low curiage head and neck therapy unit. The reason the Barnes Company invested their own money was the fact that they had this early assurance of orders for three or four units. Dr. Rubenfeld stated that the Barnes Company had enough assurance for units from the 22 members of the Board. Dr. Brucer pointed out that he did not believe that the Barnes Company had reason to feel this way inasmuch as six months after all members had been informed of the progress of the unit they now have only two definite letters of intent. Dr. Brucer then made the two following observations:

1) He reviewed the previous history of the development of the small unit, the action and approval of the various subcommittees, including the Executive Committee, and stated that he did not feel that the Board had a right to ask for a priority from the W. F. and John Barnes Company.

2) He then raised the question, if this resolution is passed, are you guaranteeing the Barnes Company 30 orders to take the place of orders they will otherwise lose?

Dr. Tice then proposed the following question for consideration: Assuming

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that the large unit would be available within a year from this date, how many members of the Board or how many member universities would purchase a small unit?

Dr. Brucer then pointed out that so far as he know Dr. Jaffe and Dr. McClure of the Teletherapy Evaluation Board had already sent letters of intent to the Barnes Company and that the only other members of the Board who had expressed an interest in the small unit were Dr. Hunt, Dr. Kelly, and Dr. Kerman. Dr. Kerman then asked what organization or individuals outside the Teletherapy Evaluation Board have expressed an interest in units. Dr. Brucer expressed a lack of definite facts but pointed out that commercial X-ray companies other than Keleket are already in the field with cobalt 60 units, and that the Barnes Company and the Keleket Company would probably feel that it would be an impossible situation for them to agree to delay their production program for six months because they would lose the little advantage they might now have in a highly competitive market. He pointed out that GE has developed the M. D. Anderson unit and is offering it for sale. The Picker Company has developed the Johns unit from Canada and has already sold some units. Also, AEC in Canada has sold a unit in Chicago, Philadelphia, Minnesota, about two in European countries, possibly five or more in Canada and possibly others. Also, Dr. Weens and at least one other person have indicated that they may construct their own low curiage teletherapy units because they thought that it could be done cheaper in their university shops. Members of the committee pointed out that all of the units except the low curiage unit now offered by the Barnes Company are large units.

The committee members again emphasized that the Barnes Company would not have gone into the manufacturing of these units if it had not been for the program of the 22 universities, and the committee felt that the Barnes Company should definitely be considerate of the universities' problem in the procurement of a low curiage teletherapy unit.

Dr. Rubenfeld pointed out that one good advantage from the current situation is that it provides an opportunity to find out how the universities really feel about the program, inasmuch as now each university is immediately faced with the responsibility of making a decision to purchase or not purchase a unit. Dr. Meschan pointed out that it would probably take the Barnes Company six months to begin producing units inasmuch as a final approval was given to the unit by Subcommittee No. 2 only three weeks ago; therefore, the request under consideration would not be an unreasonable one. At this point Dr. Kerman requested permission to amend Dr. Andrews' motion. Dr. Andrews, and Dr. Meschan who had seconded the motion, granted their approval for the following amended motion: "Whereas the W. F. and John Barnes Company has been stimulated, guided, and aided in the construction of teletherapy isotope units, and whereas a prototype model of a small curiage machine has been constructed and the design approved by the Teletherapy Evaluation Board Subcommittee No. 2, and whereas it is considered only just reward to the member universities of the Teletherapy Evaluation Board for their contribution to this development, be it hereby resolved that the Teletherapy Evaluation Board request the Barnes Company to accord to the members of the Teletherapy Evaluation Board a six month priority to purchase teletherapy units before they are made available to the profession at large. This priority shall be in effect as soon as firm contract prices are given to the member universities, and shall include all units constructed by the W. F. and John Barnes Company including the prototype unit now at Oak Ridge. This priority shall include enough units to offer one unit of each type to the participating members of the Teletherapy Evaluation Board." Motion was seconded by Dr. Meschan.

Dr. Kerman pointed out that the above resolution is a recommendation to the Executive Committee and that the Executive Committee must act on the resolution if passed. The Chairman of Subcommittee No. 5 then called for a vote on the resolution. It was carried with one dissenting vote. The Chairman then adjourned the meeting of Subcommittee No. 5 to permit the Chairman of the Executive Committee to convene the Executive Committee for consideration of the motion made by Subcommittee No. 5.

Dr. Brucer pointed out that such an action was not on the agenda and that all members of the Executive Committee were not present. Since a quorum was present and at their request he convened the Executive Committee with the following members present:

J. R. Andrews, M.D. - Bowman Gray School of Medicine
M. Brucer, M.D. - ORINS Medical Division
H. D. Kerman, M.D. - University of Louisville
C. Nurnberger, Ph.D. - University of Tennessee
S. Rubenfeld, M.D. - New York University
G. M. Tice, M.D. - University of Kansas

Members absent:

E. C. McClure, M.D. - University of Tennessee
R. Reeves, M.D. - Duke University

The Chairman of the Executive Committee acknowledged the resolution adopted by Subcommittee No. 5. He recommended it to the Executive Committee for action. Dr. Kerman was requested to read the resolution in order that the members present would be fully familiar with the resolution as worded. The Chairman of the Executive Committee then called for a discussion and it was agreed that the motion was fully understood. On a voice vote the resolution of Subcommittee No. 5 was approved, with one dissenting vote.

At this point Dr. Kerman raised the question of how the resolution should be transmitted to the Barnes Company. He pointed out that the resolution could be transmitted by telephone or by letter, and that the manner of presentation should be given considerable consideration. It was his feeling that Dr. Brucer could present it in such a manner that it would be fully acceptable to the Barnes Company. It could, however, be presented in a manner in which it would be entirely unacceptable to the company and would create ill will. Dr. Brucer pointed out that if the resolution was transmitted by letter he would then immediately receive a telephone call or a personal visit from a representative of the Barnes Company requesting additional clarifications regardless of how the letter was written. During the ensuing discussion the members of the Board expressed an opinion that the Chairman of the Committee should exercise diplomacy in presenting the resolution to the Barnes Company. The motion was made by Dr. Kerman and seconded by Dr. Tice that the resolution as approved be transmitted to the Barnes Company by letter and that the Chairman of the Executive Committee report by mail to all members of the Teletherapy Evaluation Board the decision of the Barnes Company. The motion passed with one dissenting vote.

Dr. Rubenfeld then made a motion that the proceedings of the Executive Committee and of Subcommittee No. 5 be submitted to all members of the Board. Dr. Brucer pointed out that this had been the procedure following all meetings of the Teletherapy Evaluation Board or any Subcommittee meetings of the Board, and that it

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would be followed in this matter. Dr. Rubenfeld then withdrew his motion.

The Chairman of the Executive Committee, then adjourned the meeting of the Executive Committee.

Dr. Rubenfeld recovened the meeting of Subcommittee No. 5 for the consideration of a proposed plan for treatment of cancer of the uterus as prepared by Dr. Meschan and Dr. Andrews. Dr. Meschan began a preliminary reading of the proposed treatment procedure but was soon interrupted by Dr. Andrews who pointed out that he did not feel that the Subcommittee is ready to undertake consideration of a general plan of treatment until the objectives are better defined. He then asked the question - what is going to be studied in 25 per cent research time? Dr. Andrews then stated that the things which can be studied to the greatest advantage are based on Dr. Brucer's introduction of the concept of shaped fields of radiation. He also stated that if this idea is acceptable, or if it is unacceptable, he must ask the committee to define where the Board is going with the 25 per cent of the time of teletherapy units. For example, he stated that it does not matter how complex a problem is, the physical section of the Teletherapy Evaluation Board should find how to do it. The radiologist should not be attempting to find out by using up the next ten years. It was his thinking that the Subcommittee should make a decision here about the unique problems that should be attacked with the teletherapy equipment that is to be available to the Board. Dr. Rubenfeld stated that he would go along with Dr. Andrews' line of reasoning. During the discussion following Dr. Andrews' proposal, it was stated that the present use of the term "shaped fields" is meaningless and that if it is adopted it should be defined. The definition generally agreed to by the Board members for the term "shaped fields" is:"A homogeneous field of energy absorption from a controlled beam of ionizing radiant energy in a predefined volume of tissue".

In attempting to agree on the teletherapy procedures that should be adopted for the coming year, the members of the committee held a detailed discussion of the supervoltage X-ray procedures, supplemented with radium, as now practiced at the various universities. During the lengthy discussions on the present procedures of using supervoltage X-ray in treating various diseases and stages of these diseases, Dr. Kerman asked if there was any merit in substituting teletherapy treatment for conventional voltage? Dr. Andrews and others agreed there was merit. Later in the discussion Dr. Tice suggested that the first year procedure be a simple transition from conventional supervoltage X-ray machines. Dr. Meschan then asked that the individual members outline conventional supervoltage X-ray protocols, with limits that the Board would be willing to accept for a specific problem. Dr. Kerman stated that in one year we might have as many as five or six hundred patients. If the Board could follow that one group for five years, there would be a good answer for the substitution of teletherapy for conventional X-irradiation. He then stated that if the Board just substituted teletherapy procedures for the supervoltage procedures and contributed that part of their clinical material to this program, it would be a worthwhile contribution for one year. In summarizing the lengthy discussion for the benefit of the committee, Dr. Rubenfeld pointed out (1) that the committee had been discussing how to add an investigative approach to the higher energies; (2) that Dr. Andrews had suggested that the most unique feature that the Board could possibly investigate would be shaped field therapy; (3) that at this point the Board was not able to determine the "shaped field" wanted. He added that an attempt would be made to find out, even though it might take considerable effort in the coming months. Dr. Meschan suggested a number of experimental approaches to the problem of the "shaped field". He felt that these problems

should be turned over to a physics advisory group to see whether they could express that shape in mathametical terms and if it is capable of being reproduced on a teletherapy unit. Dr. Rubenfeld them pointed out that until this could be accomplished a compromise procedure should be undertaken for the next year. In closing the summary Dr. Rubenfeld pointed out that this is nothing more than the use of high energies instead of conventional X-rays but at least it is a tentative program for the coming year.

Before adjourning the committee meeting, Dr. Rubenfeld requested the subcommittee to submit the research protocol for the anatomical region assigned to each member. Dr. Meschan pointed out that in June there was a definite plan to have all procedures submitted at this meeting. Only two plans, however, were submitted. He thinks it is advisable not to make definite plans for future meetings until such time as Dr. Rubenfeld has in his hands completed programs for each anatomical region, or at least until he has enough material available to warrant a discussion of the protocols. Dr. Rubenfeld requested that the Administrative Office of ORINS Medical Division write a letter to each member of Subcommittee No. 5 requesting the earliest possible preparation of research protocol for the anatomical region assigned to him. This letter was to be prepared for the signature of Dr. Rubenfeld. This letter has been sent out, a copy is attached as part of these minutes.

A copy of the letter sent to the Barnes Company is attached as part of these minutes. Their answer will be appended in the next mailing.

Meeting adjourned at 4:00 p.m.

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October 5, 1953

Dear _____:

The second meeting of Subcommittee No. 5, Clinical Program, was held in the Conference Room of the Medical Division, Oak Ridge Institute of Nuclear Studies on Sunday, September 27. The committee discussed what should be the teletherapy evaluation program for the coming year, and reached an unanimous agreement that preliminary plans should be based on the philosophy that the program for the next year should effect the substitution of teletherapy machines for conventional X-ray therapy procedures.

The meeting of the committee was discouraging in that all preliminary drafts of therapy procedures had not been prepared and submitted for consideration. The meeting was adjourned with the understanding that the committee would be called into session again just as soon as all suggested procedures have been submitted to the Chairman of the committee. I wish to urge each of you to submit the procedure at your earliest convenience.

Sincerely yours,

Sidney Rubenfeld, M.D.
Chairman
Subcommittee No. 5

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MINUTES OF THE JOINT MEETING OF THE OAK RIDGE INSTITUTE OF NUCLEAR STUDIES - ISOTOPES DIVISION - AND THE X-RAY INDUSTRY ON TELETHERAPY AND HUMAN RADIOGRAPHIC PROBLEMS WITH ISOTOPES.

SUNDAY, OCTOBER 3, 1953

The following attended the meeting:

Paul C. Aebersold	U. S. Atomic Energy Commission
William E. Barbour, Jr.	Tracerlab, Inc.
E. E. Beauchamp	Oak Ridge National Laboratory
Harold Berger	General Electric Co., X-ray Department
Marshall Brucer	ORINS - Medical Division
R. H. Bull	Atomic Energy of Canada Limited
L. J. Bulliet	W. F. & John Barnes Co.
T. J. Carraher	Keleket X-ray Corp.
C. P. Davis, Jr.	Westinghouse Electric Corp.
R. F. Errington	Atomic Energy of Canada Limited
F. L. Foster, Jr.	High Voltage Engineering Corp.
R. M. Gager	Victoreen Instrument Co.
Eimo Galvanoni	W. F. & John Barnes Co.
C. H. Goldie	High Voltage Engineering Corp.
J. Howard Harmon	ORINS - Medical Division
M. E. Hayes	Westinghouse Electric Corp.
C. J. Hockanadel	Oak Ridge National Laboratory
John P. Kelley	General Electric Co., X-ray Department
Gerald Kloos	North American Philips Co.
Harold P. Le Wald	Bar-Ray Products, Inc.
A. B. Lillie	Atomic Energy of Canada Limited
Rod Mason	U. S. Atomic Energy Commission
Allen Mathis	H. G. Fischer & Co.
Jim McLaughlin	U. S. Atomic Energy Commission
R. G. Millar	Keleket X-ray Corp.
George L. Mowatt	United States Radium Corp.
Halsey L. Raffman	Halsey X-ray Products, Inc.
M. E. Ramsey	Oak Ridge National Laboratory
Edward Reible	Nuclear Instrument & Chemical Corp.
J. A. Reynolds	Picker X-ray Corp.
A. F. Rupp	Oak Ridge National Laboratory
Herman E. Seeman	Eastman Kodak Co.
J. B. Stickney	Picker X-ray Corp.
E. V. Stober	Keleket X-ray Corp.
F. A. Trenkle	Westinghouse Electric Corp.
E. Dale Trout	General Electric Co., X-ray Department
John Vlach	General Electric Co., X-ray Department

The meeting was opened by Dr. Marshall Brucer who reviewed the history of the Teletherapy Evaluation Board. He then explained that this meeting was called to review the progress that had been made in the use of isotopes for external irradiation; to discuss design standardization of teletherapy units; and to emphasize that the United States Atomic Energy Commission and the Oak Ridge Institute of Nuclear Studies are not in the X-ray business and do not intend to get into it.

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The Institute, however, is developing machines that are of interest to the X-ray industry. Dr. Brucer pointed out that, in the past, criticism has been directed to the Institute because of contracts with the General Electric Company and the W. F. & John Barnes Company for the purpose of developing teletherapy units. It was pointed out that the Institute is a corporation of 30 universities in the south, southeast, and southwest regions, operating under a prime contract with the US-AEC to do a number of jobs. Part of the ORINS Medical Division program has been to develop teletherapy units. At the beginning of the teletherapy program, it was found that the Medical Division was not competent to make all decisions and other people were called in to assist in some aspects of the program. One of the first persons called in was Leonard G. Grimmett, of the M.D. Anderson Hospital for Cancer Research, whose design of the first teletherapy machine was eventually contracted to the General Electric Company.

In continuing the problem of teletherapy, ORINS decided to go further and organize a Teletherapy Evaluation Board which is open to all four year medical schools. To date, 22 universities have joined with a payment of $2,500 each as a contribution to support the teletherapy evaluation program. The Board divided itself into subcommittees to discuss various aspects of the design problems. Subcommittee No. 1 was organized to study source evaluation and shield design. (Minutes of the meetings of this subcommittee were distributed to the group.) Subcommittee No. 2 studied the principles and design of a hectocurie (100-600 curies) teletherapy unit originally suggested by Dr. Grimmett in 1948 and visualized by Dr. Aebersold in the first cobalt irradiations. Subcommittee No. 3 and 4 are subcommittees on housing and rotation problems. The work of these committees closely follows the recommendations of the National Committee on Radiation Protection, Subcommittee No. 9. Subcommittee No. 5 of the TEB was organized to develop a clinical program for the hectocurie and kilocurie machines. Minutes of Subcommittee No. 5 were not distributed at this meeting because little work has as yet been completed.

Dr. Brucer reviewed the early history of the development of the moving field idea and pointed out that the prototype unit was not designed as a practical machine but was designed for all conceivable moving field patterns. It is expected that as the research program progresses many features may prove unnecessary or impractical. There followed a hurried review of special features of the rotational unit now being constructed by the Barnes Company. The desirability and the construction features of such components as the variable aperture, the moving wedge filter, and the telescoping shield were outlined. The design criteria called for the unit to prescribe three dimensional figures while moving around a fixed focus. They allow the unit to move in any pattern within a complete sphere around the patient, except for a cone beneath the patient's bed. In complex patterns it becomes impractical to manually control any rotational unit. It is believed, however, that in the ORINS prototype model automatic control has been accomplished by the use of a simple analogue type computer. Dr. Brucer reviewed the possibility that the machine may develop such shaped patterns as illustrated by a dumbbell pattern for the treatment of cancer of the cervix.

The group's attention was called to two sets of minutes from Subcommittee No. 2. The objective of this subcommittee is to develop procedures for the use of the cobalt 60 that is now available. The specific activity of these sources is relatively low. It is usable, however, if careful attention is given to the

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design of the machine. The use of hundreds of curies, instead of thousands of curies, means that the tumor focus must be closer to the machine, thereby limiting its usefulness. Dr. Lederman, of England, suggested a hectocurie unit for the neck areas with the mass of the shield contained within a 45° angle limited by the head and shoulder masses of tissue. This was accomplished in the hectocurie machine by tilting the source wheel, thereby giving a minimum shielding mass at the "on" position and maximum shielding at the "off" position.

Subcommittee No. 6 was organized for the purpose of studying the training of clinical radiation physicists. Candidates for this training should have a Master's degree or some previous training as a clinical physicist. Also, it is desirable for the candidates to have considerable knowledge in some field other than clinical physics, such as a knowledge of isotope uses, including calibrations and the use of radiation for human therapy and diagnostic procedures. Full minutes of the meeting of Subcommittee No. 6 were not reviewed, but copies of the minutes are submitted as Appendix A of this report.

The next item on the agenda was a review of recommendations by the National Committee on Radiation Protection, Subcommittee No. 9. At the present time it appears possible that some states will adopt Subcommittee No. 9's recommendations as state statutes. It is believed that eventually most states, and possibly the federal agencies, will adopt these recommendations. Hence, they have great importance to equipment manufacturers.

Abstract from the report of Subcommittee No.9 of the National Committee on Radiation Protection. Title "Protection Against Radiation From Radium, Cobalt 60, and Cesium 137 Encapsulated Sources".

V. Medical Applications: Teletherapy

5.1 Radioisotopes as Sources for Teletherapy Apparatus

5.11 Possible sources. The radioisotopes shown in table 5 can be made available as teletherapy sources and are produced either by thermal-neutron reactions or by separation of fission products. They all emit gamma rays within an energy range suitable for teletherapy and have a half-life over 70 days.

5.12 Magnitude of sources. Most teletherapy sources can be expected to deliver between 1 and 50 r/min at a distance of 1 meter. Such sources will have exposure rates of many kiloroentgens per minute close to their surfaces and when not in their housings must be handled with remotely controlled instruments at great distances or behind thick barriers. Apparatus containing such sources must be so designed as to be practically foolproof in operation and it must be improbable for any accidents to leave the source unshielded.

5.13 Physical form of the isotope. Some isotopes used for teletherapy can exist as pure solid metals and can be cast, machined, or pressed before irradiation. The metallic state is the most stable and easily handled, and therefore the preferable form for any source. Solid sources are likely to consist of multiple

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wafers or pellets, which must be fitted into a container. Neutron and chemical corrosion can cause a dusting problem and the containers must be designed to prevent the release of highly radioactive dusts.

Some isotopes can exist only as powdered salts, e.g. europium oxide, the specific activity of which is very high. Before irradiation such salts can be mixed with aluminum powder and pressed into metallic discs to reduce the hazard of working with powdered sources. Some materials, such as cesium sulfate, have too low a specific activity to be mixed with aluminum but can be pressed to high density within their containers to reduce the hazards of the powdered form. Such containers should be doubly protected against leakage. Some radioisotopes might conceivably be used in a loose powdered form, or could be produced in a liquid form. Containers for loose powders or liquids must be specially designed to prevent accidental release of material.

5.14 Preparation of pure metallic sources. Certain sources, e.g. cobalt 60 and iridium 192, can be prepared as metals or metallic alloys of high purity. Such isotopes shall be sealed in air-tight capsules of stainless steel or other suitable material.

5.15 Testing of metallic sources before use. After the isotope is loaded into its permanent capsule, the capsule shall be scrubbed clean of contaminating radioactivity. It shall not be released by the manufacturer until a reasonable test reveals no significant contamination. A recommended test is to scrub the dry capsule with a dry filter-paper and to count the activity on the paper under standardized geometry.

5.16 Preparation of powdered sources. Certain isotopes such as cesium, europium, and radium are not made in pure metallic form. Usually the oxides or sulfates are used. It is desirable to use a compound that yields the highest volume specific activity but it is necessary that such characteristics as deliquescence, decomposition, and gas production in a high gamma radiation flux be taken into consideration.

5.17 Powdered-source capsules. Isotopes used in teletherapy shall not be sealed in glass or other breakable containers. Quantities of a few curies may be sealed in an airtight specially designed powdered-source holder as suggested in figure 2. Large sources have very high internal gamma intensities and are subject to decomposition of salts and minor contaminants, appreciable heat generation, and the potential production of gases, with a build-up of pressure within the source container. Such isotopes should be sealed in a powdered-source container and then ~~re-sealed~~ in a second safety capsule containing an air pocket as suggested in figure 3.

5.18 Testing of powdered sources before use. The manufacturer shall decontaminate and test the primary powdered-source container. The outside of the secondary container shall be free from significant contamination on the outside.

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5.2 Design of the Teletherapy Apparatus

Teletherapy apparatus may be divided into two types: single source and multiple source equipments.

5.21 Single-source units. Single-source units consist of at least three parts; a completely shielded housing adequate for the source in the "off" position, a collimating aperture, and a device to turn the beam "on" and "off". The housing may be cast of metal or of machined or sintered metals. There will be, of necessity, ports in the shield to allow for loading and opening devices.

5.22 Multiple-source units. Multiple-source units may be of many diverse designs. Where sources exist as separate units, each should meet the protection requirements of a single-source unit, except that the protection requirements for the entire apparatus shall in no case be less than those recommended for a single-source unit.

5.23 Protection requirements for the housing. The housing and collimating devices shall be so constructed that at 50 cm in any direction from the source in the "off" position, the exposure rate does not exceed 6.25 mr/hr. In the "on" position the leakage radiation shall not exceed 1% of the useful beam at the same distance from the source. A further reduction in leakage radiation will result in a decrease of secondary barrier requirements. The apparatus should be so constructed that there is reasonable assurance that the body of any person will not be within the danger range during routine time-consuming manipulations. The construction should be such that repairs and maintenance can be done safely. Adjustable beam defining diaphragms when used shall allow transmission of not more than 5% of the useful beam dose rate outside of the useful beam. The problem of pin point leaks should be resolved on the basis of whole body exposure rates.

5.24 (This section has been left out in the revision.)

5.25 Filters. Filters to harden the radiation are usually unnecessary in most teletherapy machines. In the case of some radioisotopes, for example europium 152-154, where filtration of soft gamma rays is necessary, the filter shall be a permanently affixed part of the housing.

5.26 Positioning of the source in the housing. The relationship of the source and the collimating opening shall be such that in the "off" position of the beam the moving part shall always return to a position of shielding as defined in section 5.23. In the "on" position the moving part shall always come to rest with the source and the beam collimating device accurately aligned. If a liquid "on-off" device is used, the liquid container shall be filled and emptied with less than a 5% change in exposure rate in the "on" position. If the liquid is mercury,

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periodic tests should be made for leakage of mercury vapors since they are toxic and also may affect the film badges used in monitoring personnel.

5.27 Automatic beam control. The beam control mechanisms shall be of a positive design capable of acting in any position of the housing and shall shut off automatically. In addition to the automatic closing device the apparatus shall be so designed that it can be manually turned off within minimum risk of exposure. The moving parts shall be so designed that it is highly improbable for projections, breakages, loose screws, dirt, or failure of any part to impede the closing of the source. There shall be at the housing and on the control panel a warning device that plainly indicates whether the apparatus is "on" or "off". The controls shall be provided with a timer that automatically terminates the exposure after a pre-set time.

5.28 Precautions in the "on-off" beam-control mechanism. Whatever the "on-off" shutter mechanism (solid, liquid, slide, wheels, or shutters), the closing device shall be so designed as to return automatically to the "off" position in the event of any breakdown or interruption of the activating force and shall stay in the "off" position when the force goes on again until activated from control. The beam-control shall be provided with a locking device to prevent unauthorized use.

5.3 Design of the Teletherapy Room

In general the requirements of teletherapy rooms are the same as those given in NBS Handbook 41, section 12, "Therapeutic X-ray Installation Energized by Potentials of 251 to 2,000 Kilovolts". The protection design for teletherapy rooms follows the same principles as stated in NBS Handbook 50, "X-ray Protection Design".

5.31 General structural requirements. Lead barriers shall be mounted in such a manner that they will not creep because of their own weight and shall be protected against mechanical damage. Movable barriers should not be depended upon except for emergency procedures. Protection for the useful beam shall be computed without a patient in the beam. In general, it is more economical to place the observation window so that the useful beam cannot be directed at it. In general, it is more economical to provide a maze rather than a heavy lead or steel door for access to the radiation room.

5.32 Primary protective barriers. Primary protective barriers shall be provided for any area that the useful beam may strike with the largest possible diaphragm opening. Barriers shall extend at least six inches beyond edge of the useful beam for any possible orientation. The actual protection requirements will depend upon the type and strength of the source. The barrier shall be such that at no place liable to uncontrolled habitation

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shall the radiation exceed the exposure rate of 6.25 mr/hr.

In the case of most isotopes, the radiation is not a continuous spectrum but is from either a single or multiple monoergic gamma energies. The protection requirements will be higher for a monochromatic gamma energy than for a similar peak energy from an X-ray generator.

The controls should be in a separate room or behind permanent structures. All access doors to the treatment room and other hazardous areas shall be provided with electrical interlocks; warning lights, bells, or other devices should also be provided.

5.33 Secondary protective barriers. Secondary protective barriers shall be provided for all areas exposed to leakage and scattered radiation.

5.4 Operating Procedures

The scattered radiation from the patient and from the walls and floors of most sources will be such that no other person should be allowed in the room with the patient during irradiation.

Following the reading of the teletherapy section of the new handbook, Dr. Brucer pointed out that there were many items throughout the book that might be of immediate interest to manufacturers of X-ray equipment and felt that the best way of pointing out all of these events is to summarize in a check list fashion all the items that might have some usefulness in the present discussion. The summary check list is as follows:

1. Apparatus containing high curiage sources must be so designed as to be practically foolproof in operation and it must be improbable for any accidents to leave the source unshielded.

2. Wherever there is the possibility of radioactive powders, the source must be doubly sealed. Although the Canadians do not feel that the pellet form of irradiation yields a dusting problem, the experience at ORNL is that the wafer used in American operations does give a dusting problem; therefore, we are interpreting the regulations to mean that we should use a double seal capsulation for cobalt 60.

3. The manufacturer will be responsible for assuring that the capsule has been scrubbed clean of contaminating radioactivity, and that there is no pressure build-up within the source due to gas production.

4. The protection requirements for the primary shielding in the housing of the source shall be 6.25 mr/hr at 50 cm in the "off" position.

5. In many designs where the source changes position in the "on" position the leakage radiation shall not exceed 1% of the useful beam measured at the same distance from the source.

6. The machine that should be designed so as to keep the operators body

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as far as possible away from the machine in routine time consuming operations.

7. Repair and maintenance must be possible with the source in a safe position.

8. The requirements for cones and diaphragms is the same as for X-ray machines. The leakage through the cone shall not be more than 5% of the useful beam when measured at the same distance.

9. The problem of the pin point leaks through holes and cracks in the machining of the primary shield housing should be resolved on the basis of total body radiation. This is a very difficult problem to define or to specify in protection rules and regulations. It is expected that designers of equipment will use common sense in remembering that radioactive isotopes are always "on" and that the primary consideration must be safety in routine operations.

10. Filters for radiation when necessary should be permanent parts of the housing.

11. In those designs with moving sources or moving shutters the source must be correctly alined when it moves to the "off" position. In those machines where the source moves from "on" to the "off" position, when moving into the "off" position, it should always move to the point of complete shielding. Experience has shown that minor errors in positioning can lead to unsafe exposure rates.

12. In the "on" position the moving parts shall always come to rest with the source and the beam collimating device accurately alined. Experience again has shown minor changes in the position of the source or in the position of the cone can cause very large differences in the effective isodose patterns.

13. Where a liquid such a mercury is used for "on-off" device experience has shown that incomplete filling or emptying of the liquid container can cause large differences in the transmission or shielding of the beam. A 5% exposure rate difference is considered by the handbook to be a minimum required filling and emptying tolerance. It is also pointed out that in the case of mercury the maximum allowable concentration of mercury in air is 0.1 milligrams per cubic meter. At room temperature mercury vapor when at equilibrium with the supply of mercury it is nearly 200 times this allowable concentration. It is not necessary to heat mercury to drive off sufficient vapor to contaminate the surrounding atmosphere.

14. In the case of any accident of malfunction of machinery, the design should be such that the machine automatically returns to the "off" position.

15. There should be a lock on the control panel to prevent unauthorized use.

16. The automatic beam control mechanism should operate in any position of the main housing.

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17. In addition to the automatic "off" mechanism there should be a manual shut-off easily reached in cases of emergency.

18. There should be a warning signal both on the machine and on the panel which states that the machine is either "on" or "off".

19. There should be a pre-set timer to automatically terminate exposure.

20. Any material can be used for radiation protection. Lead is not necessary but if used the problem of cold flow and the creep of lead should be taken into account.

21. There should not be a dependance on movable barriers for routine operations. Barriers which are a part of the machinery, such as in the Braestrup rotating design, are not considered a movable barrier but are really a fixed barrier in relation to the beam. The many designs which have been suggested were a separate sheet of lead or iron that is moved into position with each treatment are not considered good protection practice.

22. The useful beam protection requirements are calculated without a patient in the beam, however, there is also a necessity for calculating the radiation protection required from the scatter radiation when a patient is in the beam.

23. In general, the observation window is better placed out of the useful beam.

24. In general, it is usually better to use a maze rather than a direct door into the teletherapy room. In the case of both the observation window and the maze this is not a requirement but a suggestion on economy. In many situations it may not be practical to follow such recommendations.

25. The primary barrier is usually calculated for the useful beam with the largest cone in place and six inches beyond the edge of this beam.

26. The primary requirement for calculating shielding necessary for rooms situated around a teletherapy room is that they shall be safe no matter what is happening in the teletherapy room. The way in which "safety" is currently defined is that there should not be more than 6.25 mr/hr exposure at any area not under control of the radiation safety officer. In some cases this may be too strict a definition and an occupancy factor can be taken into account. In such places as corridors in X-ray departments too narrow for future desk space, in rest rooms not used by radiological personnel, in parking lots, utility rooms, etc. radiation protection can be based upon an expected occupancy of one quarter of full occupancy. In such places as stairways, automatic elevators, streets, closets too small for future work rooms, toilets not used by radiologic personnel, etc., radiation protection can be calculated on the basis of occasional occupancy at about .06 of full occupancy.

27. No uncontrolled area should, however, receive greater than 6.25 mr/hr.

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28. The control panel for any teletherapy machine should be in a room separate from the teletherapy machine itself.

29. There should be an electrical interlock on the doorway leading to the teletherapy room. The handbook will recommend that warning lights, bells, or other devices should also be provided in addition to the electrical interlock.

30. The teletherapy machine should be so designed so that only the patient need be in the room during treatment.

31. A "danger zone" is defined as a distance at which the gamma radiation from a sample of radioactive material is 6.25 mr/hr which corresponds to the 300 mr per 48 hour week. The subcommittee is asking that areas within this danger range should be inaccessible.

32. The subcommittee is asking that sources shall be readily distinguishable upon dismantling the instrument. It is also stated, under the section on Non-medical Applications, that it shall not be considered sufficient to calculate dose rates and danger range for multicurie sources from consideration only of the amount of activity present. For such sources an actual survey at a radiation level should be made. Consideration must be given both to primary and scattered radiation.

33. In another portion of the handbook, it is stated that an initial survey should be made at any facility to be used for the handling or storage of radioactive sources. The survey should include all storage containers, transport carriers, shields, and teletherapy equipment. The survey should be made by or under the supervision of a qualified expert who should submit a written report. No teletherapy installation should be used routinely until its safety has been established by such a protection survey. The survey should be made with a beam in the "off" postion to determine that it complies with the requirements of a protective source housing. Operation procedures based on such a survey should be established for all personnel concerned. A survey should also be made of all regions adjacent to the radiation room with the aperture open and a patient or phantom in place. Such measurements should be made for typical useful beam directions to determine the dose to personnel under the actual conditions of operation. The report should include restrictions of operation or occupancy if indicated by the measurements.

Ionization chamber measurements are required only if a prior scanning with a suitably calibrated Geiger-Muller or scintillation type of instrument indicates occupied regions to have a radiation level of over one fifth the permissible dose rate.

All teletherapy machines should be surveyed periodically. There should be an additional written report whenever a major change is made which may effect the validity of the initial survey report.

34. Personnel monitoring should be employed where radiation safety depends upon proper operating procedures. It is the feeling of the subcommittee that this includes teletherapy equipment.

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35. No attempt to remove cobalt 60 from sealed or plated containers should be made except by qualified laboratories.

36. The problem of the ultimate disposal of radioactive materials is not taken up in the handbook, but it is pointed out in the handbook that information should come from the supplier of the source. It is felt that in most cases this refers either to the Canadian or the ORNL supplier rather than X-ray equipment manufacturers.

37. A statement appears in the handbook which should be discussed carefully by the industrial group. Under section A.25 (referring to radium) the following statement appears: "Whenever size permits, capsules shall be clearly and permanently marked and be readily identifiable from a considerable distance as to their content. When sizes and shapes are not adequate, other means of identification should be employed such as plating, enameling, or electrolytic etching with different colors."

38. Another statement appears under section A.43 (referring to radium) which should be discussed in the November 6 meeting. "The manufacturer shall obtain data as to the uniformity of distribution and amount of activity and shall provide this information to the buyer or the user together with the identification of the capsule, of the metal employed for the capsule, and its wall thickness and of the type and purity of the radium salt used." Although these sections refer primarily to radium, it may be of value to discuss their meaning in so far as other isotopes are concerned.

Following the discussion on radiation protection, Dr. Hochanadel of ORNL discussed some of the recent work on the use of chemical dosimeters. (See appendix B)

The group adjourned for lunch.

The afternoon session reconvened for discussion of the problem of standardization of source capsules. The group readily agreed that, to facilitate the trade-in for machines and sources, it is desirable to standardize at least the external specifications for the source capsule. For example, if an individual has a kilocurie source he could double its life by transferring it from a kilocurie to a hectocurie machine. To show one concept of a source capsule, Dr. Brucer demonstrated the ORINS capsule which was designed to meet the requirements of the NCRP and of the Isotopes Processing Division of the Oak Ridge National Laboratory. This design will take all forms of cobalt now offered for sale by the US-AEC. The container, however, will not take all cesium sources.

The encapsulation of cobalt cannot be done except with remote handling devices located behind thick shields. Such equipment is available in Oak Ridge or in Canada. Arthur F. Rupp, of the Isotopes Development Department of ORNL, was introduced to discuss the problems of high curiage source encapsulation. He started the discussion by stating that the ORNL's interest in a standardized capsule stems from requests for the Laboratory to load the capsules. He stated that the capsules should be mechanically simple and easy to seal, and that the seal should be designed to be free from leakage in order to meet the NCRP recommendations. Mr. Rupp reviewed the ORINS source holder to show how its design

arranged the cobalt 60 sources to give a minimum of self absorption. Mr. Rupp next outlined the difficult manipulations which can be involved in remote handling, such as screwing together parts or by sealing with pressure. Mr. Rupp emphasized the necessity for a large container for the reason that a small source can be placed in a large hole with shims, but a larger source cannot be easily adapted to a small container.

Mr. Rupp stated that it was theoretically possible to get very high specific activity cobalt but that ORNL had so far averaged less than 20 curies per gram. The Laboratory hopes to get (maybe) 35 curies per gram and conceivably they could get 50 curies per gram. These different specific activity sources are going to involve variations in size and it would be well to have as much flexibility as can be designed into a teletherapy machine. Also, the present size of a cesium source is about 3 x 3 cm. At the present time ORNL believes that it can cut down on the height of the cesium source, but it would be desirable to get maximum space in the design of the source wheel.

Mr. Rupp indicated that ORNL favors the lead inner seal with a pressure closing of the first or inner seal, with the second and third seals made by screwing down an outer cap. ORNL has encapsulated some sources by soldering the components; a fire, however, might cause this seal to be broken.

At this point Dr. Aebersold requested that the program be turned over to Mr. R. F. Errington who discussed the Canadian capsule and manufacturing problems.

Mr. Errington agreed with Mr. Rupp's statement that the design of the teletherapy unit should leave as much room as possible in the machine for sources. He pointed out that he might have an ulterior motive behind his recommendation because the Canadians are making cobalt in a little different way than does the US-AEC. Generally speaking, they have 85 curies per gram material which is made in pellet form from millimeter wire. When the pellets are placed in a capsule they have an average density of about one half of solid cobalt. Mr. Errington indicated that they did not like the cobalt wafers they used a few years ago and are now using the small pellets. The wafer sources are considered as having had their day and will not be re-irradiated. However, they are providing for the re-irradiation of the cobalt pellets.

Mr. Errington examined the ORINS capsule and stated that the capsule they are now using is not quite so complicated because their pellets can be poured in and a top put on. In examining the outside of the ORINS capsule, he stated that it is essentially the same except that the Canadian capsule is a hex-sided unit.

Dr. Brucer asked Mr. Errington if he thought it logical to make a capsule that could be transferred to other machines as the source curiage gets smaller. Mr. Errington agreed that it was a very good idea unless in so doing you place a terrific storage and handling problem on the manufacturer. At this point Dr. Aebersold said that he thought it was appropriate to state that, at the present time, the cobalt sources have no resale value to the Commission. It is possible, however, that individuals could solve this problem by selling the decayed source to someone else. Mr. Errington agreed that it was not cheap to re-irradiate; however, he pointed out that the Canadians are pioneering this problem. If they can prove it is economical then maybe the US-AEC would consider it. He further stated that, at the present time, people are thinking in terms of using 35 or 40 curies per

gram and that after a few years they may be thinking of using higher curiage per gram. At that stage other considerations will be coming in to affect the picture of re-irradiation.

A question from the floor asked about the maximum economical size of cobalt 60 sources. Dr. Brucer stated that it had (almost) been decided that the "Johns" 2 cm size is the most feasible; however, the Argonne National Laboratory is now setting up a 1 cm diameter source which will give a little better penumbra. Dr. Brucer further stated that there was a good deal of agreement that a 2 cm to 2.5 cm source is probably the largest economical source for use. Mr. Errington said that he hoped not, but that you can get almost anything you want if you are willing to pay for it.

In closing, Mr. Errington stated that anyone was welcome to the specific details of the Canadian capsule; however, he wanted to emphasize that he did not think it was any better than other capsules under discussion. Dr. Brucer asked Mr. Errington if he would be willing to go along with a standardized outside specification for the source holder in order that Canadian sources could be interchanged with American sources. Mr. Errington said that his company would be in favor of standardization. Dr. Brucer then asked the group if there were any objections to the idea of standardizing the outside size and shape of the source container. No objections were expressed.

Mr. R. G. Millar, of the Keleket X-ray Company, asked whether, if the price of cobalt 60 is $10 per curie and you have a 2000 curie source with an initial cost of $20,000, you could, at the end of five years, trade in the remaining approximate 1000 curies and save $10,000 on the purchase price of another 2000 curie source. Dr. Aebersold stated that this type of question had been answered as a matter of policy in the negative and stated that the US-AEC considers it easier to use fresh cobalt in making radioactive cobalt 60 sources. Dr. Brucer interrupted to point out that the difficulty in receiving, unpacking, and re-packing sources for re-irradiation was the reason he wanted everybody to go to ORNL for the Monday demonstration. The group could thus get a comprehensive understanding of the problems involved in loading and unloading radioactive sources. Mr. Millar stated that his reason for exploring this problem was that, in his recent talks to prospective customers, he found that medical people are assuming that a decayed source can be traded in on a new source or can be irradiated at a reduced cost. Dr. Aebersold said that the Commission had never told anyone or implied that there would be any trade-in value and that it would be necessary for the manufacturers of teletherapy units to educate their customers regarding this policy.

The next item for discussion was the size of the source container. Mr. Rupp again said he thought the group should be talking about minimum dimensions of the hole in the source wheel of the teletherapy unit. For example, the source holder for cesium need not have a larger diameter, but that the height would be greater. Therefore, if the source wheel is designed with a deep hole, the machine could use both cobalt and cesium sources. Dr. Brucer asked if the group was talking about interchanging only cobalt sources or if the group was talking about interchanging cesium with cobalt sources. Dr. Aebersold said that he did not believe you would ever want to interchange cobalt for cesium. It was his belief that you would have to design a special machine to do what a cesium unit would be capable of doing. Dr. Brucer said that he did not feel that many people would be wanting to interchange cesium and cobalt sources because the collimating

devices on all machines are going to be built for certain penumbra size and will not be interchangeable.

After considerable discussion, the group agreed that the inside diameter of the hole in the source wheel would be 2 inches by 1.75 inches with a tolerance of -0 + .015.

Mr. Trout of G.E. asked if ORNL was going to make the capsule. Mr. Rupp said that ORNL at present would only do the encapsulation; therefore, he felt it desirable to standardize the capcules. The Laboratory could, however, operate whichever way fitted the program best.

Dr. Aebersold then opened his discussion of cobalt procurement policy by saying that the US-AEC was not in the teletherapy equipment business and did not intend to get into it. He pointed out that this is somewhat different from Canadian policy, and stated that he was not being critical. It was his intention, rather, to show the difference in policy between the two governments. The Atomic Energy of Canada Limited, under their policy, can produce both the radioactive source and the machine, and they can thus sell an integrated teletherapy unit. The US-AEC has always felt that government facilities are for making radioactive materials, whereas the handling and processing, insofar as possible, should be done by private industry. For example, private industry is doing the special processing of radioactive iodine, phosphorus, and gold for pharmaceutical purposes.

For sealed sources in the lower energy range, the US-AEC sells cobalt in various size pieces. The customer encapsulates them or finds a private company which will encapsulate them for him. However, at the higher levels of activity, for health and safety reasons, the US-AEC has felt that it still has to stay in the encapsulation business. Dr. Aebersold then went on to point out that the US-AEC desires to see free competition develop among the manufacturers of teletherapy units. His own feeling is that the US-AEC would like to see as many manufacturers get into the teletherapy business as is economically possible.

The US-AEC does not desire to have a continuing priority system for the distribution of sources if it can be avoided. Because of the short current supply, however, the plan is to fill purchase orders or letters of intention on a first come, first served basis. The Commission's priority system is based on allocating sources in blocks of five. Each manufacturer will be allowed to indicate his intent to purchase as many as five sources, and when his customers have placed purchase orders or letters of intention for five units, the manufacturer will then be allocated another block of five sources. This simple priority system should allow every manufacturer to sell at least five units, and would also prevent one manufacturer from buying out the market.

Dr. Aebersold stated that the only concern the Commission has in any of the applications for isotopes is the radiological safety exercised by the applicant. He pointed out that up until a year or two ago, the Isotopes Division of the US-AEC had to look over the design of each unit and try to determine the safety of its design. This job is now being done by the NCRP, Subcommittee No. 9; and after publication of the NCRP Handbook, the Commission will ask only that each manufacturer certify that his machine meets the standards recommended by the subcommittee.

Another way in which the US-AEC may get into the picture is through the

publication of health and safety standards. At the present time they are thinking of a maximum exterior surface contamination of .05 microcurie of a beta or gamma emitter. Dr. Aebersold stated that the organizations present at this meeting will not have to worry about such requirements because ORNL will be loading the sources and will make the necessary tests for contamination. However, if the source is ever removed from a teletherapy unit, it would be the US-AEC's recommendation that a test be made to determine any surface contamination.

The Commission is following the recommendations of the Subcommittee on Human Applications in authorizing radiomaterials for teletherapy units. This subcommittee has recommended that the US-AEC not allocate a source to anyone without his being a licensed physician in good standing with the local medical society and with at least three years experience in radiation therapy. The experience requirements can be interpreted to mean three years experience with a 250 kv X-ray unit or its equivalent, but not necessarily with supervoltage or high energy radiation. It is the feeling of the Commission that these are rather liberal criteria.

Dr. Aebersold again stated that the design of the therapy unit, the design of the source and the loading of the teletherapy unit will be the manufacturers' responsibility. The US-AEC will rely on the manufacturer to certify that all recommendations of the NCRP have been met. If a private physician, however, wishes to make and load his own unit, then the criterion of three years experience is not sufficient and the US-AEC will want to know much more about his equipment, how it is designed, how he is going to load it and a number of other safe usage factors.

Dr. Aebersold recognizes that neither the manufacturers group nor the AEC can be responsible for medical ethics; however, he feels that the first teletherapy units should be placed in the hands of physicians of high standing so that there is a certainty of good practice. It was his thinking that if the units got into the hands of people who will ballyhoo them or will use unethical procedures to get wide newspaper coverage, such persons will be doing the whole field of teletherapy a disservice.

Dr. Brucer asked if there was any difference in the availability of hectocurie and kilocurie sources. Dr. Aebersold said that he thought that just as fast as manufacturers could sell a unit and get it installed, the US-AEC would be able to produce the cobalt. It is not believed that anybody will be waiting for a source for either the low or high curiage teletherapy unit.

Mr. Trout wanted to know if the customer or the manufacturer would have to fill out US-AEC Form 313 for the procurement of the radioactive source. Dr. Aebersold replied that the manufacturer should first file a Form 313 for five sources for any specific activity between 1 and 2000 curie sources and indicate that these are for resale. Following the receipt of Form 313, US-AEC will then make an allocation for five sources on the basis of the manufacturers' certification that the specifications of his machine meet all requirements of the NCRP. The application should give the Commission, in addition, some idea of the design and safety features of the unit, the intensity of radiation around the head, and other pertinent information. After the allocation of five sources has been made, the manufacturer will, upon completion of a sales agreement, request his customer to submit a Form 313, stating that he is going to purchase a teletherapy unit from the manufacturer and indicate how many curies and what specific activity is

desired for the unit. The customer, after receiving his US-AEC authorization, will file a purchase order with the ORNL calling attention to the US-AEC authorization number. If the purchaser is not ready to write a purchase order, he may send a letter of intent stating that he wishes to purchase the previously specified source at some stated time in the future. When the manufacturer has sold five units, he will submit another Form 313 and request an allocation of five additional sources. Mr. Hillar asked if his company should file Form 313 for five hectocurie sources and another one for five kilocurie sources. Dr. Aebersold indicated that two separate forms would be honored. Mr. Trout asked whether a customer with a general authorization would need to file the Form 313. Dr. Aebersold stated that when a customer is in possession of a general authorization, he should follow the procedure as outlined previously, except he would state that the source is to be purchased under their general authorization. Mr. J. R. Mason, of the US-AEC, stated that there was alternate procedure, whereby the manufacturer could purchase the source outright for installation in a teletherapy unit and then resell it to the customers. Dr. Aebersold stated that he thought it was best to have the customer buy directly from the ORNL. Then the handling and loading charges would be billed directly to the customer and not to the manufacturer of the equipment. He also pointed out that the manufacturer of the equipment cannot be responsible for the material being sold by the ORNL. For example, only ORNL can certify the number of curies that are being shipped.

At this point Dr. Aebersold requested from the representatives of the X-ray industry an estimate of the number of hectocurie and kilocurie units that will be sold in the next few years. If there is to be a large number of units in each type, it will be necessary for the US-AEC to commit enough reactor facilities for the production of these sources and for replacement sources very shortly. Following considerable discussion on this point, it was agreed that, after a short recess following the present discussion, the representative of each company would submit unsigned estimates of the future requirements for each size teletherapy unit. Dr. Aebersold said that the estimate need not be binding because the production situation was not too critical and indicated that the US-AEC hopes to make at least 30 kilocurie sources within the next year. He then went on to point out that if a thousand curie sources was being irradiated in a reactor and the customer was not able to accept delivery, the source could remain in the reactor for a short period of time. The customer, however, could receive a source of such strength that it would be beyond the maximum capacity of the shielding head and the unit would not comply with the provisions of the NCRP Subcommittee No. 9. Dr. Aebersold recommended that each teletherapy unit have a statement on the unit to indicate the upper limit of the number of curies that the unit can hold and still meet the Subcommittee's recommendations.

Dr. Aebersold also pointed out that the US-AEC has a overriding commitment to national security. Although this type of cobalt 60 cannot be used for military puposes, if a national emergency should occur, it is possible that the US-AEC could not guarantee to keep the production of cobalt at a high level. There are a few reactors, however, in which this sort of cobalt can be made as a by-product, and might be produced without interfering with military priorities.

For the benefit of the X-ray companies, Dr. Aebersold reviewed the Commission's policy on selling radioactive sources. He pointed out that ORNL will measure each cobalt unit against a calibrated ionization chamber and will certify (within limits) the curiage on each wafer. The manufacturer and the purchaser will have to determine the economic factors of additional curiage versus self

absorption. Mr. Stickney of the Picker X-ray Company stated that he thought his company would have to guarantee an output to the customer. Mr. Errington stated that this business of output versus curiage may have been misunderstood. If you set an output you want to get from wafers with a given specific activity and a given diameter, you may have to build up quite a bit more to get the desired output. For example, 15 wafers with a specific activity of 100 curies per wafer would not equal 1500 curies when stacked in their source container.

Dr. Aebersold again mentioned the delayed removal of cobalt sources from a reactor. For example, if a requested 95 curie wafer is up to that level in January, and the customer is not ready to receive shipment, the US-AEC could leave the wafer in the reactor, and the specific activity would go higher than 95 curies per wafer. However, this holding procedure is limited by reactor safety considerations.

Dr. Aebersold then reviewed the Commission's price policy for cobalt sources. He stated that once the specific activity per gram exceeds 10 curies per gram, the price will go up. He quoted the US-AEC price of $50 per curie for the first two curies and then $5 per each additional curie for specific activities ranging up to 10 curies per gram. Wafers having a specific activity of from 10 to 50 curies per gram would sell at $7.50 per curie. This price might again increase to $10 per curie or higher at 100 curies per gram. He then emphasized that these prices are just for the radioactive cobalt and do not include the cost of encapsulation.

A question from the floor requested a quotation of a cost estimate of putting 10 wafers in a source holder similar to the ORINS design. Mr. Rupp promised an estimated price after the recess. He wanted to know whether ORNL would be requested to load the encapsulated source into a shipping container or into the shielding head of the teletherapy unit. Some difficulties might be incurred in trying to get the teletherapy heads into the hot cells of ORNL for remote manipulation.

Some discussion of the sizes of cobalt sources followed. Very generally cobalt 60 sources of about 300 curies give an effective 4 to 5 r/min at a meter; 1000 curies give 15 r/min at a meter; and 1500 curies give an effective 20 to 22 r/min at a meter. It was then pointed out that 50 curies per gram is approximately 450 curies per cubic centimeter and the best you can do with cesium is 100 curies per cubic centimeter. Therefore, a curie of cesium and a curie of cobalt should not be compared. This is one reason why it is not safe to talk of selling so many r's per minute. For example, 100 curies of cesium 137 per cubic centimeter is approximately equivalent to 25 curies of cobalt. The differences in energy and specific activity make an entirely different problem of design for cesium. Sources will be bigger, the shielding requirements less, and the half-life longer. Further, the economics of cesium is not now known.

The group adjourned for a recess and reconvened at about 3:30 p.m.

Dr. Brucer requested Mr. Rupp to give his estimates on what it would cost to load a cobalt 60 source holder similar to the ORINS design. Mr. Rupp stated that, with the customer furnishing a source holder, the cost of loading cobalt 60 in the hectocurie range would be $200 or less; for the kilocurie sources the laboratory will load for $500 or less. Mr. Rupp emphasized that these prices were for loading the source only and do not include the price of fabricating a capsule

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or the price of the cobalt sources.

Dr. Brucer then requested a summary of the X-ray Industries' estimate of the number of teletherapy units that could be sold in the hectocurie and in the kilocurie ranges. In the hectocurie ranges the total estimate for the periods 1953 through 1960 varied from 35 to 275. The estimate for the kilocurie units varied from 35 to 315 units.

In a discussion of the design characteristics of the hectocurie teletherapy unit now on display at ORINS, it was pointed out that the stainless steel source holder would have to be fabricated of hevimet if 600 curie sources are to be placed in the unit. Mr. Errington wanted to know if it would be possible to get a thin enough face by using hevimet. He was informed that a representative of the Carboloy Company had previously stated that the face of a hevimet source holder could be milled to approximately 20 mils. Mr. Errington replied that with stainless steel you are losing from 3 to 5 per cent of the effective beam. He pointed out that to get equivalent efficiency from hevimet, the face of the source containers would have to be approximately 4 mils. The group then proposed a standard source holder of 2 inches outside diameter by 1 3/4 inches high. Such a capsule, with some modification, would be able to take the maximum size of the Canadian sources. General agreement was reached on these dimensions; however, Mr. Stickney stated that he was going to need a device for holding the capsule inside the source wheel. Other suggested modifications included threading the outside periphery of the capsule so that it could be screwed into the source wheel. Mr. Stickney offered for consideration his company's design which follows this principle. Several members of the group agreed with this design. Mr. Rupp called attention to the fact that most manufacturers are using hevimet for the source wheel and possibly for the source container. Serious consideration must be given to the fact that hevimet threads will be very brittle, and once a threaded capsule is started incorrectly either the source wheel or the capsule would be destroyed.

The use of a snap ring was suggested for positioning the source capsule. Mr. Stickney said his company has had very bad luck with snap rings, even where people could see the work they were doing. Another suggestion visualized the use of a hevimet cylinder that would slide inside a steel container. Mr. Errington pointed out that he did not feel it would be possible to decide an engineering or physics problem in a meeting of this type. The group agreed with Mr. Errington and requested Dr. Brucer to prepare a design or alternate designs to be presented for study at a November meeting.

Mr. Mason asked if the X-ray industry would prefer to have ORNL sell packaged sources or whether they would prefer to have their own machine shop make the source container and send it to the Laboratory for loading. The majority of the representatives agreed that they would prefer to buy a packaged unit from ORNL. With this statement Dr. Brucer agreed that he would prepare a suggested standard source container and would try to obtain the concurrence of ORNL and, if time permitted, he would send the prints to the Canadians for their comment. The group decided to meet on November 6, 1953 to discuss only the problem of a standard source capsule.

The last item on the agenda was the question of industrial participation in teletherapy board proceedings. Dr. Brucer stated that the teletherapy evaluation program is operated on public funds; therefore, proceedings of the Board

are open to anybody interested. Invitations to this meeting were sent to all members of the X-ray industry that advertised in the American Journal of Roentgenology, Radiology, and Nucleonics.

Dr. Brucer informed the group that the organizational meeting for the TEB did not approve the idea of industrial participation in the Board's proceedings. However, this does not prevent the Board or the Institute from engaging the representatives from the industrial X-ray industry on a consultant basis, nor does it prohibit the organization of an industrial group. Dr. Brucer then requested comments on how better participation might be affected, and asked the group if they wanted to continue this sort of meeting or if they wanted to depend on industrial representatives visiting ORINS. Mr. Stickney stated that he would like to see these meetings held more often than once every four years. Mr. Davis, of the Westinghouse Electric Corp, and Mr. Millar, of Keleket, said they were in favor of additional meetings. It was agreed by the entire group that these meetings should be held every six months until the rapid developments in teletherapy die down or until it is decided to discontinue the meetings by general agreement among the representatives.

Mr. Millar stated that he did not feel that a meeting six months from the time of this meeting would serve the needs of some members of the X-ray industry. He pointed out that there should be another meeting in the very near future, restricted to the standardization of the source capsule alone. Mr. Trout said he thought the objectives of these meetings could be considerably clarified if this group would state what is to be done with a set of plans after a machine is designed and offered for sale to the medical profession. He thought such a statement would indicate the trend of events and would influence the participation of the X-ray industry. Dr. Brucer pointed out that as soon as any idea is developed within any ORINS program it must become public property. Mr. Millar felt the need for a clearer statement of ORINS policy. For example, in talking about a complete set of manufacturing plans it depends somewhat on the circumstances under which a unit is developed. If the device is developed and drawings are prepared by some manufacturer with their own funds, it is a little different from development carried on by the manufacturer under contract with the US-AEC. Mr. Trout wanted to know if any company was offering for sale the unit that has been demonstrated at ORINS. Dr. Brucer said that rumors are to the effect that the Keleket Company has plans for a sales program based on this or similar units. Dr. Brucer then explained how the hectocurie machine was designed and developed. First, he called attention to the fact that eight companies of the X-ray industry had been requested to bid on the large rotational teletherapy machine. The bidder selected was the Barnes Company. He pointed out that this selection was made following standard government procurement procedures as required by the ORINS contract. During the development of the rotational teletherapy unit by the Barnes Company, Dr. Brucer and representatives of the Company explored the idea of a hectocurie teletherapy unit. The data relative to this small machine has been available to everybody, but inasmuch as ORINS was working with the Barnes Company, they did get into the picture early. It was pointed out that the machine on display at ORINS was completely financed by the Barnes Company. Dr. Brucer then stated that when the Barnes Company gave ORINS a set of preliminary plans for the hectocurie unit, they knew that this information immediately became public property. The Barnes Company was aware that these plans had been shown to the Picker X-ray Company whose representative had visited the ORINS Medical Division. It was pointed out that if representatives from other companies had come down, their representative would have been shown this same set of prints and given the same

information. ORINS, through this meeting, is making an all-out effort to show everything they have regarding this and any future units. This action is in conformance with the ORINS belief that everything is public property and that there is no other way the Institute can work. Mr. Stickney stated that he thought it was generally understood that this factor is inherent in all government contracts.

Dr. Brucer again asked for suggestions on continuing the meeting. Mr. Millar said that he thought the teletherapy program had developed fast enough that another general meeting in six months is desirable. He called attention to the problem of standardization of design of teletherapy machines and suggested that at the next general meeting everybody of the X-ray industry should be invited as well as representatives from institutions who have developed their own designs.

Dr. McLaughlin, of the New York Operations office of the US-AEC, asked about the design and manufacture of units for biological studies in the low curiage range. Dr. Brucer pointed out that some work is being done in this field, and that some people are thinking of very large sources up to ten and twelve thousand curies. Dr. Brucer stated that this program could easily become a matter of discussion for the industrial group.

It was decided by the group that there will be a meeting of all interested industrial representatives on November 6, 1953, at 9:00 a.m. at ORINS, Oak Ridge, to consider the standardization of source encapsulation. During February, Dr. Brucer will prepare and distribute a tentative agenda for a spring meeting to be held in April in Oak Ridge. Participants are requested to offer suggestions for specific items to be included on the program.

The group adjourned.

1136272

REVISED SUGGESTIONS FOR A MULTICURIE COBALT 60 CAPSULE FOR HECTO-KILOCURIE SOURCES.

Following Suggestions by Members of X-Ray Industry of October 4th Conference at Oak Ridge. Prepared for Discussion at the November 6th Conference to be held at Oak Ridge.

The cobalt 60 capsule is made of four basic pieces numbered 1, 2, 3 (and 5, 6, 7, or 8) as shown on the accompanying illustration.

1. The Face Plate Container.

The face plate container is a piece of metal designed to hold the other pieces. It has a face plate (A) which is a 20 mil (or as thin as possible) piece of metal used as an insert of steel brazed into place into Hevimet, or a piece ground down from a solid piece of Hevimet, or whichever metal is decided upon. The front end has a beveled opening large enough to allow the passage of the gamma rays from the largest possible cobalt 60 source, and three lug openings (C) in the front of the face for manipulating the source with remote handling tools. The edges (D) can be rounded for those capsules ~~which~~ that are to be used as free floating bearings, or a secondary bearing surface (4) can be inserted in those machines so designed. The use of the bearing surface does not affect the use of the capsule for other machine designs.

There is a 3 x 3 cm cylinderical opening in the container to accept the Canadian pellet type sources, ~~and~~ it represents the largest possible source ~~which~~ that can be used in the capsule. At (E) there is a depression milled into the face plate container to allow for a pressed fit cap. This represents the first or primary seal. If the entire face plate container is made of steel, it decreases the radiation by 36 per cent through the 14/32 inch wall. If made of Hevimet, there is a 63 per cent reduction. (These per cent reductions are defined in the same way that a half value layer is said to give a 50 per cent reduction.)

There is a rounded groove at (F) to allow the acceptance of a 1/8 inch lead wire for sealing and a beveled flat at (G) to cut into a lead seal placed in the cover (2) at position (G). One of the questions in this design is the strength of a face plate (A). The radiation loss from 20 mils of steel is about 2 per cent and from 20 mils of Hevimet is almost 4 per cent. The seal of steel to Hevimet in ~~the case of~~ a bi-metal design opens up the serious probability of failure.

2. The Cover.

The cover is a piece of steel or Hevimet ~~which~~ that can be screw sealed at either, or both, of two places (G) and (F). In this piece the key problem of fastening to the machine comes up. If the ORINS-Barnes-Keleket idea is followed, no screw threads are necessary on the outside surface at (H). The Picker idea is to have screw threads in this position. The argument against the ORINS-Barnes-Keleket idea of a free floating bearing is that it would cut into the surface, ~~and~~ pick up dirt, and impede the rotation of a wheel device. The argument against the Picker idea of a screw thread at (H) is that any remote manipulation into a screw is difficult, and if made of a brittle Hevimet the threads can be broken and would destroy the use of the entire source. An alternate suggestion has been to put an insert at (J) ~~which~~ that could be plugged for those who did not use the screw thread idea. This, however, destroys the primary objective of making a uniform standardized source capsule for everybody, since it would demand the difficult insertion or

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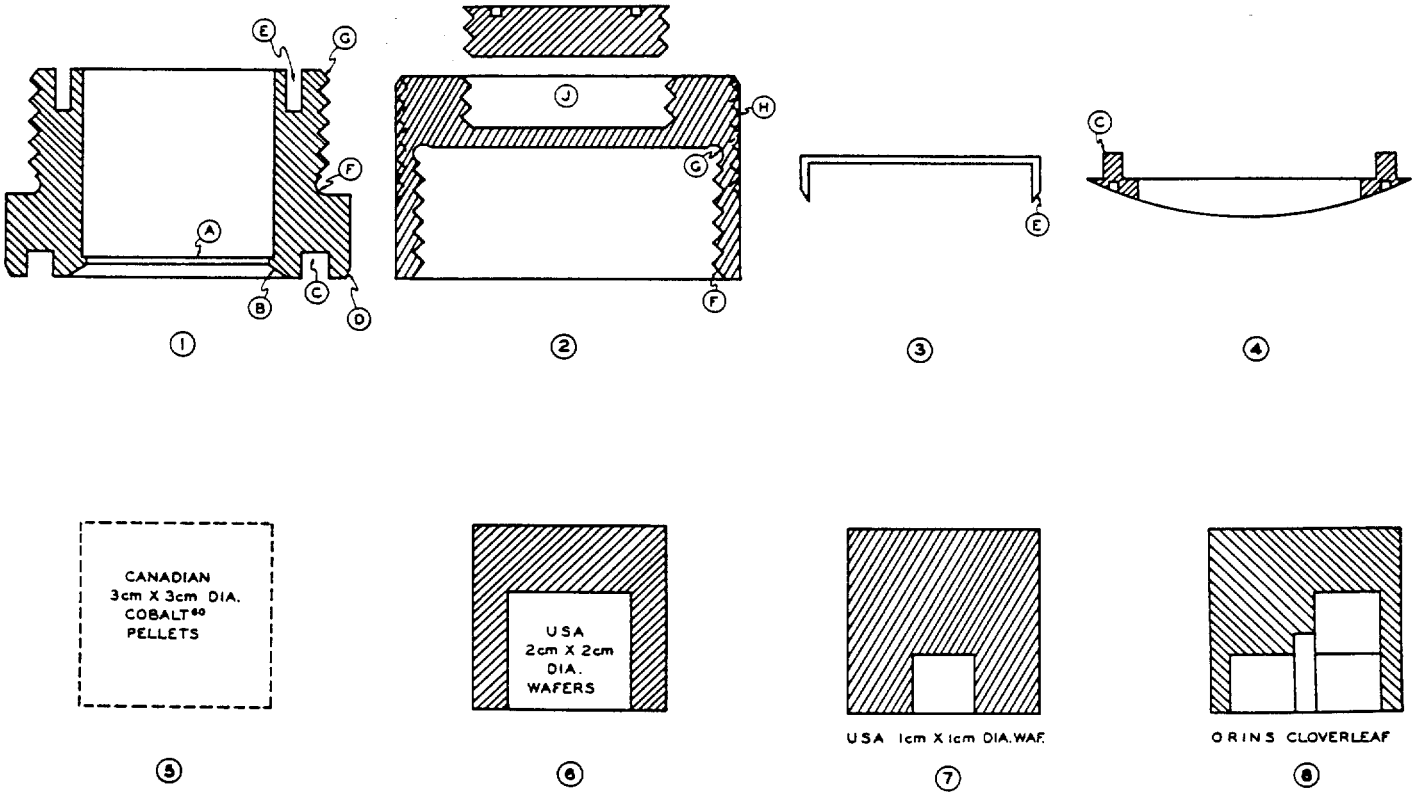

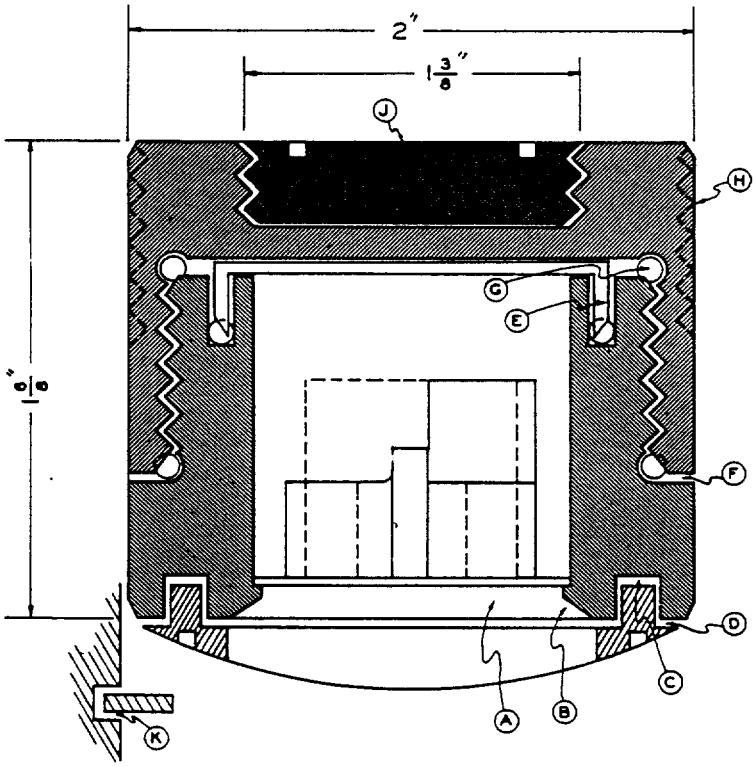

PROPOSE
MULTICURIE Co^{60}
STANDARD CAPSULE

Negative No. 1399

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release of the plug during field loading of a hot source.

Instead of using flats on the outer surface or a Hex design, which will cause a reduction in shielding of from 10 per cent to 25 per cent, the suggestion has been to put 2 lug inserts like those at (C) into the side of the cover near point (H). The cover has the same thickness and shielding characteristics as the side wall.

3. The Primary Seal Cap.

This is a pressed seal cap similar to that shown in the original ORINS model. It can be thick enough to meet the problems of strength. As a primary seal only, it carries no weight; since it can be thin (steel at 20 mils thickness) there is only a very minor loss in shielding, but, as pointed out by the Canadians, a 2 per cent loss of $20,000 is still money.

4. Adapter for Bearing Surface.

This piece could be used without destroying the universal adaptability of the capsule to other machine designs. It will partially overcome the criticism of free floating bearing capsules.

5. to 8. Adapters.

These adapters should be made of Hevimet or some heavy shielding material to fit any source within the maximum size allowed. The capsule without any adapter (5) is for use with the Canadian pellet sources. The adapter with the 2 cm diameter American wafer (6) will allow a total of 7/8 inches on the bottom, reducing the exposure rate by 85 per cent in Hevimet or 59 per cent in steel; and 5/8 inches on the sides with a 75 per cent reduction in exposure rate in Hevimet or 47 per cent in steel. The No. 7 adapter is for the 1 cm wafer or No. 8 adapter for the ORINS cloverleaf pattern. Any other pattern could be adopted within the maximum 3 cm diameter by 3 cm high opening in the face plate container.

LOADING PROCEDURE:

In loading this source capsule, the Canadians would pour in pellets as they now do with their own source capsule. ORNL would load the adapter as now done for the current cloverleaf type capsule, drop the face plate container over it and press it on to the primary seal cap, then invert and screw on the cover.

If such a design were adopted, ORNL and AEC-Canada could sell their sources as calibrated capsules using a standardized measurement procedure ~~which~~ that could be calibrated to fit each machine design. Such a source container could be numbered according to a standard system and its characteristics recorded as recommended by NCRP, Subcommittee No. 9. The use of a screw thread at the base of the cover (H), as proposed by Picker, involves the loss of only about 2 per cent in shielding. The use of lug openings at (H) can probably be considered a pinhole type leak as defined in the Subcommittee No. 9 report. The use of flats in the place of lug openings causes an appreciable loss of shielding up to 25 per cent over a wide area. The use of a snap ring for a fastener for this capsule, to be put in place in the open beam as shown at (K), is probably safe up to a 300 curie source, but is not recommended beyond this curiage. Therefore, it is probably not a good idea.

Representatives who intend to be at the November 6 meeting should be prepared

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to discuss the design of the source capsule as it affects their own particular machine.

At least the following considerations should be remembered in making suggestions for changes:

a. There should be a universal adaptability to any machine or shutter design without the necessity for modifying the source container itself. For this reason, the addition of part (J) is unreasonable.

b. Any maintenance on the source capsule must be done when it is "cold". It is extremely expensive, in both time and money, to ship sources back and forth to special laboratories. We are trying to design a capsule ~~which~~ that can lengthen the useful life of a given kilocurie source to five or six possible half-lives without further modification.

c. Insofar as possible, the container should add to and not detract from the shielding. This is particularly important in small machine designs, which might want to use the 1 per cent leakage provision of the NCRP Handbook or where there is the problem of sliding shutters.

d. The next step in standardization will be the service problem of field loading sources. The source capsule must be adaptable to an easy and safe loading procedure. It would be highly advantageous to have it loaded into a standard field loading device.

e. We have agreed to consider cobalt 60 sources as a special problem and standardize with only this source in mind. Nevertheless, we should consider the adaptability of this container to other sources.

f. We should consider carefully the problem of materials; steel, lead, Hevimet, tantalum, uranium, and perhaps other metals are available for use.

g. It should be remembered that the shielding reductions are on a semilog proportional type curve. It is easy to shield the first few per cent but very different to shield the last few per cent of radiation. The thickness of source capsule we are discussing is close to a tenth value layer. Shavings at this area represent many pounds of shielding material on the outer surface of the machine.

We are sending this letter to all representatives present at the October meeting and in addition are asking the following representatives to be present at the November 6 meeting. If there is any other person who has a legitimate interest we request that you invite ~~them~~ him to attend the meeting. The following additional persons are specifically invited:

1. A representative of the Washington Office of AEC, who can give authoritative advice, cost, and fabrication data on the probability of using uranium for this particular piece of all future cobalt machines.

2. A representative from AEC-Canada and ORNL who are in a position to approve

or disapprove the design from the standpoint of loading, sales, costs, etc. in their organizations.

3. Representatives from the Isotopes Division of the US and Canada who are responsible for allocation and distribution of sources.

4. Representatives from the Carboloy Company to advise us on the machining, cost and use of Hevimet.

5. Representatives from the Fan Steel Metallurgical Corp., North Chicago, Illinois.

6. Representatives from the National Lead Company, Cincinnati, Ohio, and O. G. Kelly Company, Johnson City, Tennessee, who can give us advice on other materials ~~which~~ that might be used.

   I would appreciate knowing the names of any other companies who make a heavy shielding metal so that they can be invited or you may extend the invitation.

7. Any member of any X-ray manufacturing company who is interested. Those companies who are contemplating the manufacture of cobalt 60 machines are particularly urged to attend.

8. Representatives from the NCRP to advise on the adherence of our design to the recommendations of Subcommittee No. 9.

9. Representatives from the American College of Radiology.

To a large extent, this meeting can decide many of the problems of source encapsulation. If a design is to be standardized it must be acceptable to all of the probable participating users of the capsule. If such a design is standardized the cost of cobalt 60 sources can be effectively reduced. In order to assure ourselves that we do have the co-operation of as many ultimate consumers as possible, we will propose at this meeting that the participating members allow the decisions to be published in all radiology journals with a request for criticisms and advice. We will propose that letters be sent to all three of the American radiology journals, the English journals, representatives at Harwell and Lillestrom, Norway asking for their criticisms and advice and whether they can follow the standard design. We will propose that the standard design be tentatively accepted by all participating companies and that there should be a final meeting in approximately one year to vote on ~~a standardized~~ standardization of the cobalt 60 source capsule.

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Marshall Brucer,
Chairman
ORINS Medical Division

1136277

CALIBRATION OF CHEMICAL DOSIMETERS FOR MEASURING X-RAYS OR GAMMA-RAYS.

Oak Ridge National Laboratory - Chemistry Division

C. J. Hochanadel

I. Introduction

The problems of dosimetry are common to a number of fields including radiology, radiation chemistry and radio-biology. Most of the literature on the subject has been contributed by the radiologists who have been faced with these problems for many years. Almost all dose measurements in the past were based on measurements of ionization produced in air, although there have been a few calorimetric measurements and also some measurements based on chemical or physical changes in condensed systems. The first serious study of chemical dosimeters was made by Fricke and co-workers in 1927 when they studied the oxidation of ferrous sulfate induced by X-rays. With the advent of the atomic energy program, the effects of radiation on chemical and physical properties of materials became of fundamental importance, and the use of radiation-induced chemical reactions for dosimeters received increased attention. In the future this type of dosimeter will probably be used more widely in all fields in which dosimetry is important.

II. Some Advantages of Chemical Dosimeters

(1) A dosimeter system can be chosen which has the same radiation absorption properties as the specimen.

(2) A liquid dosimeter can assume any geometry.

(3) They can be used in non-uniform radiation fields.

(4) They can be used under conditions in which the specimen absorbs an appreciable fraction of the incident energy.

(5) They are convenient to use and allow rapid measurement.

III. Choice of a Suitable Dosimeter System

(1) A wide variety of chemical changes brought about by radiation ~~have~~ has been proposed for use as dosimeters. These include decomposition reactions, oxidation-reduction reactions, polymerization reactions, decoloration of dyes, etc.

The choice of a suitable dosimeter depends in part upon particular requirements and on individual preferences. However, I think a suitable dosimeter should meet as many as possible of the requirements listed in Table 1. At present we have no ideal system ~~which~~ that meets all requirements, nor are we ever likely to have such a dosimeter. Most radiation chemists now favor the oxidation of ferrous sulfate in air saturated 0.8N sulfuric acid solution as a dosimeter, and Table 1, the properties of this reaction are compared with those listed for an ideal dosimeter.

(2) The important problem, however, is the accurate calibration of one or more chemical dosimeters against which other dosimeters can be calibrated as they are developed.

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TABLE 1

Properties of a Good Chemical Dosimeter	The Ferrous Sulfate Dosimeter
(1) Radiation absorption same as for systems under study.	(1) Dilute solutions or low Z materials such as tissue (~ air and water equivalent 10 kv. to 10 Mev.)
(2) Yield independent of radiation quality.	(2) 15 kvp to 25 Mvp.
(3) Yield independent of radiation intensity.	(3) 1 r/min to 7.5×10^6 r/min.
(4) Adequate sensitivity.	(4) ~ 1000 r to 50,000 r (air saturated solution) still greater range (degassed solution).
(5) Convenient to use: (a) Shelf reagents—air equilibrated solutions. (b) Stable in storage. (c) Stable product. (d) Easy and sensitive analysis.	(5) Yes (a) Yes, (Organic impurities increase the yield: Cl^- eliminates the effect). (b) Reasonably (Very slow air oxidation). (c) Yes (d) Direct optical absorption easiest (Colorimetric method with orthophenanthroline is the most sensitive).
(6) Simple reaction: (a) Preferably zero order in reactant. (b) Product not affected by radiation. (c) Yield independent of changes in pH, dissolved gas, etc. during radiation. (d) Zero temperature coefficient. (e) Simple reaction mechanism.	(6) As simple as most reactions: (a) 10^{-4} to 1 M. (Slow $Fe^{++}+H_2O_2$ reaction after irradiation in dilute solutions.) (b) No Fe^{+3} reduction in .8N acid. (c) Yield drops when O_2 is depleted. (d) About 5% increase from 2° to 65° C. (e) As simple as most reactions. Has received more attention than any other reaction.

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IV. Methods for Calibrating Chemical Dosimeters

(A) Measurements of Ionization in Air; the Dose in Roentgens:

The standard of dose, the Roentgen, is defined in terms of ionization produced in air and corresponds to the adsorption of a quantity of energy, which is approximately the same at all wave lengths, varying only with the energy required to produce an ion pair at any given wave length. The energy absorbed by any other material placed in the same radiation field can be calculated from the dose in Roentgens by multiplying by the ratio of absorption coefficients of the material and air at the particular wave lengths used. This implies a knowledge of the spectrum of the radiation and of the absorption coefficients in that spectral region. The calculation can be made fairly accurately for low atomic number materials and in the wave length region where Compton absorption predominates. For high "Z" materials and in the low energy or high energy region, the accuracy in making this conversion is poor.

(1) Measurements with the Standard or Free Air Ionization Chambers:

The dose in Roentgens is calculated from the ionization produced by the secondary electrons in a known volume of air. A necessary condition is that photon-electron equilibrium be established in the gas itself, and that there be no contribution from electrodes or walls. The method is thus limited to photons of energy less than 100 kv. unless extremely large spacing or high pressure is used.

(2) Cavity or Thimble Type Ionization Chambers:

(a) Principle

For higher energy radiation, the dose in Roentgens can best be measured using an "air-wall" cavity ionization chamber, in which a small volume of air is surrounded by a sufficient thickness of "air-equivalent" material to insure complete photon-electron equilibrium in the wall and gas cavity system. When used under the proper conditions, the cavity chamber gives the energy absorbed in the wall of the chamber, from the measured ionization produced in the enclosed gas, according to the equation developed by Gray:

$$E_w = J_g W_g \frac{S_w}{S_g}$$

where, expressed per unit mass or per unit volume, Ew represents the energy absorbed in the wall material, Jg is the number of ionizations produced in the gas, Wg is the energy required to produced an ion pair in the gas, and S is the stopping power for secondary electrons (when x-rays or γ -rays are the incident radiation) and for walls made of "air equivalent" material,

$$\frac{S_w}{S_g} = 1 \text{ and } E_{air} = J_{air} W_{air}$$

thereby giving a measure of dose in Roentgens. In principle, the energy absorbed in any material could be measured by constructing a chamber having

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walls of that material or of something equivalent to that material in radiation absorption properties. If the gas in the cavity were also of the same composition as the walls, or at least "equivalent", then no correction for stopping power would be necessary. Since in practice it is usually not possible to fulfill these conditions, it is necessary to correct for differences in stopping powers and absorption coefficients, neither of which are known accurately. For example, energy absorption in water might be measured by constructing a water (or water equivalent) wall chamber containing water vapor in the cavity, or energy absorption in tissue might be measured using a chamber with "tissue equivalent" (usually a plastic) walls and containing "tissue equivalent" gas (usually a mixture of hydrocarbons and other gases).

It can be shown from the Gray equation, that two materials W_1 and W_2 are "equivalent" when

$$\frac{\mu_1}{S_{W_1}} = \frac{\mu_2}{S_{W_2}}$$

where μ is the absorption coefficient and S the stopping power.

(b) Requirements in Using a Cavity Chamber

(1) 100% efficiency in collecting the ions produced.

(2) Sufficient wall thickness to attain electron equilibrium and to exclude particles from the outside.

(3) Cavity dimensions small compared with the range of secondary electrons.

(4) Uniform intensity over the chamber.

(a) Proper geometry.
(b) Negligible attenuation.

(5) Wall material requirements.

(a) Same $\bar{Z}$ as the gas (e.g. air wall chamber).
(b) Or same $\bar{Z}$ as material of interest (e.g. tissue).
(c) Collecting electrodes same $\bar{Z}$ as the wall.

A chamber used by us is shown in Figure 1. A more versatile design, which allows compensation for wall thickness and cavity dimension requirements, is the Failla extrapolation chamber ~~which~~ that consists of two parallel plates that can be adjusted in order to change cavity size and wall thickness.

(B) Calorimetric Measurements

The direct method for measuring energy absorption is by calorimetry. However, ~~in the case of~~ when X-rays or γ-rays, the amount of energy absorbed is usually so small that accurate measurement is difficult. Also, the method is inconvenient because of the equipment and technique required

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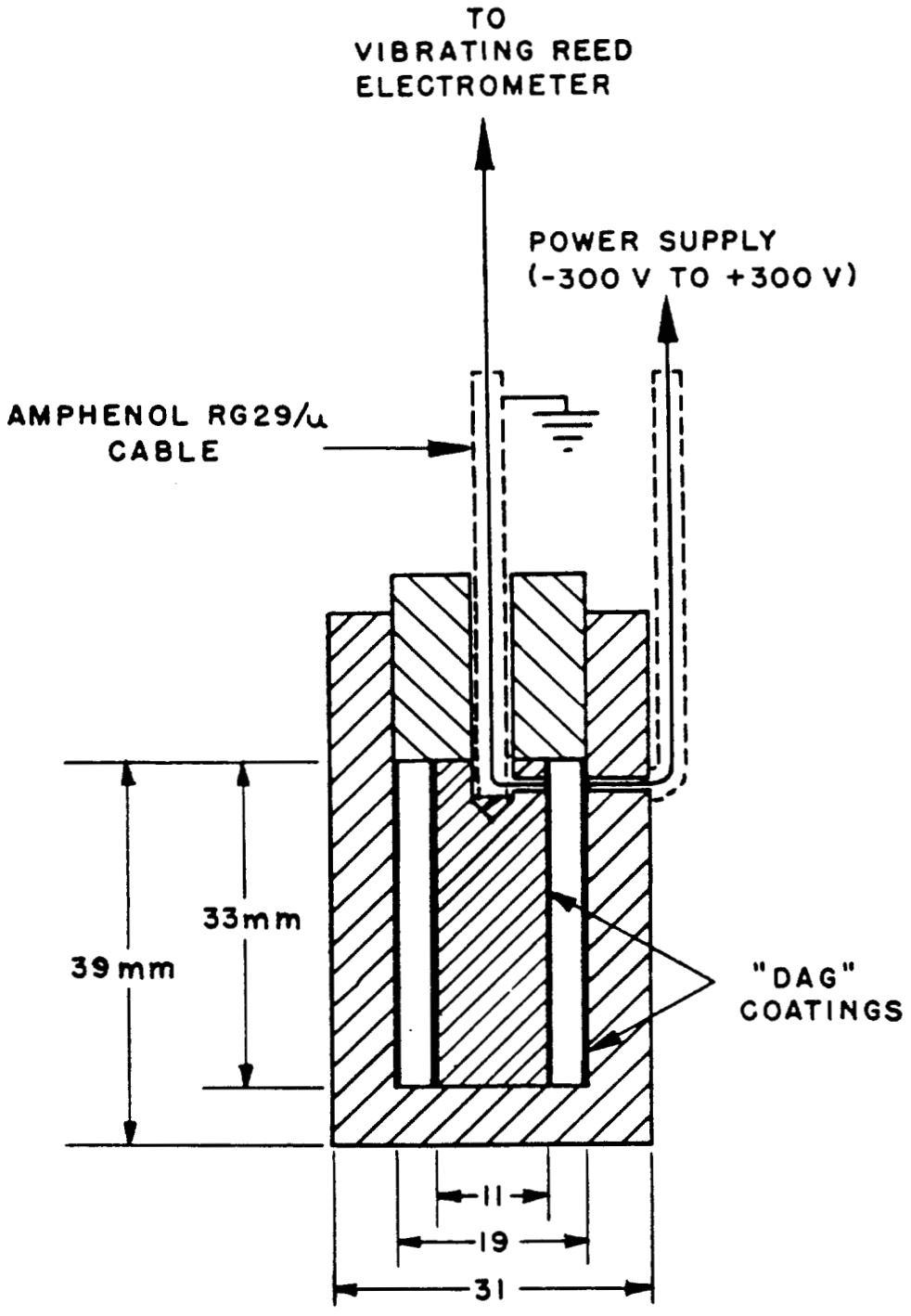

FIGURE 1
SECTION THROUGH CENTER OF CYLINDRICAL
POLYSTYRENE ION CHAMBER

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and is not adaptable to routine laboratory measurements. The method has been used by us, and later by others, to determine the rate at which gamma-ray energy was absorbed by water. Comparing this rate with the rate for oxidation of ferrous sulfate in the same apparatus, the absolute yield in this reaction was determined. The apparatus used by us is shown in Figure 2. Adiabatic conditions were maintained using a heater in the cavity of the lead shield to adjust continually the temperature of the calorimeter jacket to that of the water sample. Measurements were made at intensities of 25, 75, 225 roentgens per second using 300 curie and 1500 curie cobalt sources, one of which is shown in Figures 3 and 4.

(C) Charge-Energy Measurements

Using a beam of charged particles such as that provided by a Van de Graaff generator or cyclotron, the power input can be determined by measuring the particle energy and the charge input. Using an electron beam, the chief uncertainty in the method is back scattering. That is, what fraction of the energy absorbed was contributed by electrons which entered the sample and were scattered out without being measured? For low $\bar{Z}$ targets and particle energies of 1 or 2 Mev, the energy contributed by particles which are later scattered back out is of the order of 5%. Several determinations of the yield for ferrous sulfate oxidation have been made using electron beams. Electrons are expected to produce the same chemical effect as X-rays or γ-rays where the action is through Compton recoil electrons.

(D) Internal β^- particle Sources:

Several determinations of the yield for ferrous sulfate oxidation have been made using internal β^- sources such as P^{32} and S^{35}. Total energy absorbed was determined from the total number of disintegrations (4π absolute β^- counting) and the average energy per disintegration. The chief sources of error lie in determining these quantities and estimating the energy lost in the container walls.

(E) Results Obtained for the Oxidation of Ferrous Sulfate by X-rays, Gamma-rays and Electrons.

The results listed in Table 2 indicate serious differences among the various measurements, with most results ranging around either 15.6 or 20. The differences may result either from errors in energy measurements or from incomplete understanding of the reaction mechanism. Most of the more recent results, obtained by three different methods, tend to favor the value 15.6. The fact that there is disagreement among the various results for the absolute yield should not, however, detract from the fact that chemical dosimeters do offer a number of advantages.

The reduction of ceric sulfate is often used as a dosimeter. Values obtained by various workers for the ratio of yields of ferrous oxidation to ceric reduction range from 6.0 to 6.8. It is generally agreed that yields for ceric reduction are less reproducible and more susceptible to effects of impurities. Typical dose-concentration curves for the two reactions are shown in Figure 5.

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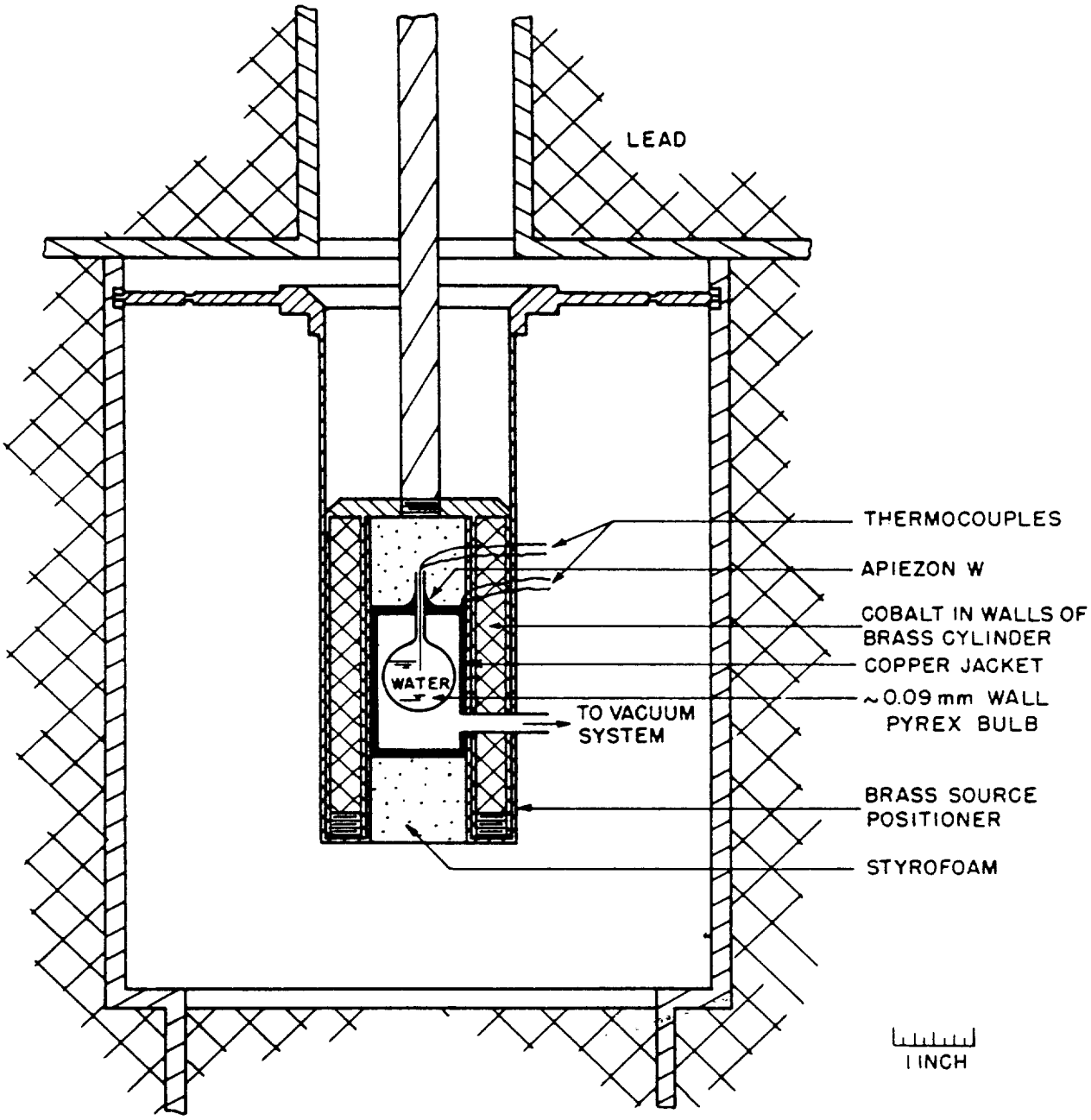

FIGURE 2
CALORIMETER FOR MEASUREMENT
OF GAMMA RAY ENERGY ABSORBED IN WATER

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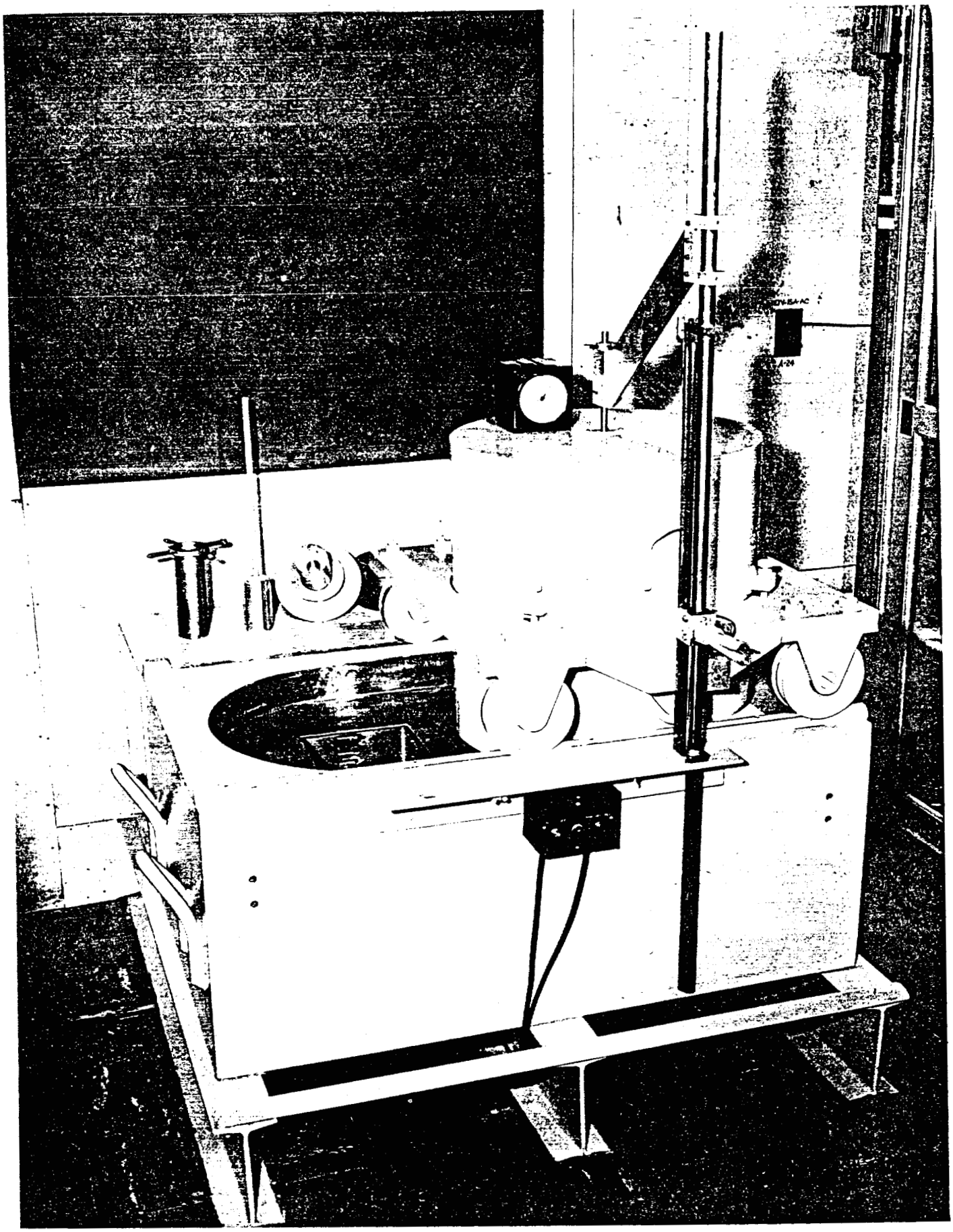

FIGURE 3

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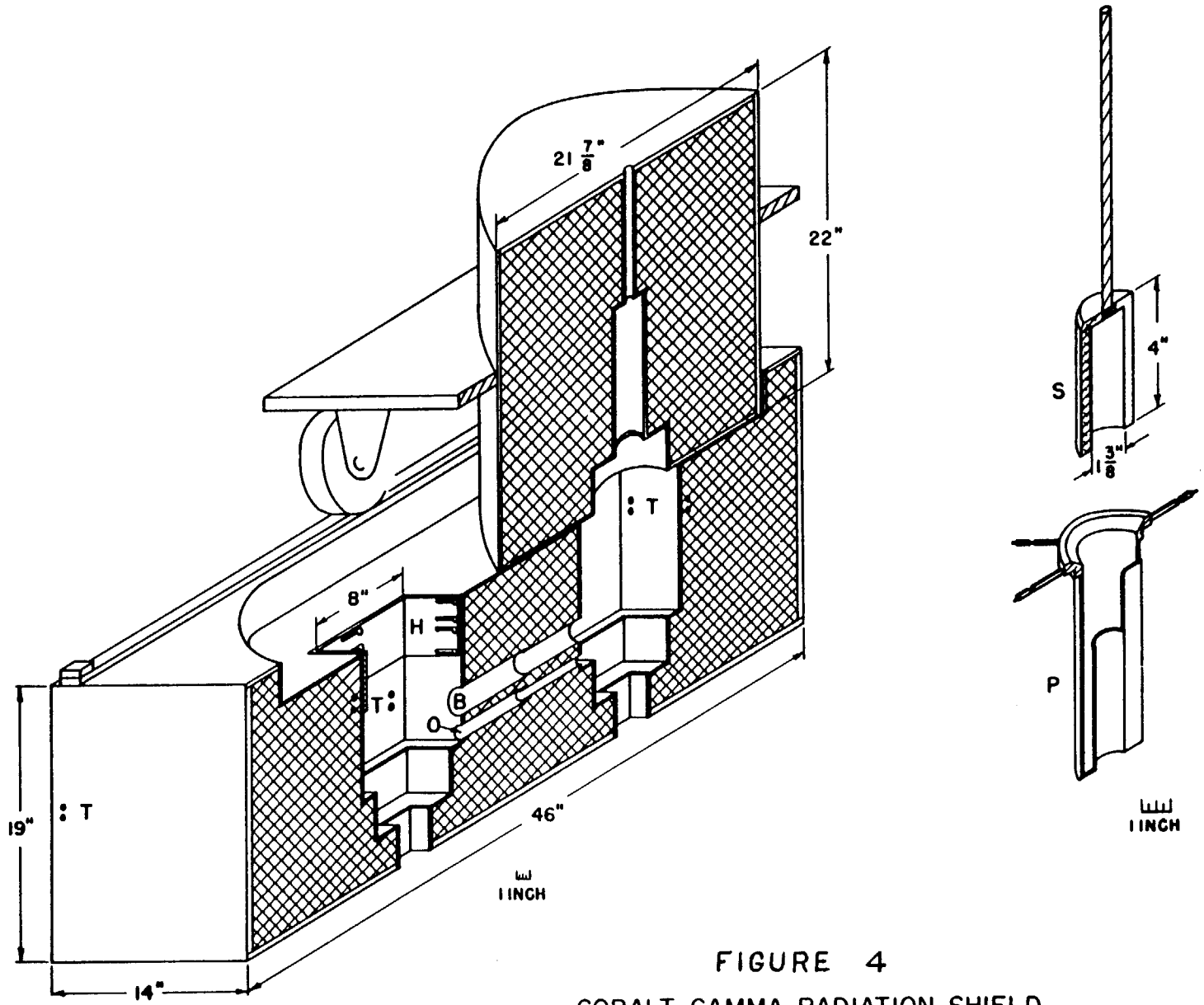

FIGURE 4

COBALT GAMMA RADIATION SHIELD

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TABLE 2

Yields for Ferrous Sulfate Oxidation by X-rays, γ-rays and Electrons.

(Ionization)	$G(Fe^{+2})$
Fricke	18.0
Shishacow	15.9
Miller	19.9, 20.3 ± 1.0
Hardwick	20.4
Todd, Whitcher	20.3
Hochanadel, Ghormley	17.2 (1)
Ebert, Boag	20.3
Rigg, Stein, Weiss	20.5
Magart, Shapiro	20.
Spinks, et al.	15.8, 15.4
Rosenzweig	14.9 to 17.1

(Calorimetry)	$G(Fe^{+2})$
Hochanadel, Ghormley	15.6 ± 0.3
Davison, Proctor, Goldblith	20.2
Lazo, Burton	15.5
(Charge and Energy)	
Hochanadel, Ghormley	16.8 (2)
Allen, Saldick	15.6 ± 0.2
Internal β' Sources	
Hardwick	20.2, 21.1

$G(Fe^{+2})$ refers to the number of ferrous ions oxidized per 100 electron volts absorbed in the solution.

) Assuming $S_{polystyrene} = S_{air}$. We believe $S_{Poly} = 1.10\ S_{air}$.

(2) Making no correction for back scattering which, if made, would lower the yields.

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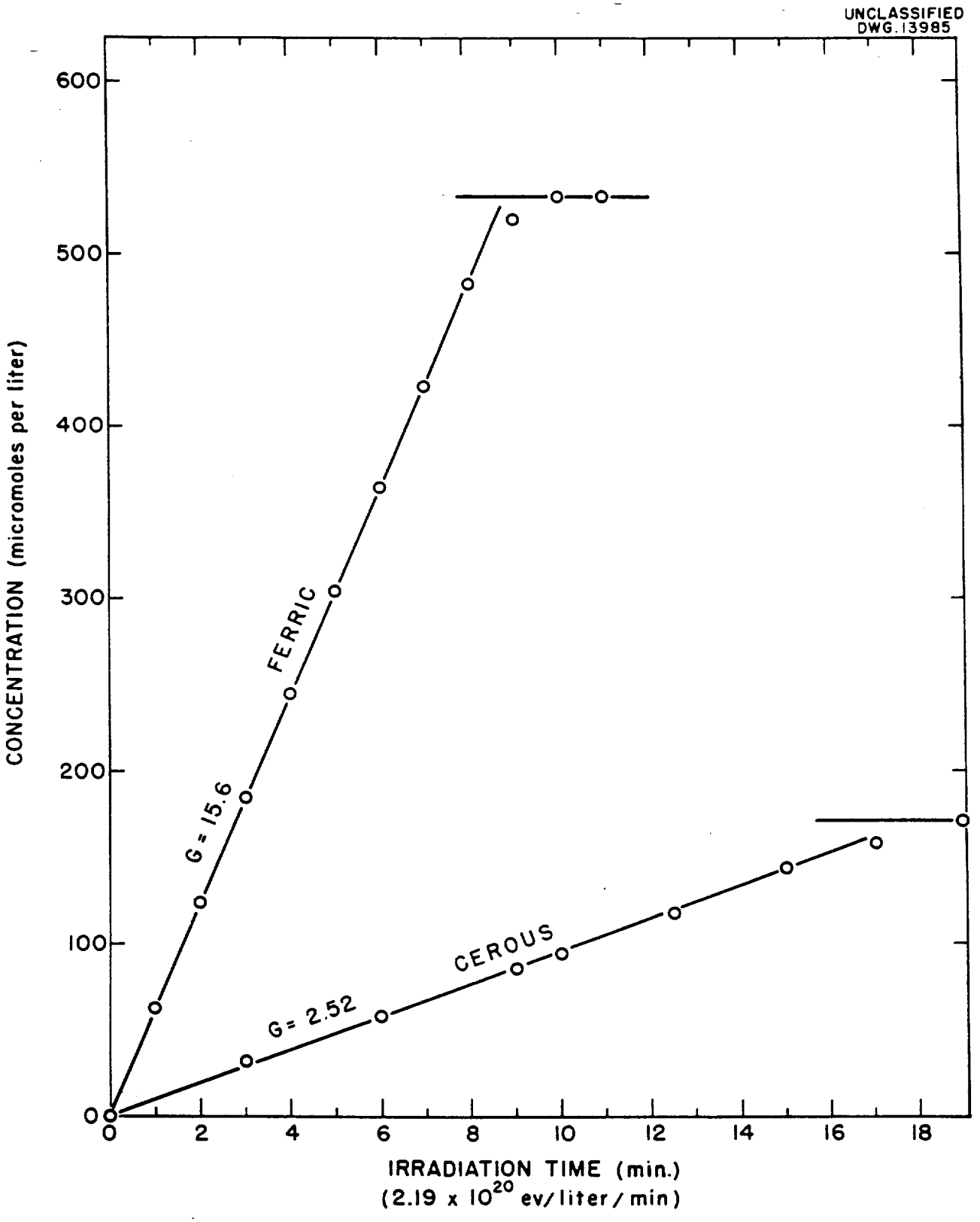

FIGURE 5 – TYPICAL CONCENTRATION vs. DOSE CURVES FOR THE OXIDATION OF FERROUS SULFATE AND THE REDUCTION OF CERIC SULFATE BY COBALT GAMMA RAYS

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MINUTES OF THE SECOND JOINT MEETING OF THE X-RAY INDUSTRY, OAK RIDGE INSTITUTE OF NUCLEAR STUDIES, ISOTOPES DIVISION - UNITED STATES ATOMIC ENERGY COMMISSION AND THE ATOMIC ENERGY OF CANADA LIMITED, AND THE OAK RIDGE NATIONAL LABORATORY

Held at the Medical Division
Oak Ridge Institute of Nuclear Studies

November 6, 1953 - 9:00 a.m.

Present:

Beauchamp, E. E.	Oak Ridge National Laboratory
Brucer, Marshall	ORINS - Medical Division
Bullket, L. J.	W. F. & John Barnes Company
Carraher, T. J.	Keleket X-Ray Corporation
Gillespie, J. S.	Carboloy Department, G. E. Company
Green, D.	Picker X-Ray Corporation
Harmon, J. H.	ORINS - Medical Division
Hollstein, O. C.	Picker X-Ray Corporation
Judkins, Malcolm F.	Firth Sterling Corporation
LeWald, Harold P.	Bar-Ray Products, Inc.
Lillie, Alan B.	Atomic Energy of Canada Limited
Macon, J. R.	Carboloy Department, G. E. Company
Mason, J. R.	U. S. Atomic Energy Commission
Moffett, J. J.	Atomic Energy of Canada Limited
Reed, William H.	P. R. Mallory and Company
Rose, J. M.	Fansteel Metal Corporation
Rupp, A. F.	Oak Ridge National Laboratory
Savage, T. E.	National Lead Company
Spayth, F.	P. R. Mallory and Company
Stickney, J. B.	Picker X-Ray Corporation
Stober, E. V.	Keleket X-Ray Corporation
Trenkle, F. A.	Westinghouse Electric Corporation
Wagner, R. J.	Westinghouse Electric Corporation
Wellborn, W. W.	Firth Sterling Corporation
Yancey, R. W.	Fansteel Metal Corporation

To prepare these minutes a running audograph record was dictated by Mr. Harmon throughout the meeting. The record includes much repetition of discussion and occasionally personal names were lost in the rapid interchange of ideas. These minutes were prepared with the hope of retaining all of the ideas presented but some of the repetition has been deleted.

I. INTRODUCTION

Dr. Brucer opened the meeting with a review of the minutes of the previous October 4 meeting. The first factor to consider is the problems of radioactive dust from Co^{60} sources. The National Committee on Radiation Protection, Subcommittee No. 9, has recommended that Co^{60} be considered as having a potential dusting hazard. Also the US-AEC producers concur in the belief that radioactive cobalt cannot be produced without the potentiality of dusting and flaking; therefore, encapsulation will require a double seal. A second factor to consider

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is the material to be used in the design and fabrication of the source container. A third factor is the thickness and density of the presenting face of the source capsule. Any increase in the thickness or density of the presenting face produces a rapid drop-off of the primary beam. A fourth factor is the "off" position of the source in the shielding head. For example, in the ORINS-Barnes prototype design, the "off" position of the source is behind a shielding block of tungsten. The design and spacing of the presenting face of the source capsule permits primary beam leakage through the shielding head, and this leak is considerably more than a pinpoint leak.

II. MATERIAL FOR SOURCE CONTAINER

The first item on the agenda was a discussion of materials usable for fabricating a standardized source container. For example, in one design, if of stainless steel the container would reduce the radiation by 35 per cent; if of tungsten alloy by 63 per cent; and if of uranium by 72 per cent. Mr. Judkins pointed out that the tungsten alloy could be obtained to a specific gravity of 18.6, which is close to the shielding properties of uranium. Dr. Brucer stated that he had just received information from the US-AEC that small amounts of uranium might be available for fabricating source containers.

A number of members presented arguments against the use of uranium. Mr. Rupp pointed out that there were difficulties in machining uranium which might be new to some manufacturers in private industry. The health hazards were mentioned briefly. The current uncertainty of commercial use of uranium in about 5 pound blocks is a definite problem to private persons and it is questionable whether the added administrative procurement problems are overcome by the relatively small increase in efficiency when used in this particular source capsule. The group seemed to be unanimous in preferring a tungsten alloy at present but uranium could be substituted without any major change in any of the designs.

Mr. Green suggested the use of steel. This, in general, was acceptable. It was pointed out, however, that to use steel would be to lose the benefit of effective shielding close to the source, where it is most desirable to have maximum shielding. The same arguments hold as for the uranium-tungsten relationship but here there is a considerable gain in shielding efficiency. Dr. Lillie pointed out that the extra shielding in the head, required by the use of steel for source container, was not so critical as the metal's machineability characteristics, which make it suitable for building a thin face on the source container. It was pointed out that measurements on the ORINS-Barnes hectocurie machine shielding a Co^{60} source of 450 curies, and with the source container fabricated of steel, requires an additional 1.25 inches of lead on the perimeter of the shielding head over what would be necessary with the proposed tungsten alloy source capsule. Thus, there is appreciable saving in space and weight with correct capsule design.

The manufacturers of tungsten alloy were shown two suggested source container designs by Barnes and Picker and were asked if they could manufacture them. Mr. Gillespie said they could but it would not be easy to make the thin face. Mr. Judkins said, that with all the gadgetry on the outside, his company could make such a capsule but with difficulty. Mr. Reed said tungsten alloy could be fabricated to these designs and agreed on the difficulties of the thin face.

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Mr. Yancey requested information about the stress placed on the thin presenting face and asked whether aluminum or aluminum alloy of 2 mil thickness was usable. It was pointed out that a face made of steel reduces the primary beam by about 2 per cent; if aluminum is used the reduction would be less than 1 per cent; if tungsten alloy close to 6 per cent. Mr. Green pointed out a problem of corrosion of dissimilar metals under various conditions. Mr. Yancey, Dr. Lillie and Mr. Stickney discussed the effects of corrosion caused by extreme ionization by the beam, and by galvanic corrosion of dissimilar metals.

Mr. Yancey then asked about possible rupture of the source container face. Mr. Rupp stated that he felt that the stress of the face was quite critical. Dr. Brucer stated that in making physical measurements of the beam, ORINS technicians are frequently turning the machine up and resting test tubes on the container face. This could be a common procedure in chemical and physical measurements and there will be a remote possibility of puncturing a thin face.

Mr. Macon asked if the source container could be plated. Dr. Moffett stated that this was just an introduction of another dissimilar metal and that they would much prefer to work with a single one. Mr. Rupp emphasized that the attenuation at the face is a function of the density and absorption coefficient, and it is desirable that each be kept as low as possible but at the same time maintain enough strength to retain the source in the capsule. It was pointed out that customers are paying for radiation and every time you add another per cent radiation loss the customer is losing value.

Mr. Wellborn suggested the possibility of brazing an aluminum, brass, or stainless steel face to a tungsten alloy container. Mr. Stickney said that it would be difficult to get a good hermatic seal with aluminum brazed to tungsten alloys. Dr. Moffett stated that we did not have enough experience with dissimilar metals to assure a good brazed face for a source box. He pointed out that dissimilar metals, if moist, would cause trouble; however, if maintained under dry condition they might not create any problem.

Dr. Moffett stated that in his own thinking the machinability of the tungsten alloy would be quite a problem; however, inasmuch as the manufacturers of tungsten alloys felt that this would not be a problem, the Canadians would go along with a tungsten alloy source box. Mr. Gillespie pointed out that in trying to machine across grain in either steel or tungsten alloy, the thin window would be excessively fragile and he would not trust it. Mr. Judkins and Mr. Reed concurred with Mr. Gillespie's statement. Mr. Judkins said that in machining the window from an integral piece, there are also the problems of other machining operations such as boring, facing, turning, and threading. He then stated that tungsten alloys are easier to machine than stainless steel. Dr. Moffett said he was convinced that welding a face plate in a tungsten alloy capsule is sound. If, however, there is any serious doubt about the long term efficiency of the brazing, then stainless steel is the best metal to use to get a reasonable thickness of window without losing too much radiation. Mr. Stober suggested fabricating a tungsten alloy capsule and using a cup of stainless steel. Mr. Rupp again suggested serious consideration of the possibility of the breaking of the face plate.

Dr. Moffett emphasized that it is pretty well established that the window must be of stainless steel and that we are faced with a brazing or mechanical sealing. Mr. Gillespie illustrated a diaphragm seal wedged between the cap and container wall by two rings of soft solder. Mr. Yancey pointed out that we cannot

obtain all desirable properties in a single metal and suggested that corrosion of dissimilar metals could be avoided by making the window face out of nickel, which is compatible with tungsten alloys. Mr. Judkins concurred in the suggested use of nickel. Dr. Moffett agreed that it would serve equally as well as stainless steel.

Mr. Rod Mason reminded the group that earlier in the discussion it was demonstrated that with the Barnes' source in the "off" position there are not close tolerances between the source and the outside shield resulting in small leakage beams of radiation. He then asked whether nickel, a less dense material in a critical position, would reduce the radiation protection in the "off" position. Dr. Brucer pointed out that the ORINS-Barnes' prototype had considerable ($\frac{1}{2}$ inch) tolerance between the face of the container and the tungsten shielding block embedded in the lead shielding head. This error in design could be corrected in the standardized capsule and must be kept in mind.

III. DESIGN OF SOURCE CONTAINER

To start a discussion of the source container design, Mr. Stickney illustrated a design proposed for his company's teletherapy machine. Mr. Judkins noted the external threads on the container and suggested that the box be designed so that the full threads would have four slots perpendicular to the threads to permit inserting the source container and turning it 90 degrees for locking.

Mr. Bulliet presented the ORINS-Barnes design of a source container, which has no external threads. The capsule is inserted into a smooth bored hole in the shutter wheel and is held in position by a snap ring. Mr. Bulliet stated that objections have been raised to the snap ring; and to overcome these objections the Barnes Company has been studying other designs for holding the capsule in the shutter wheel. Mr. Bulliet emphasized that the Barnes engineers are not yet completely satisfied with the external thread for holding the container in position. His company has tentatively discussed a design that will make the capsule a free floating bearing. Mr. Bulliet then outlined two objections to this free floating bearing design. The first problem is the difficulty of maintaining smooth bearing surfaces with a tungsten alloy working against bronze. The second difficulty is preventing the source container from snagging in the portal. Designs for avoiding these problems were discussed by Mr. Bulliet. A comparison of the Picker container and the ORINS-Barnes container shows that where the latter container has three parts, the former design eliminates one of them. Mr. Mason wanted to know whether the NCRP recommendations specify that there must be a double wall completely around the source; this was not so stated in the recommendations. Dr. Brucer stated that the face plate seal on the Picker capsule could be tested to prove that it is hermatically sealed before loading; and his experience on the NCRP, Subcommittee No. 9 would lead him to believe that the design would meet the recommendations of the Subcommittee. The double seals were specified because, after loading, it is impossible to test the container to determine whether it is hermatically sealed. A seal which can be pre-tested is not a critical point in the design.

Mr. Yancey discussed a design that could be sealed by pressure. The design would be sealed by forcing the cap into position against a soft solder seal causing the solder to flow between the sides of the cap and container. Mr. Yancey estimated that it would require a few thousand pounds per square inch to make the closure. Mr. Rupp said that ORNL had high level barrier equipment adequate for obtaining up to 50,000 pounds per square inch. Mr. Yancey asked whether the cobalt would ever

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be removed from the container. Mr. Stickney stated that the Canadians might want to take the Co^{60} out for re-irradiation. Dr. Moffett agreed that there would be no problem in removing the cobalt from any of the three suggested designs. Mr. Gillespie pointed out the problem of breaking the seals with rough handling in remotely controlled operations.

Mr. Stober brought up for consideration the suggestion of a stainless steel cup that would fit inside a tungsten alloy source container. The face of the cup would be 10 mils thick and the cup would stand on the shoulder of the tungsten alloy container. This design would eliminate the necessity of brazing a face plate to the presenting face of the capsule. It was pointed out that this suggestion could be used in each of the three designs suggested so far. The cup could be sealed by screwing a cap down against lead ring seals located on the lip of the stainless cup.

Mr. Judkins questioned if lead ring seals would have a tendency to tear when applying force by screwing down the container top and not produce a continuous seal. Mr. Gillespie concurred with this thought and emphasized that with the press fit the metal would flow freely. The question was asked whether there would be a tendency for the lead to continue flowing and whether the seal would break down over a year or two. Dr. Brucer stated that two years experience with pressed seals had not produced any leaks. Mr. Rupp stated that with sources going into the pile over a period of years, ORNL has found that a perfect welded joint is not an easy matter and requires very skillful handling with specialized equipment. ORNL has never experienced any difficulty with the lead seals either in screw down or press fits.

Mr. Wellborn reviewed the discussion on the brazed face plate and stated that such a seal is capable of being tested by air pressure or vacuum before assembly of the capsule. Mr. Stickney pointed out that his company would make the brazed joint by having the brazing compound flow into the opening by capillary action, under high temperature. Also, when the cap is screwed tight, the inner wall of the container would press against the face plate making an extra seal. Mr. Yancey asked Mr. Stickney whether there was any objection to using the stainless steel cup, eliminating the welding of the face plate. Mr. Stickney had no objection but pointed out that it required an additional piece in the assembly. Also, using the can in the Picker design would require inverting the can after loading. After considerable discussion it was agreed that the loading procedures could be accomplished easily with any of the designs so far presented.

The group then considered a summary of the proceedings to this point, as exemplified by the three designs, which were drawn on the chalk board. Each suggested design would have only one seal if a can is to be used. Mr. Gillespie suggested that the stainless steel cup and the brazed face plate in front of the primary beam could be used to obtain a double seal.

Mr. Gillespie questioned the desirability of threads on the outside of the source container. Mr. Stickney said that there must be some way of fastening the source container into the wheel, and indicated that his company would be glad to consider any feasible method of fastening the source to the wheel. Mr. Gillespie suggested the use of a set of screws recessed into the side of the source container at an angle of approximately 30 degrees with respect to the vertical axis of the container. Mr. Stober stated that to screw an externally threaded source container

into position would require special tools to make changes from one unit to another, and suggested that the locking device be a part of the head. With such a design anyone with knowledge of how to unlock the device could readily transfer or field load sources. It was pointed out that this suggestion was compatible with the Keleket design and the Canadian design, but that it doesn't quite fit the Picker unit.

The discussion reverted back to the problem of sizes and Dr. Brucer wanted to know whether a 3 centimeter source would be standard from Canada. Dr. Lillie stated that the Canadians would continue using some wafers. Dr. Moffett pointed out that probably within a year, higher specific activity cobalt would be available and it would be feasible to use smaller size sources. Dr. Brucer pointed out that if there is going to be standardization, it is still desirable to keep the source container as large as possible, since, in the event of heavy demand for war materials, the X-ray industry could then resort to low energy cobalt.

Mr. Wagner questioned the possibility of cracks occurring in the stainless steel cup previously discussed. Mr. Gillespie and Mr. Wellborn agreed that the stainless steel cup could be drawn without any breaks occurring in the face or wall of the cup. This statement assumed a minimum wall thickness of 10 mils.

The question came up again about how to eliminate the outside thread on the source capsule and Mr. Hollstein said the Picker X-Ray Company could design their machine without these outside screws. They still felt, however, that it was the best procedure. Mr. Stickney said he still felt that the external thread was much safer, because the container would have to back out several times, whereas the set screw could make one or two turns and the container would fall out. Mr. Stober wanted to know why it was deemed advisable to fasten the container to the source wheel. Why not have the container floating as a free bearing as suggested by the Barnes Company? To discuss the wear factor the group made the assumption that a teletherapy source wheel would make a revolution 40 times a day, 365 days a year. With this magnitude of a wear problem, it was felt that the source capsule could be a free floating bearing.

Mr. Carraher stated that a free floating source capsule would rotate with the opening of the source wheel, and asked whether this rotation would change the source isodose pattern. Mr. Carraher was informed that current measurements do not indicate any change in isodose patterns.

There was considerable discussion around all of the designs presented and one design, embodying features of each, rapidly took shape. It consisted of one external piece, an internal cap and an internal plug. It has the advantages of not requiring manipulation of the internal parts after loading. No stresses can be placed on the internal parts. There is a thin face in the cup which can be pretested. It has only three parts. It affords excellent shielding in all critical dimensions. It has a double seal. Only on one point was there a disagreement, and that was on the problem of the external screw thread. There appeared to be 1/8 inch available on the external surface which could be used for some kind of a fastening device. Mr. Stickney agreed to attempt to work out a solution within this 1/8 inch. In the problem of the height of the container, it appeared that it might be necessary and desirable to add a short additional length for the internal screw thread.

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Dr. Lillie requested that a final summary be made of the specifications agreed upon, and Mr. Stickney was requested to prepare a sketch of the container (see Fig. 1). Mr. Gillespie suggested that the group make final approval after a design was drawn to scale by Mr. Stickney.

POST-MEETING NOTE

Mr. Stickney has drawn the suggested source capsule to scale and has added the necessary materials and size specifications. The Picker engineers have found that they can include the external Acme screw thread in the allowed space. It was found necessary to add the 1/8 inch extra length to give an adequate number of threads on the internal plug. It is intended that a sub-assembly be made of the outer sleeve, the cap, and one lead ring. The lead ring is expanded in place holding the assembly loosely together. A second sub-assembly of the other lead ring and the plug can also be made ahead of time. Thus, only two pieces have to be handled with the remote manipulators. Otherwise, the design is as determined in the meeting.

The external thread decreases the shielding by only a small percentage and in essentially the same position as allowed by the single depression using a set screw. Since the hole is in a non-critical area it is of little consequence and has the advantage of allowing a screwed-in source capsule for those who so desire. The suggestion has been made that each source capsule be stamped with a suppliers identification code and a number on both front and rear faces so that a positive identification can be made with a mirror and telescope either in position or in the shipping container, and that records be kept on each source.

These minutes will be distributed as suggested in the preliminary notes. If no serious objections are voiced we will publish the design as a joint recommendation next January.

Marshall Brucer, M.D.
Chairman
The Medical Division

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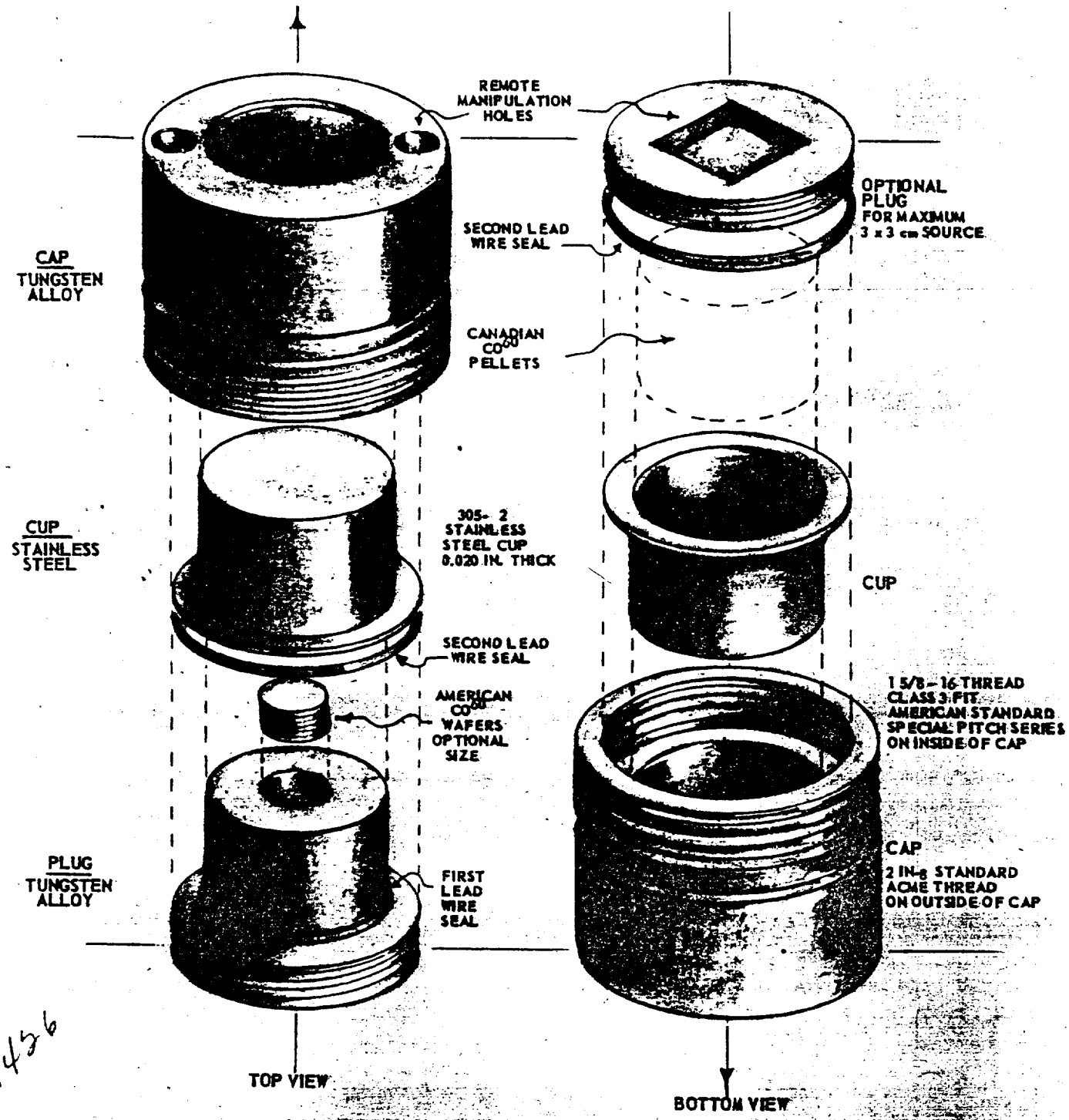
STANDARD CO^{60} SOURCE CAPSULE

TENTATIVE ADOPTION 6 NOV. 1953
BY MEMBERS OF
X-RAY INDUSTRY
CANADIAN AND U.S. AEC
AT ORINS. OAK RIDGE



DESIGNED FOR HECTOCURIE AND KILOCURIE TELETHERAPY UNITS

MAXIMUM SIZE OF CAPSULE 2 INCH DIAM x 1 7/8 INCH LENGTH

MAXIMUM SIZE OF SOURCE 3 cm DIAM x 3 cm LENGTH

CONSTRUCTION DRAWINGS MAY BE OBTAINED FROM MEDICAL DIVISION - O.R.I.N.S OAK RIDGE, TENN.

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Teletherapy Minutes
1954
Anderson Files

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December 14, 1953

TO: ALL MEMBERS OF THE TELETHERAPY EVALUATION BOARD

SUBJECT: AGENDA FOR THE ANNUAL MEETING OF THE TELETHERAPY EVALUATION BOARD

+ Robert N. Cooley, M.D. - Univ. of Texas - Medical Branch

The current members, alternates and consultants to the Teletherapy Evaluation Board are as follows:

	+ James F. Kelly, Jr., M.D.	-	Creighton University
Members & Alternates:	~~+ J. Robert Andrews, M.D.~~	-	Bowman Gray School of Medicine
	Marshall Brucer, M.D.	-	ORINS Medical Division
	+ Walter J. Burdette, M.D.	-	Louisiana State University
	+ David S. Carroll, M.D.	-	University of Tennessee
	+ Vincent Collins, M.D.	-	Baylor University Graduate School
	+ George Cooper, M.D.	-	University of Virginia
	+ Gilbert H. Fletcher, M.D.	-	M.D. Anderson Hospital
	+ Arthur C. Guyton, M.D.	-	University of Mississippi
	~~Frank E. Hoeckes, Ph.D.~~	-	~~University of Kansas~~
	+ H. B. Hunt, M.D.	-	University of Nebraska
	~~John A. Isherwood, M.D.~~	-	~~Baylor University Graduate School~~
	+ Henry Jaffe, M.D.	-	University of Southern California Cedars of Lebanon Hospital
	~~James F. Kelly, Jr., M.D.~~	-	~~University of Nebraska~~
	+ Herbert D. Kerman, M.D.	-	University of Louisville
	+ James E. Lofstrom, M.D.	-	Wayne University
	+ C. C. McClure, M.D.	-	Vanderbilt University
	+ Frederick Mandeville, M.D.	-	Medical College of Virginia
	+ Isadore Meschan, M.D.	-	University of Arkansas
	~~Carl E. Nurnberger, Ph.D.~~	-	~~University of Tennessee~~
	+ Robert Reeves, M.D.	-	Duke University
Dr. Alfred S. Berne ←	+ Paul Riemenschneider, M.D.	-	Syracuse Memorial Hospital
	+ William H. Riser, M.D.	-	Medical College of Alabama
	+ Sidney Rubenfeld, M.D.	-	Bellevue Medical Center
	+ Galen M. Tice, M.D.	-	University of Kansas
	~~John Tolan~~	-	~~Emory University~~
	+ H. Stephen Weens, M.D.	-	Emory University
	~~Robert J. Shalek, Ph.D.~~	-	~~M. D. Anderson Hospital~~
Consultants:	Carl B. Braestrup	-	Francis Delafield Hospital
	Clayton Hale	-	Syracuse Memorial Hospital
	Kenneth R. Loeffler	-	Jefferson Davis Hospital
	S. Allan Lough	-	Francis Delafield Hospital

Oak Ridge
State University of New York
New York University

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The agenda for the meeting is as follows:

1. Adoption or revision of Bylaws of the Teletherapy Evaluation Board.

2. Review of minutes of the Subcommittees.

   a. Subcommittee No. 1 - Source Evaluation and Shield Design
   b. Subcommittee No. 2 - Small Source Design
   c. Subcommittee No. 3 - Rotational Methods
   d. Subcommittee No. 4 - Housing Design
   e. Subcommittee No. 5 - Clinical Program
   f. Subcommittee No. 6 - Clinical Physicists Training Program

Dr. Rubenfeld will be asked to present the Subcommittee No. 5 work. Dr. Hoecker will be asked to present the Subcommittee No. 6 work. Dr. Jaffe will be asked to present his solution on the Subcommittee No. 4 problem. A new simplified system for determining room shielding on some of the problems it involves will be presented by Dr. Brucer.

3. Review of the actions of the Executive Committee not previously discussed in Subcommittee reviews.

   a. Statement of purpose of TEB published in Radiology
   b. The proposal for an AEC contract
   c. The Barnes contract for the prototype machine

4. Current membership on the Teletherapy Evaluation Board.

5. Election of Chairman of the Teletherapy Evaluation Board.

6. Election to membership on the Executive Committee.

   In the absence of an approved method, the vote will be taken as suggested in the current proposed Bylaws. Dr. Brucer will meet with three members prior to the meeting to form a nominating committee.

7. Additional business of the Teletherapy Evaluation Board.

   The Executive Committee will add to or revise this agenda at its meeting prior to the meeting of the entire TEB. Members of the TEB are requested to send in suggestions for additional items for discussion on the agenda within the next week.

MARSHALL BRUCER, M. D.
Chairman Medical Division
P. O. Box 117
Oak Ridge, Tenn.

Marshall Brucer, M.D.
Chairman
The Executive Committee

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MINUTES OF THE EXECUTIVE COMMITTEE, TELETHERAPY EVALUATION BOARD
IN SESSION JANUARY 9, 1954

Members present: Dr. C. C. McClure - Vanderbilt University
Dr. Herbert D. Kerman - University of Louisville
Dr. Robert Reeves - Duke University
Dr. Galen M. Tice - University of Kansas
Dr. Carl Nurnberger - University of Tennessee
Dr. Marshall Brucer - ORINS Medical Division
Dr. Sidney Rubenfeld - Bellevue Medical Center

The Chairman of the executive committee opened the meeting with a review of an agenda prepared by the executive committee for submission to the Teletherapy Evaluation Board.

Item 1. Bylaws. Discussion was delayed for a detailed report of Item 2.

Item 2. Review of minutes of subcommittees. Dr. Brucer made a summary of the work of the subcommittees.

A. Subcommittee No. 1, Source Evaluation and Shield Design, has not yet completed their original assignment. It was suggested that this subcommittee be continued for further study and evaluation of data to be collected from the hectocurie teletherapy unit and the kilocurie rotational teletherapy unit.

B. Subcommittee No. 2, Small Source Design, has designed and approved a low curiage teletherapy unit which has been manufactured by the W. F. & John Barnes Company of Rockford, Illinois, and offered for sale by the Keleket X-ray Corporation. The original design has resulted in a unit price exceeding the early cost estimates. It was recommended that the subcommittee be continued to study other designs with an attempt to obtain a hectocurie unit at one half the present cost of the Barnes unit.

C. Subcommittee No. 3, Rotational Methods, has not been able to function because a rotational unit has not been available. It is expected that the subcommittee will begin its study in the latter half of this calendar year.

D. Subcommittee No. 4, Housing Design, has completed a series of studies on housing design problems, and the report has been used by the University of Southern California for designing a room to house the teletherapy unit manufactured by the W. F. & John Barnes Company. Dr. Jaffe will present for further study his adaptation of space to house the hectocurie unit at the Cedars of Lebanon Hospital. It was felt that the facilities had been over designed resulting in a much higher cost than originally anticipated. It was recommended that this subcommittee continue its efforts to simplify the design criteria. It was suggested that Dr. Jaffe's housing design be presented to the TEB with the suggestion that the Board authorize Subcommittee No. 4 to accept this design as a basis for further study.

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E. Subcommittee No. 5, Clinical Program, will report to the TEB on the efforts and recommendations of this subcommittee through the chairman, Dr. Rubenfeld.

F. Subcommittee No. 6, Clinical Physicist Training Program, will make its report to the Board through Dr. Hoecker. The executive committee was informed that the Board of Directors of the Oak Ridge Institute of Nuclear Studies and the United States Atomic Energy Commission had made certain recommendations with respect to the program of this subcommittee.

Item 3. Actions of the executive committee not previously discussed in subcommittee reviews.

A. The statement of purpose of the TEB published in Radiology required no action by the executive committee.

B. The proposal for the AEC contract was to be discussed but required no immediate action by the executive committee. It was pointed out that this proposal is an obligation for each university and that the members present would be informed about the proposals that had been submitted. The executive committee should be prepared to discuss any question raised by member institutions.

Item 4. Current TEB membership. No action by the executive committee was required. Dr. Brucer reported that no institution had withdrawn from the TEB and that there was a possibility of two additional medical schools requesting membership sometime within the near future.

Item 5. Election of Chairman of the TEB.

Item 6. Election to membership on the executive committee.

Item 7. Additional business of the TEB.

Items 5, 6, and 7 did not require consideration by the executive committee except as they related to the provisions of the bylaws to be studied and recommended to the Board, January 10, 1954.

At this point, Dr. Rubenfeld suggested that the TEB give serious study to the costs incurred in treating patients with teletherapy units as compared with the costs of conventional X-ray therapy. He made a motion that the TEB request the American Board of Radiology to undertake a study to determine the over-all cost of radiation therapy, comparing conventional X-ray costs with estimated teletherapy costs. Dr. Brucer stated that such a study would entail considerable cost and effort and asked whether any member of the executive committee had a suggestion about how such a project could be started. Dr. Kerman was of the opinion that such information would be valuable; however, he did not believe the study was a function of the executive committee or the TEB. Dr. Brucer stated that such a request would require the executive committee's careful definition of the scope and objectives of such a project. Dr. Brucer reported that such a study had been made and it was found that the cheapest unit to get and operate was a 250 kv X-ray machine. When consideration is given to the usefulness factor in terms of depth dose, however, the kilo-cesium teletherapy achine appears to be the most economical, with cobalt teletherapy units falling in

second place, and high energy accelerators following.

Dr. Brucer was of the opinion that the Medical Research Council of England had made a study but that their report had not been published. Dr. Reeves stated it might be worth while to learn what information is available from surveys made 6 or 8 years ago by the Blue Shield and agencies advocating socialized medicine.

It was agreed that any attempt to make the study suggested by Dr. Rubenfeld should be very broad and should include all cost factors such as administrative costs; overhead and maintenance; and procurement of facilities such as equipment, real estate, building, land, etc. Dr. Tice also pointed out that the cost would have to give consideration to the amount of time the X-ray and teletherapy equipment is used. Dr. Tice quoted from a previous report by Dr. Hoecker showing that the time varies greatly with different machines and institutions.

Dr. McClure said he thought that a large number of people might be interested in such cost data and that it would be desirable to have a detailed study made. Dr. Reeves stated that the Dean of the Duke University Medical School had, within the past two or three weeks, requested such information to justify the purchase of a teletherapy unit for that university. Dr. Kerman, for the purpose of discussion, agreed that the information might be worth collecting; however, he wanted to know how an organization would go about collecting the information and how it would be possible to get a reasonable application of the data once it is available. Dr. Brucer thought the cost data would have to be expressed in cost per roentgen depth dose. This should be a fairly easy cost estimate to obtain; it would be necessary, however, to use other factors such as space, amount of maintenance, etc.

Dr. Rubenfeld modified his motion to read: "In order to properly evaluate the practical application of teletherapy units, the TEB shall request the American College of Radiology to furnish any information available on the relative cost of radiation therapy, giving comparative costs of private and institutional radiation therapy". The motion was seconded by Dr. McClure and carried by a unanimous voice vote.

Following adjournment for lunch, the executive committee began a detailed study of a proposed set of bylaws for submission to the TEB.

The preamble of the bylaws was accepted as written in the proposed draft.

Article I, Membership: Dr. Kerman suggested that the membership requirements read: ".....other institutions recommended by the Executive Committee and approved by the Teletherapy Evaluation Board". The suggested change was approved.

Article II, Institutional Representation: This section was approved with minor modifications in wording.

Article III, Powers of the Teletherapy Evaluation Board:

Paragraphs 1 and 2 were approved as written except for the addition of a sub-item which delegates to the TEB the authority "To elect new member institutions to the Teletherapy Evaluation Board".

Paragraph 3 was approved as written in the proposed draft.

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Paragraph 4 was amended to add the following: The Teletherapy Evaluation Board shall ".....b. Elect a person to act as Executive Secretary for one year".

Paragraph 5 was approved as written (later amended by action of the Board).

Paragraph 6 was amended to read: ".....A request to call a meeting of the Board shall state the purpose or purposes of the proposed meeting".

Article IV, Membership of the Executive Committee:

Paragraph 1 was amended to read as follows: "The Executive Committee shall consist of seven persons and the Executive Secretary to the Board. The secretary shall not have a vote on Executive Committee actions. A majority of the committee shall constitute a quorum for transacting business".

Paragraph 3 was accepted with minor modifications in wording.

Paragraph 4 was accepted with minor modifications in wording.

Paragraph 8 was modified to read: "the Executive Committee shall meet at the call of the Chairman or a majority of the Committee as often as necessary and in any event not less than twice during the calendar year".

Paragraph 2 originally read: "The membership of the Executive Committee shall have at least one person from the Oak Ridge Institute of Nuclear Studies, at least one physicist, and at least four persons from member institutions." When this paragraph was read, Dr. Rubenfeld pointed out that this would permit a person from a nonmember institution to serve as an appointee on the executive committee. Dr. Brucer agreed that this was correct. He then referred to the provision of the Institute Bylaws whereby the Council has elected persons from nonaffiliated institutions to serve on the Board of Directors. Dr. Rubenfeld expressed strong objections to such a procedure, and stated that, in his opinion, no person should serve on the executive committee unless he was a representative from a member institution. Dr. Rubenfeld then made the following motion: "The membership of the executive committee shall consist of the Chairman of the ORINS Medical Division, one physicist from a member institution, and five persons from the Teletherapy Evaluation Board". Dr. Nurnberger observed that if "member institutions" included the Oak Ridge Institute of Nuclear Studies then Dr. Rubenfeld's motion would permit ORINS to have two members on the executive committee. Dr. Brucer stated that the original wording of the bylaws had been selected to guarantee that the executive committee membership would have at least one person from the Oak Ridge Institute of Nuclear Studies, at least one physicist, and at least four persons from members institutions. In this manner, the TEB would always have a majority representation and

at the same time would have freedom of selecting eminently qualified persons to serve on the executive committee. It was Dr. Brucer's opinion that this assured majority would guarantee the interest of the member institutions and would leave the Board considerable freedom in electing executive committee members. Dr. Rubenfeld's motion would be limiting the Board in its freedom of action, without accomplishing any additional safeguards for the interest of the member institutions. For example, the TEB can always elect only members of the Board if that should be their wishes; Dr. Rubenfeld's motion, however, would prevent the Board from ever electing a noninstitutional representative without a two-thirds vote to amend the bylaws. Dr. Tice and Dr. Reeves felt majority representation on the TEB could be assured by vote of the TEB.

Dr. Nurnberger again suggested that the executive committee should represent as many different institutions as possible rather than being dominated by more than one representative from any institution. It was suggested that Dr. Rubenfeld amend his motion by adding "There shall be only one member from any one institution".

Dr. McClure wanted to know whether the executive committee could obtain the services of recognized authorities on a consultant basis. It was stated that this provision was available to the TEB, the executive committee, and all subcommittees. Dr. Kerman felt that the executive committee should have five members from the TEB at all times as a majority to guarantee the actual control of any policy pertaining to the TEB. It might be desirable, however, to get more freedom of action and a broader understanding of problems involved, if noninstitutional persons serve as members of the executive committee. He stated that it is the responsibility of the executive committee to serve the interests of the member universities and if there were doubts that this could be done by outside membership on the committee, then Dr. Brucer's recommendation should be disregarded and Dr. Rubenfeld's motion should be accepted. Dr. Kerman, however, did not feel that it would make too much difference inasmuch as control of policy would still rest in the majority representation of members from the TEB. Dr. Rubenfeld again stated that this was a committee of the TEB and, therefore, it should contain only representatives from the Board.

Dr. Nurnberger offered an amendment to Dr. Rubenfeld's motion to read: "The membership of the executive committee shall consist of the Chairman of the ORINS Medical Division, one physicist from a member institution, five persons from the TEB, and not more than one person from any one member institution". The amendment was seconded by Dr. McClure and unanimously carried by voice vote. Dr. Rubenfeld's amended motion was then seconded by Dr. Tice. The motion was then voted down by a vote of 5 to 2.

Dr. Brucer stated that inasmuch as there were strong opinions in favor of the defeated motion, he recommended that the discussion of the motion, and the original wording of the bylaws, be presented to the full TEB for their action. This recommendation met with the unanimous approval of the executive committee.

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Paragraph 5 was amended to read: "All persons duly elected or appointed to the Executive Committee shall have one vote on its actions regardless of their qualification to vote on Board actions".

Article V, Powers of the Executive Committee: This section was approved with minor modification in wording.

Article VI, Membership of the Subcommittees:

Paragraph 5 was approved with minor modification in wording.

Paragraph 1 was amended to read: "Membership to subcommittees shall be appointive by the Executive Committee or by the Board".

The executive committee agreed unanimously to delete the sentence: "The membership of each subcommittee shall be limited to a maximum of nine persons". This paragraph originally contained the same provision for membership representation as suggested for the executive committee. Dr. Rubenfeld again brought up for discussion the advisability of limiting membership on subcommittees only to persons from member institutions. He asked Dr. Brucer if, in his analysis of the function of these subcommittees, it could be arranged for consultants to come in from time to time for discussion on the more complex problems under consideration. Dr. Brucer stated that this had been the procedure followed during the past year. He also stated that on the invitation of some subcommittees there had been invitations extended to industrial representatives to sit in on various meetings. Dr. Rubenfeld asked whether there had been any occasion to call in any radiologists or physicists. Dr. Brucer pointed out that radiologists and physicists could have been called in but so far as he remembered they had not, inasmuch as there was a radiologist or physicist present at each subcommittee meeting. Dr. Rubenfeld stated that he was trying to decide for himself whether subcommittee membership should be limited to members of the Board with the privilege of calling in outside consultants when the necessity arose. Following this discussion, it was unanimously agreed that membership on the subcommittees should be decided by the TEB.

Paragraph 6 was amended to read: "The authority of the subcommittees is in making recommendations to and advising the Executive Committee".

Paragraph 2 was accepted with minor modifications in wording.

Article VII, Travel Policy: This article was adopted with minor modifications in wording.

Article VIII, Consultants: This article was adopted with minor modifications in wording.

Article IX, Publication Policy: This article was deleted from the proposed bylaws by unanimous consent.

Article X, Amendment or Suspension of Bylaws: This article was adopted as originally written.

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Following a short review of the year's activity the committee adjourned.

Marshall Brucer, M.D.
Chairman
The Teletherapy Evaluation Board

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December 14, 1953

TO: ALL MEMBERS OF THE EXECUTIVE COMMITTEE OF THE TELETHERAPY EVALUATION BOARD

SUBJECT: AGENDA AND CALL FOR MEETING OF THE EXECUTIVE COMMITTEE

Marshall Brucer, M.D.	-	ORINS Medical Division
Herbert D. Kerman, M.D.	-	University of Louisville
C. C. McClure, M.D.	-	Vanderbilt University
Robert Reeves, M.D.	-	Duke University
Sidney Rubenfeld, M.D.	-	Bellevue Medical Center
Galen M. Tice, M.D.	-	University of Kansas
Carl Nurnberger, Ph.D.	-	University of Tennessee

The annual meeting of the Teletherapy Evaluation Board will be preceded by a meeting of the Executive Committee on Saturday, January 9, 1954 at 9:00 a.m. in the Conference Room of the Medical Division, ORINS, Oak Ridge, Tennessee.

The agenda for the Executive Committee meeting will be as follows:

1. To review the agenda for the annual meeting of the Board and to suggest additional items for discussion.

2. To review the Bylaws of the Teletherapy Evaluation Board.

3. To make recommendations for the 1954 Subcommittees.

MARSHALL
Chairman
P. O. Box 117
Oak Ridge, Tenn.

Marshall Brucer, M.D.
Chairman
The Executive Committee

1136306

December 14, 1953

TO: ALL MEMBERS OF THE TELETHERAPY EVALUATION BOARD

SUBJECT: AGENDA FOR THE ANNUAL MEETING OF THE TELETHERAPY EVALUATION BOARD

The current members, alternates and consultants to the Teletherapy Evaluation Board are as follows:

Members & Alternates:	J. Robert Andrews, M.D.	-	Bowman Gray School of Medicine
	Marshall Brucer, M.D.	-	ORINS Medical Division
	~~Walter J. Burdette, M.D.~~	-	Louisiana State University
	David S. Carroll, M.D.	-	University of Tennessee
	Vincent Collins, M.D.	-	Baylor University Graduate School
	George Cooper, M.D.	-	University of Virginia
	Gilbert H. Fletcher, M.D.	-	M.D. Anderson Hospital
	~~Arthur C. Guyton, M.D.~~	-	University of Mississippi
	Frank E. Hoecker, Ph.D.	-	University of Kansas
	~~H. B. Hunt, M.D.~~	-	University of Nebraska
	John A. Isherwood, M.D.	-	Baylor University Graduate School
	Henry Jaffe, M.D.	-	University of Southern California
	James F. Kelly, Jr., M.D.	-	University ~~of Nebraska~~
	Herbert D. Kerman, M.D.	-	University of Louisville
	James E. Lofstrom, M.D.	-	Wayne University
	C. C. McClure, M.D.	-	Vanderbilt University
	~~Frederick Mandeville, M.D.~~	-	Medical College of Virginia
	~~Isadore Meschan, M.D.~~	-	University of Arkansas
	Carl E. Nurnberger, Ph.D.	-	University of Tennessee
	Robert Reeves, M.D.	-	Duke University
	Paul Riemenschneider, M.D.	-	Syracuse Memorial Hospital
	William H. Riser, M.D.	-	Medical College of Alabama
	Sidney Rubenfeld, M.D.	-	Bellevue Medical Center
	Galen M. Tice, M.D.	-	University of Kansas
	John Tolan	-	Emory University
	H. Stephen Weens, M.D.	-	Emory University
	~~Robert J. Shalek, Ph.D.~~	-	M. D. Anderson Hospital
Consultants:	~~Carl B. Braestrup~~	-	Francis Delafield Hospital
	~~Clayton Hale~~	-	Syracuse Memorial Hospital
	Kenneth R. Loeffler	-	Jefferson Davis Hospital
	~~S. Allan Lough~~	-	Francis Delafield Hospital

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The agenda for the meeting is as follows:

1. Adoption or revision of Bylaws of the Teletherapy Evaluation Board.

2. Review of minutes of the Subcommittees.

   a. Subcommittee No. 1 - Source Evaluation and Shield Design
   b. Subcommittee No. 2 - Small Source Design
   c. Subcommittee No. 3 - Rotational Methods
   d. Subcommittee No. 4 - Housing Design
   e. Subcommittee No. 5 - Clinical Program
   f. Subcommittee No. 6 - Clinical Physicists Training Program

Dr. Rubenfeld will be asked to present the Subcommittee No. 5 work. Dr. Hoecker will be asked to present the Subcommittee No. 6 work. Dr. Jaffe will be asked to present his solution on the Subcommittee No. 4 problem. A new simplified system for determining room shielding on some of the problems it involves will be presented by Dr. Brucer.

3. Review of the actions of the Executive Committee not previously discussed in Subcommittee reviews.

   a. Statement of purpose of TEB published in Radiology
   b. The proposal for an AEC contract
   c. The Barnes contract for the prototype machine

4. Current membership on the Teletherapy Evaluation Board.

5. Election of Chairman of the Teletherapy Evaluation Board.

6. Election to membership on the Executive Committee.

   In the absence of an approved method, the vote will be taken as suggested in the current proposed Bylaws. Dr. Brucer will meet with three members prior to the meeting to form a nominating committee.

7. Additional business of the Teletherapy Evaluation Board.

   The Executive Committee will add to or revise this agenda at its meeting prior to the meeting of the entire TEB. Members of the TEB are requested to send in suggestions for additional items for discussion on the agenda within the next week.

MARSHALL BRUCER, M. D.
Chairman Medical Division
P. O. Box 117
Oak Ridge, Tenn.

Marshall Brucer, M.D.
Chairman
The Executive Committee

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BYLAWS OF THE TELETHERAPY EVALUATION BOARD

PREAMBLE

The Teletherapy Evaluation Board is a co-operative program established for the purpose of investigating, developing, and evaluating radioisotopes for teletherapy. The Board functions are conducted through the Oak Ridge Institute of Nuclear Studies under a prime contract with the United States Atomic Energy Commission.

ARTICLE I

Membership

1. Membership on the Teletherapy Evaluation Board is open to A.M.A. accredited four-year medical schools, the Oak Ridge Institute of Nuclear Studies, and any other institution recommended by the Executive Committee of the Board and approved by the Board of Directors of the Oak Ridge Institute of Nuclear Studies. Members who meet these requirements are admitted by application and acceptance by the Board of Directors of the Oak Ridge Institute of Nuclear Studies. Each institution holding membership shall pay the sum of $2,500 to the Oak Ridge Institute of Nuclear Studies for the purpose of partially defraying the program costs. (August 8 Meeting, p. 4, Item 4, and June 3 Meeting of the Executive Committee, p.6.)

ARTICLE II

Institutional Representation

1. An executive officer of each participating institution shall appoint one voting member as its representative on the Board. He shall be known as a member of the Teletherapy Evaluation Board. Alternate members may be appointed as consultants to the Medical Division of the Oak Ridge Institute of Nuclear Studies on recommendation of the members, and shall be permitted to vote in the absence of the member. Other consultants may be

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appointed to the Board upon recommendation of the Executive Committee but shall not have voting privileges. The member or his alternate shall have the power to cast the vote of his institution and shall act for his institution on all questions relating to the teletherapy program.

2. The Teletherapy Evaluation Board shall investigate, develop, and evaluate radioisotopes for teletherapy for the purpose of advising, consulting, and recommending to the Oak Ridge Institute of Nuclear Studies a co-operative program to be conducted on a basis mutually agreeable to the participating institutions. Actual programs carried out by the Oak Ridge Institute of Nuclear Studies are conducted in accordance with the Institute's prime contract with the United States Atomic Energy Commission and are subject to action by the officers of the Institute.

3. Each representative shall serve for such period as may be determined by the executive head of his institution, provided that such term of service shall in any event be limited to the period during which the institution he represents is entitled to membership on the Teletherapy Evaluation Board.

ARTICLE III

Powers of the Teletherapy Evaluation Board

1. The Teletherapy Evaluation Board shall have the responsibility for directing a comprehensive co-operative program to investigate, develop, and evaluate radioisotopes for teletherapy. The Board shall elect an Executive Committee which shall have delegated powers as set forth in Article V.

2. The Teletherapy Evaluation Board shall meet once each year:

   a. To request and receive from the Executive Committee such reports as it deems necessary or desirable.

   b. To confer with and advise the Executive Committee on matters of policy.

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c. To review the progress of the Subcommittees.

d. To elect members to the Executive Committee.

3. The Chairman of the Teletherapy Evaluation Board shall appoint and meet with at least three members who are not already members of the Executive Committee prior to the annual meeting to form a nominating committee. Their nominations shall be presented to the annual meeting for the election of the Executive Committee.

4. The Teletherapy Evaluation Board shall elect by majority vote one of its members to act as Chairman for one year.

5. A majority of the members of the Board shall constitute a quorum at all meetings of the Board for transacting business.

6. The Chairman may call special meetings of the Board whenever he deems it expedient or he shall call such meetings when requested to do so by the Executive Committee. A request from the Executive Committee to call a meeting of the Board shall state the purpose or purposes of the proposed meeting.

ARTICLE IV

Membership of the Executive Committee

1. The Executive Committee shall consist of seven members, and a majority of members present and voting shall constitute a quorum for transacting business.

2. Membership on the Executive Committee shall be elected by a majority of the Teletherapy Evaluation Board members present and voting at an annual or called meeting. Members of the Executive Committee shall be elected for a term of two years and shall be eligible for re-election except that the 1954 election shall elect three members for one year to allow overlap of appointments.

3. When vacancies on the Executive Committee occur between meetings of the Teletherapy Evaluation Board, the Executive Committee may appoint

qualified persons to serve as interim members until the next meeting of the Board.

4. The Executive Committee shall meet as often as necessary and in any event not less than twice during the calendar year.

5. The membership on the Executive Committee shall have at least one person from the Oak Ridge Institute of Nuclear Studies, at least one qualified physicist, and at least four persons from the member institutions.

ARTICLE V

Powers of the Executive Committee

1. The Executive Committee shall meet twice during the calendar year or more often if necessary and shall have the following powers:

   a. To appoint any and all Subcommittees necessary for organizing and promoting the teletherapy evaluation program. The Executive Committee shall have power to define the scope of effort assigned to each Subcommittee, to delegate to each Subcommittee authority necessary for the performance of its duties, and shall have authority to disband any Subcommittee at its own discretion. Each Subcommittee shall, in writing, be fully identified by title and be given a statement of objectives for which it was organized.

   b. To prepare an agenda for meetings of the Teletherapy Evaluation Board and any meetings of Subcommittees.

   c. To act in an advisory capacity to the Board of Directors of the Oak Ridge Institute of Nuclear Studies on use of the teletherapy fund.

   d. To act upon recommendations of any Subcommittee.

ARTICLE VI

Membership of the Subcommittees

1. The duties and organization of Subcommittees will be by action

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of the Executive Committee or by action of the Teletherapy Evaluation Board at its annual meeting.

2. Membership to Subcommittees will be appointed by the Executive Committee. The membership of each Subcommittee shall be limited to a maximum of nine persons. At least one person shall be from the Oak Ridge Institute of Nuclear Studies, at least one person shall be a qualified physicist, and at least a majority shall be from member institutions on each Subcommittee.

3. The authority of the Subcommittees is in recommending and advising the Executive Committee. Any person may be appointed to a Subcommittee on action of the Executive Committee without respect to membership on the Teletherapy Evaluation Board. Voting on Subcommittee matters shall be informal and all participants of the Subcommittees shall be allowed to vote whether or not they are from member institutions.

4. Subcommittee membership shall be reviewed by the Executive Committee prior to each annual meeting and reappointments or new appointments shall be made at the first meeting of the Executive Committee following each annual meeting of the Teletherapy Evaluation Board.

ARTICLE VII

Travel Policy

1. The expenses incurred by an appointed representative or his alternate, or by another appointed consultant, in attending official meetings of the Teletherapy Evaluation Board, the Executive Committee, or any Subcommittee meeting shall be reimbursed by the Oak Ridge Institute of Nuclear Studies in accordance with the representative's consultant contract in existence at the time of travel. For any official meeting of the Board or its Subcommittees, expenses shall be paid only for the official representative or his alternate. At no time shall the expenses for more than one representative from any institution be reimbursed for any one

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meeting. (August 8 Meeting, p. 5, Item 5.)

2. For each meeting of the Teletherapy Evaluation Board, the Executive Committee or a Subcommittee, the Chairman of the Medical Division shall prepare for each representative called in meeting a request for performance under the consultant contract in effect between that representative and the Institute. (August 8 Meeting, p. 5, Item 5.)

ARTICLE VIII

Consultants

1. Each participating institution is entitled to one representative on the Teletherapy Evaluation Board. Each representative may recommend specialists to the Oak Ridge Institute of Nuclear Studies for consideration in appointment to the Institute's staff of consultants. (August 8 Meeting, p. 5, Item 6.)

ARTICLE IX

Publication Policies

1. The publication policies shall be those currently in effect for the Medical Division of the Oak Ridge Institute of Nuclear Studies. A copy is attached as an appendix to these bylaws.

ARTICLE X

Amendment or Suspension of Bylaws

1. The Bylaws of the Teletherapy Evaluation Board may be amended or suspended by two-thirds vote of the members present and voting at any given meeting.

These Bylaws of the Teletherapy Evaluation Board of the Oak Ridge Institute of Nuclear Studies were adopted by the Board on _____.

_____
Chairman
Teletherapy Evaluation Board

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NAME	TIME OF PICK UP	PLACE OF PICK UP
Dr. G. M. Tice Univ. of Kansas	603 842 Delta 4 30 Confirm 4 30	4 30 Med Div.
Dr. James Lofstrom Wayne Univ.	Confirm 603 Delta 842 4 30 or before	4 30 Med Div -
Dr. Sidney Rubenfeld New York Univ. (Brooklyn)	643 Dl 406 Air 5 15	5 15 Hotel
Dr. Herbert Kerman Univ. of Louisville	803 Delta 444	5 15 Hotel
Dr. Robert Reeves Duke Univ.	Confirm Cap. 715 506	5 15 Hotel
Dr. James Kelly, Jr. Creighton Univ.	Confirm 803 Dl. 444 Delta	5 15 Hotel
Dr. R. K. Loeffler	Tomorrow	
Dr. William Riser, Jr. Univ. of Alabama	405 Capital Have ride	
Dr. Vincent Collins Baylor	Tomorrow	
Dr. David S. Carroll Univ. of Tennessee	3 00	3 00 Med. Div.
Dr. Paul Riemenschneider State Univ. of N.Y. (Syracuse)	8 45 715	715 Tomorrow A.M. Hotel
Dr. Carl Nurnberger Univ. of Tenn.	With Dr. McClure	
Dr. & Mrs. Henry Jaffe U. SC.	5 00 Called -	
Dr. C. C. McClure Vanderbilt	Car	
Colonel John Isherwood Baylor-alt	Tomorrow	
Dr. J. R. Andrews Bowman Gray	Southern 715 tomorrow	8 00 ? 6 15 Hotel
Dr. Frank Hoecker Univ. of Kansas	Car Southern - troll room will be for Lorain 4 W 15 to Wash 1 45 P.M. tonight	8 00 ?
Dr. George Cooper Univ. of Virginia	With Dr. McC	
Dr. Gilbert Fletcher M.D. Anderson	447 Delta - 3 58	2:15 Med Div 2:15

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H. Stephen Weens Emory Univ.		
Walter J. Burdette Louisiana State Univ.		
Frederick B. Mandeville Medical College of Virginia		
I. Meschan ~~Univ. of Arkansas~~		
A.C. Seyton Univ. of Missippi		
Howard B. Hunt Univ. of Nebraska		

John Tolan

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MINUTES OF THE NOMINATING COMMITTEE
IN SESSION SATURDAY NIGHT, JANUARY 9, 1954

Members present: Dr. David S. Carroll - University of Tennessee
Dr. Henry Jaffe - University of Southern California
Dr. James F. Kelly, Jr. - Creighton University
Dr. John A. Isherwood - Baylor University Graduate School
Dr. Vincent Collins - Baylor University Graduate School
Dr. Kenneth R. Loeffler - Jefferson Davis Hospital
Dr. James E. Lofstrom - Wayne University
Dr. Marshall Brucer - Chairman, Medical Division, ORINS

The executive committee, in the absence of an approved set of bylaws, has approved the above group acting as a nominating committee.

Dr. Brucer opened the meeting of the nominating committee by reviewing the January 9th meeting of the executive committee. It was stated that the executive committee, by a vote of five to two, went on record in favor of an executive committee consisting of one representative from the Oak Ridge Institute of Nuclear Studies, one physicist, and at least four members from member institutions. A minority of the executive committee, however, had expressed a desire to restrict the membership to persons from member institutions, and the executive committee had agreed to submit both recommendations to the Teletherapy Evaluation Board for final decision.

Dr. Collins asked whether the nominating committee should give consideration only to those members of the Teletherapy Evaluation Board who had been most active in the program during the past year, and Dr. Brucer stated that this need not be true. It was his opinion that this committee should consider the nomination of individuals who would best represent the interest of the member institutions. Dr. Collins wanted to know whether the nominating committee should nominate a slate of candidates to be voted on as a group or whether the nominations should include more than seven people required to complete the executive committee, thereby allowing the Teletherapy Evaluation Board to cast votes for individual members. It was agree that the nominations would be for a slate of seven representatives from member institutions.

Dr. Lofstrom pointed out that the executive committee, for the past year, had consisted of members representing a wide geographic representation and asked whether there was any reason for this pattern. Dr. Brucer replied that no set rule had been established. This factor, however, did have some merit inasmuch as the Board membership represents all geographic areas.

Dr. Jaffe asked whether there was any provision in the bylaws that would exclude a previous member from being re-elected to the executive committee. It was pointed out that to date a set of bylaws had not been adopted; however, the bylaws to be recommended on the following day would make provisions for continuity on the executive committee in that one half of the membership of this committee would come up for re-election each year. Also, members on the executive committee could be re-elected for a succeeding term.

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Dr. Jaffe asked whether the Teletherapy Evaluation Board would adopt the bylaws as a first item on the agenda. If so then the election of officers would be controlled by the newly adopted bylaws. The nominating committee was told that the bylaws would be the first item on the agenda of the Board meeting and that the election of officers would be controlled by the adopted bylaws.

Dr. Lofstrom suggested that inasmuch as the Board had to decide whether membership on the executive committee is to be limited to Board members, he would suggest that the nominating committee nominate only persons having membership on the Board. By this procedure the slate of nominees would then meet any action taken by the Board with respect to membership on the executive committee. Dr. Jaffe asked Dr. Brucer whether, in his previous experience, he would consider it helpful to have outside members on the executive committee. Dr. Brucer replied that it was not necessary because he could always bring in any person as a consultant. The arguments for both systems were reviewed. Dr. Jaffe then stated that he had not known much about executive committee meetings during the past and asked Dr. Brucer whether there were any members on the present executive committee who were vital to the program and should be continued on the committee. Dr. Brucer stated that to answer this question would be influencing the decisions of the nominating committee. Dr. Lofstrom then wanted to know whether the attendance had been good and Dr. Brucer stated that in all four meetings of the executive committee, the attendance had been excellent. Following this discussion Dr. Lofstrom made a motion that nominations for the executive committee be limited to persons representing member institutions. The motion was seconded by Dr. Jaffe and unanimously carried by voice vote.

Dr. Collins wanted to know whether this committee should make more than seven nominations then select the slate by voting for the seven nominees. The committee was informed that the proposed bylaws provided for the election of members to the executive committee by plurality vote, and it was suggested that the nominating committee adopt the same procedure.

Each of the members presented a number of candidates for the executive committee nomination. From the 10 names presented, with each member of the nominating committee casting secret ballots, the following seven nominees to the executive committee were selected: Dr. Brucer, Dr. Nurnberger, Dr. Kerman, Dr. Collins, Dr. Jaffe, Dr. Lofstrom, and Dr. McClure.

The nominating committee then discussed the problem of selecting those members who would be elected for one- and two-year terms. Dr. Jaffe made a motion that Dr. Kerman and Dr. McClure be elected for one year. The motion was seconded by Dr. Kelly and unanimously carried by voice vote. Dr. Carroll made a motion that Dr. Brucer be re-elected for one year and that the remaining nominees be proposed for a two-year term. The motion was seconded by Dr. Lofstrom and unanimously carried by voice vote. Dr. Carroll made a motion that this be the only slate of candidates selected by the nominating committee. The motion was seconded by Dr. Isherwood and unanimously carried by voice vote.

The nominating committee then studied recommendations for membership to the various subcommittees of the Teletherapy Evaluation Board. The nominating committee was informed that the proposed bylaws provided only that the nominating committee prepare a slate of suggested membership on each subcommittee to be presented as a suggestion to the executive committee. The executive committee, in accordance with

the authority delegated by the proposed bylaws, would make appointments to the subcommittees at the first meeting to be held in early February 1954. It was pointed out that the Teletherapy Evaluation Board might change this provision in the proposed set of bylaws and the nominating committee should be prepared to offer a slate of candidates to be elected by the Board membership if the Board should elect to write such a provision in the bylaws. Dr. Jaffe asked whether there were any objections to letting members of the present subcommittees serve in their present capacity. The committee was informed that there were no objections to this procedure if the nominating committee and if the Teletherapy Evaluation Board saw fit. It was thought desirable, however, that consideration be given to the duties and responsibilities of each subcommittee, with an effort toward obtaining those people who are specifically interested in this phase of the Board's program. Also, it was pointed out that special consideration should be given to the membership of Subcommittee No. 5 inasmuch as this subcommittee would have one of the greatest responsibilities for the Board's program within the coming year. Following a discussion the following slate of subcommittee members was agreed upon:

#1	Kerman	#2	Jaffe
	Carroll		Isherwood
	Tolan		Kelly
	Nurnberger		Weens
#3	Loeffler	#4	Lofstrom
	Andrews		Riemenschneider
	Mandeville		Reeves
	McClure		Rubenfeld
#5	Collins	#6	Hoecker
	Meschan		Burdette
	Cooper		Riser
	Tice		Hunt
			Guyton

Dr. Isherwood made a motion that this slate of subcommittee members be approved as a suggestion to the executive committee to be elected by the Teletherapy Evaluation Board on January 10, 1954. The motion was seconded by Dr. Loeffler and unanimously carried by voice vote.

Marshall Brucer, M.D.
Chairman,
The Teletherapy Evaluation Board

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MINUTES OF THE ANNUAL MEETING OF THE TELETHERAPY EVALUATION BOARD
SUNDAY, JANUARY 10, 1954

Members present: Dr. Gilbert H. Fletcher - M. D. Anderson Hospital
Dr. John A. Isherwood - Baylor University Graduate School
Dr. James F. Kelly, Jr. - Creighton University
Dr. Kenneth R. Loeffler - Jefferson Davis Hospital
Dr. Vincent Collins - Baylor University Graduate School
Dr. Robert Reeves - Duke University
Dr. William H. Riser - Medical College of Alabama
Dr. Frank E. Hoecker - University of Kansas
Dr. Henry L. Jaffe - University of Southern California
Dr. James E. Lofstrom - Wayne University
Mr. John Tolan - Emory University
Dr. Herbert D. Kerman - University of Louisville
Dr. Carl E. Nurnberger - University of Tennessee
Dr. David S. Carroll - University of Tennessee
Dr. Galen M. Tice - University of Kansas
Dr. Paul Riemenschneider - Syracuse Memorial Hospital
Dr. Sidney Rubenfeld - Bellevue Medical Center
Dr. C. C. McClure - Vanderbilt University
Dr. H. Stephen Weens - Emory University
Dr. J. Robert Andrews - Bowman Gray School of Medicine
Dr. George R. Cooper - University of Virginia
Dr. Robert Ball - ORINS Medical Division
Dr. Marshall Brucer - ORINS Medical Division

Item 1 of Agenda. Adoption of Bylaws

The meeting was opened with a review of the Teletherapy Evaluation Board Bylaws as recommended by the executive committee.

Preamble

The preamble was adopted without any changes.

Article I. Membership

Dr. Brucer requested that careful consideration be given to the definition of "members". Also, he stated that there are three kinds of votes authorized by the proposed bylaws. For example, voting on the Teletherapy Evaluation Board is an institutional vote cast by a duly appointed representative who may delegate this vote to his alternate. Voting on the executive committee is by persons elected to the committee, and in some instances the person may be an alternate representative or a consultant from a member institution. On the subcommittees every appointed person has a vote and need not necessarily be a member of the TEB or the executive committee.

Article I was adopted with minor modifications in wording.

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Article II. Institutional Representation

No revision was suggested from the floor.

Article III. Powers of the Teletherapy Evaluation Board

Paragraph 2. It was pointed out that the executive committee had changed subparagraph "d" to read: "To elect persons to the Executive Committee".

Paragraph 3. Dr. Brucer pointed out that paragraph 3 gave the chairman of the TEB considerable power in the selection of executive committee members. Dr. Jaffe stated that the wording would also allow the chairman to meet with all nonmembers of the executive committee to act as a nominating committee. This procedure had proved successful for the selection of a slate of nominees for the year 1954. Dr. Andrews moved the approval of paragraph 3 as worded: "Prior to the annual meeting the Chairman of the Teletherapy Evaluation Board shall appoint and meet with at least three members, who are not already members of the Executive Committee, to form a nominating committee. Their nominations shall be presented to the annual meeting for the election of the Executive Committee". The motion was seconded by Dr. Riemenschneider and carried unanimously by voice vote.

Paragraph 4, Subparagraph b. The Board approved the executive committee's recommendation to elect an executive secretary.

Paragraph 5. The proposed section provided that a majority of the Board members would constitute a quorum. Dr. Andrews stated that a majority of the members might not be present at a called meeting; then the Board could not transact business. Dr. Rubenfeld thought it desirable to reduce the majority to one-third of the Board membership. Dr. Brucer stated that this would take a lot of power from the Board, whereas in the previous day's meeting of the executive committee considerable effort had been brought to increase the withholding power of the Board. Dr. Lofstrom moved that the word "majority" be stricken and "not less than forty per cent" be substituted. The motion was seconded by Dr. Rubenfeld and unanimously carried by voice vote.

Paragraph 7. Dr. Riemenschneider made a motion that notice of meetings of the Teletherapy Evaluation Board and an agenda be sent to members at least one month prior to such a meeting. The motion was seconded by Dr. Kelly. Dr. Jaffe wanted to know what would happen if it became necessary to call an emergency meeting. It was stated that the primary function of the Board is to determine policy, and that other items requiring immediate action would be handled by the executive committee. Dr. Riemenschneider's motion was approved unanimously.

Article IV. Membership of the Executive Committee

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Paragraph 1. Paragraph 1 was changed to read: "The Executive Committee shall consist of seven persons and the Executive Secretary to the Board. The secretary shall not have a note on Executive Committee actions. A majority of the committee shall constitute a quorum for transacting business".

Paragraph 3. Unanimously approved except that the first sentence was changed to read: "Membership on the Executive Committee shall be elected by a plurality of the Teletherapy Evaluation Board members present and voting at an annual or called meeting".

Paragraphs 4 and 8. Approved with minor modifications in wording.

Paragraph 2. To introduce discussion on Paragraph 2, Dr. Brucer informed the TEB of the executive committee's action on the previous day in approving membership requirements on the executive committee. He outlined in detail the thinking of the majority of the executive committee as well as the minority opinion. (See notes of executive committee meeting, January 9, 1954, Article 4, paragraph 2, pages 4 and 5.) Dr. Brucer stated that the executive committee acts for the Board and as such is responsible for the interests of the institutions holding membership on the TEB. He stated that by the proposed wording of the bylaws, the Board would have a guaranteed majority to assure protection for the Board's interest in all actions; however, by the minority amendment, the Board would unduly be limiting itself with no great advantage gained from such limitation.

Dr. Andrews said that he would not elect an executive committee to do business if the executive committee did not fully represent the Board. He then offered a motion that the executive committee be composed of a representative of the Oak Ridge Institute of Nuclear Studies, and six authorized institutional representatives duly appointed to the TEB. In the discussion that followed, it was pointed out that this motion would deprive the executive committee of the benefit of a physicist, except on a consultant basis, inasmuch as no member institution had seen fit to appoint a physicist as an official representative. Dr. Weens stated that, in his opinion, the executive committee should have the services of a physicist, and under this motion it would be necessary to request some institution to appoint a physicst as an official representative.

Dr. Cooper asked whether it was primarily the function of the executive committee to conduct the business on a legislative basis and whether a physicist could be called in as a consultant if needed. It was stated that the executive committee not only conducted legislative business, but was also responsible for the full program of the Board. In many instances, the committee would be evaluating the work of subcommittees in order to make recommendations to the Board. Dr. Jaffe said he thought it would be desirable that the executive committee have a real scientific function and not just a legislative function; therefore, membership of a physicist is urgently needed.

Again, Dr. Brucer pointed out that if the Board desired all seven

members to be from member institutions, it would always have that prerogative under the proposed wording of the bylaws, and to accept Dr. Andrews' motion would be restricting unnecessarily the Board's freedom of action. Dr. Hoecker stated that the use of a consulting physicist is not always practical inasmuch as it is not always easy to foretell what actions of the executive committee might require a consulting physicist.

Dr. Andrews called for action on his motion and the Board was reminded that a second had not been made. Dr. Cooper seconded the motion. Dr. Lofstrom and Dr. Collins expressed objection to the wording of the motion because it would prevent physicists from serving on the executive committee. Dr. Lofstrom offered an amendment to Dr. Andrews' motion adding "With the exception that one physicist from a member institution be elected". The motion was seconded by Dr. Rubenfeld. Dr. Jaffe then pointed out that this permitted more than one member from one institution to serve on the executive committee. Dr. Lofstrom, with the consent of Dr. Rubenfeld, added the following to his amendment of Dr. Andrews' motion: "Not more than one person from a member institution shall be elected to the Executive Committee". The amendment to the motion was carried by voice vote. The amended motion read as follows: "The Executive Committee shall be composed of one member from the Oak Ridge Institute of Nuclear Studies, one physicist from a member institution, five members from the Teletherapy Evaluation Board, and not more than one person from a member institution". The amended motion was then carried with two dissenting votes.

Article V. Powers of the Executive Committee

Article V was accepted with minor modifications in wording.

Article VI. Membership of the Subcommittees

Paragraph 5. Accepted with minor modifications in wording.

Paragraph 1. Dr. Riemenschneider stated that subcommittees were only making studies and formulating recommendations to the executive committee; therefore, in his opinion, it would be wise to have subcommittee membership open to any persons as long as there is a majority of institutional members. He thus made a motion that the second sentence of paragraph 1 read: "At least one person shall be from the Oak Ridge Institute of Nuclear Studies, at least one person should be a physicist, and at least a majority on each subcommittee shall be from member institutions". Dr. Lofstrom seconded the motion and it was unanimously carried by voice vote.

Paragraphs 2 and 6. Approved with minor modifications in wording.

Paragraph 3. Paragraph 3 was added with unanimous consent of the Board and reads as follows: "Each subcommittee shall elect a chairman from its members".

Paragraph 4. Paragraph 4 was added with the unanimous consent of the

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Board and reads as follows: "The Chairman of the Teletherapy Evaluation Board shall be an ex officio member of each subcommittee".

Article VII. Travel Policy

Dr. Lofstrom and Dr. Andrews pointed out that the bylaws made no limitation on the number of people who might attend meetings of the TEB. A majority of the members expressed an opinion that limitations on travel by individual members should not be written into the bylaws; however, a policy should be adopted by the Board. Dr. Lofstrom made a motion that it be the travel policy of the TEB to limit travel expenses to the members of the Board, alternates, and consultants, but that not more than two people from any one institution be reimbursed for travel to any Board meeting. The motion was seconded by Dr. Rubenfeld and unanimously carried by voice vote.

Dr. McClure offered a motion that travel to executive committee meetings be limited to members of the executive committee and invited consultants. The motion was seconded by Dr. Jaffe and unanimously carried by voice vote.

Dr. Riemenschneider made a motion that the travel policy for subcommittees be the same as approved for executive committee meetings. The motion was seconded by Dr. Jaffe and unanimously carried.

At this point Dr. Kerman requested further consideration of Article IV by asking who would be chairman of the executive committee. In the discussion that followed, it was apparent that no provision had been made for the election of the chairman of the executive committee. Dr. Lofstrom made a motion that the executive committee elect one of its members as chairman. The motion was seconded by Dr. Kerman and unanimously carried.

Dr. Jaffe made a motion that the Chairman of the Board be an ex officio member of the executive committee unless otherwise elected. Motion was seconded by Dr. Loeffler and unanimously carried by voice vote.

Article VIII. Consultants

This Article was unanimously accepted as written.

Article IX. Amendment or Suspension of Bylaws

This Article was unanimously accepted as written.

The action on Article IX ended the discussion of the bylaws of the Teletherapy Evaluation Board. Dr. Brucer stated that these bylaws would have to be reviewed by the Institute and AEC legal authorities and finally approved by the Board of Directors of the Institute. The approved bylaws can then be submitted to the executive committee for final approval and adoption. Dr. Riemenschneider made a motion that the bylaws be approved as amended in the meeting of the TEB on January 10, 1954, subject to review by the legal authorities of the Institute and United States Atomic Energy Commission, and approval by the Board of Directors of the Institute, and that

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the executive committee be authorized to officially adopt modifications to be suggested by the legal authorities and the Board of Directors of the Institute. The motion was seconded by Dr. McClure and unanimously carried by voice vote.

Dr. Weens suggested a glossary of terms to help interpret the bylaws. This suggestion was unanimously adopted without a vote.

Item 2. Review of Minutes of the Subcommittees

Dr. Rubenfeld, Chairman, Subcommittee No. 5, Clinical Program, reported that the subcommittee had met twice during the past year, and had attempted to develop therapeutic procedures for both the hectocurie and kilocurie teletherapy units. Also, the subcommittee had recommended that each participating medical school devote 25 per cent of teletherapy procedures to a pattern established by the TEB. By this procedure, each medical school would be making a relatively small contribution to a voluminous pile of medical data on similar diseases, which had been treated by a standard teletherapy clinical procedure.

Dr. Rubenfeld reported that in June 1953, the subcommittee had agreed on an anatomical division of the body and had assigned individual teams to formulate standard procedures for neoplastic disease occurring in these regions. At a second meeting of Subcommittee No. 5, held on September 27, 1953, Dr. Meschan and Dr. Andrews presented a proposed plan for the treatment of cancer of the uterus; however, the subcommittee deviated from the discussion of this plan when there was introduced a discussion on "shaped fields".

It was reported that Dr. Kerman had submitted a proposed procedure for treatment of cancer of the bladder; and Dr. Rubenfeld reported that he had prepared a suggested procedure of treatment of cancer of the ovaries.

Dr. Hoecker reported on the activities of Subcommittee No. 6, the Clinical Radiation Physicists Training Program. He reported that Subcommittee No. 6 had met on August 29, 1953, had outlined a program for the training of clinical physicists, and had suggested possible methods for financing such a training program. Dr. Hoecker reported that this detailed program had been submitted to others for comment and that there had developed a lengthy discussion about whether a clinical radiation physicist should be on the level of a Ph.D., M.D., M.A., or an A.B. Dr. Hoecker reported that it was the opinion of Subcommittee No. 6 that an individual could not function adequately as a clinical radiation physicist with little or no background in biology or medicine. The immediate need is for candidates on a Master's degree level; however, once the candidates received the clinical radiation physicist training, a portion probably would be qualified for continuing their studies to a Ph.D. degree. Dr. Hoecker stated that from his own personal point of view, the clinical radiation physicist should continue to broaden his background if he is to work cooperatively and sympathetically with a radiologist. This cannot be accomplished so long as a clinical radiation physicist has only an A.B. degree in pure physics and is used by the radiology department only to calibrate and standardize X-ray and teletherapy units. This program should move, eventually, in the direction of a Ph.D. degree, if a clinical radiation physicist is to work to maximum effectiveness. His training should include special training in biochemistry, mathematics, anatomy, and physiology, as well as physics. Dr. Hoecker reported that he had presented his views to Dr. Lockwood, Chairman of the Board of the American College

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of Radiology, and this year president of the American Radiological Society. Dr. Lockwood had expressed a general agreement with Dr. Hoecker's views on the background and academic training of clinical radiation physicists. The program of Subcommittee No. 6 was of sufficient importance that a meeting was called of the certified physicists and radiologists who were at the Chicago meeting of the American College of Radiology. This conference was held on Wednesday of that week and it was attended by 65 or 70 people. The group was well represented with radiologists and certified physicists and resulted in a detailed discussion on the need and function of clinical radiation physicists. This discussion resulted in the appointment of a committee of the American Board of Radiologists to study the academic and educational requirements for the certification of clinical radiation physicists. Dr. Williams of the Mayo Clinic was appointed chairman of the committee and the first meeting is to be held in the near future.

Dr. Hoecker reviewed the request of the Board of Directors of the Institute for clarification on the clinical radiation physicists training program. He stated that it was the general opinion of many persons that this is not a Ph.D. training program, neither is it an educational program in a basic science. The program as now written is complicated by the fact that it must of necessity cross departmental lines in the universities. In general, the deans of most schools feel that a university would not be performing a service in a basic science but would be performing the functions of a trade school. Dr. Hoecker stated that this is the attitude that he experienced at the University of Kansas when he was trying to set up the present program for training clinical radiation physicists. Dr. Hoecker felt that Subcommittee No. 6 had a tremendous responsibility for selling the concept that a clinical radiation physicist is really a biophysicist with a greater variety of fundamental and basic science involved than in other restricted fields of science.

Dr. Hoecker closed his report with a request that Dr. Brucer outline the steps that had been taken to obtain financial support for the clinical radiation physicists training program. Dr. Brucer stated that he had made a request to the US-AEC for the establishment of fellowships for the training of the clinical radiation physicist. The Division of Biology and Medicine had expressed enthusiastic approval of the training program; however, they did not feel that the AEC should finance the program. The Division of Biology and Medicine suggested that the TEB make an effort to obtain fellowships financed by the National Science Foundation, National Institute of Health, or private agencies. The Commission follows a policy of setting up fellowships only to supply specially trained personnel as required by the US-AEC or their direct contractors. The National Science Foundation usually limits itself to financing Ph.D. fellowships; therefore, Dr. Hoecker will have to sell the program as a new field which, in some respects, is similar to biophysics, but having a greater variety of fundamental and basic science involved.

In the discussion that followed, Dr. Andrews stated that so far as he knew only the American Board of Radiology has defined a radiological physicist and questioned the advisability of a medical professional board undertaking the certification of clinical radiation physicists. Dr. Lofstrom moved the adoption of Dr. Hoecker's report. The motion was seconded by Dr. Jaffe and carried by voice vote.

Dr. Jaffe was requested to report on his organization's design of a room to

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house a hectocurie teletherapy unit. Dr. Jaffe reported that his installation of the hectocurie teletherapy unit probably represents the most difficult possible housing requirement. The room in which he is installing the teletherapy unit measures 13½ by 13 feet by 8 feet high, and is adjacent to dressing rooms and toilets. Dr. Jaffe explained that his design is based on the criteria developed by Subcommittee No. 4. His design is complicated by the fact he had to design maximum shielding in three walls in order to rotate the hectocurie machine. A reputable construction firm had submitted an actual bid of $19,000, against an expected cost of $5,000. Dr. Jaffe pointed out the implication that this cost had on the hectocurie teletherapy program. For example, the unit now exceeds, by approximately 100 per cent, the original price range which the Teletherapy Evaluation Board hoped to reach for such a unit; if the installation cost for the unit is going to be $15,000 to $20,000, then the hectocurie teletherapy program is no longer competitive with 250 kv X-ray.

Dr. Jaffe suggested that Subcommittee No. 4 use his installation as a basis for further study with the objective of reducing the housing cost factor. It was his feeling that the committee would have a tangible plan to work with and if possible they could analyze each item of cost. Dr. Jaffe emphasized that the design architect was following the specifications as developed by Subcommittee No. 4 and it was his personal opinion that probably these specifications were too rigid. Dr. Brucer stated that Subcommittee No. 9 of the National Committee on Radiation Protection has been revised and it would be desirable that Subcommittee No. 4 of the Teletherapy Evaluation Board take under study the revised standards for radiation protection in housing teletherapy units. Dr. Lofstrom made a motion that Subcommittee No. 4 adopt Dr. Jaffe's plan as a basis for further study with an effort to reduce the design criteria and cost to a minimum necessary for adequate protection. The motion was seconded by Dr. Weens and unanimously carried. (Since the meeting, Dr. Lofstrom has submitted his solution to the housing problem and the committee will now have two active designs to work with.)

Item 3. Review of Actions of the Executive Committee not Previously Discussed in Subcommittee Reviews

Dr. Brucer called attention to the statement of purpose of the Teletherapy Evaluation Board as published in the May 1953 issue of Radiology. He informed the Board of the action of the executive committee in authorizing this publication and asked whether any member wished to comment on the statement of purpose. No comments were offered from the floor.

Dr. Brucer called attention to the proposal for an AEC contract as previously recorded in the various meetings of the Teletherapy Evaluation Board and subcommittees. Dr. Andrews asked whether any university had completed such a contract with the Commission. It was stated that no university had completed a contract. Mr. Tolan asked whether any university had submitted a proposal and the Board was informed that Dr. Jaffe was the only one who had submitted one. Dr. Riemenschneider wanted to know when each university should submit a proposal and how final the proposal should be when submitted to the Commission. Dr. Brucer stated that this was a decision for each member university; however, it was his thinking that a proposal should be submitted as soon as each university feels that it is in a position to start fulfilling its portion of the contract. One criterion would be the availability of a machine to start the research or reasonable assurance that a

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machine would be obtained in the near future.

Item 4. Current Membership on the Teletherapy Evaluation Board

Dr. Brucer informed the Teletherapy Evaluation Board that at the present time, there are two possible new admissions to the Board. These two nominations are dependent upon each university's completion of the establishment of a formal four-year medical school. The Board was informed that no medical school had withdrawn from the Teletherapy Evaluation Board.

Item 5. Election of the Chairman of the Teletherapy Evaluation Board

Dr. Brucer, retiring chairman, declared the meeting open for the nomination of a Chairman of the Teletherapy Evaluation Board to serve for the coming year. Dr. Kerman nominated Dr. Brucer; the nomination was seconded by Dr. Rubenfeld. Dr. Carroll made the motion that nominations cease and that Dr. Brucer be elected by acclamation. The motion was seconded by Dr. Andrews and unanimously carried.

Dr. Brucer declared the meeting open for the election of an executive secretary. Dr. Lofstrom nominated Howard Harmon and nomination was seconded by Dr. Kerman. Nomination was approved by voice vote.

Item 6. Election of Members on the Executive Committee

Dr. Brucer declared the meeting open for election of membership to the executive committee by calling attention to the statement on the agenda which suggested that in the absence of an approved method, Dr. Brucer would meet with three members prior to the meeting of the Board to form a nominating committee. The Board was informed that this committee had met on Saturday night, January the 9th, and consisted of the following: Drs. Carroll, Jaffe, Kelly, Isherwood, Collins, Loeffler, and Lofstrom, with Dr. Brucer presiding as chairman. This committee had nominated and, by a plurality vote, selected the following slate of nominees for the executive committee: Dr. Herbert Kerman to serve one year, Dr. Nurnberger to serve two years, Dr. Collins to serve two years, Dr. Jaffe to serve two years, Dr. Lofstrom to serve two years, Dr. McClure to serve one year, and Dr. Brucer to serve one year.

Dr. Brucer pointed out that this slate of nominees agreed with all provisions of the bylaws as adopted in the morning session of the Board meeting. Dr. Brucer then declared the meeting open for nominations from the floor. Dr. Riemenschneider made a motion that the executive secretary cast one ballot for the slate of nominees. The motion was seconded by Dr. Cooper and unanimously carried.

Dr. Brucer informed the Board that the nominating committee also made a slate of members for each subcommittee. This slate will be presented to the first meeting of the executive committee, probably sometime in February. The Board was informed that the bylaws authorized the executive committee to appoint the membership of each subcommittee unless the Board wished to exercise this prerogative. Without the benefit of a motion and vote, the Board unanimously agreed that this prerogative would be delegated to the executive committee. Dr. Brucer then read the slate of suggested committee membership as recorded in the minutes of the January 9th meeting of the nominating committee.

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Item 7. Additional Business of the Teletherapy Evaluation Board

Dr. Brucer reported on the joint efforts of the Institute, X-ray Industry, United States Atomic Energy Commission, and Atomic Energy of Canada Limited, to agree upon a standardized capsule for teletherapy sources. The attached drawings represent the specifications agreed upon.

The meeting was opened for any additional business from the floor. None was suggested and Dr. Lofstrom made a motion that the Teletherapy Evaluation Board meeting be declared adjourned. The motion was seconded by Dr. Jaffe and unanimously carried by voice vote.

Marshall Brucer, M.D.
Chairman
The Teletherapy Evaluation Board

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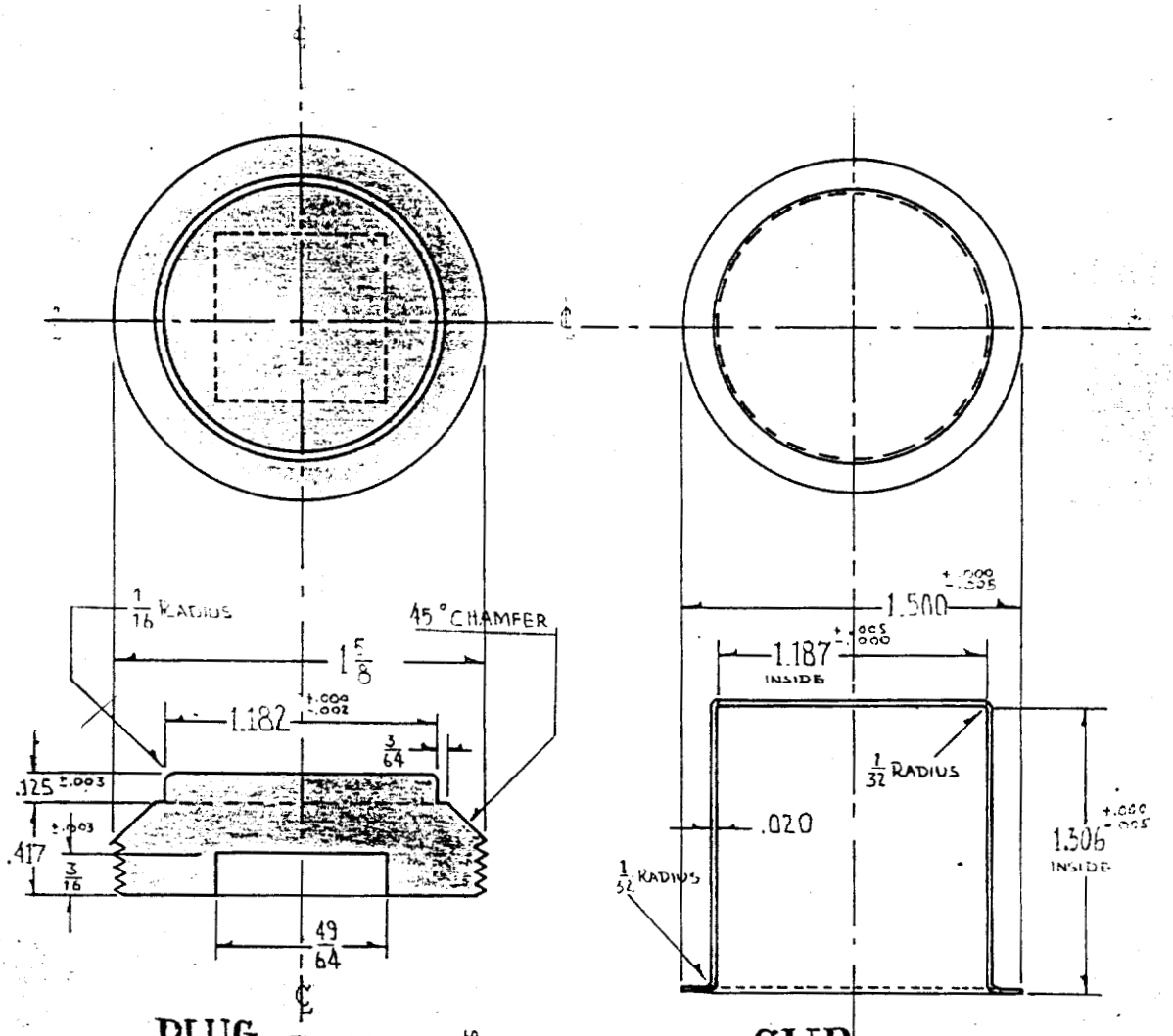

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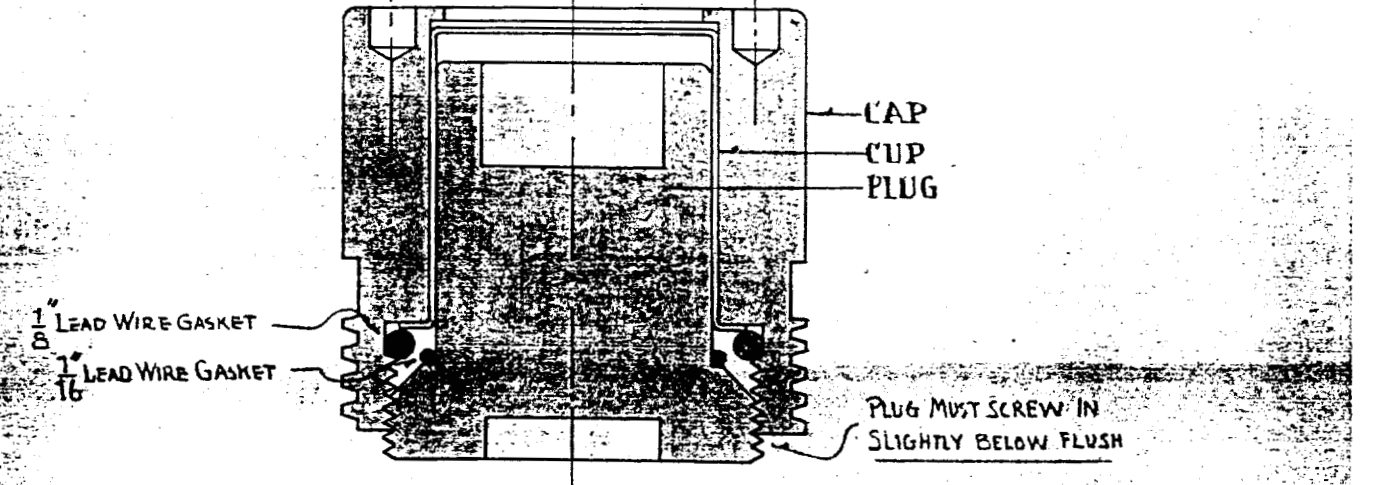

STANDARD Co^{60} SOURCE CAPSULE

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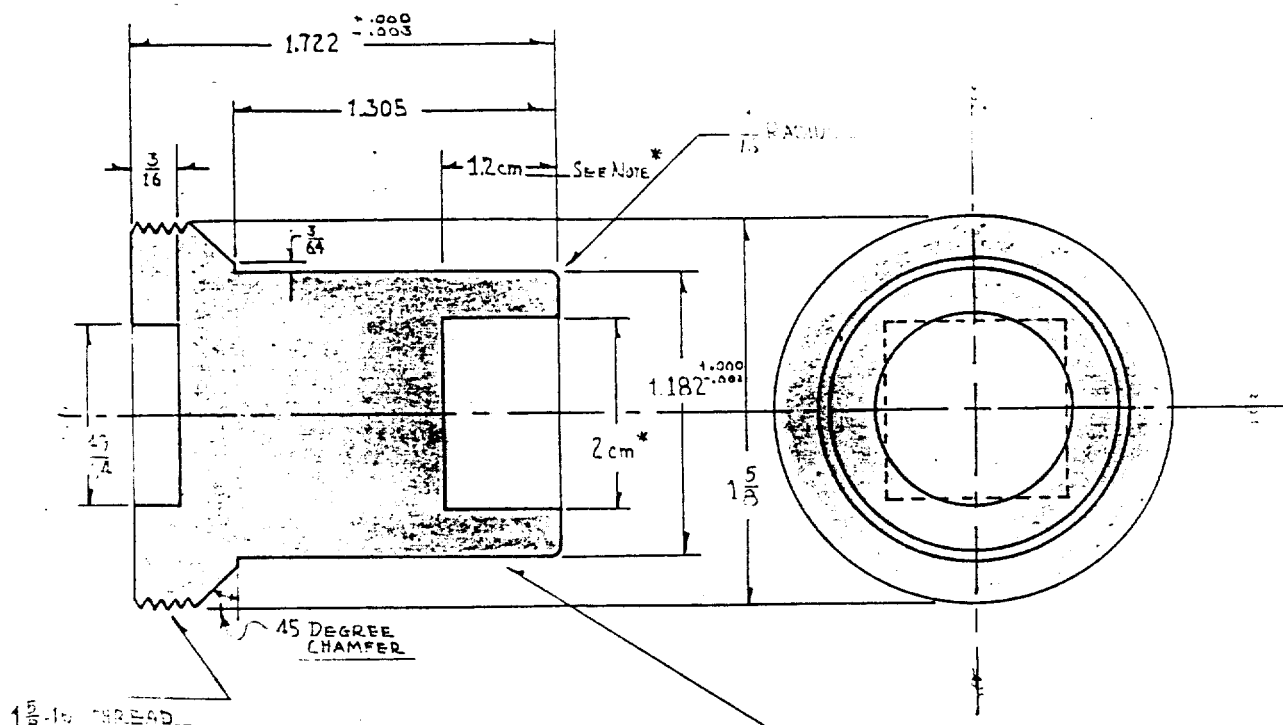

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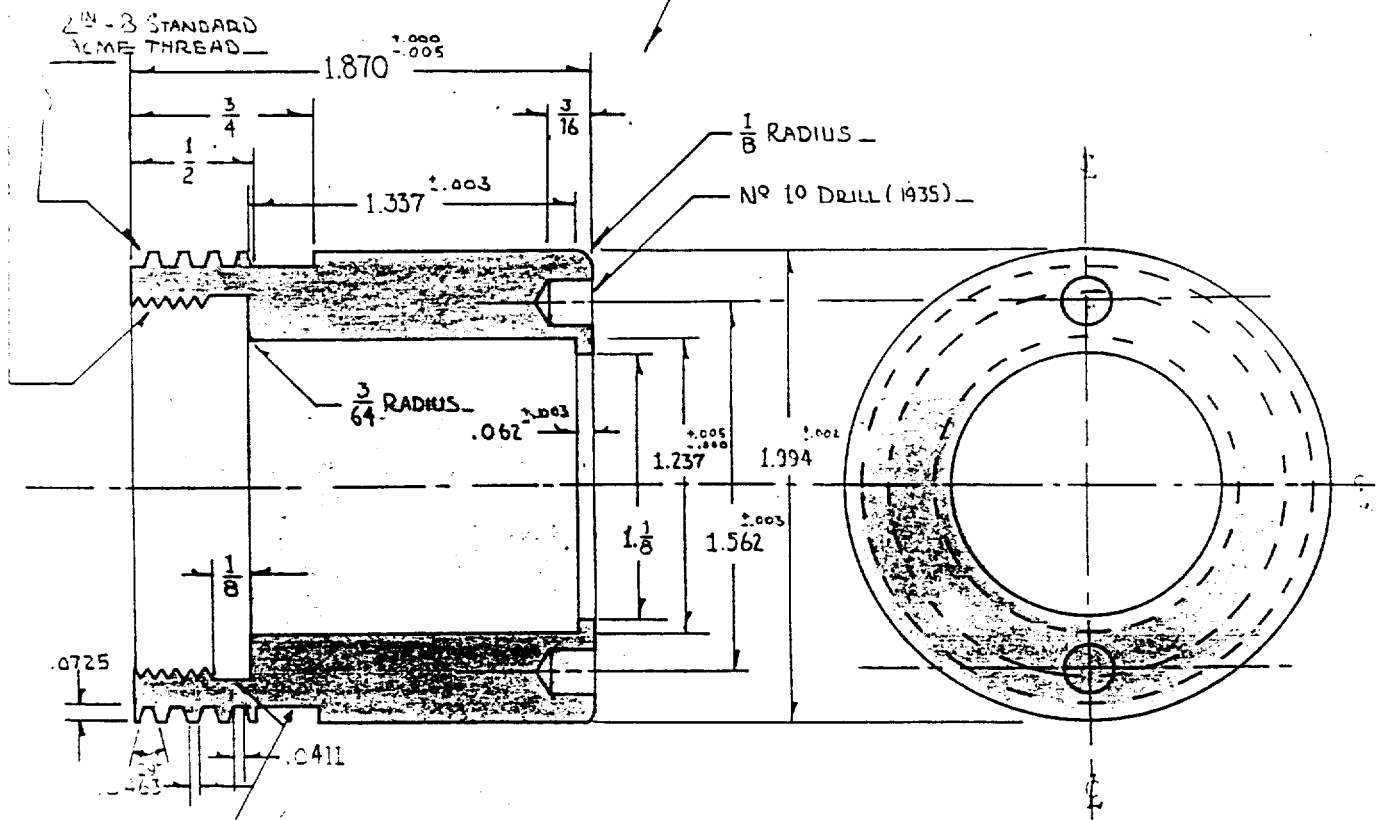

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MARCH 6, 1954 MEETING OF THE EXECUTIVE COMMITTEE OF THE TELETHERAPY EVALUATION BOARD

Members Present:	Dr. Vincent Collins	- Baylor University Graduate School
	Dr. H. D. Kerman	- University of Louisville
	Dr. James Lofstrom	- Wayne University
	Dr. C. C. McClure	- Vanderbilt University
	Dr. Carl E. Nurnberger	- University of Tennessee
	Dr. Marshall Brucer	- ORINS Medical Division

1. AEC Contract Proposal-Statement of TEB Program.

Dr. Brucer opened the meeting by reviewing a letter from the Medical Branch, Division of Biology and Medicine, US-AEC, requesting a formal statement of the program and objectives of the clinical research program of the TEB. It was emphasized that the statement should be available to the Commission by May 1, 1954, inasmuch as the Commission will at that time review the first research proposals submitted by member universities.

The Executive Committee recognized the responsibility of Subcommittee No. 5, Clinical Program, for formalizing such a statement, however, because of the urgency, a preliminary draft was made by the Executive Committee and sent to members of Subcommittee No. 5 for study and approval in the April 17 meeting. The preliminary statement is attached to these minutes as Appendix A. Dr. Vincent Collins, a member of the Executive Committee and Subcommittee No. 5, was requested to coordinate the activities of both committees in drafting a final statement.

Dr. Collins stated that patients to be treated under the clinical research program of the TEB would not always be suitable for measuring the program's effectiveness by the five-year survival criteria. Therefore, other criteria should be codified to permit a statistical analysis of the end results. He then recommended one or more consultant statisticians for Subcommittee No. 5. Dr. Collins reviewed the curriculum vitae of Drs. Harold Tivey and Carl E. Hopkins, of the University of Oregon, and suggested that they be considered as consultants available to Subcommittee No. 5.

2. Subcommittee Membership and Dates of Meetings.

The Executive Committee reviewed and approved the recommendations for Subcommittee memberships made by the nominating committee at the January 9 meeting, with the exception that Dr. H. D. Kerman be added to Subcommittee No. 5. The approved subcommittees and scheduled meetings are as follows:

Subcommittee	Membership	Date
5 Clinical Program	Dr. Vincent Collins Dr. Isadore Meschan Dr. George Cooper Dr. Galen Tice Dr. H. D. Kerman	April 17

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Subcommittee	Membership	Date
2 Small Source Design	Dr. Henry Jaffe Col. John Isherwood Dr. James Kelly Dr. Stephen Weens Dr. Harold W. Lewis	June 12
1 Source Evaluation and Shield Design	Dr. H. D. Kerman Dr. David Carroll Dr. Carl Nurnberger Mr. John Tolan	July 10
3 Rotational Methods	Dr. Kenneth Loeffler Dr. Robert Andrews Dr. Frederick Mandeville Dr. C. C. McClure	August 14
4 Housing Design	Dr. James Lofstrom Dr. Paul Riemenschneider Dr. Robert Reeves Dr. Sidney Rubenfeld	September 20
6 Clinical Physicist Training Program	Dr. Frank Hoecker Dr. Walter Burdette Dr. William Riser Dr. Howard Hunt Dr. Arthur Guyton	Octoboer 9

3. Cost Problems of Cobalt 60.

Dr. Brucer informed the committee that recent calculations of cost per rhm of cobalt 60 sources at a specific activity of 10 curies/gram indicate that kilocurie sources may not be the most economical to use for teletherapy. The calculations were based on four factors: total curiage, specific activity, diameter, and height of a right cylinder. The calculations also assumed that the right cylinder would consist of a number of wafers, irradiated and stacked to produce a uniform distribution of radiation.

The comparative costs of rhm delivered to a tumor must reflect the cost of the source, the teletherapy unit, and housing; however, the critical factor is the efficient utilization of a therapy unit. The treatment time of a kilocurie unit may be one-third the time required for a hectocurie unit, but the dead time on each machine reduces this advantage to a minimum.

Dr. Brucer suggested that these factors be studied during the next meeting of Subcommittee No. 2, Small Source Design. Dr. Lofstrom suggested that no final decision be made until more experience is obtained from the operation of both units. Dr. Collins suggested that the TEB carry to completion the programs for the hectocurie and kilocurie units, and that the Board extend its program to include multiple units for stationary and rotational therapy. The suggestion of Dr. Collins was made as a motion by Dr. Lofstrom. The motion was seconded by Dr. Collins and carried.

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4. Rules of Procedure.

The Executive Committee reviewed the proposed bylaws as adopted by the TEB at its annual meeting of January 10, and as revised by the Institute Board of Directors in a meeting on February 16. The committee approved the Board of Directors' recommendations that the bylaws be called "Rules of Procedure" and that a termination of the program be provided for. Dr. Lofstrom made a motion that the Rules of Procedure be adopted as revised by the Institute Board of Directors. The motion was seconded by Dr. McClure and carried. (See Appendix B.)

5. Radiation Shielding Properties of Marble.

Dr. Brucer reviewed the results of recent tests to determine the shielding properties of marble, and recommended that Subcommittee No. 4 review the results at the September meeting.

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Appendix A

THE CLINICAL RESEARCH PROGRAM OF THE TELETHERAPY EVALUATION BOARD

The Clinical Research Program of the Teletherapy Evaluation Board has as its primary objective the evaluation of supervoltage radiation in cancer therapy. The member medical schools shall accomplish this objective by pooling their efforts and clinical material over a period of years so that statistical significance may be assured.

Each of the participating schools will have at least one teletherapy machine plus other equipment in the lower energy range. Twenty-five per cent of the time of the teletherapy machine will be devoted to a program jointly arrived at, following specific treatment patterns approved by the Board. The other 75 per cent of the time of each machine will be on problems of specific interest to the individual school.

Each of the schools will contribute information on a parallel series of studies using conventional techniques and 200 kvp equipment. A uniform system of records and clinical classifications for each disease chosen for study is now in process of development. Before general adoption, a pilot run of the classification and record system will be accomplished by the initial group of five or six schools ready to start this year. This initial group will work closely with Subcommittee No. 5, which is primarily responsible for the design of the clinical experiment. The results of their study will be presented to the entire TEB at the next annual meeting for general approval.

The program details will follow a number of general lines of procedure.

1. A limited series of types of cancer will be chosen. They will be from three classifications.

    a. Radiocurable cancers in which, for one reason or another, supervoltage is perferable.

    b. Potentially radiocurable cancer in which cure with conventional therapy is seldom achieved.

    c. Cancers in which palliation only may be expected.

2. The conventional end point of five year survival is an inadequate evaluation mechanism except in 1-a. The ultimate value of the isotope radiation machines may be unrelated to their ability to match or surpass the survival rates of conventional therapy. Therefore, in spite of the difficulty and dangers of codifying intangibles, subjective impressions, and economic factors, some of these other criteria for evaluation must be devised to allow an assessment of all types of cancer listed under 1. The specific points assessed in the recording system will be:

    a. Survival Rate: Survival rates will be standardized on a life table basis when sufficient data has been gathered. Since such a standardization can be accomplished only on large samples of specific population groups, simpler methods comparing a matched series treated with conventional techniques will be used on the early data.

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b. Indices of Morbidity: Any change in the natural course of the untreated disease is an effective index of the effect of the treatment. Although most of the judgments concerning a change in the course of the disease are subjective impressions, these form the body of data upon which the final judgment of any treatment is based. Some factors such as a return to useful occupation, decreased nursing time, use of narcotics, and time in hospital can easily be codified and are especially valid upon comparison with parallel series in the same organization.

c. Evaluation of the Cause of Death: In many of the cancers an excellent index of the effectiveness of treatment is an evaluation of the immediate cause of death. If radiation therapy changes the terminal pattern of events, such changes can be codified to allow an assessment of the effectiveness of the therapy.

d. Distribution of Disease at Death: There are six main classifications that will allow a rank order assessment of the results of therapy, based upon the distribution of the disease at death and the incidence of complications due to radiation.

CLASSIFICATION FOLLOWING AUTOPSY

A. Therapy was started at primary site to irradiate only known site of cancer.

1. No persistent disease at primary site, no distant metastases.

   a. No complications at primary site due to radiation.

   b. Complications at primary site did not appreciably affect morbidity.

   c. Complications at primary site did appreciably affect morbidity.

   d. Complications at primary site did contribute to cause of death.

2. No persistent disease at primary site, with distant metastases.

   a. No complications at primary site due to radiation.

   b. Complications at primary site did not appreciably affect morbidity.

   c. Complications at primary site did appreciably affect morbidity.

   d. Complications at primary site did contribute to cause of death.

3. With persistent disease at primary site, no distant metastases.

   a. No complications at primary site due to radiation.

   b. Complications at primary site did not appreciably affect morbidity.

   c. Complications at primary site did appreciably affect morbidity.

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d. Complications at primary site did contribute to cause of death.

4. With persistent disease at primary site, with distant metastases.

a. No complications at primary site due to radiation.

b. Complications at primary site did not appreciably affect morbidity.

c. Complications at primary site did appreciably affect morbidity.

d. Complications at primary site did contribute to cause of death.

B. Therapy was started at secondary site, or at primary site with other areas of cancer known to exist.

1. No persistent disease at site of therapy.

a. No complications at primary site due to radiation.

b. Complications at primary site did not appreciably affect morbidity.

c. Complications at primary site did appreciably affect morbidity.

d. Complications at primary site did contribute to cause of death.

2. With persistent disease at site of therapy.

a. No complications at primary site due to radiation.

b. Complications at primary site did not appreciably affect morbidity.

c. Complications at primary site did appreciably affect morbidity.

d. Complications at primary site did contribute to cause of death.

C. Incidence of known complications in specific diseases.

In addition to the general codification of the cause of death following therapy, certain specific complications, which are of significance in conventional techniques, will be especially studied. For example, in the treatment of bronchogenic carcinoma, the incidence of bronchial hemorrhage is especially significant; in the esophagus the incidence of perforation into the mediastinum; in brain tumors the degree and persistence of epilation, bone necrosis, alteration of neurological sequellae; in breast tumors the incidence of recurrence in the chest wall.

D. Economic and social factors.

Some of the factors that may be of decisive importance but do not necessarily relate to any particular point in therapy should also be studied. How often is a planned course of therapy completed? How serious was the discomfort of the treatment period? What was the total cost of therapy? To what grade of activity was the patient returned?

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E. Physical factors in dosimetry.

There will be a continuing study of the skin area, time-dose relationship, the comparison of integral dose with systemic reaction, and an attempt will be made to develop a more satisfactory theory of organ-specific integral dose criteria.

The program will not be a static one but will be under the constant scrutiny of Subcommittee No. 5. The specification of the first few diseases will be completed by early summer. Following an initial pilot run by the first few schools, diseases will be added to the list. A portion of the program is written specifically for the hectocurie machine without rotation. It is expected that simple rotational patterns will be developed as a second step and will be followed by more complex combined techniques.

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Appendix B

RULES OF PROCEDURE OF THE TELETHERAPY EVALUATION BOARD

PREAMBLE

The Teletherapy Evaluation Board has been established for the purpose of carrying out a co-operative program for the investigation, development, and evaluation of radioisotopes for teletherapy. It is expected that the objectives of this initial co-operative phase of the program will be attained within approximately five years. The Board will remain in existence only for the duration of this phase of the program. The Board has been established as a unit of the Medical Division of the Oak Ridge Institute of Nuclear Studies the operations of which are carried our under a prime contract with the United States Atomic Energy Commission.

DEFINITIONS

Teletherapy Evaluation Board: The Teletherapy Evaluation Board hereinafter called the "Board" shall be a group of persons, who are under consultant contracts with the Oak Ridge Institute of Nuclear Studies, and who have been delegated authority by the proper officer of their educational insituttion to represent their institution in all Board proceedings.

Member Institutions: A member institution is any four-year medical school or other organization which has been admitted for membership on the Board under the procedures states in Article I.

Member: A member is a person who has been appointed by a member institution to represent that institution's interest on the Board.

Alternate Member: An alternate member shall be such person as has been proposed by a Board member or member institution for a consultant contract with the Institute to represent the member institution on the Board in the absence of a regular member or to otherwise participate in the proceedings if so authorized by the Executive Committee or by the

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Board.

Executive Committee Member: An Executive Committee member is a person elected to the Executive Committee in accordance with Article IV.

Subcommittee Member: A subcommittee member is a person appointed to serve on a subcommittee under the provisions of Article VI.

ARTICLE I

Membership

Membership on the Board is open to A.M.A. accredited four-year medical schools, the Oak Ridge Institute of Nuclear Studies, and any other institution recommended by the Executive Committee and approved by the Board. Members who meet these requirements shall be admitted by application to and acceptance by the Board of Directors of the Oak Ridge Institute of Nuclear Studies. Each institution holding membership shall pay the sum of $2,500 to the Oak Ridge Institute of Nuclear Studies for the purpose of partially defraying the program costs.

ARTICLE II

Institutional Representation

1. An executive officer of each participating institution shall appoint one voting member, who shall be made a consultant to the Oak Ridge Institute of Nuclear Studies, Medical Division, as its representative on the Board. He shall be known as a member of the Teletherapy Evaluation Board. Alternate members may be appointed as consultants to the Oak Ridge Institute of Nuclear Studies, Medical Division, on recommendation of the institutional members and shall be permitted to vote in Board actions in the absence of the regular member. Other consultants may be appointed to the Board upon recommendation of the Executive Committee, but shall <u>not</u> have voting privileges in Board actions. The member or his alternate shall have the power to cast the vote of his institution in Board actions

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and shall act for his institution on all questions relating to the proceedings and functions of the Board.

2. The Board shall investigate, develop, and evaluate radioisotopes for teletherapy for the purpose of advising, consulting, and recommending to the Oak Ridge Institute of Nuclear Studies a co-operative program to be conducted on a basis mutually agreeable to the participating institutions. Actual programs carried out by the Oak Ridge Institute of Nuclear Studies shall be conducted in accordance with the Institute's prime contract with the United States Atomic Energy Commission and are subject to action by the officers of the Institute.

3. Each representative shall serve for such period as may be determined by the executive head of his institution, provided that such term of service shall in any event be limited to the period during which the institution he represents is entitled to membership on the Board.

ARTICLE III

Powers of the Teletherapy Evaluation Board

1. The Board shall have the responsibility for investigating and developing a comprehensive co-operative program to evaluate radioisotopes for teletherapy. The Board shall elect an Executive Committee which shall have delegated powers as set forth in Article V.

2. The Board shall meet at least once each year for the following purposes, among others:

a. To request and receive from the Executive Committee such reports as it deems necessary or desirable.

b. To confer with and advise the Executive Committee on matters of policy.

c. To review the progress of subcommittees.

d. To elect persons to the Executive Committee.

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e. To recommend new member institutions to the Teletherapy Evaluation Board.

3. Prior to the annual meeting the Chairman of the Board shall appoint and meet with at least three members, who are not already members of the Executive Committee, to form a nominating committee. Their nominations shall be presented to the annual meeting for the election of the Executive Committee.

4. The Teletherapy Evaluation Board shall:

a. Elect by the majority vote of the members present, and voting, one of its members to act as Chairman for one year.

b. Elect by the majority vote of the members present, and voting, a person (not meaning a Board member) to act as Executive Secretary for one year.

5. Not less than 40 per cent of the members of the Board shall constitute a quorum for transacting business at all meetings of the Board.

6. The Chairman may call special meetings of the Board whenever he deems it expedient or he shall call such meetings when requested to do so by a majority of the Executive Committee or a majority of the Board. A request to call a meeting of the Board shall state the purpose or purposes of the proposed meeting.

7. Notice of meetings of the Board and an agenda of the business to be transacted thereat shall be sent to members at least one month prior to such a meeting.

ARTICLE IV

Membership of the Executive Committee

1. The Executive Committee shall consist of seven persons and the Executive Secretary to the Board. The secretary shall not have a vote on Executive Committee actions. A majority of the committee shall constitute

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a quorum for transacting business.

2. The membership on the Executive Committee shall include at least one person from the Oak Ridge Institute of Nuclear Studies, at least one physicist, and all members of the Executive Committee shall be from member institutions. Not more than one person from any institution shall be a voting member of the Executive Committee.

3. Membership on the Executive Committee shall be elected by a plurality of the Board members present and voting at an annual or called meeting. Members of the Executive Committee shall be elected for a term of two years and shall be eligible for re-election except that the 1954 election shall elect three members for one year to allow overlap of appointments.

4. When vacancies on the Executive Committee occur between meetings of the Board, the Executive Committee may appoint qualified persons to serve as interim members of the Executive Committee until the next meeting of the Board.

5. All persons duly elected or appointed to the Executive Committee shall have one vote on its actions regardless of their qualification to vote on Board actions.

6. The Executive Committee shall elect a Chairman from its members.

7. Unless otherwise elected as a member of the Executive Committee the Chairman of the Board shall be an ex officio member of the Executive Committee with full powers and privileges.

8. The Executive Committee shall meet at the call of the Chairman or a majority of the Committee as often as necessary and in any event not less than twice during each calendar year.

ARTICLE V

Powers of the Executive Committee

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The Executive Committee shall have the following powers, among others:

a. To appoint any and all subcommittees necessary for organizing and promoting the teletherapy evaluation program. The Executive Committee shall have power to define the scope of effort assigned to each subcommittee, to delegate to each subcommittee authority necessary for the performance of its duties, and shall have, at its own discretion, authority to discharge any subcommittee. Each subcommittee shall, in writing, be fully identified by title and be given a statement of objectives for which it was appointed.

b. To act in an advisory capacity to the Board of Directors of the Oak Ridge Institute of Nuclear Studies on use of the teletherapy fund.

c. To act upon the recommendations of any subcommittee.

d. To prepare the agenda for meetings of the Board. New business may be introduced from the floor.

ARTICLE VI

Membership Duties and Authority of the Subcommittees

1. Membership to subcommittees shall be appointive by the Executive Committee or the Board. At least one person shall be from the Oak Ridge Institute of Nuclear Studies, at least one person should be a physicist, and at least a majority on each subcommittee shall be from member institutions. Any person may be appointed to a subcommittee on action of the Executive Committee without respect to membership on the Board. Voting on subcommittee matters shall be informal and all participants of the subcommittees shall be allowed to vote whether or not they are from member institutions.

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2. Subcommittee membership shall be reviewed annually by the Executive Committee. Reappointments or new appointments shall be made at the first meeting of the Executive Committee following each annual meeting of the Board.

3. Each subcommittee shall elect a chairman from its members.

4. The Chairman of the Board shall be an ex officio member of each subcommittee.

5. The duties and organization of subcommittees shall be by action of the Executive Committee or by action of the Board at its annual or any called meeting.

6. The authority of subcommittees is limited to the making of recommendations to an advising the Executive Committee.

ARTICLE VII

Travel Policy

1. The expenses incurred by an appointed representative or his alternate, or by another appointed consultant, in attending official meetings of the Board, the Executive Committee, or any subcommittee meeting shall be reimbursed by the Oak Ridge Institute of Nuclear Studies in accordance with the representative's consultant contract in existence at the time of travel.

2. For each meeting of the Board, the Executive Committee, or a subcommittee, the Chairman of the Medical Division of the Oak Ridge Institute of Nuclear Studies shall prepare, for each member or consultant notified to attend, a request for performance under the consultant contract in effect between that member or consultant and the Oak Ridge Institute.

ARTICLE VIII

Consultants

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Each representative on the Board may recommend specialists to the Oak Ridge Institute of Nuclear Studies for consideration in appointment to the Institute's staff of consultants.

ARTICLE IX

Amendment or Suspension of Rules of Procedure

These Rules of Procedure may be amended or suspended by a two-thirds vote of the members present and voting at any regular or called meeting.

These Rules of Procedure of the Teletherapy Evaluation Board of the Oak Ridge Institute of Nuclear Studies were adopted by the Board on January 10, 1954.

_____
Chairman
Teletherapy Evaluation Board

Approved

_____

_____
Date

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MINUTES, APRIL 17, 1954, MEETING OF SUBCOMMITTEE NO. 5, CLINICAL PROGRAM, TELETHERAPY EVALUATION BOARD

Members Present: Dr. Vincent C. Collins -- Baylor University Graduate School
Dr. I. Meschan -- University of Arkansas
Dr. Harold Tivey -- University of Oregon Medical School*
Dr. Marshall Brucer -- ORINS Medical Division**

Members Absent: Dr. Herbert D. Kerman -- University of Louisville
Dr. Galen M. Tice -- University of Kansas
Dr. George R. Cooper -- University of Virginia

* Consultant to Subcommittee No. 5.
** Arrived late due to difficulty in travel.

I. Clinical Research Program:

The subcommittee meeting was opened with a review of the preliminary statement of the objectives and program procedure of the Teletherapy Evaluation Board (TEB). (See Appendix A, Minutes of March 6, 1954 Meeting of Executive Committee.) The preliminary statement was approved as submitted by the Executive Committee except for the addition of the following general criteria governing lesions suitable for testing the advantages of teletherapy units.

1. Incidence of lesions to be treated should be high among participating institutions when considered together, rather than to expect each lesion to be high in each participating institution.

2. Conflict with firmly established local policy for treatment by other modalities should be avoided.

3. Simple staging of the extent of disease should be possible.

4. Some objective or subjective evidence of the effect of the treatment on the patient and on the disease should be possible of measurement in terms of weeks or months, rather than of years.

5. Proposed treatment plans must be simple to facilitate general acceptance.

II. Statistical Evaluation of Therapy Procedures:

At the suggestion of Dr. Collins, Drs. Harold Tivey and Carl Hopkins, University of Oregon, have been appointed as consultants to Subcommittee No. 5. Dr. Tivey was present and discussed some of the factors involved in the statistical analysis of medical results from teletherapy procedures. He pointed out that patients treated under a program having the enthusiastic support associated with cobalt 60 teletherapy units would receive greater medical attention to the primary and associated diseases. This greater attention could bias any statistical study and the factor will have to be evaluated.

Dr. Tivey suggested a limited statistical control group for each

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type of lesion to be studied. The controls would be patients treated by conventional X ray at participating medical schools. These controls could be obtained in the early stages of a given program and then discontinued unless each participating school wishes to add additional control cases. Each participating institution should make its contribution to the control group.

Dr. Tivey suggested that the factors for statistical analysis would include survival time from onset of disease to first treatment and hospitalization; severity of symptoms; time the patient is able to spend at his usual activities; pain as indicated by narcotic requirements; radiological changes in soft tissue, involved bone skin changes, bone atrophy and necrosis; temporary side effects to skin; and other laboratory data. It was agreed that each therapy procedure with data sheets would be submitted to Drs. Tivey and Hopkins to study and to recommend changes that would permit a better statistical evaluation of therapy procedures.

III. Maintenance of Record:

Dr. Tivey asked what procedure would be followed for collecting and correlating the data from participating medical schools. Dr. Meschan stated that the subcommittee, as constituted in 1953, had planned that all data be recorded on simplified data sheets and be sent to the Oak Ridge Institute of Nuclear Studies for collection and evaluation. This previous recommendation was agreeable to the present committee members.

Dr. Meschan stated that since the program is expensive and that only 25 per cent of machine time is to be devoted to the program the records requirement should not be too great. The members strongly recommended the maintenance of adequate records for deposit at ORINS for statistical studies and evaluation. The data sheets are to be in simple tabular form to facilitate mechanical tabulation and summary. The records deposited at ORINS should include microscope slides of autopsy and biopsy specimens. The ORINS pathologist will correlate a joint evaluation of the collected data.

IV. Lesions Selected for Study:

Dr. Collins pointed out that approximately six participating medical schools will soon have hectocurie units ready for use, and recommended that immediate plans be developed for a preliminary test study with these units. He also recommended that the immediate planning be concentrated on potentially radiocurable tumors in the lung, brain, and larynx. Once the procedures for these lesions are well established, the subcommittee will then expand the program to include other lesions.

The subcommittee designed four suggested data sheets for cancer of the lung. The suggested forms are to be sent to other members for review and recommendations. (See Appendix A.)

Plans were developed for specific procedures for cancers of the larynx and brain. Dr. Collins, chairman, will request each member of the subcommittee to assume responsibility for modifying each of the procedures. The draft copies will be submitted to Dr. Collins.

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It was agreed that the procedures for a given tumor would impose as little control as possible upon the participating schools. The program will request that 25 per cent of each teletherapy unit be used on patients with a specified tumor, and that the patient be selected in accordance with a table of random numbers.

V. Calibration of Hectocurie Units:

Dr. Tivey asked the subcommittee how it would be able to determine the comparability of radiation dose delivered by different machines. The subcommittee recommended that ORINS develop a check phantom with fixed portals for use as a standard calibration device. The Institute should establish a standard operating routine, fully described in the operating instructions, and arrange for checking the equipment of each participating medical school.

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CARCINOMA OF THE LUNG
TEB STUDY

ORINS Accession No.

at time of: Diagnosis ☐
Treatment ☐

IDENTIFICATI

NAME _____ AGE _____ SEX _____
ADDRESS _____ WEIGHT _____ RACE _____
HOSPITAL NO. _____ INSTITUTION _____
OCCUPATION _____ HUSBAND'S OCCUPATION _____

DIAGNOSIS

Family History

HISTORY

RELATED SYMPTOMS (Circle Earliest)	DATE OF ONSET	DURATION IN WEEKS To Dx		To Rx
1. Cough				
2. Weight loss				
3. Hemoptysis				
4. Pain				
5. X-ray: 1st suggestive finding				
Prev. neg. X-ray				
Pleural effusion				
Other				

Previous Diseases: TB ☐ Recurrent Pneumonia ☐ Bronchiectasis ☐ Other ☐

OCCUPATIONAL EXPOSURES

	Yes	No	Explanation of Positive Occupational Exposure
Benzol, oils, tars, etc.			
Radiation			
Mining			

SMOKING HISTORY

	Yes	No	Ccc.	Age Began	No. of Years	How Much
Pipe						
Cigars						
Cigarettes						
Cigarette Cough						
Chronic Mucositis						

INITIAL APPRAISAL

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ADDITIONAL SIGNIFICANT DISEASE

PRESENT ILLNESS

CV ☐ GI ☐ Skeletal ☐ Nervous System ☐ Urinary ☐ Reproductive ☐ Metabolic ☐

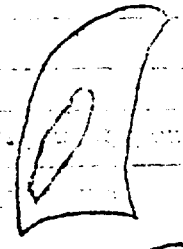
Is patient a suitable risk for pneumonectomy? Yes ___ No ___

Explain:

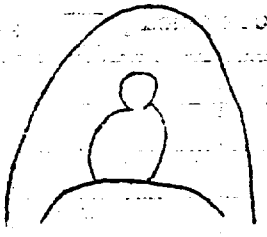
DESCRIPTION OF DISEASE

Physical Findings

X-ray Findings (List chest & others)



☐ Hilar
☐ Peripheral
☐ Cavitary
☐ Pancoast
☐ Multiple Nodules



OPERATIVE FINDINGS

Pleural Fluid Yes ☐ No ☐ Cytologic Studies Yes ☐ No ☐

Explanation

PATHOLOGY

DIAGNOSED BY:	SQUAMOUS	ADENOCARCINOMA	UNDIFFERENTIATED
Institution ☐			
ORINS ☐			
Consultant ☐			

Physician's Signature

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CARCINOMA OF THE LUNG
TEB STUDY

ORINS
Accession No.

SUMMARY OF THERAPY

PATIENT _____ HOSPITAL NO. _____

Factors: Co 60: rhm _____

X-Ray: kvp ____ hvl ____ filter ____ ma ____

Fields:

No.
Size

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

AP diameter of chest _____, Lat diameter of chest _____. (At treatment level)

Fields:

1.
2.
3.
4.
5.

Radiation Sickness *
Skin Reaction: Dry *
Wet
Hospital Days *
Usual Occupation *

Field	Size	Inclusive Days of treat.	No. of treatments	Max. dose on skin	Dose center Tumor	Max. Dose	Min. Dose
1.							
2.							
3.							
4.							
5.							
6.							

Total elapsed days _____ Tumor Dose _____

Integral dose estimate _____

* Check if applicable

SUMMARY OF THERAPY

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DAILY RECORD OF TREATMENT

Day	Date	Field Treated	Field Size	SSD	r/m in air at SSD	Minutes Treated	Quantity on Disease				Op.
							Depth	%	Day r	Total r	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
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CARCINOMA OF THE LUNG
TEB STUDY

FOLLOW-UP

ORINS
Accession No.

PATIENT _____ HOSPITAL NO. _____

INFORMANT (Patient or Other) _____

Months after 1st day of Rx V = Completed NS = No show

2	4	6	9	12	18	24	36	48	60	120

No. of weeks since previous follow-up _____

Activity since previous follow-up	No. Weeks
Normal activity	
Reduced activity	
Confined to home or nursing home	
Confined to bed	
Confined to hospital	

Persisting Symptoms:

Cough ☐ Hemoptysis ☐ Pain ☐

Weight: Loss ☐ Gain ☐ No change ☐

Appetite: Loss ☐ Gain ☐ No change ☐

Strength: Loss ☐ Gain ☐ No change ☐

Other _____

Narcotics: Type _____ Approximate Requirements _____

	Extension of Tumor	Other Significant Disease (Write name of disease)
Pulmonary		
Gastro-Intestinal		
Skeleton		
Nervous System		
Cardiovascular		
Urinary		
Reproductive		
Metabolic		

Notes _____

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FOLLOW-UP

RADIATION SIDE EFFECTS

SKIN CHANGES

Pigmentation	☐	Telangiectasia	☐
Atrophy	☐	Sub-dermal Fibrosis	☐
Radiation Necrosis	☐	Moist desquamation	☐

Lung Changes _____

Bone Changes _____

Gastro-intestinal Changes _____

Other _____

LABORATORY DATA

White Blood Count _____ Hemoglobin _____ Hematocrit _____

Evidence of: (1) Hemoptysis ☐ (2) Hematuria ☐

(3) Tarry stools ☐ (4) Ecchymosis ☐

Special Laboratory Procedures: _____

Additional Treatment:

Supplementary ☐ Supportive ☐ Pain relief ☐ Other significant disease ☐

ADDITIONAL PROGRESS NOTES: _____

EVALUATION

CLINICAL EVALUATION OF TREATMENT: _____

Signature of Physician

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CARCINOMA OF THE LUNG
TEB STUDY

ORINS Accession No.

TERMINAL EVALUATION

PATIENT _____ HOSPITAL NO. _____

INFORMANT (~~Patient or other~~) _____

Months after 1st day of Rx

2	4	6	9	12	18	24	36	48	60	120

Total Treatment Days _____ (Visits for Rx, follow-up at office, clinic, or hospital)

Hospital Days _____ (or fraction thereof)

	No. Weeks
Normal activity	
Reduced activity	
Confined to home or nursing home	
Confined to bed	
Confined to hospital	

DURATION	No. Weeks
Onset to death	
Diagnosis to death	
Therapy to death	

Date of Death _____ Date of Autopsy _____

THERAPISTS'S EVALUATION OF TREATMENT _____

INSTRUCTIONS TO PATHOLOGIST

A series of 8 tissue blocks should be sent in to ORINS

1. Full thickness skin block from skin in center of treated area.
2. Full thickness skin block from skin well outside of treated area.
3. Tissue blocks from bone (including marrow) in center of treated area.
4. Tissue blocks from bone (including marrow) well outside of treated area.
5. Tissue block from edge of tumor in center of treated area.
6. Tissue block from tumor outside of treated area if possible (or slide of previous biopsy).
7. Tissue block from intervening normal lung in center of treated area.
8. Tissue block from intervening normal lung well outside of treated area.

Make diagram to indicate the area from which blocks were removed. A copy of the Autopsy Protocol should be attached to this report.

TERMINAL EVALUATION

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CLASSIFIED BY THERAPIST

CLASSIFIED BY PATHOLOGIST

CLASSIFICATION AT DEATH
(Compared with status at time of start of therapy)

Therapy was started at primary site to irradiate only site of cancer known at that time.

TERMINAL CLASSIFICATION IS:

1. No persistent disease at primary site. No distant metastases.

   a. No complications at primary site due to radiation.
   b. Complications at primary site did not appreciably affect morbidity.
   c. Complications at primary site did appreciably affect morbidity.
   d. Complications at primary site did contribute to cause of death.

2. No persistent disease at primary site. Distant metastases present.

   a. No complications at primary site due to radiation.
   b. Complications at primary site did not appreciably affect morbidity.
   c. Complications at primary site did appreciably affect morbidity.
   d. Complications at primary site did contribute to cause of death.

3. With persistent disease at primary site. No distant metastases.

   a. No complications at primary site due to radiation.
   b. Complications at primary site did not appreciably affect morbidity.
   c. Complications at primary site did appreciably affect morbidity.
   d. Complications at primary site did contribute to cause of death.

4. With persistent disease at primary site. Distant metastases present.

   a. No complications at primary site due to radiation.
   b. Complications at primary site did not appreciably affect morbidity.
   c. Complications at primary site did appreciably affect morbidity.
   d. Complications at primary site did contribute to cause of death.

Therapy was started at secondary site, or at primary site with other areas of cancer known to exist.

TERMINAL CLASSIFICATION IS:

1. No persistent disease at site of therapy.

   a. No complications at primary site due to radiation.
   b. Complications at primary site did not appreciably affect morbidity.
   c. Complications at primary site did appreciably affect morbidity.
   d. Complications at primary site did contribute to cause of death.

2. With persistent disease at site of therapy.

   a. No complications at primary site due to radiation.
   b. Complications at primary site did not appreciably affect morbidity.
   c. Complications at primary site did appreciably affect morbidity.
   d. Complications at primary site did contribute to cause of death.

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TENTATIVE AGENDA FOR THE MAY 14 AND 15, 1954 THIRD
INDUSTRIAL CONFERENCE ON TELETHERAPY

FRIDAY MORNING

9:00 a.m....Cost curiage and rhm output of cobalt 60.....Brucer.....ORINS
10:00 a.m....Current production, schedules, and problems - U.S.A.....Aebersold.....AEC
10:30 a.m....Current production, schedules, and problems - Canada.....Canadian Representative
11:00 a.m....Discussion of production problems
11:30 a.m....Problems of source strength calibration and loading.....Beauchamp.....ORNL
12:00 noon...LUNCH

FRIDAY AFTERNOON

1:30 p.m....Discussion of policy of allocation of cobalt 60....Led by Aebersold.....AEC
2:30 p.m....Review of final requirements for teletherapy protection....Brucer.....ORINS
3:00 p.m....Essential data a manufacturer must supply to the customer.....Stickney.....Picker
3:15 p.m....Essential data a customer must get from the manufacturer.....Lofstrom.....Wayne
3:30 p.m....Discussion of "Essential Data"
4:00 p.m....The requirements for a shipping container.....Stober.....Keleket
4:30 p.m....Should the shipping container be "standardized"? - Discussion

SATURDAY MORNING

9:00 a.m....The requirements in instrument design for measuring cobalt 60.....Managan.....Victoreen
New sources for teleradiation
9:30 a.m.....Pile produced.....Butler.....ORNL
10:00 a.m.....Cyclotron produced.....Green.....ORNL
10:30 a.m....Open discussion
11:30 a.m....The development of the atomic energy industry.....Luntz.....Nucleonics
12:00 noon...ADJOURNMENT

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A STANDARD COBALT 60 TELETHERAPY SOURCE CAPSULE

Prior to 1953 the design and construction of a cobalt 60 teletherapy machine was a highly individualized research project. The immediate and widespread recognition of the value of cobalt 60 has lead to many diversified and ingenuous designs both here and in Europe. During the past year several X-ray companies have selected designs for teletherapy machines suitable for commercial production. In each machine, whatever its design, there must be a source capsule to seal the raw cobalt 60, and the characteristics of this capsule are related to the economic problems of the source itself.

Cobalt 60 must be produced in a nuclear reactor. For multicurie sources relatively large volumes of cobalt are used, and if this cobalt is incorrectly placed in the reactor, it can stop the chain reaction. Although the shapes and sizes of cobalt 60 sources that can be used are manifold, the characteristics of neutron irradiation make small pieces essential. Since each source must stay in a reactor for a year or so, and since each separate piece comes out of the reactor with exceedingly high activity, the problems of production, handling, loading, sealing, and avoiding contamination make the manufacture of a cobalt 60 source a surprisingly complex technological problem. Because of the necessity for special remote handling tools, economy has dictated a small number of standard source sizes. For various reasons the two producers of high curiage cobalt 60, Atomic Energy of Canada Limited and the United States Atomic Energy Commission, have chosen a limited variety of sizes ranging from small pellets to wafers 2 cm in diameter. With these standard sizes, it is possible to devise high activity sources of almost any required number of curies.

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The problems of loading a series of pieces of cobalt 60 so that they can be used as a teletherapy source presents an additional serious problem requiring specialized tools and equipment. The National Committee on Radiation Protection, Subcommittee No. 9 has recently devised and will shortly publish in Handbook 54 the results of its study on how cobalt 60 can be "safely" encapsulated. There is, therefore, an accepted standard for encapsulation of sources.

Since a cobalt 60 source decays to half its output in a little over five years, a therapist starting out with a kilocurie source will ultimately have a source too "cold" for his own machine but still containing a large number of curies. Since the capital investment is based upon the number of curies originally present, a partially decayed source that is no longer usable represents a sizable investment in wasted curies. Can such a source be reirradiated in a reactor for half the original cost? The United States Atomic Energy Commission points out that reactors are designed to admit "cold" pieces and discharge "hot" pieces. A modification of the reactor to permit admission of "hot" pieces (and a partially decayed teletherapy source is still very "hot") limits the adaptability of the reactor and is exceedingly expensive. It is the United States Atomic Energy Commission's position that it is cheaper to start with inactive cobalt for each source even if it is necessary to discard many curies of cobalt 60. Since teletherapy is only a small part of the total benefit (and expense) of a high flux reactor, the therapist must accede to this judgment. It appears that in a few years there will be a problem of what to do with half-strength cobalt 60 sources.

The Canadians, with a different set of priorities and for reasons just as valid, have demurred at this point and believe that it is possible

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to reirradiate partially decayed sources.

When only very high curiage cobalt 60 machines were considered, the problem of the partially decayed source was a big factor in the economy of cobalt 60. One paid for twice as much as he could use. Recently, however, the Teletherapy Evaluation Board has developed a cobalt 60 machine that is designed for a maximum of 600 curies. This machine can use the sources that are no longer useful in kilocurie machines. The design of a 200 curie machine is also planned. A few machines in the 50 to 100 curie range have already been constructed. The possibility of the industrial use of lower curiage sources is as yet unexplored. If sources could be transferred conveniently from one machine to another, the cobalt 60 would maintain a decreasing but considerable value and the effective economic half life of the isotope could be extended from five years to 20 or 30 years.

For sources to be transferred from one machine to another, they must now be unloaded from a well sealed capsule and reloaded. This is a technical problem of considerable magnitude and may easily cost more than it is worth. There is an easier and cheaper answer. The standardization of a capsule for all sources of cobalt 60 of all sizes and curiages would allow each one to be transferred in its capsule from machine to machine with no more than a handling charge. In October 1953, the representatives from 14 X-ray equipment manufacturers met with the Isotopes Division of the United States Atomic Energy Commission, the Atomic Energy of Canada Limited, and the Oak Ridge National Laboratory at the Medical Division of the Oak Ridge Institute of Nuclear Studies for a discussion of the current problems of teletherapy. It was decided at this meeting, after a review of the advantages and disadvantages of standardization, that it was to the best interest

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of the therapist, the industry, and the manufacturers of cobalt 60 that a source capsule for teletherapy machines be standardized. It was felt that there had been sufficient experience with encapsulation of high energy sources to permit design of a capsule that would meet every requirement of the therapist, the reactor technician, and the manufacturer. In November a special meeting was held and by subsequent correspondence such a capsule was designed. The now accepted standard source capsule is shown in Fig. 1. It consists of five separate pieces: a tungsten alloy cap and plug, a stainless steel cup, and two lead wire seals. The over-all size of the capsule is a right cylinder 2 inches in diameter by 1 5/8 inches long. Detailed drawings of the capsule are available from the Medical Division, Oak Ridge Institute of Nuclear Studies. The standard cobalt 60 source capsule is designed to meet the following requirements:

1. Size of Source: The standard cobalt 60 source capsule must be adaptable to all projected source sizes of Canada and the United States. The largest Canadian source is a right cylinder 3 cm in diameter by 3 cm high. This maximum dimension fixed the inside dimensions of the capsule since all sizes of projected cobalt 60 wafers of the United States can be accommodated within this space.

2. Activity of Source: The capsule must be able to contain the largest number of curies feasible for expected teletherapy use. Based upon material having a specific activity of 50 curies/gram, which is now obtainable, the design accommodates a total activity of more than 4,000 curies of cobalt 60.

3. Material of Capsule: The capsule must in itself be a part of the primary radiation shield since it is in the most economical position

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for shielding. All of the materials less dense and with lower atomic number than tungsten were discarded for obvious reasons. The platinum metals and gold were discarded because of high cost. Permission to use uranium was granted by the United States Atomic Energy Commission but this material was rejected by the industry. It was believed that the high cost and difficulties in fabrication of uranium more than outweighed its slight advantage over tungsten alloy as a radiation shield. In the present design, tungsten alloy completely surrounds the source except in the direction of the primary beam. In the directions immediately adjacent to the primary beam there is a particularly critical shielding problem, and the present design has a wide forward shoulder to give maximum shielding in this area. All of the screw threads are at the rear, in less critical areas.

4. Airtight Seals: The capsule must have a positive sealing system. This should be a double hermetic seal to prevent the leakage of particles of cobalt 60, which can flake and dust off of the raw cobalt 60 source material. The present design has two lead wire seals. The first large wire primary seal is partially pressure-welded into position by an incomplete seating of the plug. This will allow preassembly of the cap and cup as a single unit. The second small lead wire will be pre-fitted to the plug and upon final assembly the two preassembled pieces will be screwed into place under high torque; there will be a cold flow of lead into the screw threads and between the cap and cup to form a continuous airtight seal. Such a system has been in use for a number of years and there is sufficient experience to give confidence in its success. It will be difficult to break such a seal for removal of the cobalt 60. It is not intended in the U.S.A., however, that such a source

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capsule will ever be unloaded and reloaded. If reloading is necessary, it will be possible with special tools to cut off the top window of the stainless steel cup.

5. Loading of Capsule: The capsule must be easily loaded with the cobalt 60 of both Canada and the United States. The problems of multi-curie loading, which requires remote handling equipment behind thick shields, are not to be passed off lightly, and the designer of a special source container may easily find that the cost of loading exceeds the cost of cobalt 60. The present design is suitable for the methods of loading of both Canada and the United States, and only one set of jigs will be necessary for all types of sources.

6. Manipulation of the Source Capsule: It should be possible to manipulate and position the source capsule without applying pressure to the movable and critical parts. The present design is such that the only movable part, the plug, is seated slightly below flush so that it need never be touched after loading. The only critical thickness is in the presenting face of the steel cup and this is protected by a shoulder of tungsten. The only part that need be handled by remote control equipment is the solid outer cap.

7. The Radiation Window: The presenting face of the source capsule, which makes up the window that the useful beam of cobalt 60 traverses, should be sufficiently strong to resist breakage but must be as thin as feasible so that the attenuation of the beam will be minimal. A two per cent attenuation will cost from $100 to $400 in initial output and will add a few minutes to each treatment. Since even thin faces of metal will give attenuation of a few per cent, a poorly designed capsule for a high activity source can be expensive. The present design uses an 0.02 inch

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cover of stainless steel, which is regarded as the best compromise between strength and attenuation.

8. Emplacement of the Source Capsule: Some teletherapy machines will hold the source capsule in place by mechanical pressure, some will use a screw thread, and some will have a simple shelf arrangement. One design has visualized the capsule as a free floating bearing. The present design has had to allow any of these methods of emplacement.

The adoption of this standard source capsule by the manufacturers of cobalt 60 of both Canada and the United States does not preclude any person from designing or using a cobalt 60 source and capsule of any size or shape he may wish. The increased cost of special loading facilities, however, must be borne by each purchaser and, in the United States, the capsule must meet the requirements of the National Committee on Radiation Protection. There have been many surprises arising out of the adaptation of cobalt 60 for teletherapy and in this field, which is fluid and highly competitive, it is to the credit of the X-ray industry that they have been able to co-operate on the one factor that might easily have led to a serious economic problem and waste of a significant amount of cobalt 60. They have adopted a standard source capsule with the aim of reducing the cost of cobalt 60 equipment. The manufacturers realize that such early standardization might easily be outmoded by the rapid development of new types of teletherapy machines. For this reason it has been agreed that the industry will meet about twice each year to discuss the current development problems of teletherapy equipment. During the next two years there will be an extensive study of the experience with the present standard source capsule, and late in 1955 the problem of a standardized source capsule will be reviewed by the entire industry. Criticisms of the present

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design and suggestions for its improvement will be welcomed.

(The design presented here represents the combined efforts of many representatives of the organizations listed, and in the present publication I am serving only as a reporter of the conclusions reached.)

Marshall Brucer, M.D.
Chairman, The Medical Division
Oak Ridge Institute of Nuclear Studies
Oak Ridge, Tennessee
(Under contract with the United States
Atomic Energy Commission)

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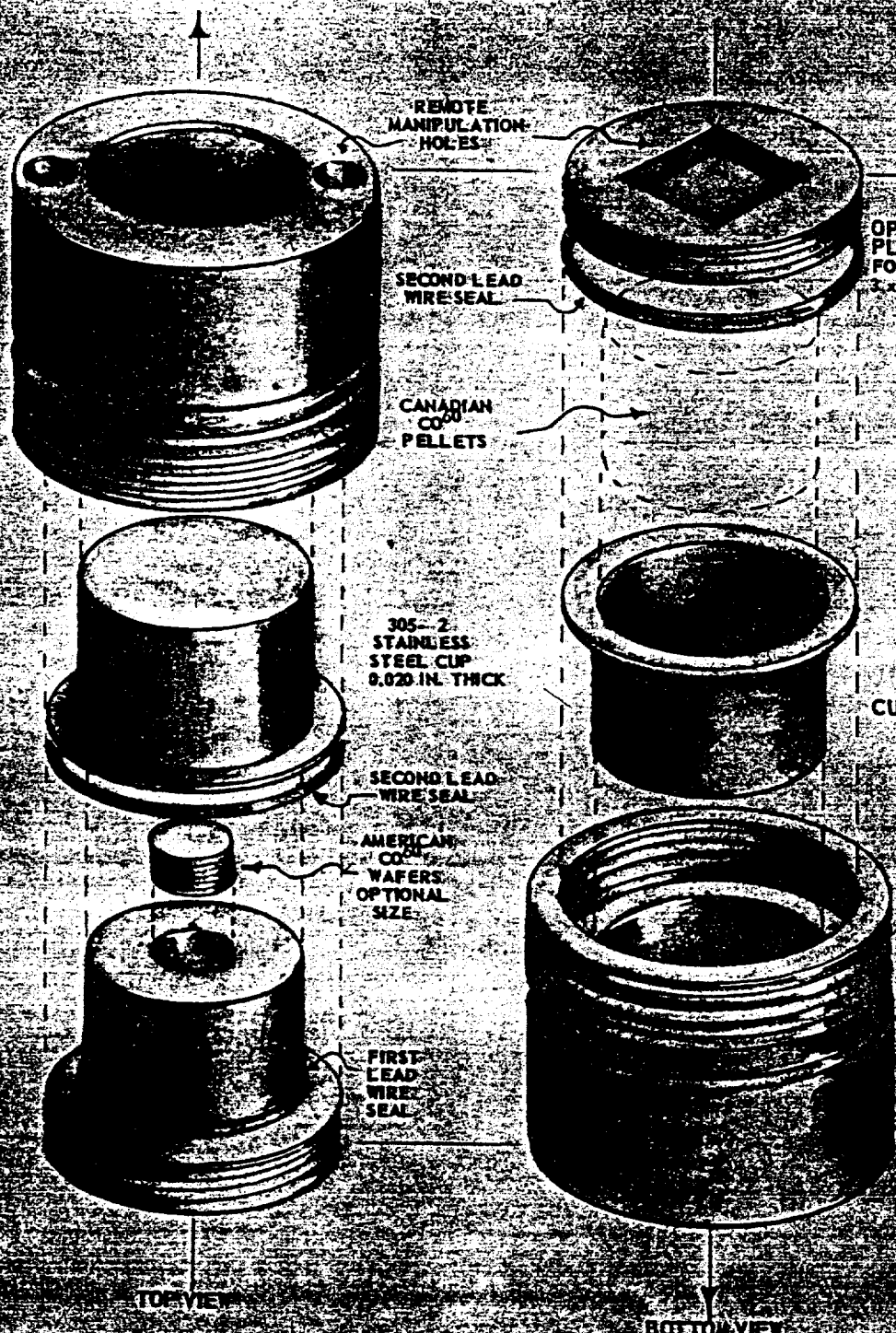
STANDARD CO^{60} SOURCE CAPSULE

TENTATIVE ADOPTION 6 NOV. 1953
BY MEMBERS OF
X-RAY INDUSTRY
CANADIAN AND U.S. AEC
AT ORINS, OAK RIDGE



DESIGNED FOR HECTOCURIE AND KILOCURIE TELETHERAPY UNITS

MAXIMUM SIZE OF CAPSULE 2 INCH DIAM x 1 7/8 INCH LENGTH

MAXIMUM SIZE OF SOURCE 3 cm DIAM x 3 cm LENGTH

CONSTRUCTION DRAWINGS MAY BE OBTAINED FROM MEDICAL DIVISION, O.R.I.N.S. OAK RIDGE, TENN.

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COBALT 60: COST, CURIAGE, AND rhm OUTPUT

Marshall Brucer and Howard Harmon*

The ever increasing use of cobalt 60 has made it desirable to tabulate a definitive review of the cost, curiage, and rhm output of various arrangements of raw cobalt 60 wafers, especially as they are used in teletherapy sources.

Along with the tables included in this review is a statement on "A Standard Cobalt 60 Teletherapy Source Capsule" and a statement on "An Available Cobalt 60 Source for Teletherapy". Much of the material in these two statements complements the material to be found in Tables 1 through 11.

The use of cobalt 60 has been an explosive phenomenon in the field of deep therapy. A number of manufacturers of X-ray equipment have privately ventured the opinion that electrical generators of X rays are already outmoded except at the very low and very high energies. The reason for this rapid acceptance is not to be found in the biological reaction to cobalt 60 gamma rays. For therapy purposes the reaction is about the same at all reasonable energies.

If a distinction can be made between the physical characteristics of the cobalt 60 beam in tissue, and the reaction of the tissue itself, then a cobalt 60 beam does have a superior penetration in depth to that in current standard equipment. Also, the secondary electrons, incident from the first layer of the skin, penetrate below the region where skin can be damaged (but this might be interpreted as an improper removal of a safeguard to therapy). The extent of scattered radiation out of the primary beam in tissue is markedly lessened with cobalt 60. But these advantages have all been achieved with properly designed high voltage electrical generators. The big advantage of cobalt 60 is economic and in the freedom allowed the designers of equipment.

The essential economic factor in radiation therapy equipment is not the capitol

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* Work done at the Medical Division, Oak Ridge Institute of Nuclear Studies, Inc., Oak Ridge, Tennessee, under contract with the United States Atomic Energy Commission.

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nvestment in a machine. This is a one shot expense which can be amortized over a period of years. The essential costs are in such things as the continuing labor cost of a radiotherapist's time and the time of his technical staff. The prorated cost of the use of hospital space and of cleaning, heating, and repairing this space is a big factor. Since such costs are highly varied and somewhat out of the control of hospital management, the only real control a board of trustees has over the cost of radiotherapy is in their investing in the purchase of equipment that allows the most efficient use of the time of the technical staff. The X-ray industry has had many years to develop X-ray equipment to its present high peak of efficiency. They are only beginning to think of cobalt 60 equipment and many improvements can be expected in the next few years. An excellent illustration of changing opinion can be found in an argument comparing the treatment cost for hectorcurie and kilocurie cobalt 60 machines.

At the present commercial prices of cobalt 60 machines it is possible to install two hectocurie (600 rhm) machines for about $75,000 or one kilocurie (1800 rhm) machine for about $85,000. Treatment with these machines is identical. All of the gadgetry to make a kilocurie machine more effective can also be put on a hectocurie machine. The only difference is that at the longer distances it will take about twice as long to give the same treatment with a hectocurie machine. However, about half of the treatment time of any machine is used in getting the patient positioned, in cleaning up, and in the inevitable dead time between patients. The following table describes some of these factors:

	Two Hectocurie Machines		One Kilocurie Machine
Cost of Machine	$25,000	$25,000	$50,000
Cost of Treatment Room	7,500	7,500	10,000
Cost of Cobalt 60	5,000	5,000	25,000
Total Machine Cost	$75,000		85,000

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'erage setup time per patient	5 minutes	5 minutes
Average treatment time per patient	30 minutes	10 minutes
Average clean up and dead time	10 minutes	10 minutes
Total treatment time	45 minutes for 2 pts.	25 minutes for 1 pt.
Number of patients per day	21 patients	19 patients

With correctly designed equipment, if a radiotherapy staff can handle 20 patients a day, it follows that they can handle these patients on two machines just as easily as on one machine in which case the use of two hectocurie machines becomes more economical than one kilocurie machine. In spite of the fact that the treatment time for any one patient is three times as long with the hectocurie machine, the dilution of treatment time with various kinds of dead time make the total treatment time only about twice as long for a machine with only one-third of the output. With the long treatment time on the hectocurie machine one set of technicians and a thera-'st can easily keep two machines in alternate operation with plenty of dead time between patients.

There are other advantages. Two hectocurie machines can be serviced alternately without stopping a schedule of treatments whereas with one kilocurie machine a serious problem in maintenance stops all treatments. The kilocurie machines cannot be used at short source to skin distances (SSD). The hectocurie machine can be used at both 50 and 35 cm SSD and where extreme depth penetration is unnecessary the smaller machine when used at its shortest SSD has a higher output than that of the larger machine used at its shortest SSD. Although it is true that a kilocurie machine is more efficient than a hectocurie machine in an over-all treatment schedule, it is not necessarily more efficient than two hectocurie machines. The $10,000 saving in cost will support a physicist, which in itself will improve a therapy department more than any item of machinery.

There is one other item — the maintenance of equipment, which looms large in the cost of radiation therapy. Tubes and transformer troubles are an ever present

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unpredicatable cost of X-ray generators. Little maintenance trouble is possible in the simple machinery of the cobalt 60 device. The only routine problem is the decay of cobalt 60. But this decay is predictable and can be planned well in advance. The ever present problem of the calibration of an electrical generator of X rays is done once with cobalt 60 and the calibration from then on is read off a printed chart. The problems concerned with isodose patterns in X ray devices can be solved in a cobalt 60 machine with one set of standard isodose curves.

The therapeutic advantages of the hectocurie design was originally stated to be very limited and probably confined to head and neck lesions. Since these machines have been made available not one of the purchasers is considering such a limitation. Rather the machine has been put into direct competition with a 250 kvp X ray generator. Even with so little information available the impressions we have been able rather indicate a very high probability that the hectocurie machines will be at least as useful and might be more useful, and they will certainly be more popular than either the X ray or the larger cobalt 60 machines. If there is some validity to the foregoing argument, then many kinds of cobalt machines may be designed and this will demand sources of various curiages.

Such a source design must consider many factors but to simplify the problem some of these factors may be almost taken for granted.

1) The source must be made up from thin wafers into a right cylinder. (The reasons for this are described in the article by Brucer, Pollard, Leiter, and Scarf; Nucleonics 11, No. 2, Feb. 1953.)

2) The size must have a maximum diameter of 3 cm. This is rather arbitrary but in any source much beyond 3 cm in diameter the penumbra of the machines becomes unacceptable. In the lower output machines where treatment is at a shorter SSD the num diameter must be reduced to about 2 cm. The penumbra at a 2.3 cm maximum, 1.9 cm minimum diameter, which is achieved by the double overlapping cloverleaf design, is just barely within the acceptability reached by the Grimmett and the

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ohns designs. We cannot allow a wider penumbra but if we make a much better penumbra with a smaller source we would allow more latitude in the design of cones that are now tightly restricted to a 30 cm collimation distance.

3) In regard to the best diameter for a source, the rule is still "the smaller the better".

4) The source must fit the standard source capsule. The restriction involved is only in the length of 3 cm, which actually is not a restriction since the cost factor overwhelmingly reinforces this decision.

5) The total curiage should ultimately aim at outputs of 600 rhm and 1800 rhm. The hectocurie machine was designed for a maximum of 600 rhm. This is an arbitrary decision but is logically based upon extensive study of experiences with 250 kvp X ray machines. Most current machines are used at about 10 to 50 rmm. Some therapists will complain of faster, and an equal number will complain of slower rates. The treatment distance with the hectocurie machine can go as low as 35 cm, hence, a 600 rhm machine will have outputs that can roughly be diagramed in the following figures.

Treatment Distance	Depth Dose at 10 cm of Water as % of Skin Dose	Approximate Equivalent Peak X-ray Voltage	rmm on Delivery	rmm after 5¼ years	rmm after 10½ years
1 meter	64%	2.5 Mev	10	5	2½
70 cm	56%	2.0 Mev	20	10	5
50 cm	51%	1 Mev	40	20	10
35 cm	43%	400 kvp	80	40	20

By multiplying the rmm figures by approximately 3 the same tables can be used for an 1800 rhm machine, except that the 35 cm treatment distance is not possible and in many machines the 50 cm treatment distances are not possible. At the longer SSD a higher output machine can probably be used more efficiently but the cost of the machine also increases markedly. A lower output could also be used and is preferred by some therapists but would not meet general approval.

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Before any definite decisions are made on the standardization of source sizes, one should review the complete picture of the cost, the curiage, and the rhm output of various sources. Such a review is partially possible from the tables and figures herein presented.

Table 1

Table 1 shows the effect of source length on transmission and cost. A right cylinder source is used with the beam coming out of the end face of the cylinder. The data are computed for a 1 cm diameter rod, but such factors as the fractional transmission, the per cent of theoretical maximum transmission, and the per cent gain with added length will fit any diameter rod. As the length of the rod increases, as shown in Column 1, there will be more and more self-absorption so that there is a theoretical maximum length beyond which there is no added output in spite of the added curiage. Column 2 shows the volume of a 1 cm diameter rod at various lengths. The specific activity for Table 1 was calculated at 5 curies/gram or 43.5 curies/cm^3. A uniform distribution of the active cobalt 60 was assumed. In Column 4 there is computed the total rhm obtainable from the number of curies shown in Column 3 assuming 1.35 rhm per curie of cobalt 60. From Dixon's function on fractional transmission Column 5 was computed, which allowed the calculation of the total rhm of each specific length with self-absorption taken into account. From this column it was possible to calculate in Column 8 the per cent of the theoretical maximum transmission at each length. In column 9 it can be seen that as the length increases there is a rapid increase in the per cent output up to 2 cm after which it begins to fall markedly. It would appear from this that the most economical source length will certainly not be beyond 3 cm in length. On page 2 of Table 1 these same factors are computed when specific activities of 10, 50, and 100 curies per gram are considered. On page 3 of Table 1 are given some of the data used to calculate Dixon's self-absorption functions. Notice that in Table 1 the cost factor was very simply arrived at. These cost factors will be changed in the last tables in this series

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to a more reasonable estimate of actual cost.

Table 2

Table 2 shows the effect of source length and specific activity. The same type of data as were used in Table 1 is used in Table 2 except that in this case the specific activity is changed from 1 to 100 curies per gram.

Table 3 and 4

In Tables 3 and 4 the total curiage and the rhm output in various sizes of right cylinder sources were computed for four different specific activities. Table 3 shows the effect of various source lengths and source diameters at 5 curies per gram. The same figures can be used for 50 curies per gram by multiplying each figure by 10. In Table 4 the 10 and 100 curie per gram specific activities are given.

The data from Table 3 showing the total curiage for various lengths and diameters of sources are shown graphically in Fig. 1. The data are shown for 5 curies per gram but this can be converted for the 50 curie per gram specific activity by multiplying the abscissa by 10.

In Fig. 2 the same type of total curiage data is shown for various lengths and diameter sources for the 10 and 100 curie per gram material.

In Figs. 3 and 4 the effect of changing length and diameter of source on the rhm output is shown for both the 5 and 50 curie per gram material and the 10 and 100 curie per gram material.

From these data a number of general conclusions can be made. Figure 5 shows a three dimensional chart giving many lengths of sources and many diameters of sources. These two factors are plotted against a total number of curies and on the three dimensional surface so achieved it can be shown that any reasonable output can be achieved with many source sizes, but these will always be within a well defined total range of curies.

Figure 6 shows a three dimensional graph of the cost of the radiation in terms

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dollars per rhm for various source lengths and specific activities. From this three dimensional surface it can be seen that with an increase in source lengths at any specific activity there is a rapid increase in the cost of cobalt 60, but that there is a minimum at a short source length. The point at which this minimum cost occurs on the source length axis changes with various source diameters. It is also shown that the cost decreases generally with increasing specific activity. However, since the price of cobalt 60 changes at 10 and 50 curies per gram there is a step where there otherwise would be a smooth surface. There is a peak at the very low specific activity thin wafers, which is a highly uneconomical use of cobalt 60. The same figures are redrawn in Fig. 7 to show the effect not only of increasing length but also of increasing diameter. For a specific activity of 10 curies per gram the surface is shown complete. The minimum cost is at a length of about 0.5 to 1 cm length at all diameters, except at the very small diameter sources where the decreased rhm results in a marked cost peak. The same type of graph occurs but at different levels with the other specific activities.

Tables 5 through 8

In Tables 5 through 8 the data from Tables 3 and 4 were recomputed to state the cost of the total source and the cost per rhm when calculated to include many more factors than the raw cobalt 60 cost as used on the previous tables. Notice that the cost factors as explained on the page preceeding Table 5 have been changed. In addition to the cost of the source material there is included a cost of $210 for the standard source capsule. There is included a handling charge of $10 for each source. The loading charges are included and a shipping charge, which is based upon a simplified system of computing shipping charges, has been added. The cost, however, does not include rental on a shipping container or the cost of loading the source into a teletherapy machine. An example can be given to show how these figures are interpreted. If it is decided to design a cobalt 60 source with an output of approximately 600 rhm, on Table 4 we find such an output can be achieved by using a 2 cm

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ameter source 3 cm long which gives an output of 614 rhm and uses 820 curies of activity. From Table 6 it can be seen that the 3 cm length of 2 cm diameter cobalt 60 will cost about $4,190 or about $6.82 per rhm. This, however, is not the total cost of the source but is only the cost of the cobalt 60 in the source. When we add the source capsule, handling, loading, and all costs except shipping, this cost increases, as shown on Table 6A, to $4,760 or $7.75 per rhm. If the source were shipped to New York City the cost then would increase to $4,812; if it were shipped to San Francisco it would increase to $4,903.

To give a better picture of the meaning of Tables 5 through 8 a number of specific examples have been selected and are shown in Figs. 8 through 11. In Fig. 8 a 1 cm diameter source was chosen at 50 curies per gram specific activity. With increasing lengths of the source the total rhm is shown as the heavy line. The light line shows total curiage, the dotted line shows the total cost of the source, and another dotted line shows the cost per rhm. In Fig. 9 is shown the results when a 1.5 cm diameter source is used. Figure 10 shows the same factors when a 2 cm diameter source is used at 10 curies per gram and Fig. 11 at 50 curies per gram specific activity.

In Fig. 12 there is shown the effect of adding the handling charges to the cost of the raw cobalt 60. Without handling charges 10 curie per gram material has an advantage over the 50 curie per gram, but the 50 curie per gram has an advantage over 11 curie per gram material. Since handling costs are fixed charges within wide ranges of activity, the handling charges are more effective in the lower specific activity material and hence 50 curie per gram material is economically better than the 10 curie per gram material. At 11 curies per gram the cost is even higher.

Tables 9, 10, and 11

To get a better picture of the effect of specific activity on the total curiage and rhm output, Tables 9, 10, and 11 are computed to show the data for three reasonable standard source sizes, a 1 cm, a 1.5 cm, and a 2 cm diameter rod. At

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various lengths and various specific activities the total curies are shown in the first part of the table and the rhm output in the second part of each table. In Table 11A, the 2 cm diameter source size was taken and the costs were computed for the source alone and for the encapsulated source shipped to New York City. This was then converted to cost per rhm.

From the data on Tables 9 to 11 the cost of a 2 cm diameter source has been recomputed. Instead of making the change in cost due to specific activity at 10 and 50 curies per gram a change is made at 10, 30, 50, and 70 curies per gram. Since it is impossible to administer an accounting system with a continuous change in cost with changing specific activity some breaks must be made. However, with the simple system of making the break at 10 and 50 curies per gram, the use of more easily available 20 and 30 curie per gram material involves a penalty. This penalty can easily be obviated and the cost-specific activity curves smoothed out by making the breaks somewhat more frequent.

Almost anything of reasonable size can be irradiated in a nuclear reactor. With proper consideration of the time relationships, almost any reasonable specific activity up to 100 curies per gram can be achieved, but this cannot be done without affecting cost. However, on a production line scheduled to produce many sources, a reactor cannot be efficiently operated unless there is some standardization of cost, sizes, shapes, and irradiation time.

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Co 60

THE EFFECT OF SOURCE LENGTH ON TRANSMISSION AND COST

Right Cylinder Rod Source -- Data for 1 cm Diameter Rod
Cross Sectional Area = 0.7854 cm^2 -- Volume = 0.7854 cm^3 at 1 cm Length
rhm for 1 Curie = 1.35 -- 1μ for Co 60 Through Co 59 is 0.44 cm^{-1}

Length cm	Volume cm^3	Curies*	rhm without self absorption	fractional** transmission	rhm with self absorption	$I/\sigma A$***	% of theoretical maximum ‡	% gain with added length	cost of total source $ ††	cost per unit rhm $
0.1	0.078	3.42	4.62	.970	4.48	0.097	4.26	---	110	24.55
0.5	0.393	17.10	23.09	.900	20.78	0.451	19.84	15.58	180	8.66
1	0.785	34.16	46.12	.825	38.05	0.825	36.30	16.46	265	6.96
2	1.571	68.34	92.26	.664	61.26	1.328	58.43	22.13	435	7.10
3	2.356	102.49	138.36	.555	76.79	1.665	73.26	14.83	605	7.87
4	3.142	136.68	184.52	.469	86.54	1.876	82.54	9.28	775	8.95
5	3.927	170.82	230.61	.404	93.17	2.020	88.88	6.34	945	10.14
6	4.712	204.97	276.71	.352	97.40	2.112	92.92	4.04	1115	11.44
7	5.498	239.16	322.87	.310	100.09	2.170	95.48	2.56	1290	12.88
8	6.283	273.31	368.97	.275	101.47	2.200	96.80	1.32	1460	14.38
9	7.069	307.50	415.13	.247	102.54	2.223	97.81	1.01	1630	15.89
10	7.854	341.65	461.23	.223	102.85	2.230	98.12	0.31	1800	17.50
15	11.781	512.47	691.83	.151	104.47	2.265	99.66	1.54	2655	25.41
20	15.708	683.30	922.46	.113	104.65	2.269	99.83	0.17	3510	33.54
max. = $\frac{1}{\mu}$ (2.2727)	1.785	77.65	104.82	1.000	104.82	2.273	100.00	0.17	---	---

* Calculated at specific activity of 5 curies/gram or 43.5 curies/cm^3 uniform distribution.

** From Dixon's Function $F_{\frac{1}{2}}(\mu a)$ see graph.

*** I = rhm with self absorption; σ = rhm without self absorption/cm^3; A = cross section area

$$\sigma A = \frac{104.82 \times 0.7854}{1.785} = 46.12$$

‡ Theoretical maximum is defined as $I \max = A\sigma/\mu$

†† Cost = $100 for first 2 curies plus $5 for each additional curie or fraction thereof.

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Co 60

	10 CURIES PER GRAM					50 CURIES PER GRAM			100 CURIES PER GRAM		
Length cm	Curies*	rhm without self absorption	rhm with self absorption	cost of total source $ **	cost per unit rhm	rhm with self absorption †	cost of total source $ †	cost per unit rhm	rhm with self absorption††	cost of total source $	cost per unit rhm
0.1	6.79	9.17	8.89	125	14.06	44.8	348	7.76	88.9	1660	18.67
0.5	34.19	46.16	41.54	265	6.37	207.8	1368	6.58	415.4	4400	10.59
1	68.30	92.21	76.07	335	4.40	380.5	2650	6.96	760.7	7810	10.26
2	136.68	184.52	122.52	775	6.32	612.6	5215	8.51	1225.2	14650	11.95
3	204.97	276.71	153.57	1115	7.26	767.9	7773	10.12	1535.7	21480	13.98
4	273.35	369.02	173.07	1460	8.43	865.4	10337	11.94	1730.7	28320	16.36
5	341.65	461.23	186.34	1800	9.65	931.7	12903	13.84	1863.4	35150	18.86
6	409.94	553.42	194.80	2140	10.98	974.0	15460	15.87	1948.0	41980	21.55
7	478.33	645.75	200.18	2485	12.41	1000.9	18025	18.00	2001.8	48820	24.38
8	546.62	737.94	202.93	2825	13.92	1014.7	20590	20.29	2029.3	55650	27.42
9	615.00	830.25	205.07	3165	15.43	1025.4	23148	22.57	2050.7	62480	30.46
10	683.30	922.46	205.71	3510	17.06	1028.5	25713	25.00	2057.1	69310	33.69
15	1024.95	1383.68	208.93	5215	24.96	1044.7	38523	36.87	2089.3	103480	49.52
20	1366.60	1844.91	209.21	6925	33.10	1046.5	51333	49.05	2092.1	137640	65.79
max. = $\frac{1}{\mu}$ 2.2727	155.30	209.66	209.65	—	—	1048.2	—	—	2096.5	—	—

* Curiage calculated at 10 curies/gram or 87 curies/cm^3 uniform distribution.

** Cost = $5/curie plus $100 for first 2 curies.

† Curiage calculated at 50 curies/gram or 435 curies/cm^3 uniform distribution; therefore cost = $7.50/curie plus $100 for first 2 curies.

†† Curiage calculated at 100 curies/gram or 870 curies/cm^3 uniform distribution; therefore cost = $10.00/curie plus $100 for first 2 curies.

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Co 60 through Co 59

Calculation of Self Absorption Function $F\frac{1}{2}$ (μa)
(From Dixon, W. R., Nucleonics 8: 68, April 51)

length	½ length = a	μ = 0.44 cm^{-1} aμ	(see graph) fractional transmission	rhm x A
.1	.05	.022	.970	3.6285
.5	.25	.11	.900	18.1348
1	.5	.22	.825	36.2226
2	1	.44	.664	72.4610
3	1.5	.66	.555	108.668
4	2	.88	.469	144.922
5	2.5	1.10	.404	181.121
6	3	1.32	.352	217.328
7	3.5	1.54	.310	253.582
8	4	1.76	.275	289.789
9	4.5	1.98	.247	326.043
10	5	2.20	.223	362.250
15	7.5	3.30	.151	543.363
20	10	4.40	.113	724.500
2.27 (max)	1.13636	—	1.000	82.3256
				σA = 46.12

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Co 60

THE EFFECT OF SOURCE LENGTH AND SPECIFIC ACTIVITY ON THE COST OF COBALT 60 RADIATION
(Right Cylinder Source - Density of Co = 8.7)

1 to 10 curies = $5.00/curie plus $100 for the first two curies
10 to 50 curies = $7.50/curie plus $100 for the first two curies
50 to 100 curies = $10.00/curie plus $100 for the first two curies

curies/gram	curies/cm^3	length = 0.1 cm, volume = 0.07854 cm^3, fractional transmission = .970					length = 1.0 cm, volume = 0.7854 cm^3, fractional transmission = .825				
		total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $
1	8.7	0.68	0.92	0.89	50	56.18	6.8	9.2	7.6	125	16.46
2	17.4	1.37	1.85	1.79	100	55.86	13.7	18.5	15.3	160	10.45
3	26.1	2.05	2.77	2.69	105	39.03	20.5	27.7	22.9	195	8.51
6	52.2	4.10	5.54	5.37	115	21.41	41.0	55.4	45.7	295	6.45
10	87.0	6.83	9.22	8.94	125	13.98	68.3	92.2	76.1	435	5.71
11	95.7	7.52	10.15	9.85	145	14.72	75.2	101.5	83.7	655	7.82
20	174.0	13.67	18.45	17.90	190	10.62	136.7	184.5	152.2	1113	7.31
30	261.0	20.50	27.68	26.85	243	9.05	205.0	276.8	228.4	1623	7.10
40	348.0	27.33	36.90	35.79	295	8.24	273.0	369.0	304.4	2140	7.03
50	435.0	34.17	46.13	44.75	348	7.77	341.7	461.3	380.6	2650	6.96
51	443.7	34.85	47.05	45.64	430	9.42	348.5	470.5	388.2	3570	9.19
60	522.0	41.00	55.35	53.69	490	9.12	410.0	553.5	456.6	4180	9.15
70	609.0	47.83	64.57	62.63	560	8.94	478.3	645.7	532.7	4870	9.14
90	783.0	61.50	83.03	80.54	700	8.69	615.0	830.3	685.0	6230	9.09
100	870.0	68.33	92.25	89.48	770	8.60	683.3	922.5	761.1	6920	9.08

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Co 60

curies/gram	length = 5.0 cm, volume = 3.927 cm^3, fractional transmission = .404					length = 10 cm, volume = 7.854 cm^3, fractional transmission = .223				
	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $
1	34	46	19	265	14.24	68	92	21	435	20.71
2	68	92	37	435	11.69	137	185	41	775	18.90
3	102	138	56	605	10.82	205	277	62	1115	17.98
6	205	277	112	1115	9.97	410	554	124	2140	17.25
10	342	461	186	1800	9.67	683	922	206	3510	17.03
11	376	507	205	2905	14.17	752	1015	226	5725	25.33
20	683	922	372	5215	14.01	1367	1845	411	10338	25.15
30	1025	1384	559	7773	13.90	2050	2768	617	15460	25.05
40	1367	1845	745	10338	13.87	2733	3690	823	20590	25.01
50	1708	2306	932	12895	13.83	3417	4613	1029	25713	24.98
51	1742	2352	950	17500	18.42	3485	4705	1049	34930	33.30
60	2050	2768	1118	20588	18.41	4100	5535	1234	41080	33.29
70	2392	3229	1305	24000	18.39	4783	6457	1440	47920	33.27
90	3075	4151	1677	30830	18.38	6150	8303	1852	61580	33.26
100	3417	4613	1864	34250	18.37	6833	9225	2057	68410	33.25

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Co 60

curies/gram	length = 15 cm, volume = 11.781 cm^3, fractional transmission = .151					length = 20 cm, volume = 15.708 cm^3, fractional transmission = .113				
	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $
1	103	138	21	605	28.94	137	185	21	775	37.25
2	205	277	42	1115	26.67	273	369	42	1460	35.01
3	308	415	63	1630	25.99	410	554	63	2140	34.24
6	615	830	125	3165	25.23	820	1107	125	4190	33.52
10	1025	1384	209	5215	24.95	1367	1846	209	6925	33.13
11	1127	1521	230	8538	37.12	1503	2029	229	11358	49.52
20	2050	2768	418	15460	36.98	2733	3689	417	20583	49.35
30	3075	4151	627	23148	36.91	4100	5535	625	30835	49.34
40	4050	5468	826	30460	36.87	5466	7379	834	41080	49.25
50	5125	6919	1045	38523	36.86	6833	9225	1042	51333	49.25
51	5227	7056	1065	52350	49.15	6970	9410	1063	69780	65.64
60	6150	8303	1254	61580	49.10	8200	11070	1251	82080	65.62
70	7175	9686	1463	71830	49.09	9566	12914	1459	95740	65.61
90	9225	12454	1881	92330	49.08	12299	16604	1876	123070	65.60
100	10249	13838	2090	102570	49.07	13666	18455	2085	136740	65.58

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Table 3

Co^{60}

TOTAL CURIAGE AND rhm OUTPUT IN VARIOUS SIZES OF RIGHT CYLINDER SOURCES
FOR SPECIFIC ACTIVITIES OF
5 curies/gram or 43.5 curies/cm^3
(50 curies/gram or 435 curies/cm^3 is given figure x 10)

Source Diameter cm.	0.1 cm length 4.26% of max.		0.5 cm length 19.84% of max.		1 cm length 36.30% of max.		2 cm length 58.43% of max.		3 cm length 73.26% of max.		4 cm length 82.54% of max.		I max. rhm
	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	100%
0.1	0.04	0.04	0.17	0.21	0.35	0.33	0.70	0.61	1.04	0.77	1.35	0.87	1.05
0.5	0.87	1.12	4.26	5.20	8.53	9.51	17.1	15.3	25.6	19.2	34.1	21.6	26.2
1.0	3.39	4.47	17.1	20.8	34.1	38.1	68.3	61.4	102.5	76.9	136.7	86.7	105
1.5	7.70	10.05	38.4	46.8	76.9	85.7	153.7	137.9	230.6	172.9	307.5	194.8	236
2.0	13.6	17.8	68.3	83.1	136.7	152.1	273.3	244.8	410.0	307.0	546.6	345.8	419
2.5	21.4	27.9	106.7	130.0	213.5	237.8	427.1	382.7	640.6	479.8	854.1	540.6	655
3.0	30.8	40.2	153.7	187.1	307.5	342.3	615.0	551.0	922.5	690.8	1,229.9	778.4	943
4.0	54.7	71.4	273.3	332.7	546.6	608.8	1,093.3	979.9	1,639.9	1,228.6	2,186.6	1,384.2	1,677
5.0	85.4	111.6	429.4	520.0	854.1	951.4	1,708.2	1,531.4	2,562.4	1,920.1	3,416.5	2,163.4	2,621

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Table 4

Co^{60}

TOTAL CURIAGE AND rhm OUTPUT IN VARIOUS SIZES OF RIGHT CYLINDER SOURCES
FOR SPECIFIC ACTIVITIES OF
10 curies/gram or 87 curies/cm^3
(100 curies/gram or 870 curies/cm^3 is given figure x 10)

Source Diameter cm.	0.1 cm length 4.26% of max.		0.5 cm length 19.84% of max.		1 cm length 36.30% of max.		2 cm length 58.43% of max.		3 cm length 73.26% of max.		4 cm length 82.54% of max.		I max. rhm 100%
	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	
0.1	0.08	0.08	0.34	0.42	0.70	0.76	1.40	1.22	2.08	1.54	2.70	1.74	2.1
0.5	1.74	2.24	8.52	10.4	17.1	19.0	34.2	30.6	51.2	38.4	68.2	43.2	52.4
1.0	6.78	8.94	34.2	40.16	68.2	76.2	136.6	122.8	205.0	153.8	273.4	173.4	210
1.5	15.4	20.1	76.8	93.6	153.8	171.4	307.4	275.8	461.2	345.8	615.0	389.6	472
2.0	27.2	35.6	136.6	166.2	273.4	304.2	546.6	489.6	820.0	614.0	1,093.2	691.6	839
2.5	42.8	55.8	213.4	260.0	427.0	475.6	854.2	765.4	1,281.2	959.6	1,708.2	1,081.2	1,310
3.0	61.6	80.4	307.4	374.2	615.0	684.6	1,230.0	1,102.0	1,845.0	1,381.6	2,459.8	1,556.8	1,887
4.0	109.4	142.8	546.6	665.4	1,093.2	1,217.6	2,186.6	1,959.8	3,279.8	2,457.2	4,373.2	2,768.4	3,354
5.0	170.8	223.2	858.8	1,040.0	1,708.2	1,902.8	3,416.4	3,062.8	5,124.8	3,840.2	6,833.0	4,326.8	5,241

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Tables 5A - 6A - 7A and 8A

Co 60

The Total Cost of Co 60 Sources of Various Dimensions
at Specific Activity Stated on Table

Cost includes following factors:

Specific activity of 5 curies per gram = $100 for first 2 curies plus $5.00 per curie for each additional curie or fraction thereof.

Specific activity of 10 curies per gram = $100 for first 2 curies plus $5.00 per curie for each additional curie or fraction thereof.

Specific activity of 50 curies per gram = $150 for first 2 curies plus $7.50 per curie for each additional curie or fraction thereof.

ecific activity of 100 curies per gram = $200 for first 2 curies plus $10.00 per curie for each additional curie or fraction thereof.

Standard Source Capsule = $210 for each source
Handling Charge = $10 for each source

Loading Charge = $200 up to 750 curies
= $350 up to 2000 curies
= $500 over 2000 curies

Shipping Charges = 1000 lbs for sources up to 750 curies
= 2000 lbs for sources up to 2000 curies
= 4000 lbs for sources over 2000 curies

Shipping to New York City and Denver by Motor Freight
Shipping to San Francisco by Rail Freight

This charge does not include rental on shipping container or cost of loading source capsule into teletherapy machine.

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Table 5

CO^{60}

THE COST OF CO^{60} SOURCES OF VARIOUS DIMENSIONS
AT A SPECIFIC ACTIVITY OF
5 curies/gram or 43.5 curies/cm^3
cost of 5 curie /gram sources is $5 per
curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm Length Cost in $		0.5 cm Length Cost in $		1 cm Length Cost in $		2 cm Length Cost in $		3 cm Length Cost in $		4 cm Length Cost in $	
	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm
0.1	30	750.00	40	190.48	40	105.26	50	81.97	75	97.40	75	86.21
0.5	30	26.78	115	22.12	135	14.20	180	11.76	220	11.46	265	12.27
1.0	110	24.61	180	8.65	265	6.96	435	7.08	605	7.87	775	8.94
1.5	130	12.94	285	6.09	475	5.54	860	6.24	1,245	7.20	1,630	8.37
2.0	160	8.99	435	5.23	775	5.10	1,460	5.96	2,140	6.97	2,825	8.17
2.5	200	7.17	625	4.81	1,160	4.88	2,230	5.83	3,295	6.87	4,365	8.07
3.0	245	6.09	860	4.60	1,630	4.76	3,165	5.74	4,705	6.81	6,240	8.02
4.0	365	5.11	1,460	4.39	2,825	4.64	5,560	5.67	8,290	6.75	11,025	7.96
5.0	520	4.66	2,240	4.31	4,365	4.59	8,635	5.64	12,905	6.72	17,175	7.94

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5 CURIES PER GRAM OR 43.5 CURIES PER CM^3

Table 5A

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	450	11,250.00	460	2,190.48	460	1,210.53	470	770.49	495	642.86	495	568.97
N.Y.C.	479	11,975.00	489	2,328.57	489	1,286.84	499	818.03	524	680.52	524	602.30
Denver	489	12,225.00	499	2,376.19	499	1,313.16	509	834.43	534	693.51	534	613.79
S.F.	521	13,025.00	531	2,528.57	531	1,397.37	541	886.89	566	735.06	566	650.57
0.5	470	419.64	535	102.88	555	65.06	600	39.22	640	33.33	685	31.71
N.Y.C.	499	445.54	564	108.46	584	68.46	629	41.11	669	34.84	714	33.06
Denver	509	454.46	574	110.38	594	69.64	639	41.76	679	35.36	724	33.52
S.F.	541	483.04	596	114.62	626	73.39	671	43.86	701	36.51	756	35.00
1.0	530	118.57	600	28.85	685	17.98	855	13.93	1,025	13.33	1,195	13.78
N.Y.C.	559	125.06	629	30.24	714	18.74	884	14.40	1,054	13.71	1,224	14.12
Denver	569	127.29	639	30.72	724	19.00	894	14.56	1,064	13.84	1,234	14.23
S.F.	601	134.45	671	32.26	756	19.84	926	15.08	1,096	14.25	1,266	14.60
1.5	550	54.73	705	15.06	895	10.44	1,280	9.28	1,665	9.63	2,050	10.52
N.Y.C.	579	57.61	734	15.68	924	10.78	1,309	9.49	1,694	9.80	2,079	10.67
Denver	589	58.61	744	15.90	934	10.90	1,319	9.56	1,704	9.86	2,089	10.72
S.F.	621	62.07	776	16.58	966	11.27	1,351	9.80	1,736	10.04	2,121	10.89
2.0	580	32.58	855	10.29	1,195	7.86	1,880	7.68	2,560	8.34	3,245	9.38
N.Y.C.	609	35.66	884	10.64	1,224	8.05	1,909	7.80	2,589	8.43	3,274	9.47
Denver	619	34.78	894	10.76	1,244	8.18	1,919	7.84	2,599	8.47	3,284	9.50
S.F.	651	36.57	926	11.14	1,266	8.32	1,951	7.94	2,631	8.57	3,316	9.59
2.5	620	22.22	1,045	8.04	1,580	6.64	2,650	6.92	3,715	7.74	4,935	9.13
N.Y.C.	649	23.26	1,074	8.26	1,609	6.77	2,679	7.00	3,744	7.80	4,987	9.22
Denver	659	23.62	1,084	8.34	1,619	6.81	2,689	7.03	3,754	7.82	5,012	9.27
S.F.	691	24.77	1,116	8.59	1,651	6.94	2,721	7.11	3,786	7.89	5,078	9.39
3.0	665	16.54	1,280	6.84	2,050	5.99	3,585	6.51	5,275	7.64	6,810	8.75
N.Y.C.	694	17.26	1,309	7.00	2,079	6.07	3,614	6.56	5,327	7.71	6,862	8.82
Denver	704	17.51	1,319	7.05	2,089	6.10	3,624	6.58	5,352	7.75	6,887	8.85
S.F.	736	18.31	1,351	7.22	2,121	6.20	3,656	6.64	5,418	7.84	6,953	8.93

1136388

Table 6

CO^{60}

THE COST OF CO^{60} SOURCES OF VARIOUS DIMENSIONS
AT A SPECIFIC ACTIVITY OF
10 curies/gram or 87 curies/cm^3
cost of 10 curie/ gram sources is $5 per
curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm Length Cost in $		0.5 cm Length Cost in $		1 cm Length Cost in $		2 cm Length Cost in $		3 cm Length Cost in $		4 cm Length Cost in $	
	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm	Per Source	Per rhm
0.1	30	375.00	40	95.24	50	65.79	75	61.48	105	68.18	105	60.34
0.5	100	44.64	135	12.98	180	9.47	265	8.66	350	9.11	435	10.07
1.0	125	13.98	265	6.60	435	5.71	775	6.31	1,115	7.25	1,460	8.42
1.5	170	8.46	475	5.07	860	5.02	1,630	5.91	2,400	6.94	3,165	8.12
2.0	230	6.46	775	4.66	1,460	4.80	2,825	5.77	4,190	6.82	5,560	8.04
2.5	305	5.46	1,160	4.46	2,225	4.68	4,365	5.70	6,500	6.77	8,635	7.99
3.0	400	4.98	1,630	4.36	3,165	4.62	6,240	5.66	9,315	6.74	12,390	7.96
4.0	640	4.48	2,825	4.24	5,560	4.57	11,025	5.62	16,490	6.71	21,960	7.93
5.0	945	4.23	4,385	4.22	8,635	4.54	17,175	5.61	25,715	6.70	34,255	7.92

1136389

Table 6A

10 CURIES PER GRAM OR 87 CURIES PER CM^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	450	5,625.00	460	1,095.24	470	618.42	495	405.74	525	340.91	525	301.72
N.Y.C.	479	5,987.50	489	1,164.29	499	656.58	524	429.51	554	359.74	554	318.39
Denver	489	6,112.50	499	1,188.10	509	669.74	534	437.70	564	366.23	564	324.14
S.F.	521	6,512.50	531	1,264.29	541	711.84	566	463.93	596	387.01	596	342.53
0.5	520	232.14	555	53.37	600	31.58	685	22.39	770	20.05	855	19.79
N.Y.C.	549	245.09	584	56.15	629	33.11	714	23.33	799	20.81	884	20.46
Denver	559	249.55	594	57.12	639	33.63	724	23.66	809	21.07	894	20.69
S.F.	591	263.84	626	60.19	671	35.32	756	24.71	841	21.90	926	21.44
1.0	545	60.96	685	17.06	855	11.22	1,195	9.73	1,535	9.98	1,880	10.84
N.Y.C.	574	64.21	714	17.78	884	11.60	1,224	9.97	1,564	10.17	1,909	11.01
Denver	584	65.32	724	18.03	894	11.73	1,234	10.05	1,574	10.23	1,919	11.07
S.F.	616	68.90	756	18.82	926	12.15	1,266	10.31	1,606	10.44	1,951	11.25
1.5	590	29.35	895	9.56	1,280	7.47	2,050	7.43	2,820	8.16	3,585	9.20
N.Y.C.	619	30.80	924	9.87	1,309	7.64	2,079	7.54	2,849	8.24	3,614	9.28
Denver	629	31.29	934	9.98	1,319	7.70	2,089	7.57	2,859	8.27	3,624	9.30
S.F.	661	32.89	966	10.32	1,351	7.88	2,121	7.69	2,891	8.36	3,656	9.38
2.0	650	18.26	1,195	7.19	1,880	6.18	3,245	6.63	4,760	7.75	6,130	8.86
N.Y.C.	679	19.07	1,224	7.36	1,909	6.28	3,274	6.69	4,812	7.84	6,182	8.94
Denver	689	19.35	1,234	7.42	1,919	6.31	3,284	6.71	4,837	7.88	6,207	8.97
S.F.	721	20.25	1,266	7.62	1,951	6.41	3,316	6.77	4,903	7.98	6,273	9.07
2.5	725	12.99	1,580	6.08	2,645	5.56	4,935	6.45	7,070	7.37	9,205	8.5
N.Y.C.	754	13.51	1,609	6.19	2,674	5.62	4,987	6.52	7,122	7.42	9,257	8.56
Denver	764	13.69	1,619	6.23	2,684	5.64	5,012	6.55	7,147	7.45	9,282	8.58
S.F.	796	14.27	1,651	6.35	2,716	5.71	5,078	6.63	7,213	7.52	9,348	8.65
3.0	820	10.20	2,050	5.48	3,585	5.24	6,810	6.18	9,885	7.15	13,110	8.42
N.Y.C.	849	10.56	2,079	5.56	3,614	5.28	6,862	6.23	9,937	7.19	13,214	8.49
Denver	859	10.68	2,089	5.58	3,624	5.29	6,887	6.25	9,962	7.21	13,265	8.52
S.F.	891	11.08	2,121	5.67	3,656	5.34	6,953	6.31	10,028	7.33	13,396	8.60

1136390

Table 7

Co^{60}

THE COST OF CO^{60} SOURCES OF VARIOUS DIMENSIONS
AT A SPECIFIC ACTIVITY OF
50 curies/gram or 435 curies per cm^3
Cost of 50 curie/ gram sources is $7.50 per
curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	40	100.00	100	47.62	110	28.95	138	22.62	168	21.82	190	21.84
0.5	153	13.66	408	7.85	730	7.68	1,368	8.94	2,005	10.44	2,643	12.24
1.0	340	7.61	1,368	6.58	2,643	6.94	5,208	8.48	7,773	10.11	10,338	11.92
1.5	663	6.60	2,965	6.34	5,853	6.83	11,613	8.42	17,380	10.05	23,148	11.88
2.0	1,105	6.21	5,208	6.27	10,338	6.80	20,583	8.41	30,835	10.04	41,080	11.88
2.5	1,690	6.06	8,088	6.22	16,098	6.77	32,118	8.39	48,130	10.03	64,143	11.87
3.0	2,395	5.96	11,613	6.20	23,148	6.76	46,210	8.38	69,273	10.03	92,328	11.86
4.0	4,188	5.87	20,583	6.19	41,080	6.74	82,083	8.37	123,078	10.02	164,080	11.85
5.0	6,490	5.82	32,290	6.21	64,143	6.74	128,200	8.37	192,265	10.01	256,323	11.85

1136391

Table 7A

50 CURIES PER GRAM OR 435 CURIES PER CM^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	480	1,200.00	520	247.62	430	113.16	558	91.48	588	76.36	610	70.11
N.Y.C.	509	1,272.50	549	261.43	559	147.11	587	96.23	617	80.13	639	73.45
Denver	519	1,297.50	559	266.19	569	149.74	597	97.87	627	81.43	649	74.60
S.F.	551	1,377.50	591	281.43	601	158.16	629	103.11	659	85.58	681	78.28
0.5	523	46.70	828	15.92	1,150	12.09	1,788	11.69	2,425	12.63	3,063	14.18
N.Y.C.	552	49.29	857	16.48	1,179	12.40	1,817	11.88	2,454	12.78	3,092	14.31
Denver	562	50.18	867	16.67	1,189	12.50	1,827	11.94	2,464	12.83	3,102	14.36
S.F.	594	53.04	899	17.29	1,399	14.71	1,859	12.15	2,496	13.00	3,134	14.51
1.0	810	18.12	1,838	8.84	3,113	8.17	5,678	9.25	8,393	10.91	10,958	12.64
N.Y.C.	839	18.76	1,867	8.98	3,142	8.25	5,707	9.29	8,445	10.98	11,010	12.70
Denver	849	18.99	1,877	9.02	3,152	8.27	5,717	9.31	8,470	11.01	11,035	12.73
S.F.	881	19.71	1,909	9.18	3,184	8.36	5,749	9.36	8,536	11.10	11.101	12.80
1.5	1,133	11.27	3,435	7.34	6,323	7.27	12,233	8.87	18,150	10.50	23,918	12.28
N.Y.C.	1,162	11.56	3,464	7.40	6,352	7.41	12,285	8.91	18,254	10.56	24,022	12.33
Denver	1,171	11.65	3,474	7.42	6,362	7.42	12,310	8.93	18,305	10.59	24,073	12.36
S.F.	1,204	11.98	3,506	7.49	6,394	7.46	12,376	8.97	18,436	10.66	24,204	12.43
2.0	1,575	8.85	5,678	6.83	10,958	7.20	21,353	8.72	31,605	10.29	41,850	12.10
N.Y.C.	1,604	9.01	5,707	6.87	11,010	7.24	21,457	8.77	31,709	10.32	41,694	12.06
Denver	1,614	9.07	5,717	6.88	11,035	7.26	21,508	8.79	31,760	10.35	42,005	12.15
S.F.	1,646	9.25	5,749	6.92	11,101	7.30	21,639	8.84	31,891	10.39	42,136	12.1[illegible]
2.5	2,160	7.74	8,708	6.70	16,718	7.03	32,888	8.59	48,900	10.19	64,913	12.01
N.Y.C.	2,189	7.85	8,761	6.74	16,770	7.05	32,992	8.62	49,004	10.21	65,017	12.03
Denver	2,199	7.88	8,785	6.77	16,795	7.06	33,043	8.63	49,055	10.22	65,068	12.04
S.F.	2,231	8.00	8,851	6.81	16,861	7.09	33,174	8.67	49,186	10.25	65,199	12.06
3.0	2,865	7.13	12,233	6.54	23,918	6.99	46,980	8.53	70,043	10.14	93,098	11.96
N.Y.C.	2,894	7.20	12,285	6.57	24,022	7.02	47,084	8.55	70,147	10.15	93,202	11.97
Denver	2,904	7.22	12,310	6.58	24,073	7.03	47,135	8.55	70,198	10.16	93,253	11.98
S.F.	2,936	7.30	12,376	6.61	24,204	7.07	47,266	8.58	70,329	10.18	93,384	12.00

1136392

Table 8

Co^{60}

THE COST OF CO^{60} SOURCES OF VARIOUS DIMENSIONS
AT A SPECIFIC ACTIVITY OF
100 curies/gram or 870 curies per cm^3
Cost of 100 curie/gram sources is $10.00 per
curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	50	62.50	120	28.57	150	19.74	220	18.03	290	18.83	350	20.11
0.5	260	11.61	940	9.04	1,790	9.42	3,500	11.44	5,200	13.54	6,900	15.97
1.0	760	8.50	3,500	8.72	6,900	9.06	13,740	11.19	20,580	13.38	27,420	15.81
1.5	1,620	8.06	7,760	8.29	15,460	9.02	30,820	11.17	46,200	13.36	61,580	15.80
2.0	2,800	7.86	13,740	8.27	27,420	9.01	54,740	11.18	82,080	13.37	109,400	15.82
2.5	4,360	7.81	21,420	8.24	42,780	8.99	85,500	11.17	128,200	13.36	170,900	15.81
3.0	6,240	7.76	30,820	8.24	61,580	9.00	122,900	11.15	184,580	13.36	246,060	15.80
4.0	11,020	7.72	54,740	8.23	109,400	8.98	218,600	11.15	328,060	13.35	437,400	15.80
5.0	17,160	7.69	85,960	8.26	170,900	8.98	341,600	11.15	512,560	13.35	683,380	15.79

1136393

Table 8A

100 CURIES PER GRAM OR 870 CURIES PER CM^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	520	650.00	640	152.38	670	88.16	740	60.66	810	52.60	870	50.00
N.Y.C.	549	686.25	669	159.29	699	91.97	769	63.03	839	54.48	899	51.67
Denver	559	698.75	679	161.67	709	93.29	779	63.85	849	55.13	909	52.24
S.F.	591	738.75	711	169.29	741	97.50	811	66.48	881	57.21	941	54.08
0.5	780	34.82	1,460	14.04	2,310	12.16	4,020	13.14	5,720	14.90	7,420	17.18
N.Y.C.	809	36.12	1,489	14.32	2,339	12.31	4,049	13.23	5,749	14.97	7,449	17.24
Denver	810	36.16	1,499	14.41	2,349	12.36	4,059	13.26	5,759	15.00	7,459	17.27
S.F.	851	37.99	1,531	14.72	2,381	12.53	4,091	13.37	5,791	15.08	7,491	17.34
1.0	1,280	14.32	4,020	10.01	7,420	9.74	14,410	11.73	21,400	13.91	28,240	16.29
N.Y.C.	1,309	14.64	4,049	10.08	7,449	9.78	14,462	11.78	21,504	13.98	28,344	16.35
Denver	1,319	14.75	4,059	10.11	7,459	9.79	14,487	11.80	21,555	14.01	28,395	16.38
S.F.	1,351	15.11	4,091	10.19	7,491	9.83	14,553	11.85	21,686	14.10	28,526	16.45
1.5	2,140	10.65	8,280	8.85	16,130	9.41	31,640	11.47	47,020	13.60	62,400	16.02
N.Y.C.	2,169	10.79	8,309	8.88	16,182	9.44	31,744	11.51	47,124	13.63	62,504	16.04
Denver	2,179	10.84	8,319	8.89	16,207	9.46	31,795	11.53	47,175	13.64	62,555	16.06
S.F.	2,211	11.00	8,351	8.92	16,273	9.49	31,926	11.58	48,306	13.97	62,686	16.09
2.0	3,320	9.33	14,410	8.67	28,240	9.28	55,560	11.35	82,900	13.50	110,220	15.94
N.Y.C.	3,349	9.41	14,462	8.70	28,344	9.32	55,664	11.37	83,004	13.52	110,324	15.95
Denver	3,359	9.44	14,487	8.72	28,395	9.33	55,715	11.38	83,055	13.53	110,375	15.96
S.F.	3,391	9.53	14,553	8.76	28,526	9.38	55,846	11.41	83,186	13.55	110,506	15.98
2.5	4,880	8.75	22,240	8.55	43,600	9.17	86,320	11.28	129,020	13.45	171,720	15.88
N.Y.C.	4,909	8.80	22,344	8.59	43,704	9.19	86,424	11.29	129,124	13.46	171,824	15.89
Denver	4,919	8.82	22,395	8.61	43,755	9.20	86,475	11.30	129,175	13.46	171,875	15.90
S.F.	4,951	8.87	22,526	8.66	43,886	9.23	86,606	11.32	129,306	13.47	172,006	15.91
3.0	6,760	8.41	31,640	8.46	62,400	9.11	123,720	11.23	185,400	13.42	246,880	15.86
N.Y.C.	6,789	8.44	31,744	8.48	62,504	9.13	123,824	11.24	185,504	13.43	246,984	15.86
Denver	6,799	8.46	31,795	8.50	62,555	9.14	123,875	11.24	185,555	13.43	247,035	15.87
S.F.	6,831	8.50	31,926	8.53	62,686	9.16	124,006	11.25	185,686	13.44	247,166	15.88

1136394

Table 9

Data for 1.0 cm diameter rod; cross sectional area = 0.7854
density of Co 60 is assumed to be 8.7 grams/cm^3

length cm	volume cm^3	total curies at various specific activities											fractional transmission
		1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g	
0.1	0.078	0.68	3.39	6.8	7.5	20.4	21.0	33.9	34.6	47	48	68	0.970
0.5	0.393	3.42	17.10	34.2	37.6	102.6	106.0	171.0	174.4	239	243	342	0.900
1	0.785	6.83	34.15	68.3	75.1	204.9	211.7	341.5	348.3	478	485	683	0.825
2	1.571	13.67	68.34	136.7	150.3	410.0	423.7	683.4	697.1	957	970	1367	0.664
3	2.356	20.50	102.49	205.0	225.5	614.9	635.4	1024.9	1045.4	1435	1455	2050	0.555
4	3.142	27.34	136.68	273.4	300.7	820.1	847.4	1366.8	1394.1	1913	1941	2734	0.469

length cm	rhm at various specific activities										
	1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g
0.1	0.9	4.4	8.9	9.8	26.7	27.5	44.4	45.3	61.5	62.8	89.0
0.5	4.2	20.8	41.6	45.7	124.6	128.8	207.8	211.9	290.4	295.2	415.5
1	7.6	38.0	76.1	83.6	228.2	235.8	380.3	387.9	532.4	540.2	760.7
2	12.2	61.2	122.5	134.7	367.5	379.8	612.6	624.9	857.8	869.5	1225.4
3	15.4	76.8	153.6	169.0	460.7	476.1	767.9	783.3	1075.2	1090.2	1536.0
4	17.3	86.5	173.1	190.4	519.2	536.5	865.4	832.7	1211.2	1228.9	1731.0

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Table 10

Data for 1.5 cm diameter rod; cross sectional area = 1.7671
density of Co 60 is assumed to be 8.7 grams/cm^3

length cm	volume cm^3	total curies at various specific activities											fractional transmission
		1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g	
0.1	0.1767	1.54	7.69	15.37	16.91	46.1	47.6	76.9	78.4	107	109	154	.970
0.5	0.8836	7.69	38.44	76.87	84.56	230.6	238.3	384.4	392.0	538	546	769	.900
1	1.7672	15.37	76.87	153.75	169.12	461.2	476.6	768.7	784.1	1076	1092	1537	.825
2	3.5343	30.75	153.74	307.48	338.23	922.4	953.2	1537.4	1568.2	2152	2183	3075	.664
3	5.3015	46.12	230.62	461.23	507.35	1383.7	1429.8	2306.2	2352.3	3229	3275	4612	.555
4	7.0686	61.50	307.48	614.97	676.46	1844.9	1906.4	3074.8	3136.3	4305	4366	6150	.469

length cm	rhm at various specific activities										
	1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g
0.1	2.0	10.1	20.1	22.1	60.4	62.3	100.7	102.7	140.1	142.7	201.7
0.5	9.3	46.7	93.4	100.0	280.2	289.5	467.0	476.3	653.8	663.4	934.3
1	17.1	85.6	171.2	188.4	513.7	530.9	856.1	873.3	1198.4	1216.2	1711.8
2	27.6	137.8	275.6	303.2	826.8	854.4	1378.1	1405.7	1929.0	1956.8	2756.4
3	34.6	172.8	345.6	380.1	1036.7	1071.3	1727.9	1762.5	2419.3	2453.8	3677.5
4	38.9	194.7	389.4	428.3	1168.1	1207.0	1946.8	1985.7	2725.7	2764.3	3893.9

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Table 11

Data for 2 cm diameter rod; cross sectional area = 3.1416 cm^2
density of Co 60 is assumed to be 8.7 grams/cm^3

length cm	volume cm^3	total curies at various specific activities											fractional transmission
		1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g	
0.1	0.314	2.73	13.66	27.3	30.5	82.0	84.7	137	139	191	194	273	.970
0.5	1.571	13.67	68.34	136.7	150.3	410.0	423.7	683	697	957	970	1367	.900
1	3.141	27.33	136.63	273.3	300.6	819.8	847.1	1366	1394	1913	1940	2733	.825
2	6.283	54.66	273.31	546.6	601.3	1639.9	1694.5	2733	2788	3826	3881	5466	.664
3	9.425	82.00	409.99	820.0	902.0	2459.9	2541.9	4100	4182	5740	5822	8200	.555
4	12.566	109.32	546.62	1093.2	1202.6	3279.7	3389.1	5466	5576	7653	7762	10932	.469

length cm	rhm at various specific activities										
	1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g
0.1	3.6	17.9	35.7	39.9	107	111	179	182	250	254	357
0.5	16.6	83.0	166	183	498	515	830	847	1163	1179	1661
1	30.4	152	305	335	913	943	1521	1553	2130	2161	3044
2	49.0	245	490	539	1470	1519	2450	2499	3430	3479	4900
3	61.4	307	614	676	1843	1905	3072	3133	4301	4362	6140
4	69.2	346	692	761	2077	2146	3461	3530	4845	4915	6922

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Table 11A

Cost of 2 cm Diameter Rod*

length cm	specific activities - curies per gram										
	1c/g	5c/g	10c/g	11c/g	30c/g	31c/g	50c/g	51c/g	70c/g	71c/g	100c/g
0.1	105 554	160 609	230 679	367 816	750 1199	772 1221	1162 1611	1570 2019	2090 2539	2120 2569	2910 3359
0.5	160 609	435 884	775 1224	1267 1716	3210 3659	3315 3764	5257 5706	7150 7599	9750 10372	9880 10502	13850 14472
1	230 679	775 1224	1460 1909	2392 2841	6285 6907	6495 7117	10380 11002	14120 14742	19310 19932	19580 20202	27510 28334
2	365 814	1460 1909	2825 3274	4650 5099	12435 13057	12847 13469	20632 21456	28060 28884	38440 39264	38990 39814	54840 55664
3	500 949	2040 2489	4190 4812	6900 7522	18585 19409	19300 20124	30885 31709	42000 42824	57580 58404	58400 59224	82200 83024
4	640 1089	2825 3274	5560 6182	9157 9779	24735 25559	25560 26384	41130 41954	55940 56764	76710 77534	77800 78624	109500 110324

* Cost on top line is for source alone. Cost on second line is for encapsulated source delivered to New York City.

$/rhm

length cm	1c/g	5c/g	10c/g	11c/g	30c/g	31c/g	50c/g	51c/g	70c/g	71c/g	100c/g
0.1	153.89	34.02	19.02	20.45	11.21	11.00	9.00	11.09	10.16	10.11	9.41
0.5	36.69	10.65	7.37	9.38	7.35	7.31	6.87	8.97	8.92	8.91	8.71
1	22.34	8.05	6.26	8.48	7.57	7.54	7.23	9.49	9.36	9.35	9.31
2	16.61	7.79	6.68	9.46	8.88	8.87	8.76	11.56	11.45	11.44	11.36
3	15.46	8.11	7.84	11.13	10.53	10.56	10.32	13.67	13.58	13.58	13.52
4	15.74	9.46	8.93	12.84	12.31	12.29	12.12	16.08	16.00	16.00	15.94

curies

1-10 = $100 for first 2 curies plus $5 per curie for each additional curie or fraction thereof.

11-50 = $150 for first 2 curies plus $7.50 per curie for each additional curie or fraction thereof.

51-100 = $200 for first 2 curies plus $10.00 per curie for each additional curie or fraction thereof.

Handling charges include shipment to New York City
- $449 up to 750 curies
- $622 up to 2000 curies
- $824 over 2000 curies

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AN AVAILABLE COBALT 60 SOURCE FOR TELETHERAPY

Marshall Brucer, M.D.*

A double overlapping cloverleaf source was designed to make maximum use of the cobalt 60 currently in plentiful supply from one of the Oak Ridge facilities. Such source material is manufactured in serendipity and can almost be considered a use for "waste" neutrons. There are no foreseeable overriding priorities that would interfere with its production. This source material is now available as 1 cm diameter and 0.32 cm diameter rods. The rods are available in lengths up to 4 cm and with specific activities ranging from 7 to 11 curies per gram.

For teletherapy use, when sources in the multihectocurie range are used, it is an advantage to have a short Source to Skin Distance (SSD) available. This will restrict the maximum allowable diameter of the source below that of a larger machine. Approximately 2 cm has been arbitrarily chosen as allowable. With this diameter approximately 30 cm collimation distance will give penumbra relationships similar to those of the larger machines. Following a trial of many arrangements, the double overlapping cloverleaf, as shown in Fig. 1, was chosen as a maximum compromise of economy, curiage, penumbra, and available materials.

The cloverleaf source consists of seven pieces of cobalt 60: six pieces are 1 cm diameter by 1 cm length, and one is 0.32 cm diameter by 1.27 cm length. The small piece is used as a central core and the larger pieces are grouped around this core in two layers. The top layer is in a cloverleaf pattern with three 1 cm rods arranged at 120° angles around the core. The bottom layer is similar but is 60° out of phase. Thus the total surface as presented to the patient contains cobalt 60 in three different depths. The depth of 6.3 per cent of the area, the central core, is 1.27 cm. The depth of 67.5 per cent of the area is 1 cm but half

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of this area is at 1 cm greater SSD; the depth of 26.2 per cent of the area is 2 cm. The maximum diameter of the source is 2.3 cm; the minimum diameter is 1.9 cm.

The source capsule for the cloverleaf design has been drilled to fit; there is thus the possibility of maximum shielding in all except the forward direction where there is no unnecessary shielding. A jig has been made to allow for simple loading. The cloverleaf fits into the standard source capsule(1).

The characteristics of the first such source to be made can be used as an example of the advantages and disadvantages of the design. These characteristics are shown in Table 1.

From Table 2 a calculation has been made of the expected roentgens per hour at a meter (rhm) from such an overlapping cloverleaf design. The calculated measurement indicates that we should expect about 476 rhm or 7.9 roentgens per minute at a meter (rmm). The actual measurement was 381 rhm or 6.35 rmm. A number of corrections can partially explain the discrepancies. There was approximately 4 per cent absorption in the steel cap of a prototype source capsule and our measurement of the output was made about two months after the measurements of the individual pieces. The calculated value was reduced to an expected 7.4 rmm.

The remaining discrepancy is probably due to the way in which the individual pieces were measured to give us the original "paid-for-value" of 452 curies. These measurements are made by the Oak Ridge National Laboratory for the purpose of determining the price of the cobalt. They are made in a lead chamber with an inch of lead attenuation between the source and the detector in a very broad beam geometry. Although the instruments are calibrated accurately they are calibrated to measure total curies and the confidence level is not better than 20 per cent. The detector "sees" an aspect of each individual piece of cobalt which might be different from that used in a teletherapy machine. In the measurement of the output of the source in the teletherapy machine we measure only a small fraction of the

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4π geometry in air even with the largest cone in the teletherapy unit, and little of the scatter build-up is included. It appears that of all these possibilities for discrepancy the use of a wide beam geometry in the calculation of curiage will give a constant bias and therefore it is to be expected that the statement of curiage on the shipping ticket will be about 10 per cent higher than if it were measured under the conditions of teletherapy use. Although the proportional difference in expected to actual output is uniform at any curiage, the absolute value assumes considerable magnitude in high curie sources.

The cost of the cobalt 60, adjusted to match the data in Table 3, for the cloverleaf source was $2,750 or $7.20 per rmm on delivery. It is not the most economical source nor is it the most economical design. It is interesting to calculate the probable cost of what might be designed as a best possible source(2) when the same or even better production facilities are used. Such a source might be a 2 cm diameter disc irradiated in thin sections. To get an output of 381 rhm as measured for the cloverleaf the length would have to be 1.4 cm and the cost per rhm would be $6.50 as shown in Table 3. Such a source could also be made of 50 curies/gram cobalt 60 in which case the source would be 0.25 cm long and cost $7.80 per rhm. If a 1.0 cm diameter source were used, the specific activity would have to be in the 50 curies/gram range and the cost would be higher. The 1 cm diameter source, with its better than necessary penumbra relationships, is already on the upswing of a rapidly rising curve of costs versus increasing specific activity. The 1.5 cm diameter source is still in the cost range comparable to the lower specific activity and appears to be an excellent source size. Since the hectocurie cobalt 60 machine is designed for a maximum of 600 rhm, Table 3 shows the cost relationships at maximum output. For comparison, similar data are shown for an 1800 rhm teletherapy machine.

A few other very important points must be considered. The higher curiage machines, which are especially valuable in rotational therapy, must use high

specific activity cobalt 60 and cannot use lower specific activities. Since the acilities for high specific activity production are limited, all of their production should be saved for those machines. High specific activity demands valuable reactor space, which must be allocated under a strict priority system. Further, the problems of handling the higher curie sources increase almost exponentially with increasing curiage. Costs in addition to those of the source shield must be taken into account. Until a few years ago there were no facilities for handling high curiage sources, and even today these are new and handling experience is limited.

The 10 curies/gram specific activity material is produced in an AEC facility that produces neutrons for various purposes not related to teletherapy. As long as such neutron production is necessary, such a production of low specific activity cobalt 60 contains a hidden subsidy. Further, this type of low specific activity cobalt 60 need not be on a strict priority allocation. There can always be a guaranteed production and it is believed that there always will be sufficient amounts available, so that the low activity material can be exported without danger of affecting the American neutron economy.

The cloverleaf design has only one advantage to recommend it, and this advantage takes ultimate precedence over all other factors at the present time and probably for some time to come; it uses cobalt 60 that is available now.

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REFERENCES

1. M. Brucer, submitted for publication in Nucleonics.
2. M. Brucer, W. G. Pollard, H. Leiter, and H. Scarf, Nucleonics **11**, No. 2, 38 (1953).

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Table 1

	1 cm rod		1/8 inch rod
Diameter	1.0 cm		0.3175 cm
Length	1.0 cm		1.27 cm
Area of Presenting Face	0.7854 cm^2		0.1008 cm^2
Volume	0.7854 cm^3		0.1280 cm^3
Weight (d = 8.9)	6.99 grams		1.14 grams
Total Weight of Source		43.08 grams	
Total Curiage (ORNL*)		452	
Average Specific Activity		10.5 cm/gram	
Average Curiage per piece	73.35 curies		12.0 curies

* Oak Ridge National Laboratory

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Table 2

Calculation of Expected Output of Cloverleaf Cobalt 60 Source

	per cent of large piece area	per cent of total area	curies	rhm without self-absorption	fractional transmission	rhm with self-absorption
1 cm deep area	72%	67.5%	316.8	427.8	0.825	352.9
2 cm deep area	28%	26.2%	123.2	166.3	0.664	110.4
1.27 cm deep area	—	6.3%	12.0	16.2	0.780	12.6
Total		100%	452		0.780	475.9 = 7.93 rmm
With corrections for decay and steel cap of prototype source capsule						445 = 7.4 rmm
Measured output						381 = 6.35 rmm

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Table 3

Cost of Cobalt 60 Sources

Cost includes cobalt 60, capsule, loading, handling, and shipment to New York City

Diameter	Length	Specific Activity	Curies	Total Cost	Cost per rhm
		6.3 rmm			
2.0 cm	1.4 cm	10 c/gm	370	$2,500	$6.50
2.0 cm	0.25 cm	50 c/gm	310	$3,000	$7.80
1.5 cm	0.4 cm	50 c/gm	320	$2,900	$7.60
1.0 cm	1.0 cm	50 c/gm	340	$3,140	$8.25
		10 rmm			
2.0 cm	2.85 cm	10 c/gm	780	$4,550	$7.60
2.0 cm	0.37 cm	50 c/gm	485	$4,250	$7.10
1.5 cm	0.65 cm	50 c/gm	515	$4,400	$7.30
1.0 cm	2.00 cm	50 c/gm	680	$5,700	$9.50
Canadian quotation	unknown sizes	?	500	$8,800	reirradiation allowance
		30 rmm			
2.0 cm	impossible	10 c/gm	---	---	---
2.0 cm	1.23 cm	50 c/gm	1650	$13,250	$7.40
1.5 cm	3.25 cm	50 c/gm	2550	$20,000	$11.00
1.0 cm	impossible	50 c/gm	---	---	---
Canadian quotation	unknown sizes				
3 cm?	3 cm max.?	?	1800	$23,220	reirradiation allowance

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CHECK LIST OF REQUIRFMENTS FOR TELETHERAPY MACHINES

Abstracted from the manuscript of Handbook 54, National Bureau of Standards.

This check list is taken directly from the final copy of Handbook 54 "Protection Against Radiation from Radium, Cobalt 60, and Cesium 137 Encapsulated Sources", National Committee on Radiation Protection, National Bureau of Standards. On Sunday, October 3, 1953, representatives of the Oak Ridge Institute of Nuclear Studies, the Isotope Division of the United States Atomic Energy Commission, Atomic Energy of Canada Limited, and the X-ray industry met to discuss teletherapy in human radiographic problems with isotopes. Most of the details from the new handbook are included in the copy of the minutes of this joint meeting. The handbook, however, will be published within the next few months and there is no need for a review of the material here. In this check list I have attempted to extract from the manuscript copy of Handbook 54 those features that are necessary for a manufacturer to consider in the design of a teletherapy machine. There is one important change from the document issued on October 3, 1953, and that concerns the protection requirements for the primary teletherapy shield. The corrected version is given in the following list. Handbook 54 is concerned only with protection problems and has quasi-legal status in that it represents the current "best possible opinion". The use of shall and should in the NBS handbook recommendations are used in the check list and are defined as follows:

> Shall denotes that the ensuing recommendation is necessary or essential to meet the currently accepted standards of protection. Should indicates advisory recommendations that are to be applied when practicable.

Check List of Protection Requirements from Handbook 54

General:

1. Foolproof Design. Teletherapy apparatus must be so designed as to be practically foolproof in operation and it must be improbable for any accidents to

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leave the source unshielded.

2. Kinds of Hazard. Hazards to be considered in the design of teletherapy machines are: a. Those harmful to human beings. b. Those that interfere with function of equipment or damage to material sensitive to radiation (photographic films).

3. Isotopes are Monoergic. Unlike X-ray machines, radioisotope sources are always "on". Hence, protection requirements are different. With most isotopes, the radiation is not a continuous spectrum but is from either single or multiple monoergic gamma energies. The protection requirements will be higher for a monoergic gamma energy than for a similar peak energy from an X-ray generator.

4. Definition of Permissible Dose. The permissible external radiation levels for long term occupational exposure will be reported in an NBS handbook soon to be published. The following is extracted from the manuscript:

> A. For adults under 45 years of age whose entire body or major portions thereof is exposed solely to X rays with full time energies less than 3 Mev from external sources for an indefinite period of years, the maximum permissible total weekly dose shall be 300 mr measured in air at the point of highest weekly dose in the region occupied by the person, provided that the actual total weekly dose in the gonads does not exceed 300 mrad. B. For persons 45 years or older similarly exposed, the corresponding maximum permissible total weekly doses shall be double the previously stated values provided that the actual total weekly dose in the lenses of the eyes does not exceed 600 mrad. C. For adults of any age whose hands and forearms (or feet and ankles) are exposed solely to X rays from external sources for an indefinite period of years the maximum permissible weekly dose shall be 1500 mrad in the skin. D. For adults of any age whose entire body or major portions thereof is exposed to ionizing radiation of very low penetrating power from external sources (half value layer less than 1 mm of soft tissue), the maximum permissible total weekly dose in the skin shall be 1500 mrad provided that the total weekly dose in the lenses of the eyes does not exceed 300 mrad. E. It is recommended that in cases in which minors may be exposed to radiation in the course of their normal activities, protective measures be taken to make sure that no minor actually receives radiation at a weekly rate higher

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than one-tenth respective basic permissible weekly doses for the critical organs. F. Permissible dose shall be applied to the total dose to which a person is exposed throughout the week. This is an important consideration in cases of simultaneous and separate exposures to more than one source of ionizing radiation.

5. How to Furnish Protection. Protection from radiation can be achieved in any one or a combination of the following factors: a. Increasing the working distance from the source of radiation. b. Reducing the time of exposure. c. Interposing attenuating (protective) barriers between the source of radiation and the person exposed.

6. Occupancy Factors. For use as a guide in planning shielding where complete occupancy data are not available the following occupancy factors can be used: a. Full occupancy (T = 1). Control space, residencies, wards, office work rooms, dark rooms, corridors, and waiting space large enough to hold desks, rest rooms used y the radiological staff and others routinely exposed to radiation, and play areas. b. Partial occupancy (T = $\frac{1}{4}$). Corridors and X-ray departments too narrow for future desk space, rest rooms not used by radiological personnel, parking lots, and utility rooms. c. Occasional occupancy (T = 1/16). Stairways, automatic elevators, streets, closets too small for future work rooms, rest rooms not used by radiological personnel.

7. The Use of Barriers. The thickness of barriers for protection against radiation can be computed in many different ways. Handbook 54 gives a detailed description of one useful method of calculating such barriers. a. For reasons of economy, barriers should be placed as near to the source as possible. The thickness of the barrier is not reduced by this procedure but the area and therefore the volume is reduced. b. Concrete, marble, and similar materials generally provide the most economical barrier, but lead may be required where the space is limited, or where it desirable to reduce the total weight of the barrier. c. All openings in barriers such as for doors, windows, and pipes, shall be provided with at least the radiation

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protection required by the surrounding barrier. d. Joints between the same or different kinds of protective materials shall be constructed to provide the same protection as that required of the adjacent material.

Transportation of Sources:

8. Regulations on Transport. Proper transportation of radioactive materials is subject to federal, state, and local regulations. Those responsible for the shipment of sources should be familiar with the current regulations of the Interstate Commerce Commission, the Post Office Department, the Civil Aeronautics Board, and the Bureau of Explosives. Various local tunnel and bridge authorities may regulate or prohibit the shipment of dangerous material through vehiclular tunnels or over major bridges.

9. ICC Regulations. The Interstate Commerce Commission does not permit shipment of over 2 curies of radium or 2.7 curies of cobalt 60 or cesium 137 in express packages. Complete ICC regulations are available from the Bureau of Explosives, Association of American Railroads, 30 Vesey St., New York 7, N.Y. (Current price $3.50).

10. CAB Regulations. The Civil Aeronautics Board will in general prohibit the shipment of teletherapy sources by air, except with special permission. Since airlines are not required to accept shipments even if they meet CAB regulations, some airlines refuse all shipments of radioactive materials.

The Source and Its Capsule:

11. Information to Buyer. Teletherapy sources are generally defined as those sources emitting gamma rays between 1 and 50 rmm. Complete information regarding construction of the capsule and shield shall be provided the buyer or user by the manufacturer.

12. Marking of the Capsule. Wherever size permits the content of the capsule shall be clearly and permanently marked and be readily identifiable from a considerable distance. When sizes and shapes are not adequate, other means of identification

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should be employed. The standard source capsule meets all of the recommendations of the handbook, except that it does not provide for marking on the source. It is expected that on teletherapy machines the same characteristics will be plainly marked on the machine.

13. Removal of Source Material. Removal of radioactive material from permanently sealed sources should be done only by those persons particularly trained and equipped to do the job. Any dismantling shall be limited to the removal of the source in its capsule.

14. Design of Source Capsule. Containers for solid sources shall be designed to prevent the release of highly radioactive dusts. Containers for loose powders or liquids shall be especially designed to prevent accidental release of the material. These containers should be doubly protected against leakage.

15. Capsule Shall be Airtight. Sources shall be sealed in airtight capsules of suitable material.

16. Contamination on Capsule. After the isotope is loaded into its permanent capsule, the capsule shall be scrubbed clean of contaminating radioactivity. It shall not be released by the manufacturer until a reasonable test reveals no significant contamination.

17. Glass Prohibited. Isotopes used in teletherapy shall not be sealed in glass or other breakable containers.

18. Gas Production. Certain teletherapy sources, which are subject to decomposition, should be sealed in a powdered source container and then resealed in a second safety capsule containing an air pocket.

The Teletherapy Apparatus:

21. Protection Requirements for the Housing. The housing and collimating vices shall be so constructed that at one meter in any direction from the source in the "off" position the maximum and average dose rates do not exceed 10 mr/hr and 1 mr/hr respectively. In order to reduce the integral dose to the patient, the

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leakage radiation in the "on" position should not exceed 1% of the useful beam both measured at one meter from the source. A reduction of the leakage radiation to 0.1% or lower will result in a more economical secondary protective barrier.

22. Multiple Source Units. In multiple source units each source should meet the protection requirements of a single source unit except that the protection requirements for the entire apparatus shall in no situation be less than those recommended for a single source unit.

23. Diaphragms. Adjustable beam defining diaphragms when used shall allow transmission of not more than 5% of the useful beam dose rate outside the useful beam.

24. Filters. Where filters to harden the radiation are considered necessary the filters shall be a permanently affixed part of the housing.

25. Line-up of Source in "OFF" Position. The relationship of the source and the collimating openings shall be such that in the "off" position of the beam the moving part shall always return to a position of shielding defined as safe.

26. Line-up of Source in "ON" Position. In the "on" position the moving parts shall always come to rest with the source and the beam collimating device accurately aligned.

27. Liquid Shutter. If a liquid "on"-"off" device is used the liquid container shall be filled and emptied with less than a 5% change in dose rate in the "on" position.

28. Mercury Shutter. If the liquid used in an "on"-"off" device is mercury, provisions should be made for periodic tests for leakage of mercury vapors, since they are toxic and may also affect the film badges used in monitoring personnel.

29. Beam Control Shutter. The beam control mechanism shall be of a positive design capable of acting in any position of the housing and shall shut off automatically. In addition to the automatic closing device, the apparatus shall be so designed that it can be manually turned off with a minimum risk of exposure.

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30. Design of Moving Parts in Shutter. The moving parts shall be so designed that it is highly improbable for projections, breakages, loose screws, dirt, or failure of any part to impede the closing of the source.

31. "ON"-"OFF" Warning. There shall be at the housing and on the control panel a warning device that clearly indicates whether the apparatus is "on" or "off".

32. Shut-off Timer. The controls shall be provided with a timer that automatically terminates the exposure after a pre-set time.

33. Automatic Closing. The closing device shall be so designed as to return automatically to the "off" position in the event of any breakdown or interruption of the activating force and shall stay in the "off" position when the force goes on again until activated from controls.

34. Control Lock. The beam controls shall be provided with a locking device to prevent unauthorized use.

The Teletherapy Room:

35. Lead Barriers. Lead barriers, if used, shall be mounted in such a manner that they will not creep because of their own weight and shall be protected against mechanical damage.

36. Movable Barriers. Movable barriers should not be depended upon except for emergency procedures. The primary beam shield affixed to a rotational device should not be considered a movable barrier.

37. Computation of Direct Beam Protection. Protection for the useful beam shall be computed without a patient in the beam. Protection for scatter shall be computed with a patient in the beam.

38. Window and Maze Designs. In general, it is more economical to place the observation window out of the direct beam and to provide a maze rather than a heavy lead or steel door for access to the radiation room.

39. Size of Primary Barrier. Primary protective barriers shall be provided for any area that the useful beam may strike with the largest possible diaphragm

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opening. These barriers shall extend at least six inches beyond the useful beam for any possible orientation.

40. Extent of Barrier. The barrier shall be such that at no place liable to uncontrolled habitation shall the radiation exceed the dose rate of 300 mr per week.

41. Position of Controls. The controls should be in a separate room or behind permanent structures.

42. Access Doors. All access doors to the treatment room and other hazardous areas shall be provided with electrical interlocks; warning lights, bells, or other devices should also be provided.

43. Secondary Barriers. Secondary protective barriers shall be provided for areas exposed to leakage and scattered radiation.

44. Only Patient Allowed in Room. The teletherapy machine and its position in the room should be so designed that only the patient should be allowed in the treatment room during irradiation.

Other Considerations Involving Nonmedical Applications

Generally, teletherapy type machines used for nonmedical applications have less strict regulations and allow for monitoring of nonroutine use by a radiological safety officer. Some of these recommendations are for sources of lower output but are useful rules to observe even in teletherapy devices.

45. Deviations Allowed Radiation Safety Officer. In the event that a situation beyond the reasonable contemplation of these recommendations is believed to exist, any deviation shall be allowed only upon authorization by the radiological safety officer after thorough survey of the conditions.

46. Labels. Labels stating type of activity, amount, and danger range, shielded and unshielded, should be attached to the source shield. Lettering should be easily read at the danger range.

46. Label for Source. The presence of a radioactive source shall be clearly

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indicated by a suitable permanent legend on the face of the instrument stating the isotope and its curiage and date. The source shall be readily distinguishable upon dismantling the instrument.

47. Handling Sources. Special remote handling equipment shall be used with sources exceeding 30 mr/hr at the surface. Movement of the source from shielded position to any other position should be accomplished by mechanical linkage or other remote control methods.

49. Calculations Insufficient. It shall not be considered sufficient to calculate dose rates and danger range from multicurie sources from consideration only of the amount of activity present. For these sources, an actual survey of the radiation levels should be made. Consideration must be given both to primary and scattered radiation.

50. Research Apparatus. Teletherapy apparatus used for research shall be subject to the same design criteria and operational precautions as those recommended for medical teletherapy apparatus except that considerations given to the protection of the patient against accidental overexposure shall not apply where animals, plants, or other experimental materials are being irradiated. Precautions, however, should be taken by means of a door lock, or alternate means, to prevent unauthorized persons from entering the teletherapy room while the beam is in the "on" position. Interlocks need not be electrically operated.

Radiation Surveys and Personnel Monitoring:

51. Initial Survey. An initial survey should be made of any facility to be used for the handling or storage of radioactive sources.

52. Repeat Surveys. If any changes are made in layout or shielding, or if there is a possibility of a fault developing through cold flow in metallic shielding, through wear, the survey should be repeated at appropriate intervals.

53. Film Surveys. For conditions in which the dose rate is expected to be low, films may be used in making an approximate survey.

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54. Chamber Surveys. Ionization chamber instruments are required only if a prior scanning with a suitably calibrated Geiger-Muller or scintillation type of instrument indicates occupied regions to have a radiation level of over one-fifth of the permissible dose rate.

55. Protection Survey. No teletherapy installation should be used routinely until its safety has been established by a protection survey.

56. Area Survey. A survey should also be made of all regions adjacent to the radiation room, with the beam on, and a patient or phantom in place.

57. Pinhole Leaks. Pinhole leaks shall be considered in terms of the possibility of a hazard to operator or patient, rather than in terms of specified exposure rates.

58. Warning Signs. Any restrictions on occupancy should be indicated by appropriate warning signs. The sign should be removed when the hazard is eliminated.

59. Personnel Monitoring. Personnel monitoring should be employed where the radiation safety depends upon proper operating procedures. A film badge, pocket dosimeter, or pocket chamber may be used.

60. Discontinued Personnel Monitoring. If a particular operation is routine or repetitive and the hazard is slight, the local exposure may be established initially without the necessity of wearing these devices continuously.

61. Instruction of Personnel. Before a person is allowed to handle radioactive sources, he should be informed of the hazards involved and how to guard against them. Such an employee should be required to read the sections of Handbook 54 pertaining to his work and the special safety rules.

62. Radiological Safety Officer. In every hospital, clinic or laboratory handling radioactive sources there shall be a radiological safety officer. The radiological safety officer shall be responsible for the establishment of satisfactory working conditions according to current standards, including those established in Handbook 54. 1136416

63. Warning Signs. Regions that are easily accessible and that cannot be continuously occupied without exceeding the maximum permissible dose should be posted to warn all concerned that this is a dangerous area.

64. Personnel Examinations. No special examinations other than those considered good medical and industrial practice should be required of personnel working with radioactivity. If there is any possibility of accidental heavy exposure to any person, a normal blood count series for any such individual would be useful as a later reference to indicate radiation damage or absence of significant radiation damage.

65. Vacation Policy. Vacations should not be considered protection against overexposure to radiation.

66. Accidents. Procedures are recommended for accidents with radioactive sources. The detailed statement of what to do in case of accident, which is a part of Handbook 54, should be read once by every person working with dangerous amounts of radioactive material. The handbook should be kept available near any location where these accidents could possibly occur.

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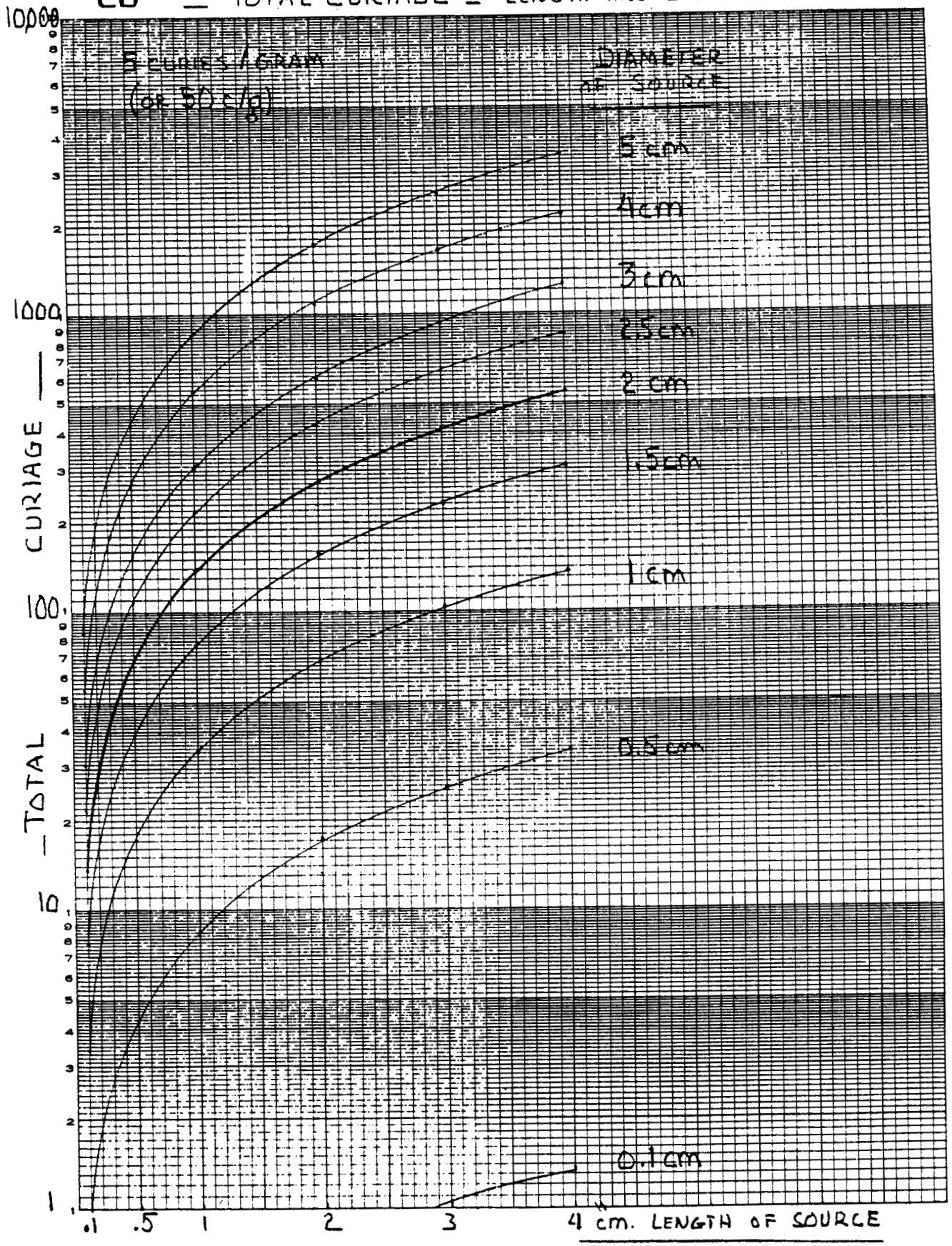
Co^{60} _ TOTAL CURIAGE _ LENGTH AND DIAMETER OF SOURCE _ TABLE 3



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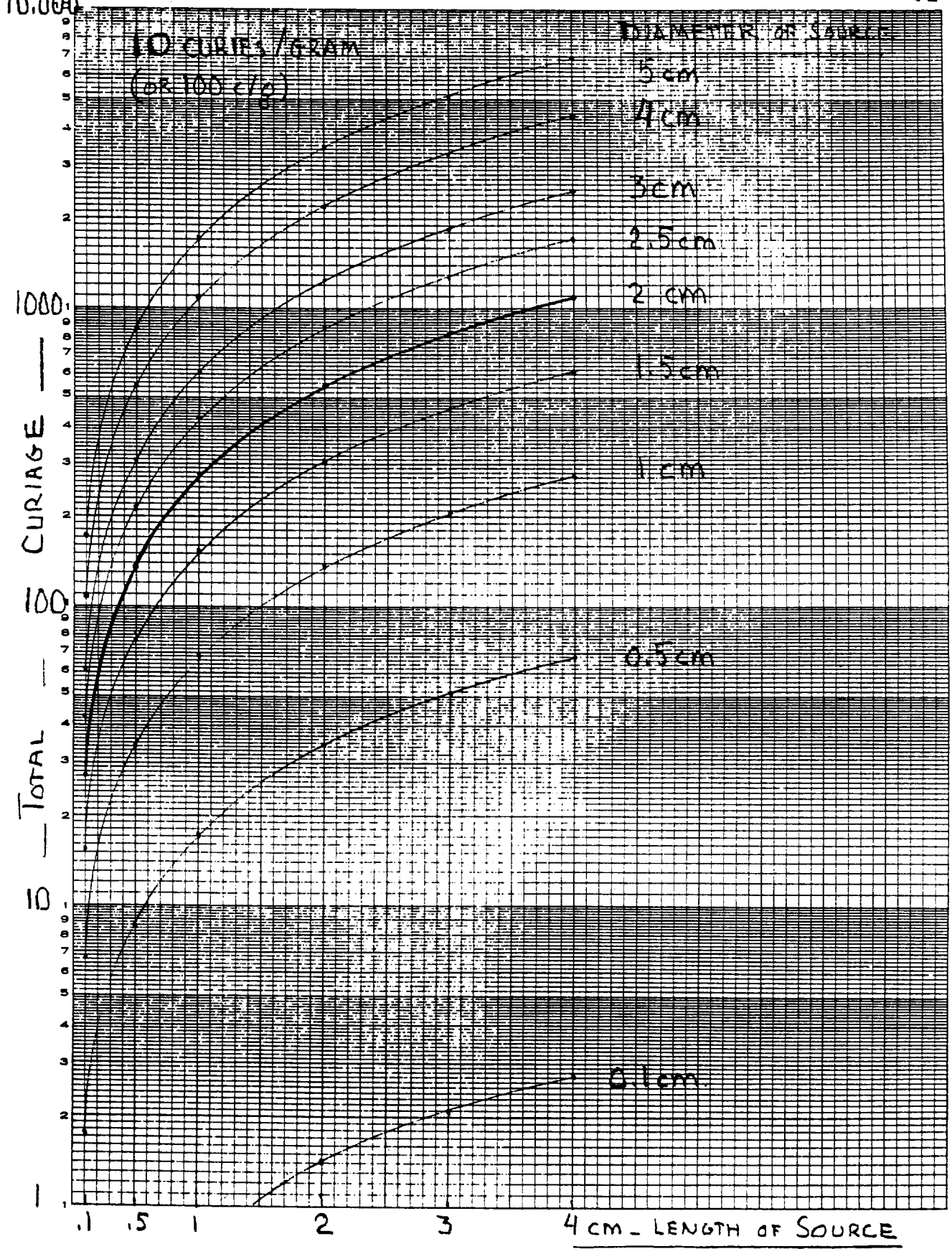
Co^{60} _ TOTAL CURIAGE _ LENGTH AND DIAMETER OF SOURCE _ TABLE 4



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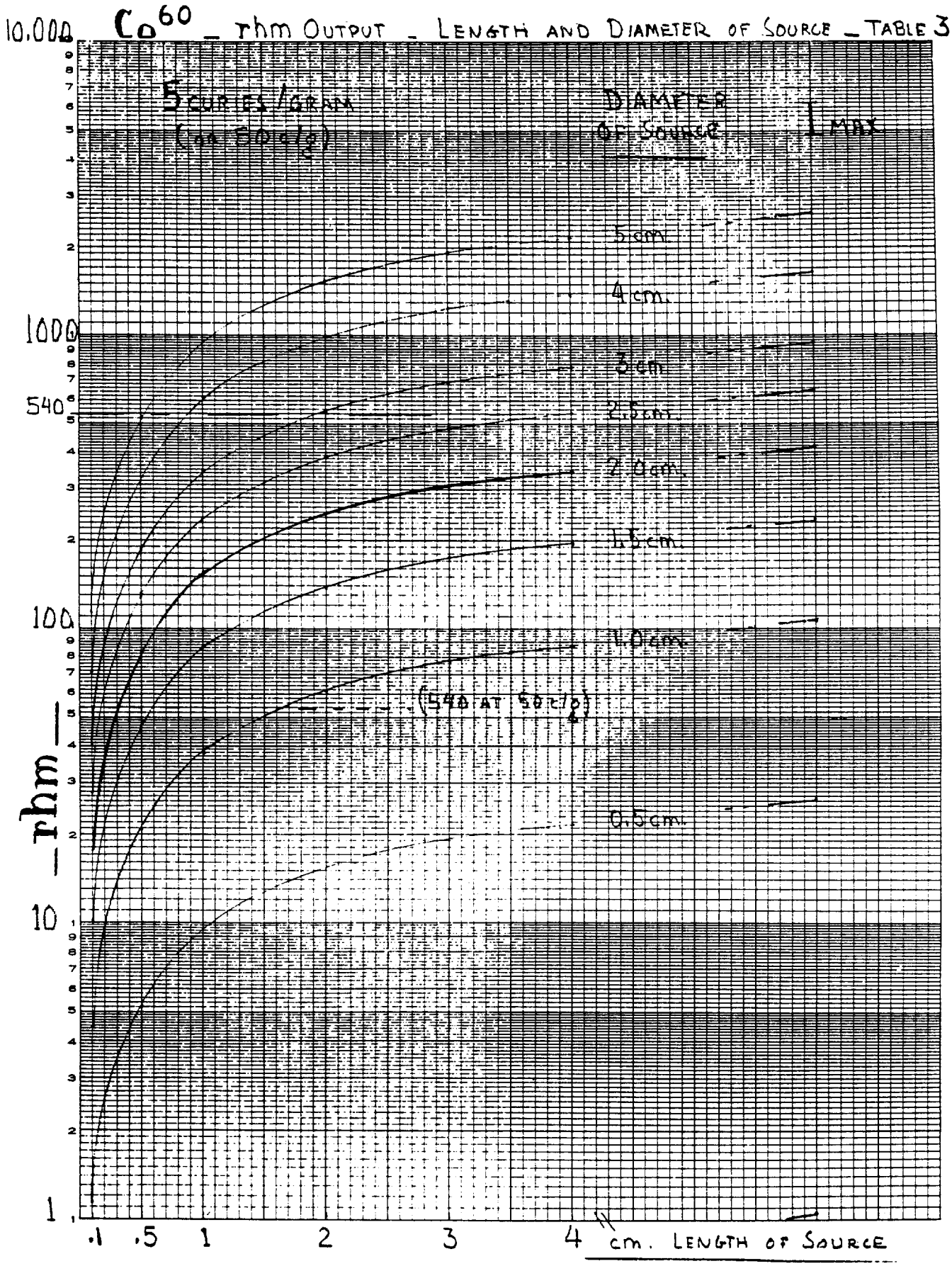
Co60 _ rhm OUTPUT _ LENGTH AND DIAMETER OF SOURCE _ TABLE 3
5 CURIES/GRAM
(Co60 80 c/g)
DIAMETER OF SOURCE
L MAX
5 cm.
4 cm.
3 cm.
2.5 cm.
2.0 cm.
1.5 cm.
1.0 cm.
(540 AT 50 c/g)
0.5 cm.
10,000
1000
540
100
10
1
rhm
.1
.5
1
2
3
4
cm. LENGTH OF SOURCE

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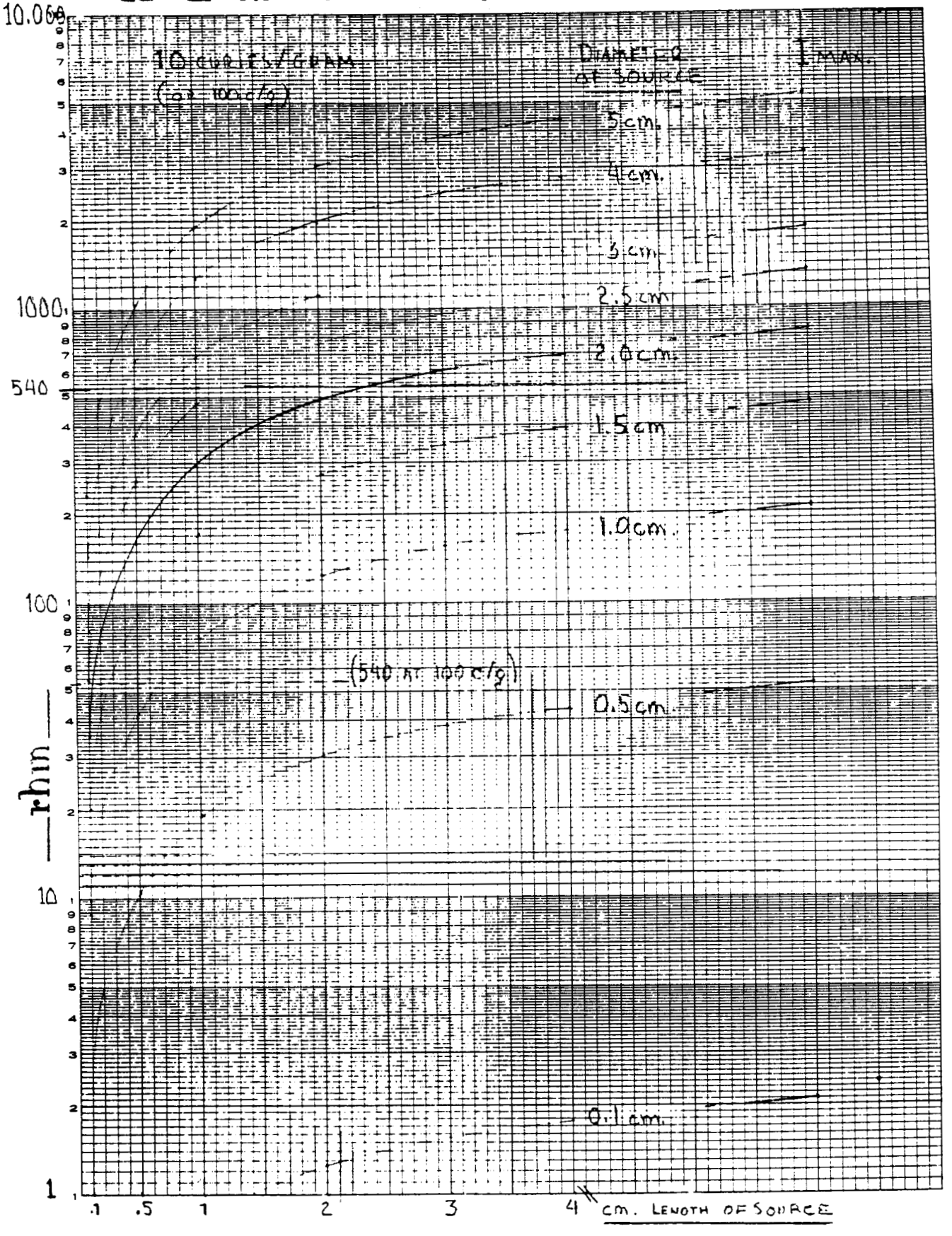
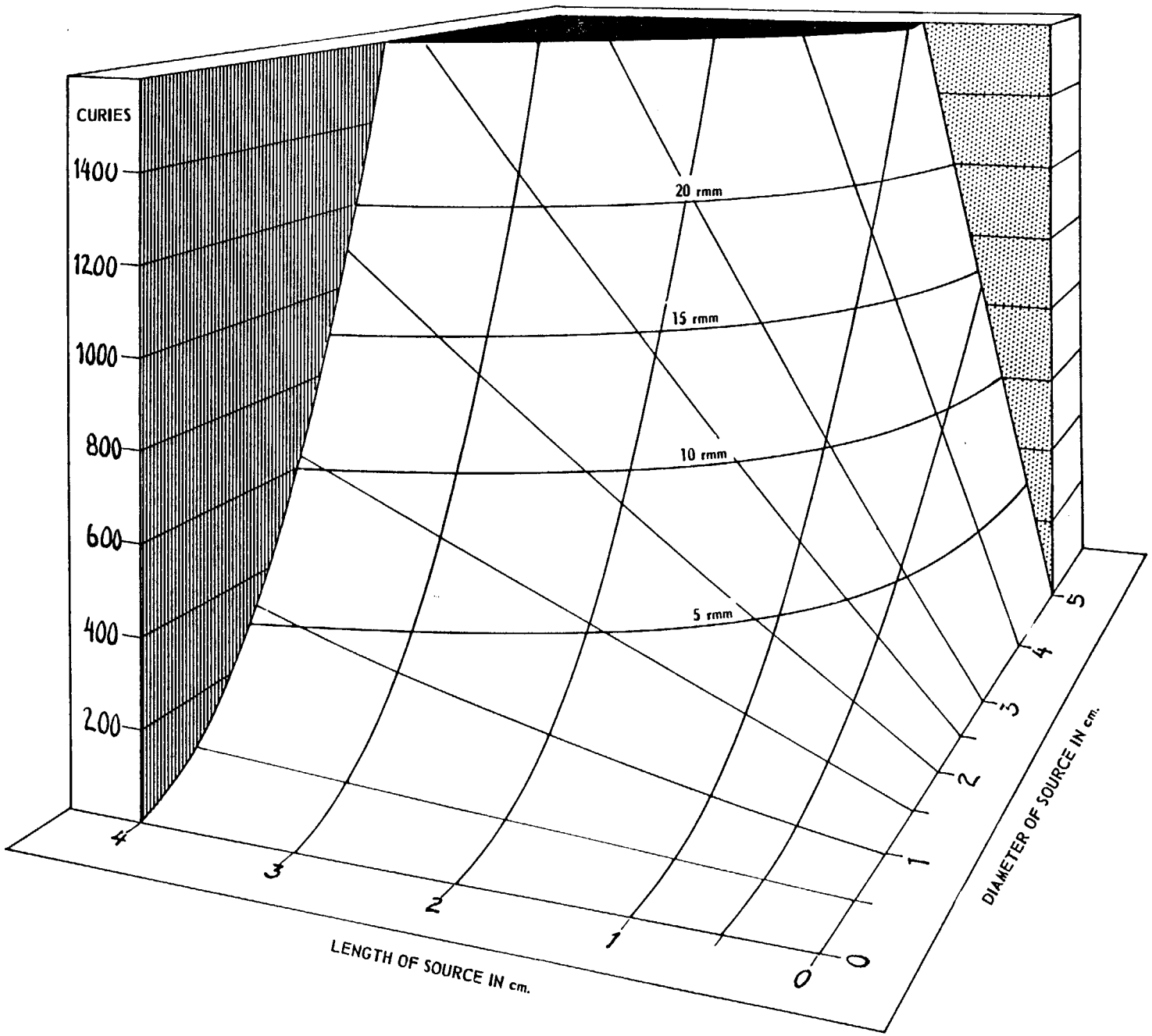
Co^{60} — rhm OUTPUT — LENGTH AND DIAMETER OF SOURCE — TABLE 4



1136421



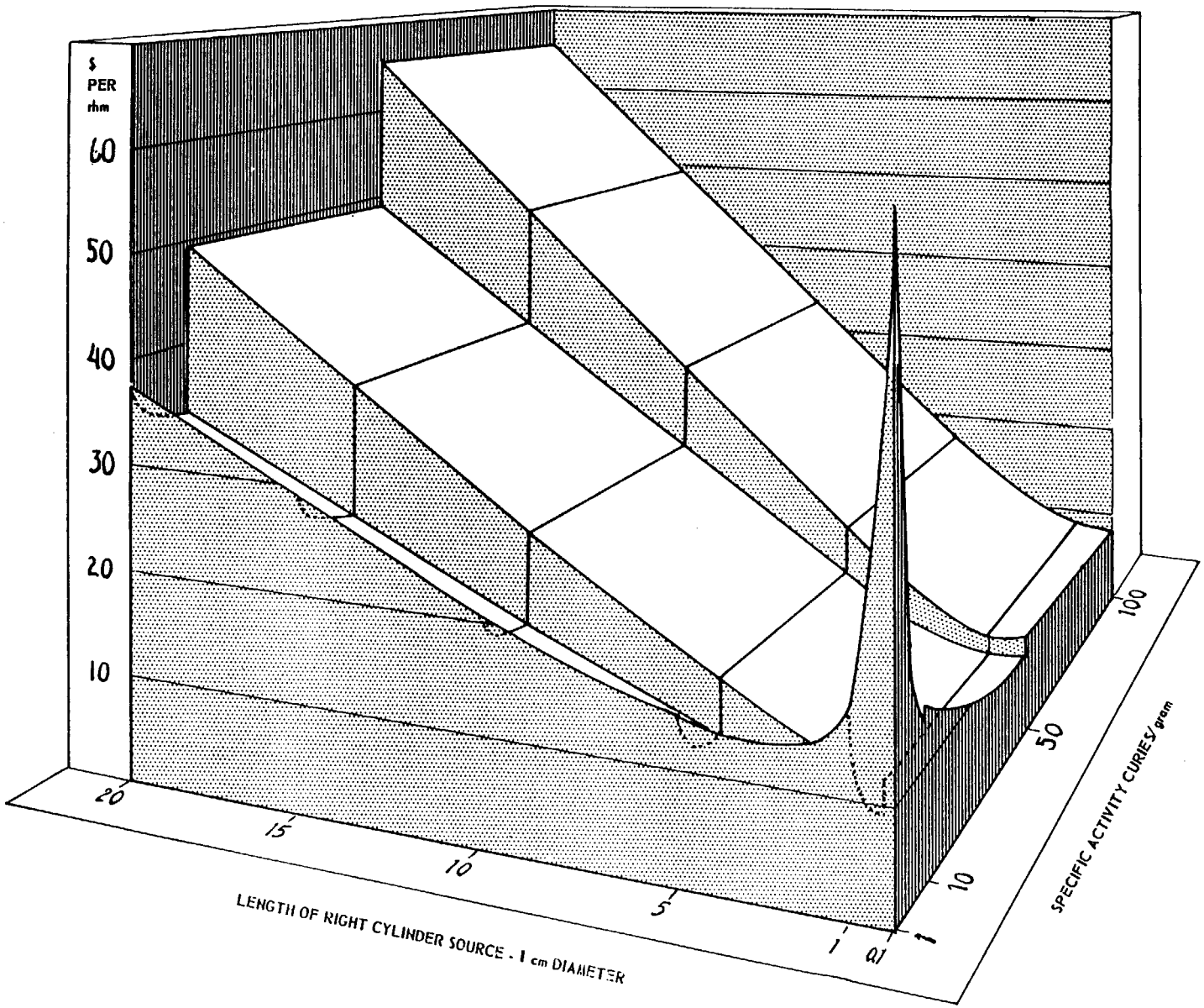
VOLUME. IN CURIES, OF CO^{60} IN A RIGHT CYLINDRICAL SOURCE

WITH RADIATION OUTPUT LEVELS

1136422

CO^{60}

THE EFFECT OF SOURCE LENGTH AND SPECIFIC ACTIVITY
ON THE COST OF RADIATION FROM CO^{60}



1-10 c/gm = $5.00/c-2 + $100
10-50 c/gm = $7.50/c-2 + $100
50-100 c/gm = $10.00/c-2 +$100

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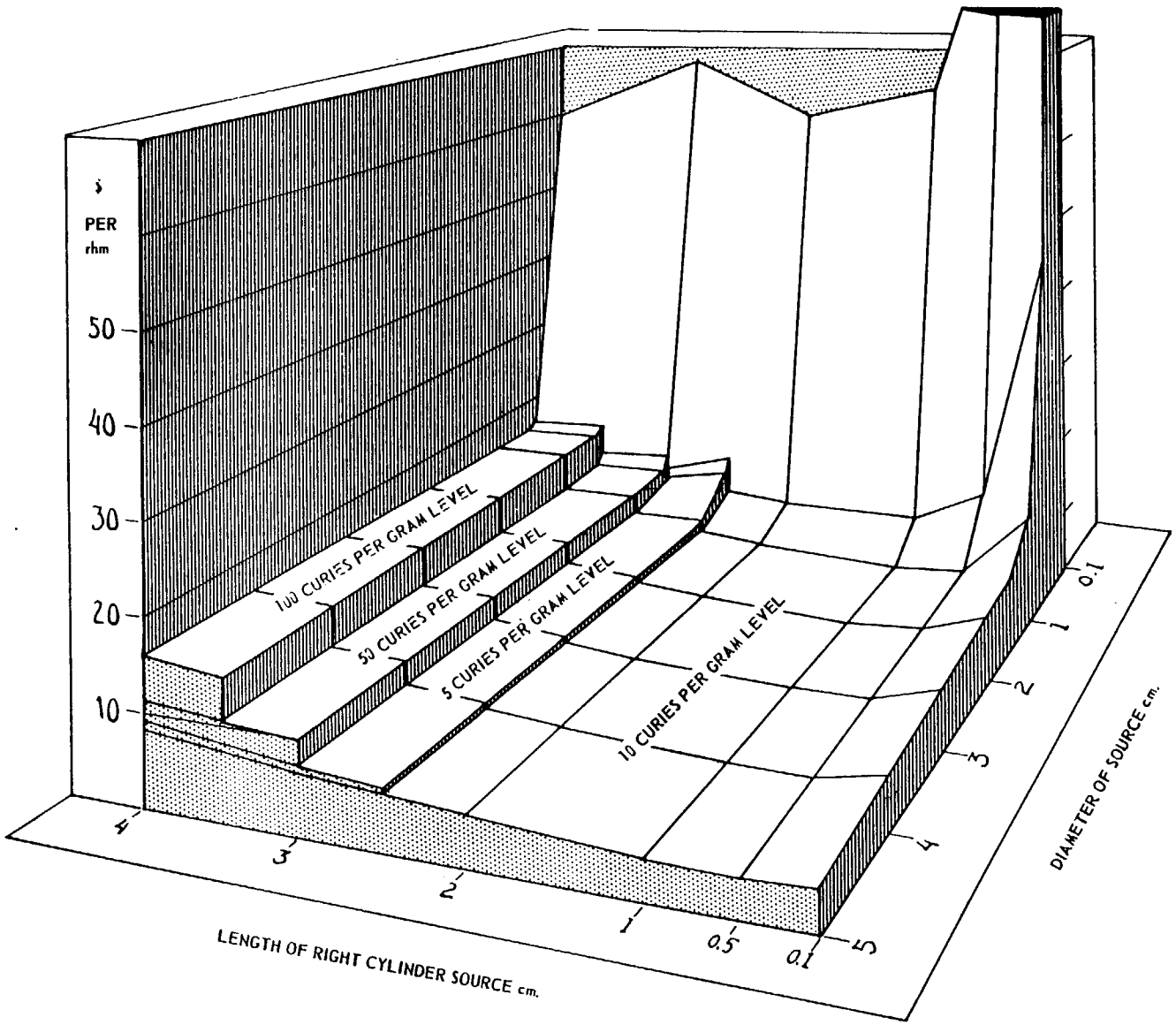
CO^{60}

THE EFFECT OF SOURCE DIAMETER AND LENGTH
ON THE COST OF RADIATION FROM CO^{60}

THE LEVEL FOR SPECIFIC ACTIVITY OF 10 CURIES PER GRAM IS SHOWN COMPLETE
THE LEVELS FOR SPECIFIC ACTIVITIES OF 5, 50 AND 100 CURIES PER GRAM IS SHOWN IN PART



1-10 c/gm = $5.00/c-2 + $100
10-50 c/gm = $7.50/c-2 + $100
50-100 c/gm = $10.00/c-2 + $100

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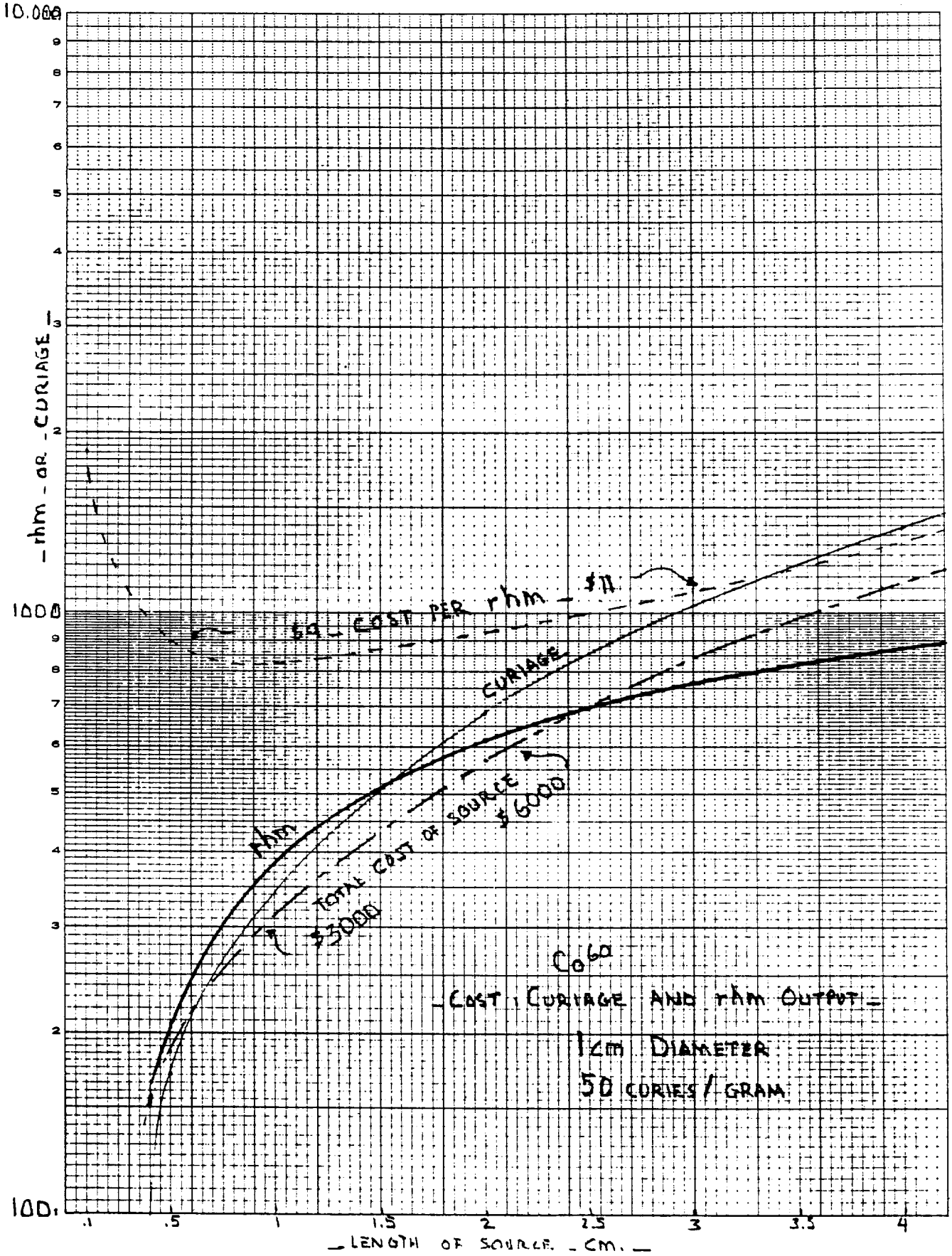
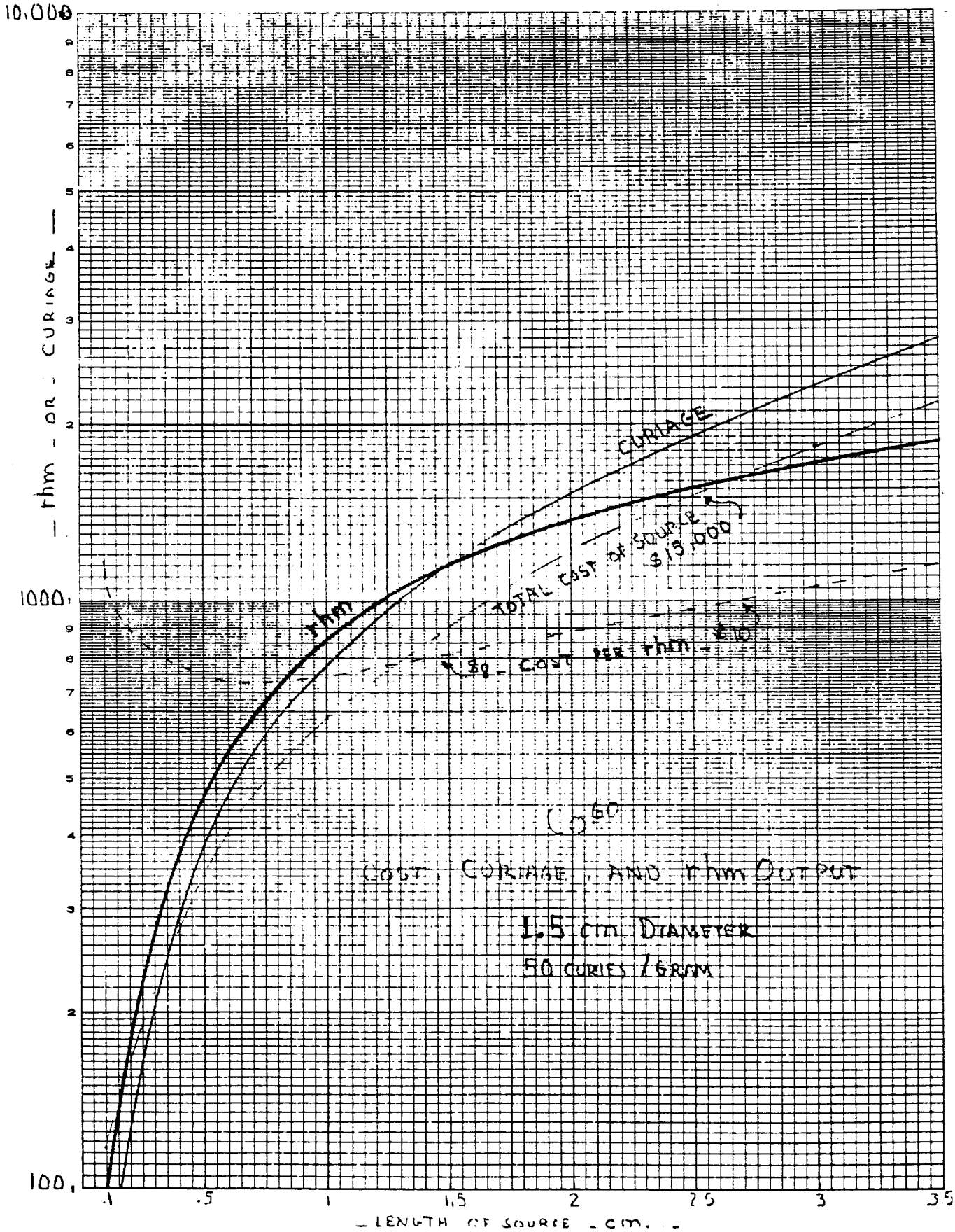
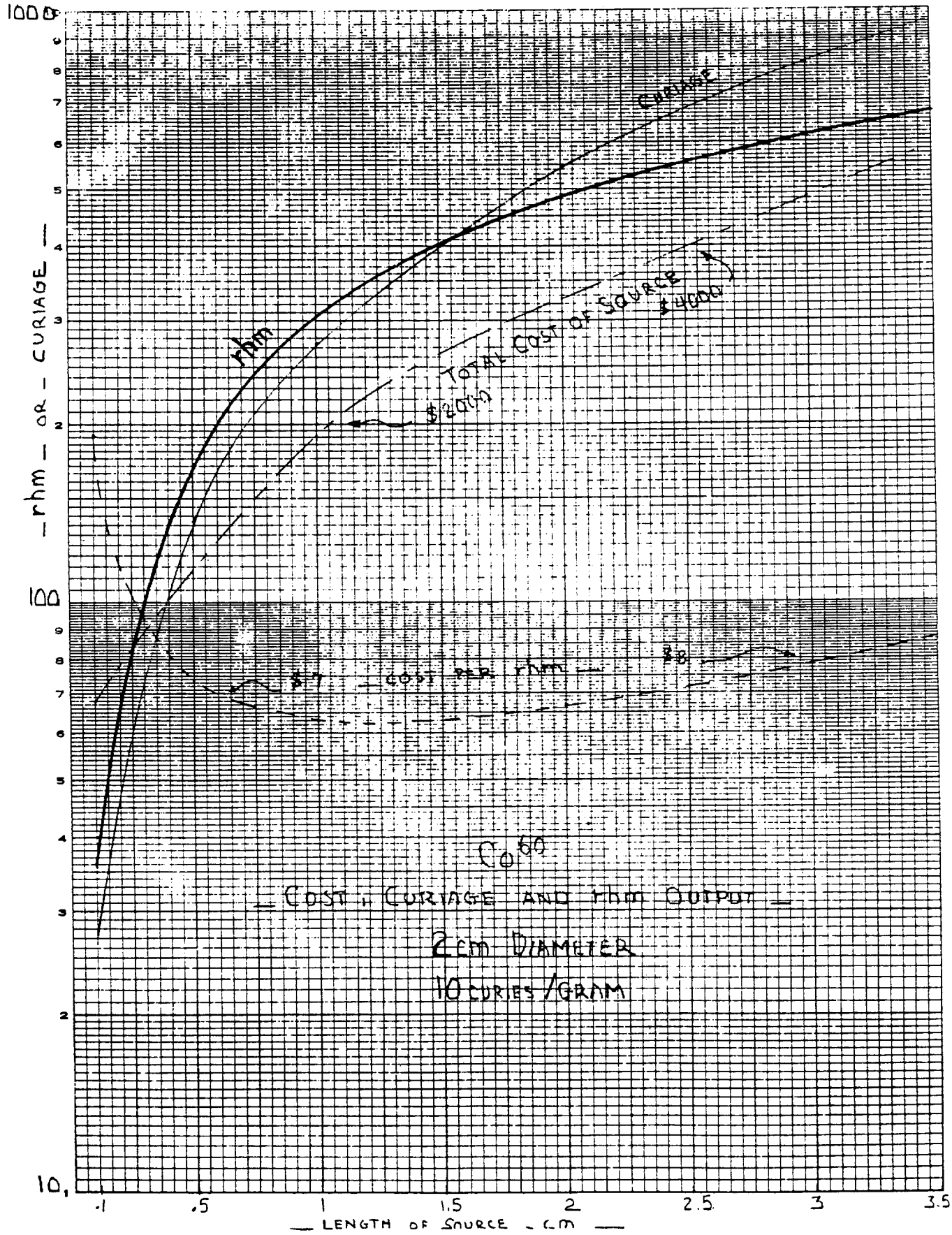

10,000
1000
100
rhm - OR - CURIAGE
$9 - COST PER rhm - $11
CURIAGE
rhm
TOTAL COST OF SOURCE
$6000
$3000
Co60
- COST, CURIAGE AND rhm OUTPUT -
1cm DIAMETER
50 CURIES / GRAM
.1
.5
1
1.5
2
2.5
3
3.5
4
- LENGTH OF SOURCE - CM. -

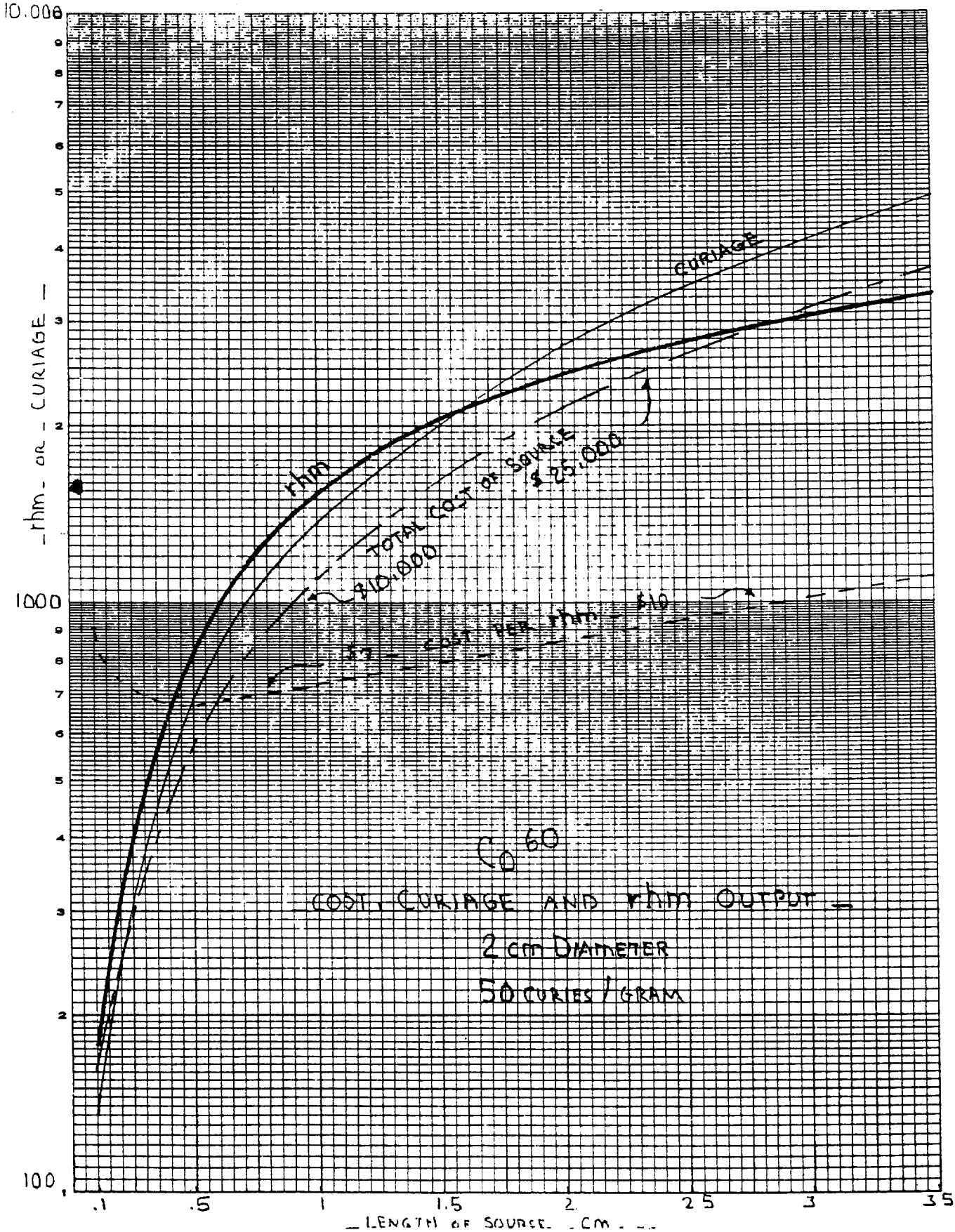
1136425


10,000
1000
100
— rhm - OR - CURIAGE —
CURIAGE
rhm
TOTAL COST OF SOURCE $15,000
30¢ - COST PER rhm - $10
Co60
COST, CURIAGE, AND rhm OUTPUT
1.5 cm DIAMETER
50 CURIES / GRAM
.1
.5
1
1.5
2
2.5
3
3.5
— LENGTH OF SOURCE - CM. —

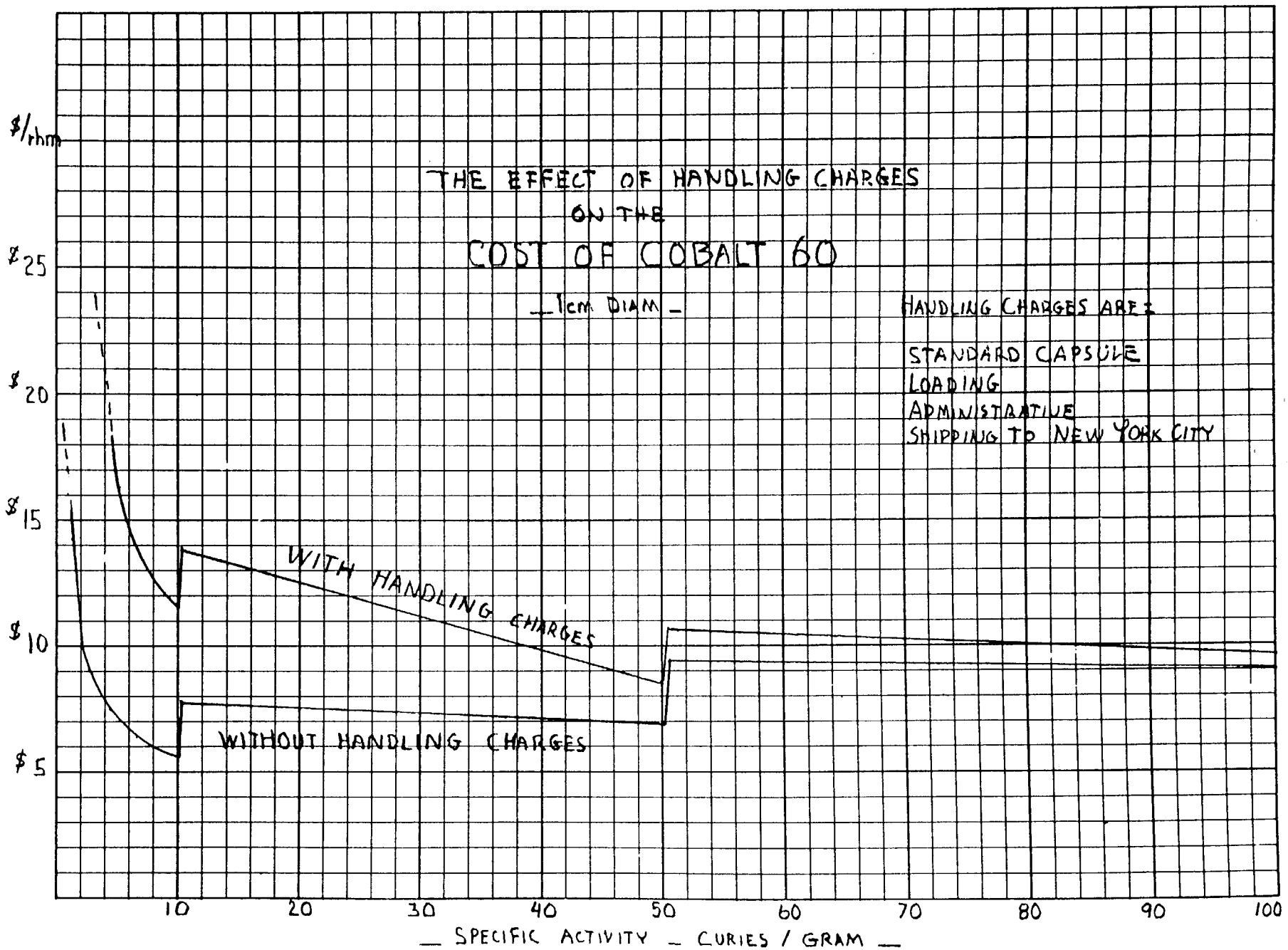
1136426


1000
100
10
rhm — OR — CURIAGE
CURIAGE
rhm
TOTAL COST OF SOURCE
$4600
$2000
$7 — COST PER rhm —
$8
Co^{60}
— COST, CURIAGE AND rhm OUTPUT —
2 cm DIAMETER
10 CURIES/GRAM
.1
.5
1
1.5
2
2.5
3
3.5
— LENGTH OF SOURCE - CM —

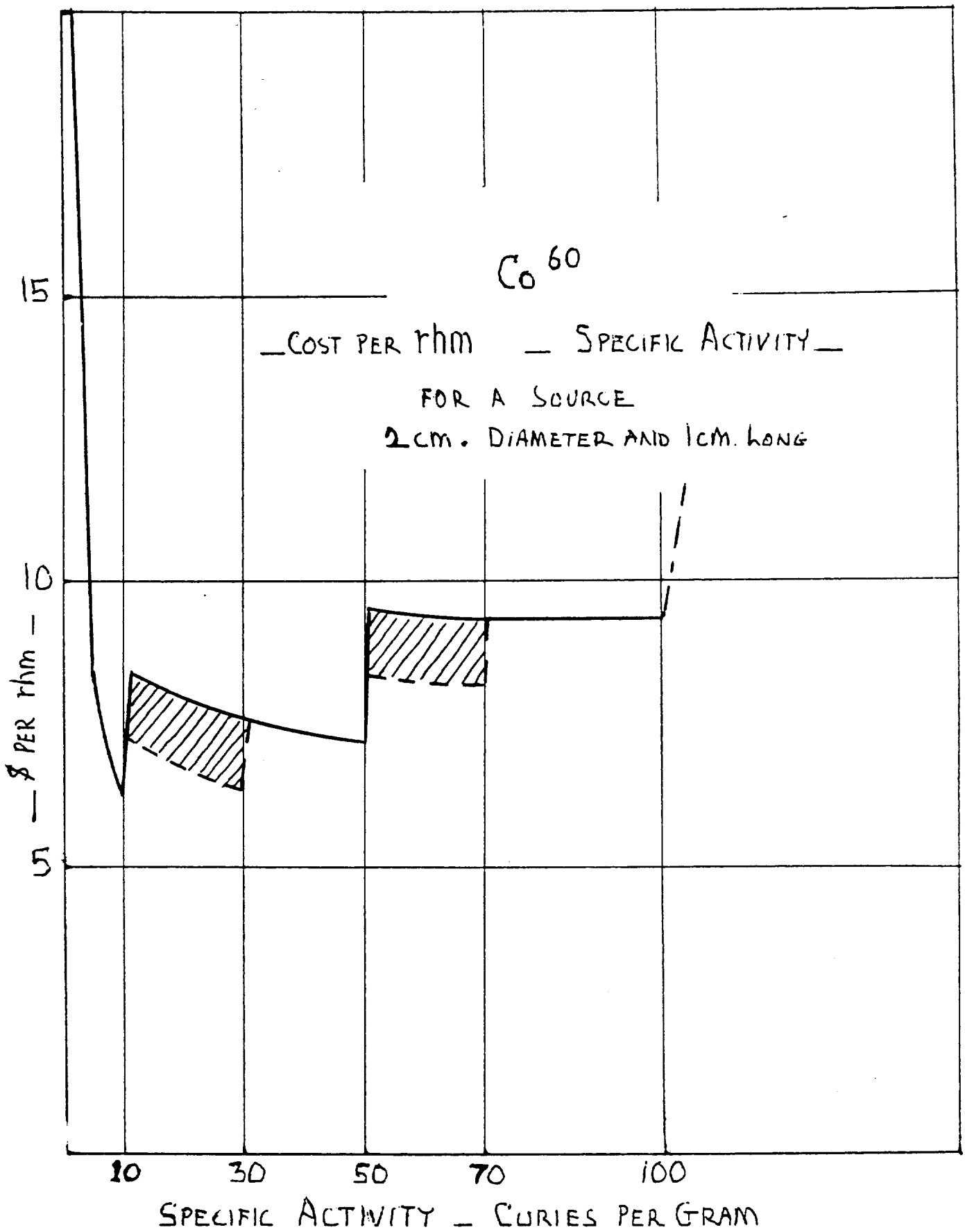
1136427


10,000
1000
100
rhm or CURIAGE
CURIAGE
rhm
TOTAL COST OF SOURCE
$25,000
$10,000
$10
COST PER rhm
$3
Co 60
COST, CURIAGE AND rhm OUTPUT
2 cm DIAMETER
50 CURIES / GRAM
.1
.5
1
1.5
2
2.5
3
3.5
LENGTH OF SOURCE CM

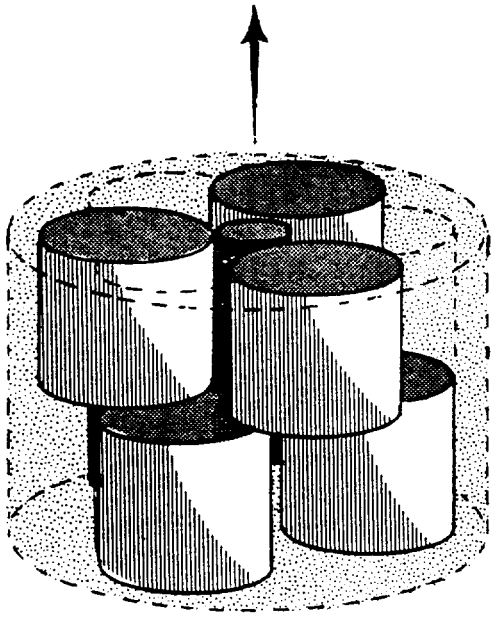
1136428


THE EFFECT OF HANDLING CHARGES
ON THE
COST OF COBALT 60
— 1cm DIAM —
HANDLING CHARGES ARE:
STANDARD CAPSULE
LOADING
ADMINISTRATIVE
SHIPPING TO NEW YORK CITY
WITH HANDLING CHARGES
WITHOUT HANDLING CHARGES
$/rhm
$25
$20
$15
$10
$5
10
20
30
40
50
60
70
80
90
100
— SPECIFIC ACTIVITY — CURIES / GRAM —

1136429


Co 60
COST PER rhm — SPECIFIC ACTIVITY
FOR A SOURCE
2 cm. DIAMETER AND 1 cm. LONG
15
10
5
$ PER rhm
10
30
50
70
100
SPECIFIC ACTIVITY — CURIES PER GRAM

1136430



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OAK RIDGE
INSTITUTE of NUCLEAR STUDIES

Medical Division

Quarterly Progress Report

Teletherapy Design Problems III

January 1 - March 31, 1954

Operating Under Contract AT-40-1-Gen-33
with the
UNITED STATES ATOMIC ENERGY COMMISSION

P. O. Box 117 Oak Ridge, Tennessee

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Not for re-publication
without authorization

AEC, Oak Ridge, Tenn. 7-12-54-550-W-25573

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INTRODUCTION

The Medical Division of the Oak Ridge Institute of Nuclear Studies has pursued a long range project for the study of teletherapy problems. Twenty-two medical schools and hospitals are cooperating with the Institute in this program.

Teletherapy Design Problems I concerned cesium 137 and was published as an AEC Report, TID-5086, first revision, May 15, 1952. Teletherapy Design Problems II told of the L. G. Grimmett Teletherapy Unit, and appeared as the ORINS Quarterly Report for the period ending September 30, 1953. The present report, Teletherapy Design Problems III, is in three sections: It includes some of the work on the cost and availability of cobalt 60, which was presented to the Third Industrial Conference on Teletherapy, May 14 and 15, 1954; some of the results of the studies of area shielding using marble as the type example (to be published by the Marble Institute of America); and the final report on the Grimmett model, which will have no further publication.

Because of the length of this report, progress notes from other sections of the Medical Division and the work from the University Relations Division are being held for publication in the next ORINS Quarterly Report.

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COBALT 60: COST, CURIAGE, AND rhm OUTPUT

Marshall Brucer, M.D.
Howard Harmon

The ever increasing use of cobalt 60 has made it desirable to tabulate a definitive review of the cost, curiage, and rhm output of various arrangements of raw cobalt 60 wafers, especially as they are used in teletherapy sources.

Following the tables included in this review are statements on "A Standard Cobalt 60 Teletherapy Source Capsule" and "An Available Cobalt 60 Source for Teletherapy," and a check list of requirements for teletherapy machines. Much of the material in these two statements complements the material to be found in Tables 1 through 11 of this paper.

The use of cobalt 60 has been an explosive phenomenon in the field of deep therapy. A number of manufacturers of X-ray equipment have privately ventured the opinion that electrical generators of X rays are already outmoded except at the very low and very high energies. The reason for this rapid acceptance is not to be found in the biological reaction to cobalt 60 gamma rays. For therapy purposes the reaction is about the same at all reasonable energies.

If a distinction can be made between the physical characteristics of the cobalt 60 beam in tissue, and the reaction of the tissue itself, then a cobalt 60 beam does have a superior penetration in depth to that in current standard equipment. Also, the secondary electrons, incident from the first layer of the skin, penetrate below the region where skin can be damaged (but this might be interpreted as an improper removal of a safeguard to therapy). The extent of scattered radiation out of the primary beam in tissue is markedly lessened with cobalt 60. But these advantages have all been achieved with properly designed high voltage electrical generators. The big advantage of cobalt 60 is economic and in the freedom allowed the designers of equipment.

The essential economic factor in radiation therapy equipment is not the capital investment in a machine. This is a one-shot expense which can be amortized over a period of years. The essential costs are in such things as the continuing labor cost of a radiotherapist's time and the time of his technical staff. The prorated cost of the use of hospital space and of cleaning, heating, and repairing this space is a big factor. Since such costs are highly varied and somewhat out of the control of hospital management, the only real control a board of trustees has over the cost of radiotherapy is in their investment in equipment that allows the most efficient use of the time of the technical staff. The X-ray industry has had many years to develop X-ray equipment to its present high peak of efficiencey. They are only beginning to think of cobalt 60 equipment, and many improvements can be expected in the next few years. An excellent illustration of changing opinion can be found in an argument comparing the treatment cost for hectocurie and kilocurie cobalt 60 machines.

At the present commercial prices of cobalt 60 machines, it is possible to install two hectocurie (600 rhm) machines for about $75,000 or one kilocurie (1800 rhm) machine for about $85,000. Treatment with these machines is identical. All of the gadgetry to make a kilocurie machine more effective can also be put on a hectocurie machine. The

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only difference is that at the longer distances it will take about twice as long to give the same treatment with a hectocurie machine. However, about half of the treatment time of any machine is used in getting the patient positioned, in cleaning up, and in the inevitable dead time between patients. The following table describes some of these factors:

	Two hectocurie machines		One kilocurie machine
Cost of machine	$25,000	$25,000	$50,000
Cost of treatment room	7,500	7,500	10,000
Cost of cobalt 60	5,000	5,000	25,000
Total machine cost	$75,000		85,000
Average setup time per patient	5 minutes		5 minutes
Average treatment time per patient	30 minutes		10 minutes
Average clean up and dead time	10 minutes		10 minutes
Total treatment time	45 minutes for 2 patients		25 minutes for 1 patient
Number of patients per day	21 patients		19 patients

With correctly designed equipment, if a radiotherapy staff can handle 20 patients a day, it follows that they can handle these patients on two machines just as easily as on one machine, in which case the use of two hectocurie machines becomes more economical than one kilocurie machine. In spite of the fact that the treatment time for any one patient is three times as long with the hectocurie machine, the dilution of treatment time with various kinds of dead time makes the total treatment time only about twice as long for a machine with only one-third of the output. With the long treatment time on the hectocurie machine, one set of technicians and a therapist can easily keep two machines in alternate operation with plenty of dead time between patients.

There are other advantages. Two hectocurie machines can be serviced alternately without stopping a schedule of treatments, whereas with one kilocurie machine a serious problem in maintenance stops all treatments. The kilocurie machines cannot be used at short SSD (source to skin distances). The hectocurie machine can be used at both 50 and 35 cm SSD; and where extreme depth penetration is unnecessary, the smaller machine when used at its shortest SSD has a higher output than that of the larger machine used at its shortest SSD. Although it is true that a kilocurie machine is more efficient than a hectocurie machine in an over-all treatment schedule, it is not necessarily more efficient than two hectocurie machines. The $10,000 saving in cost of the hectocurie machines will support a physicist, which in itself will improve a therapy department more than any item of machinery.

There is one other item: the maintenance of equipment, which looms large in the cost of radiation therapy. Tubes and transformer troubles are a constant and unpredictable cost of X-ray generators. Little maintenance trouble is possible in the simple machinery of the cobalt 60 device. The only routine problem is the decay of cobalt 60, but this decay is predictable and can be planned well in advance. The ever present task of the calibration of an electrical generator of X-rays is done once with cobalt 60, and the succeeding calibrations are read from a printed chart. The problems concerned with isodose patterns in X-ray devices can be solved in a cobalt 60

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machine with one set of standard isodose curves.

The therapeutic advantages of the hectocurie design were originally stated to be very limited and probably confined to head and neck lesions. Since these hectocurie machines have been made available, not one of the purchasers is considering such a limitation; rather, the machine has been put into direct competition with a 250 kvp X-ray generator. Even with so little information available, the impressions we have been able to gather indicate a very high probability that the hectocurie machines will be at least as useful as either the X-ray or the larger cobalt 60 machines; they might even be more useful, and they will certainly be more popular. If there is some validity to the foregoing argument, then many kinds of cobalt machines may be designed which would demand sources of various curiages.

Any source design must consider many factors, but to simplify the problem some of the following factors may be almost taken for granted:

(1) The source must be made up from thin wafers into a right cylinder*.

(2) The size must have a maximum diameter of 3 cm. This is rather arbitrary, but in any source much beyond 3 cm in diameter, the penumbra of the machines becomes unacceptable. In the lower output machines where treatment is at a shorter SSD, the maximum diameter must be reduced to about 2 cm. The penumbra at a 2.3 cm maximum, 1.9 cm minimum diameter - which is achieved by the double overlapping cloverleaf design - is just barely within the acceptability reached by the Grimmett and the Johns designs. We cannot allow a wider penumbra, but if we make a much narrower penumbra with a smaller source, we would allow more latitude in the design of cones which are now tightly restricted to a 30 cm collimation distance.

(3) In regard to the best diameter for a source, the rule is still "the smaller the better."

(4) The source must fit the standard source capsule. The restriction involved is only in the length of 3 cm, which actually is not a restriction since the cost factor overwhelmingly reinforces this decision.

(5) The total curiage should ultimately aim at outputs of 600 rhm and 1800 rhm. The hectocurie machine was designed for a maximum of 600 rhm. This is an arbitrary decision, but is logically based upon extensive study of experiences with 250 kvp X-ray machines. Most current machines are used at about 10 to 50 rmm. Some therapists will complain of faster - and an equal number will complain of slower - rates. The treatment distance with the hectocurie machine can go as low as 35 cm; hence, a 600 rhm machine will have outputs that can roughly be diagrammed in the following figures:

Treatment Distance	Depth dose at 10 cm of water as % of skin dose	Approximate equivalent peak X-ray voltage	rmm on delivery	rmm after $5\frac{1}{4}$ years	rmm after $10\frac{1}{2}$ years
1 meter	64%	2.5 Mev	10	5	$2\frac{1}{2}$
70 cm	56%	2.0 Mev	20	10	5
50 cm	51%	1 Mev	40	20	10
35 cm	43%	400 kvp	80	40	20

By multiplying the rmm figures by approximately 3, one can use the same tables for an 1800 rhm machine, except that the 35 cm treatment distance is not possible and in many machines the 50 cm treatment distances are not possible. At the longer SSD, any

* The reasons for this are described in an article by Brucer, Pollard, Leiter, and carf, Nucleonics, 11, No. 2, February 1953.

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higher output machine can probably be used more efficiently, but the cost of the machine also increases markedly. A lower output could also be used, and is preferred by some therapists, but would not meet general approval.

Before making any definite decisions on the standardization of source sizes, one should review the complete picture of the cost, the curiage, and the rhm output of various sources. Such a review is partially possible from the tables and figures herein presented.

Discussion of Table 1

Table 1 shows the effect of source length on transmission and cost. A right cylinder source is used with the beam coming out of the end face of the cylinder. The data are computed for a 1 cm diameter rod, but such factors as ~~the fractional transmission, the~~ percentage of theoretical maximum transmission, and the percentage gain with added length will fit any diameter rod. As the length of the rod increases - as shown in Column 1 - there will be more and more self-absorption, so that there is a theoretical maximun length beyond which there is no added output in spite of the added curiage. Column 2 shows the volume of a 1 cm diameter rod at various lengths. The specific activity for Table 1 was calculated at 5 curies/gram or 43.5 curies/cm3. A uniform distribution of the active cobalt 60 was assumed. In Column 4 there is computed the total rhm obtainable from the number of curies shown in Column 3, assuming 1.35 rhm per curie of cobalt 60. From Dixon's function on fractional transmission Column 5 was computed, which allowed the calculation of the total rhm of each specific length with self-absorption taken into account. From this column it was possible to calculate in Column 8 the percentage of the theoretical maximum transmission at each length. In Column 9 it can be seen that as the length increases there is a rapid increase in the percentage output up to 2 cm, after which it begins to fall markedly. It would appear from this that the most economical source length will certainly not be beyond 3 cm. On Page 2 of Table 1 these same factors are computed when specific activities of 10, 50, and 100 curies per gram are considered. On Page 3 of Table 1 are given some of the data used to calculate Dixon's self-absorption functions. It will be noticed that in Table 1 the cost factors were arrived at very simply; these cost factors will be changed in the last tables in this series to a more reasonable estimate of actual cost.

Discussion of Table 2

Table 2 shows the effect of source length and specific activity. The same type of data as were used in Table 1 are used in Table 2, except that in this case the specific activity is changed from 1 to 100 curies per gram.

Discussion of Tables 3 and 4

In Tables 3 and 4 the total curiage and the rhm output in various sizes of right cylinder sources were computed for four different specific activities. Table 3 shows the effect of various source lengths and source diameters at 5 curies per gram. The same figures can be used for 50 curies per gram by multiplying each figure by 10. In Table 4 the 10 and 100 curie per gram specific activities are given.

The data from Table 3 showing the total curiage for various lengths and diameters of sources are shown graphically in Figure 1. The data are shown for 5 curies per gram but this can be converted for the 50 curie per gram specific activity by multiplying the abscissa by 10.

In Figure 2 the same type of total curiage data is shown for various lengths and

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diameter sources for the 10 and 100 curie per gram material.

In Figures 3 and 4 the effect of changing length and diameter of source on the rhm output is shown for both the 5 and 50 curie per gram material and the 10 and 100 curie per gram material.

From these data a number of general conclusions can be made. Figure 5 shows a three dimensional chart giving many lengths of sources and many diameters of sources. These two factors are plotted against a total number of curies, and on the three dimensional surface so achieved, it can be shown that any reasonable output can be achieved with many source sizes, but the various source sizes will always be within a well defined total range of curies.

Figure 6 shows a three dimensional graph of the cost of the radiation in terms of dollars per rhm for various source lengths and specific activities. From this three dimensional surface, it can be seen that with an increase in source lengths at any specific activity there is a rapid increase in the cost of cobalt 60, but that there is a minimum at a short source length. The point at which this minimum cost occurs on the source length axis changes with various source diameters. It is also shown that the cost decreases generally with increasing specific activity. However, since the price of cobalt 60 changes at 10 and 50 curies per gram, there is a step where there otherwise would be a smooth surface. There is a peak at the very low specific activity thin wafers, which is a highly uneconomical use of cobalt 60. The same figures are redrawn in Figure 7 to show the effect not only of increasing length but also of increasing diameter. For a specific activity of 10 curies per gram the surface is shown complete. The minimum cost is at a length of about 0.5 to 1 cm at all diameters, except at the very small diameter sources where the decreased rhm results in a marked cost peak. The same type of graph occurs, but at different levels with the other specific activities.

Discussion of Tables 5 through 8

In Tables 5 through 8 the data from Tables 3 and 4 were re-computed to state the cost of the total source and the cost per rhm when calculated to include many more factors than the raw cobalt 60 cost as used on the previous tables. It will be noticed that the cost factors as explained on the page preceeding Table 5 have been changed. In addition to the cost of the source material, there is included a cost of $210 for the standard source capsule. A handling charge of $10 for each source, the loading charges, and a shipping charge (which is based upon a simplified system of computing shipping charges) are also included. The cost, however, does not include rental on a shipping container or the cost of loading the source into a teletherapy machine.

The following example can be given to show how these figures are interpreted: If it is decided to design a cobalt 60 source with an output of approximately 600 rhm, in Table 4 we find that such an output can be achieved by using a 2 cm diameter source 3 cm long which gives an output of 614 rhm and uses 820 curies of activity. From Table 6 it can be seen that the 3 cm length of 2 cm diameter cobalt 60 will cost about $4,190 or about $6.82 per rhm. This, however, is not the total cost of the source but is only the cost of the cobalt 60 in the source. When we add the source capsule, handling, loading, and all costs except shipping, this cost **increases - as shown in Table 6A** - to $4,760 or $7.75 per rhm. If the source were shipped to New York City, the cost then would increase to $4,812; if it were shipped to San Francisco, it would increase to $4,903.

To give a better picture of the meaning of Tables 5 through 8, a number of specific examples have been selected and are shown in Figures 8 through 11. In Figure 8 a 1 cm

diameter source was chosen at 50 curies per gram specific activity. With increasing lengths of the source, the total rhm is shown as the heavy line. The light line shows total curiage, the dotted line shows the total cost of the source, and another dotted line shows the cost per rhm. Figure 9 shows the results when a 1.5 cm diameter source is used. Figure 10 shows the same factors when a 2 cm diameter source is used at 10 curies per gram, and Figure 11 at 50 curies per gram specific activity.

In Figure 12 there is shown the effect of adding the handling charges to the cost of the raw cobalt 60. Without handling charges, 10 curie per gram material has an advantage over the 50 curie per gram, but the 50 curie per gram has an advantage over 11 curie per gram material. Since handling costs are fixed charges within wide ranges of activity, the handling charges are exaggerated in the lower specific activity material; hence, 50 curie per gram material is economically better than the 10 curie per gram material. At 11 curies per gram the cost is even higher.

Discussion of Tables 9, 10, and 11

To give a better picture of the effect of specific activity on the total curiage and rhm output, Tables 9, 10, and 11 are computed to show the data for three reasonable standard source sizes: a 1 cm, a 1.5 cm, and a 2 cm diameter rod. At various lengths and various specific activities the total curies are shown in the first part of each table and the rhm output in the second part of each table. In Table 11A, the 2 cm diameter source size was taken and the costs were computed for the source alone and for the encapsulated source shipped to New York City. This was then converted to cost per rhm.

From the data in Tables 9 to 11, the cost of a 2 cm diameter source has been recomputed. Instead of making the change in cost due to specific activity at 10 and 50 curies per gram, a change is made at 10, 30, 50, and 70 curies per gram. Since it is impossible to administer an accounting system with a continuous change in cost with changing specific activity, some breaks must be made. However, with the simple system of making the break at 10 and 50 curies per gram, the use of more easily available 20 and 30 curie per gram material involves a penalty. This penalty can easily be obviated and the cost-specific activity curves smoothed out by making the breaks somewhat more frequent.

Almost anything of reasonable size can be irradiated in a nuclear reactor. With proper consideration of the time relationships, almost any reasonable specific activity up to 100 curies per gram can be achieved, but this cannot be done without affecting cost. However, on a production line scheduled to produce many sources, a reactor cannot be efficiently operated unless there is some standardization of cost, sizes, shapes, and irradiation time.

1136440

Table 1

Co 60

The Effect of Source Length on Transmission and Cost

Right Cylinder Rod Source — Data for 1 cm Diameter Rod
Cross Sectional Area = 0.7854 cm^2 — Volume = 0.7854 cm^3 at 1 cm Length
rhm for 1 Curie = 1.35 — 1^{μ} for Co 60 Through Co 59 is 0.44 cm^{-1}

Length cm	Volume cm^3	Curies*	rhm without self absorption	fractional** transmission	rhm with self absorption	$I/\sigma A$ ***	% of theoretical maximum †	% gain with added length	Cost of total source $††	Cost per unit rhm $
0.1	0.078	3.42	4.62	.970	4.48	0.097	4.26	---	110	24.55
0.5	0.393	17.10	23.09	.900	20.78	0.451	19.84	15.58	180	8.66
1	0.785	34.16	46.12	.825	38.05	0.825	36.30	16.46	265	6.96
2	1.571	68.34	92.26	.664	61.26	1.328	58.43	22.13	435	7.10
3	2.356	102.49	138.36	.555	76.79	1.665	73.26	14.83	605	7.87
4	3.142	136.68	184.52	.469	86.54	1.876	82.54	9.28	775	8.95
5	3.927	170.82	230.61	.404	93.17	2.020	88.88	6.34	945	10.14
6	4.712	204.97	276.71	.352	97.40	2.112	92.92	4.04	1115	11.44
7	5.498	239.16	322.87	.310	100.09	2.170	95.48	2.56	1290	12.88
8	6.283	273.31	368.97	.275	101.47	2.200	96.80	1.32	1460	14.38
9	7.069	307.50	415.13	.247	102.54	2.223	97.81	1.01	1630	15.89
10	7.854	341.65	461.23	.223	102.85	2.230	98.12	0.31	1800	17.50
15	11.781	512.47	691.83	.151	104.47	2.265	99.66	1.54	2655	25.41
20	15.708	683.30	922.46	.113	104.65	2.269	99.83	0.17	3510	33.54
max. = $\frac{1}{\mu}$ 2.2727	1.785	77.65	104.82	1.000	104.82	2.273	100.00	0.17	--	--

* Calculated at specific activity of 5 curies/gram or 43.5 curies/cm^3 uniform distribution.

** From Dixon's Function $F\frac{1}{2}$ (μa) see graph.

*** I = rhm with self absorption; σ = rhm without self absorption/cm^3; A = cross section area $\sigma A = \frac{104.82 \times 0.7854}{1.785} = 46.12$

† Theoretical maximum is defined as I max = $A\sigma/\mu$

†† Cost = $100 for first 2 curies plus $5 for each additional curie or fraction thereof.

1136441

Table 1 (cont'd.)

Co 60

	10 CURIES PER GRAM					50 CURIES PER GRAM			100 CURIES PER GRAM		
Length cm	Curies*	rhm without self absorption	rhm with self absorption	cost of total source $ **	cost per unit rhm	rhm with self absorption†	cost of total source $†	cost per unit rhm	rhm with self absorption††	cost of total source $	cost per unit rhm
0.1	6.79	9.17	8.89	125	14.06	44.8	348	7.76	88.9	1660	18.67
0.5	34.19	46.16	41.54	265	6.37	207.8	1368	6.58	415.4	4400	10.59
1	68.30	92.21	76.07	335	4.40	380.5	2650	6.96	760.7	7810	10.26
2	136.68	184.52	122.52	775	6.32	612.6	5215	8.51	1225.2	14650	11.95
3	204.97	276.71	153.57	1115	7.26	767.9	7773	10.12	1535.7	21480	13.98
4	273.35	369.02	173.07	1460	8.43	865.4	10337	11.94	1730.7	28320	16.36
5	341.65	461.23	186.34	1800	9.65	931.7	12903	13.84	1863.4	35150	18.86
6	409.94	553.42	194.80	2140	10.98	974.0	15460	15.87	1948.0	41980	21.55
7	478.33	645.75	200.18	2485	12.41	1000.9	18025	18.00	2001.8	48820	24.38
8	546.62	737.94	202.93	2825	13.92	1014.7	20590	20.29	2029.3	55650	27.42
9	615.00	830.25	205.07	3165	15.43	1025.4	23148	22.57	2050.7	62480	30.46
10	683.30	922.46	205.71	3510	17.06	1028.5	25713	25.00	2057.1	69310	33.69
15	1024.95	1383.68	208.93	5215	24.96	1044.7	38523	36.87	2089.3	103480	49.52
20	1366.60	1844.91	209.21	6925	33.10	1046.5	51333	49.05	2092.1	137640	65.79
max. = $\frac{1}{\mu}$ 2.2727	155.30	209.66	209.65	--	--	1048.2	--	--	2096.5	--	--

* Curiage calculated at 10 curies/gram or 87 curies/cm^3 uniform distribution.

** Cost = $5/curie plus $100 for first 2 curies.

† Curiage calculated at 50 curies/gram or 435 curies/cm^3 uniform distribution; therefore cost = $7.50/curie plus $100 for first 2 curies.

†† Curiage calculated at 100 curies/gram or 870 curies/cm^3 uniform distribution; therefore cost = $10.00/curie plus $100 for first 2 curies.

113442

Calculation of Self Absorption Function $F\frac{1}{2}$ (μa)
(Fron Dixon, W. R., Nucleonics 8: 68, April'51)

length	$\frac{1}{2}$ length = a	$\mu = 0.44$ cm^{-1} $a\mu$	(see graph) fractional transmission	rhm x A
.1	.05	.022	.970	3.6285
.5	.25	.11	.900	18.1348
1	.5	.22	.825	36.2226
2	1	.44	.664	72.4610
3	1.5	.66	.555	108.668
4	2	.88	.469	144.922
5	2.5	1.10	.404	181.121
6	3	1.32	.352	217.328
7	3.5	1.54	.310	253.582
8	4	1.76	.275	289.789
9	4.5	1.98	.247	326.043
10	5	2.20	.223	362.250
15	7.5	3.30	.151	543.363
20	10	4.40	.113	724.500
2.27 (max)	1.13636	--	1.000	82.3256
				σA = 46.12

Table 2 **The Effect of Source Length and Specific Activity on the Cost of Cobalt 60 Radiation**

(Right Cylinder Source - Density of Co = 8.7)

1 to 10 curies = $5.00/curie plus $100 for the first two curies
10 to 50 curies = $7.50/curie plus $100 for the first two curies
50 to 100 curies = $10.00/curie plus $100 for the first two curies

curies/gram	curies/cm^3	length = 0.1 cm, volume = 0.07854 cm^3, fractional transmission = .970					length = 1.0 cm, volume = 0.7854 cm^3, fractional transmission = .825				
		total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $
1	8.7	0.68	0.92	0.89	50	56.18	6.8	9.2	7.6	125	16.46
2	17.4	1.37	1.85	1.79	100	55.86	13.7	18.5	15.3	160	10.45
3	26.1	2.05	2.77	2.69	105	39.03	20.5	27.7	22.9	195	8.51
6	52.2	4.10	5.54	5.37	115	21.41	41.0	55.4	45.7	295	6.45
10	87.0	6.83	9.22	8.94	125	13.98	68.3	92.2	76.1	435	5.71
11	95.7	7.52	10.15	9.85	145	14.72	75.2	101.5	83.7	655	7.82
20	174.0	13.67	18.45	17.90	190	10.62	136.7	184.5	152.2	1113	7.31
30	261.0	20.50	27.68	26.85	243	9.05	205.0	276.8	228.4	1623	7.10
40	348.0	27.33	36.90	35.79	295	8.24	273.0	369.0	304.4	2140	7.03
50	435.0	34.17	46.13	44.75	348	7.77	341.7	461.3	380.6	2650	6.96
51	443.7	34.85	47.05	45.64	430	9.42	348.5	470.5	388.2	3570	9.19
60	522.0	41.00	55.35	53.69	490	9.12	410.0	553.5	456.6	4180	9.15
70	609.0	47.83	64.57	62.63	560	8.94	478.3	645.7	532.7	4870	9.14
90	783.0	61.50	83.03	80.54	700	8.69	615.0	830.3	685.0	6230	9.09
100	870.0	68.33	92.25	89.48	770	8.60	683.3	922.5	761.1	6920	9.08

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Table 2 (cont'd.)

Co 60

curies/gram	length = 5.0 cm, volume = 3.927 cm^3, fractional transmission = .404					length = 10 cm, volume = 7.854 cm^3, fractional transmission = .223				
	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $
1	34	46	19	265	14.24	68	92	21	435	20.71
2	68	92	37	435	11.69	137	185	41	775	18.90
3	102	138	56	605	10.82	205	277	62	1115	17.98
6	205	277	112	1115	9.97	410	554	124	2140	17.25
10	342	461	186	1800	9.67	683	922	206	3510	17.03
11	376	507	205	2905	14.17	752	1015	226	5725	25.33
20	683	922	372	5215	14.01	1367	1845	411	10338	25.15
30	1025	1384	559	7773	13.90	2050	2768	617	15460	25.05
40	1367	1845	745	10338	13.87	2733	3690	823	20590	25.01
50	1708	2306	932	12895	13.83	3417	4613	1029	25713	24.98
51	1742	2352	950	17500	18.42	3485	4705	1049	34930	33.30
60	2050	2768	1118	20588	18.41	4100	5535	1234	41080	33.29
70	2392	3229	1305	24000	18.39	4783	6457	1440	47920	33.27
90	3075	4151	1677	30830	18.38	6150	8303	1852	61580	33.26
100	3417	4613	1864	34250	18.37	6833	9225	2057	68410	33.25

1136445

Table 2 (cont'd.)

Co 60

curies/gram	length = 15 cm, volume = 11.781 cm^3, fractional transmission = .151					length = 20 cm, volume = 15.708 cm^3, fractional transmission = .113				
	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $	total curies	rhm without self absorption	rhm with self absorption	cost for source $	cost per rhm $
1	103	138	21	605	28.94	137	185	21	775	37.25
2	205	277	42	1115	26.67	273	369	42	1460	35.01
3	308	415	63	1630	25.99	410	554	63	2140	34.24
6	615	830	125	3165	25.23	820	1107	125	4190	33.52
10	1025	1384	209	5215	24.95	1367	1846	209	6925	33.13
11	1127	1521	230	8538	37.12	1503	2029	229	11358	49.52
20	2050	2768	418	15460	36.98	2733	3689	417	20583	49.35
30	3075	4151	627	23148	36.91	4100	5535	625	30835	49.34
40	4050	5468	826	30460	36.87	5466	7379	834	41080	49.25
50	5125	6919	1045	38523	36.86	6833	9225	1042	51333	49.25
51	5227	7056	1065	52350	49.15	6970	9410	1063	69780	65.64
60	6150	8303	1254	61580	49.10	8200	11070	1251	82080	65.62
70	7175	9686	1463	71830	49.09	9566	12914	1459	95740	65.61
90	9225	12454	1881	92330	49.08	12299	16604	1876	123070	65.60
100	10249	13838	2090	102570	49.07	13666	18455	2085	136740	65.58

1136446

Table 3

Co^{60}

Total Curiage and rhm Output in Various Sizes of Right Cylinder Sources for Specific Activities of

5 curies/gram or 43.5 curies/cm3
(50 curies/gram or 435 curies/cm3 is given figure x 10)

Source Diameter cm.	0.1 cm length 4.26% of max.		0.5 cm length 19.84% of max.		1 cm length 36.30% of max.		2 cm length 58.43% of max.		3 cm length 73.26% of max.		4 cm length 82.54% of max.		I max. rhm
	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	100%
0.1	0.04	0.04	0.17	0.21	0.35	0.38	0.70	0.61	1.04	0.77	1.35	0.87	1.05
0.5	0.87	1.12	4.26	5.20	8.53	9.51	17.1	15.3	25.6	19.2	34.1	21.6	26.2
1.0	3.39	4.47	17.1	20.8	34.1	38.1	68.3	61.4	102.5	76.9	136.7	86.7	105
1.5	7.70	10.05	38.4	46.8	76.9	85.7	153.7	137.9	230.6	172.9	307.5	194.8	236
2.0	13.6	17.8	68.3	83.1	136.7	152.1	273.3	244.8	410.0	307.0	546.6	345.8	419
2.5	21.4	27.9	106.7	130.0	213.5	237.8	427.1	382.7	640.6	479.8	854.1	540.6	655
3.0	30.8	40.2	153.7	187.1	307.5	342.3	615.0	551.0	922.5	690.8	1,229.9	778.4	943
4.0	54.7	71.4	273.3	332.7	546.6	608.8	1,093.3	979.9	1,639.9	1,228.6	2,186.6	1,384.2	1,677
5.0	85.4	111.6	429.4	520.0	854.1	951.4	1,708.2	1,531.4	2,562.4	1,920.1	3,416.5	2,163.4	2,621

1136447

Table 4

Co 60

Total Curiage and rhm Output in Various Sizes of Right Cylinder Sources for Specific Activities of

10 curies/gram or 87 curies/cm^3
(100 curies/gram or 870 curies/cm^3 is given figure x 10)

Source Diameter cm	0.1 cm length 4.26% of max.		0.5 cm length 19.84% of max.		1 cm length 36.30% of max.		2 cm length 58.43% of max.		3 cm length 73.26% of max.		4 cm length 82.54% of max.		I max. rhm 100%
	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	curies	rhm	
0.1	0.08	0.08	0.34	0.42	0.70	0.76	1.40	1.22	2.08	1.54	2.70	1.74	2.1
0.5	1.74	2.24	8.52	10.4	17.1	19.0	34.2	30.6	51.2	38.4	68.2	43.2	52.4
1.0	6.78	8.94	34.2	40.16	68.2	76.2	136.6	122.8	205.0	153.8	273.4	173.4	210
1.5	15.4	20.1	76.8	93.6	153.8	171.4	307.4	275.8	461.2	345.8	615.0	389.6	472
2.0	27.2	35.6	136.6	166.2	273.4	304.2	546.6	489.6	820.0	614.0	1,093.2	691.6	839
2.5	42.8	55.8	213.4	260.0	427.0	475.6	854.2	765.4	1,281.2	959.6	1,708.2	1,081.2	1,310
3.0	61.6	80.4	307.4	374.2	615.0	684.6	1,230.0	1,102.0	1,845.0	1,381.6	2,459.8	1,556.8	1,887
4.0	109.4	142.8	546.6	665.4	1,093.2	1,217.6	2,186.6	1,959.8	3,279.8	2,457.2	4,373.2	2,768.4	3,354
5.0	170.8	223.2	858.8	1,040.0	1,708.2	1,902.8	3,416.4	3,062.8	5,124.8	3,840.2	6,833.0	4,326.8	5,241

1136448

Discussion of Tables 5A, 6A, 7A, and 8A

Co 60

The Total Cost of Co 60 Sources of Various Dimensions at Specific Activity Stated on Table

Cost includes following factors:

Specific activity of 5 curies per gram =	$100 for first 2 curies plus $5.00 per curie for each additional curie or fraction thereof.
Specific activity of 10 curies per gram =	$100 for first 2 curies plus $5.00 per curie for each additional curie or fraction thereof.
Specific activity of 50 curies per gram =	$150 for first 2 curies plus $7.50 per curie for each additional curie or fraction thereof.
Specific activity of 100 curies per gram =	$200 for first 2 curies plus $10.00 per curie for each additional curie or fraction thereof.

Standard Source Capsule = $210 for each source
Handling Charge = $10 for each source

Loading Charge = $200 up to 750 curies
= $350 up to 2000 curies
= $500 over 2000 curies

Shipping Charges = 1000 lbs for sources up to 750 curies
= 2000 lbs for sources up to 2000 curies
= 4000 lbs for sources over 2000 curies

Shipping to New York City and Denver by Motor Freight
Shipping to San Francisco by Rail Freight

This charge does not include rental on shipping container or cost of loading source capsule into teletherapy machine.

1136449

Table 5

Co 60

The Cost of Co 60 Sources of Various Dimensions

at a Specific Activity of

5 curies/gram or 43.5 curies/cm^3
cost of 5 curie/gram sources is $5 per curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm Length Cost in $		0.5 cm Length Cost in $		1 cm Length Cost in $		2 cm Length Cost in $		3 cm Length Cost in $		4 cm Length Cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	30	750.00	40	190.48	40	105.26	50	81.97	75	97.40	75	86.21
0.5	30	26.78	115	22.12	135	14.20	180	11.76	220	11.46	265	12.27
1.0	110	24.61	180	8.65	265	6.96	435	7.08	605	7.87	775	8.94
1.5	130	12.94	285	6.09	475	5.54	860	6.24	1,245	7.20	1,630	8.37
2.0	160	8.99	435	5.23	775	5.10	1,460	5.96	2,140	6.97	2,825	8.17
2.5	200	7.17	625	4.81	1,160	4.88	2,230	5.83	3,295	6.87	4,365	8.07
3.0	245	6.09	860	4.60	1,630	4.76	3,165	5.74	4,705	6.81	6,240	8.02
4.0	365	5.11	1,460	4.39	2,825	4.64	5,560	5.67	8,290	6.75	11,025	7.96
5.0	520	4.66	2,240	4.31	4,365	4.59	8,635	5.64	12,905	6.72	17,175	7.94

1136450

Table 5A

5 Curies/Gram or 43.5 Curies/cm^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	450	11,250.00	460	2,190.48	460	1,210.53	470	770.49	495	642.86	495	568.97
N.Y.C.	479	11,975.00	489	2,328.57	489	1,286.84	499	818.03	524	680.52	524	602.30
Denver	489	12,225.00	499	2,376.19	499	1,313.16	509	834.43	534	693.51	534	613.79
S.F.	521	13,025.00	531	2,528.57	531	1,397.37	541	886.89	566	735.06	566	650.57
0.5	470	419.64	535	102.88	555	65.06	600	39.22	640	33.33	685	31.71
N.Y.C.	499	445.54	564	108.46	584	68.46	629	41.11	669	34.84	714	33.06
Denver	509	454.46	574	110.38	594	69.64	639	41.76	679	35.36	724	33.52
S.F.	541	483.04	596	114.62	626	73.39	671	43.86	701	36.51	756	35.00
1.0	530	118.57	600	28.85	685	17.98	855	13.93	1,025	13.33	1,195	13.78
N.Y.C.	559	125.06	629	30.24	714	18.74	884	14.40	1,054	13.71	1,224	14.12
Denver	569	127.29	639	30.72	724	19.00	894	14.56	1,064	13.84	1,234	14.23
S.F.	601	134.45	671	32.26	756	19.84	926	15.08	1,096	14.25	1,266	14.60
1.5	550	54.73	705	15.06	895	10.44	1,280	9.28	1,665	9.63	2,050	10.52
N.Y.C.	579	57.61	734	15.68	924	10.78	1,309	9.49	1,694	9.80	2,079	10.67
Denver	589	58.61	744	15.90	934	10.90	1,319	9.56	1,704	9.86	2,089	10.72
S.F.	621	62.07	776	16.58	966	11.27	1,351	9.80	1,736	10.04	2,121	10.89
2.0	580	32.58	855	10.29	1,195	7.86	1,880	7.68	2,560	8.34	3,245	9.38
N.Y.C.	609	35.66	884	10.64	1,224	8.05	1,909	7.80	2,589	8.43	3,274	9.47
Denver	619	34.78	894	10.76	1,244	8.18	1,919	7.84	2,599	8.47	3,284	9.50
S.F.	651	36.57	926	11.14	1,266	8.32	1,951	7.94	2,631	8.57	3,316	9.59
2.5	620	22.22	1,045	8.04	1,580	6.64	2,650	6.92	3,715	7.74	4,935	9.13
N.Y.C.	649	23.26	1,074	8.26	1,609	6.77	2,679	7.00	3,744	7.80	4,987	9.22
Denver	659	23.62	1,084	8.34	1,619	6.81	2,689	7.03	3,754	7.82	5,012	9.27
S.F.	691	24.77	1,116	8.59	1,651	6.94	2,721	7.11	3,786	7.89	5,078	9.39
3.0	665	16.54	1,280	6.84	2,050	5.99	3,585	6.51	5,275	7.64	6,810	8.75
N.Y.C.	694	17.26	1,309	7.00	2,079	6.07	3,614	6.56	5,327	7.71	6,862	8.82
Denver	704	17.51	1,319	7.05	2,089	6.10	3,624	6.58	5,352	7.75	6,887	8.85
S.F.	736	18.31	1,351	7.22	2,121	6.20	3,656	6.64	5,418	7.84	6,953	8.93

1136451

Table 6

Co 60

The Cost of Co 60 Sources of Various Dimensions at a Specific Activity of

10 curies/gram or 87 curies/cm^3
cost of 10 curie/gram sources is $5 per curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm Length Cost in $		0.5 cm Length Cost in $		1 cm Length Cost in $		2 cm Length Cost in $		3 cm Length Cost in $		4 cm Length Cost in $	
	per Source	per rhm	per Source	per rhm	per Source	per rhm	per Source	per rhm	per Source	per rhm	per Source	per rhm
0.1	30	375.00	40	95.24	50	65.79	75	61.48	105	68.18	105	60.34
0.5	100	44.64	135	12.98	180	9.47	265	8.66	350	9.11	435	10.07
1.0	125	13.98	265	6.60	435	5.71	775	6.31	1,115	7.25	1,460	8.42
1.5	170	8.46	475	5.07	860	5.02	1,630	5.91	2,400	6.94	3,165	8.12
2.0	230	6.46	775	4.66	1,460	4.80	2,825	5.77	4,190	6.82	5,560	8.04
2.5	305	5.46	1,160	4.46	2,225	4.68	4,365	5.70	6,500	6.77	8,635	7.99
3.0	400	4.98	1,630	4.36	3,165	4.62	6,240	5.66	9,315	6.74	12,390	7.96
4.0	640	4.48	2,825	4.24	5,560	4.57	11,025	5.62	16,490	6.71	21,960	7.93
5.0	945	4.23	4,385	4.22	8,635	4.54	17,175	5.61	25,715	6.70	34,255	7.92

1136452

Table 6A

10 Curies Gamma 87 Curies/cm^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	450	5,625.00	460	1,095.24	470	618.42	495	405.74	525	340.91	525	301.72
N.Y.C.	479	5,987.50	489	1,164.29	499	656.58	524	429.51	554	359.74	554	318.39
Denver	489	6,112.50	499	1,188.10	509	669.74	534	437.70	564	366.23	564	324.14
S.F.	521	6,512.50	531	1,264.29	541	711.84	566	463.93	596	387.01	596	342.53
0.5	520	232.14	555	53.37	600	31.58	685	22.39	770	20.05	855	19.79
N.Y.C.	549	245.09	584	56.15	629	33.11	714	23.33	799	20.81	884	20.46
Denver	559	249.55	594	57.12	639	33.63	724	23.66	809	21.07	894	20.69
S.F.	591	263.84	626	60.19	671	35.32	756	24.71	841	21.90	926	21.44
1.0	545	60.96	685	17.06	855	11.22	1,195	9.73	1,535	9.98	1,880	10.84
N.Y.C.	574	64.21	714	17.78	884	11.60	1,224	9.97	1,564	10.17	1,909	11.01
Denver	584	65.32	724	18.03	894	11.73	1,234	10.05	1,574	10.23	1,919	11.07
S.F.	616	68.90	756	18.82	926	12.15	1,266	10.31	1,606	10.44	1,951	11.25
1.5	590	29.35	895	9.56	1,280	7.47	2,050	7.43	2,820	8.16	3,585	9.20
N.Y.C.	619	30.80	924	9.87	1,309	7.64	2,079	7.54	2,849	8.24	3,614	9.28
Denver	629	31.29	934	9.98	1,319	7.70	2,089	7.57	2,859	8.27	3,624	9.30
S.F.	661	32.89	966	10.32	1,351	7.88	2,121	7.69	2,891	8.36	3,656	9.38
2.0	650	18.26	1,195	7.19	1,880	6.18	3,245	6.63	4,760	7.75	6,130	8.86
N.Y.C.	679	19.07	1,224	7.36	1,909	6.28	3,274	6.69	4,812	7.84	6,182	8.94
Denver	689	19.35	1,234	7.42	1,919	6.31	3,284	6.71	4,837	7.88	6,207	8.97
S.F.	721	20.25	1,266	7.62	1,951	6.41	3,316	6.77	4,903	7.98	6,273	9.07
2.5	725	12.99	1,580	6.08	2,645	5.56	4,935	6.45	7,070	7.37	9,205	8.51
N.Y.C.	754	13.51	1,609	6.19	2,674	5.62	4,987	6.52	7,122	7.42	9,257	8.56
Denver	764	13.69	1,619	6.23	2,684	5.64	5,012	6.55	7,147	7.45	9,282	8.58
S.F.	796	14.27	1,651	6.35	2,716	5.71	5,078	6.63	7,213	7.52	9,348	8.65
3.0	820	10.20	2,050	5.48	3,585	5.24	6,810	6.18	9,885	7.15	13,110	8.42
N.Y.C.	849	10.56	2,079	5.56	3,614	5.28	6,862	6.23	9,937	7.19	13,214	8.49
Denver	859	10.68	2,089	5.58	3,624	5.29	6,887	6.25	9,962	7.21	13,265	8.52
S.F.	891	11.08	2,121	5.67	3,656	5.34	6,953	6.31	10,028	7.33	13,396	8.60

1136453

Table 7

Co^{60}

The Cost of Co^{60} Sources of Various Dimensions at a Specific Activity of

50 curies/gram or 435 curies per cm^3
Cost of 50 curie/gram sources is $7.50 per curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	40	100.00	100	47.62	110	28.95	138	22.62	168	21.82	190	21.84
0.5	153	13.66	408	7.85	730	7.68	1,368	8.94	2,005	10.44	2,643	12.24
1.0	340	7.61	1,368	6.58	2,643	6.94	5,208	8.48	7,773	10.11	10,338	11.92
1.5	663	6.60	2,965	6.34	5,853	6.83	11,613	8.42	17,380	10.05	23,148	11.88
2.0	1,105	6.21	5,208	6.27	10,338	6.80	20,583	8.41	30,835	10.04	41,080	11.88
2.5	1,690	6.06	8,088	6.22	16,098	6.77	32,118	8.39	48,130	10.03	64,143	11.87
3.0	2,395	5.96	11,613	6.20	23,148	6.76	46,210	8.38	69,273	10.03	92,328	11.86
4.0	4,188	5.87	20,583	6.19	41,080	6.74	82,083	8.37	123,078	10.02	164,080	11.85
5.0	6,490	5.82	32,290	6.21	64,143	6.74	128,200	8.37	192,265	10.01	256,323	11.85

1136454

Table 7A

58 Curies/Gram or 435 Curies/cm^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	480	1,200.00	520	247.62	430	113.16	558	91.48	588	76.36	610	70.11
N.Y.C.	509	1,272.50	549	261.43	559	147.11	587	96.23	617	80.13	639	73.45
Denver	519	1,297.50	559	266.19	569	149.74	597	97.87	627	81.43	649	74.60
S.F.	551	1,377.50	591	281.43	601	158.16	629	103.11	659	85.58	681	78.28
0.5	523	46.70	828	15.92	1,150	12.09	1,788	11.69	2,425	12.63	3,063	14.18
N.Y.C.	552	49.29	857	16.48	1,179	12.40	1,817	11.88	2,454	12.78	3,092	14.31
Denver	562	50.18	867	16.67	1,189	12.50	1,827	11.94	2,464	12.83	3,102	14.36
S.F.	594	53.04	899	17.29	1,399	14.71	1,859	12.15	2,496	13.00	3,134	14.51
1.0	810	18.12	1,838	8.84	3,143	8.17	5,678	9.25	8,393	10.91	10,958	12.54
N.Y.C.	839	18.76	1,867	8.98	3,142	8.25	5,707	9.29	8,445	10.98	11,010	12.70
Denver	849	18.99	1,877	9.02	3,152	8.27	5,717	9.31	8,470	11.01	11,035	12.73
S.F.	881	19.71	1,909	9.18	3,184	8.36	5,749	9.36	8,536	11.10	11,101	12.80
1.5	1,133	11.27	3,435	7.34	6,323	7.27	12,233	8.87	18,150	10.50	23,918	12.28
N.Y.C.	1,162	11.56	3,464	7.40	6,352	7.41	12,285	8.91	18,254	10.56	24,022	12.33
Denver	1,171	11.65	3,474	7.42	6,362	7.42	12,310	8.93	18,305	10.59	24,073	12.36
S.F.	1,204	11.98	3,506	7.49	6,394	7.46	12,376	8.97	18,436	10.66	24,204	12.43
2.0	1,575	8.85	5,678	6.83	10,958	7.20	21,353	8.72	31,605	10.29	41,850	12.10
N.Y.C.	1,604	9.01	5,707	6.87	11,010	7.24	21,457	8.77	31,709	10.32	41,694	12.06
Denver	1,614	9.07	5,717	6.88	11,035	7.26	21,508	8.79	31,760	10.35	42,005	12.15
S.F.	1,646	9.25	5,749	6.92	11,101	7.30	21,639	8.84	31,891	10.39	42,136	12.19
2.5	2,160	7.74	8,708	6.70	16,718	7.03	32,888	8.59	48,900	10.19	64,913	12.01
N.Y.C.	2,189	7.85	8,761	6.74	16,770	7.05	32,992	8.62	49,004	10.21	65,017	12.03
Denver	2,199	7.88	8,785	6.77	16,795	7.06	33,043	8.63	49,055	10.22	65,068	12.04
S.F.	2,231	8.00	8,851	6.81	16,861	7.09	33,174	8.67	49,186	10.25	65,199	12.06
3.0	2,865	7.13	12,233	6.54	23,918	6.99	46,980	8.53	70,043	10.14	93,098	11.96
N.Y.C.	2,894	7.20	12,285	6.57	24,022	7.02	47,084	8.55	70,147	10.15	93,202	11.97
Denver	2,904	7.22	12,310	6.58	24,073	7.03	47,135	8.55	70,198	10.16	93,253	11.98
S.F.	2,936	7.30	12,376	6.61	24,204	7.07	47,266	8.58	70,329	10.18	93,384	12.00

1136455

Table 8

Co 60

The Cost of Co 60 Sources of Various Dimensions

at a Specific Activity of

100 curies/gram or 870 curies per cm^3
Cost of 100 curie/gram sources is $10.00 per
curie plus $100 for the first 2 curies

Source Diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	50	62.50	120	28.57	150	19.74	220	18.03	290	18.83	350	20.11
0.5	260	11.61	940	9.04	1,790	9.42	3,500	11.44	5,200	13.54	6,900	15.97
1.0	760	8.50	3,500	8.72	6,900	9.06	13,740	11.19	20,580	13.38	27,420	15.81
1.5	1,620	8.06	7,760	8.29	15,460	9.02	30,820	11.17	46,200	13.36	61,580	15.80
2.0	2,800	7.86	13,740	8.27	27,420	9.01	54,740	11.18	82,080	13.37	109,400	15.82
2.5	4,360	7.81	21,420	8.24	42,780	8.99	85,500	11.17	128,200	13.36	170,900	15.81
3.0	6,240	7.76	30,820	8.24	61,580	9.00	122,900	11.15	184,580	13.36	246,060	15.80
4.0	11,020	7.72	54,740	8.23	109,400	8.98	218,600	11.15	328,060	13.35	437,400	15.80
5.0	17,160	7.69	85,960	8.26	170,900	8.98	341,600	11.15	512,560	13.35	683,380	15.79

1136456

Table 8A

100 Curies/Gram or 870 Curies/cm^3

source diameter cm	0.1 cm length cost in $		0.5 cm length cost in $		1 cm length cost in $		2 cm length cost in $		3 cm length cost in $		4 cm length cost in $	
	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm	per source	per rhm
0.1	520	650.00	640	152.38	670	88.16	740	60.66	810	52.60	870	50.00
N.Y.C.	549	686.25	669	159.29	699	91.97	769	63.03	839	54.48	899	51.67
Denver	559	698.75	679	161.67	709	93.29	779	63.85	849	55.13	909	52.24
S.F.	591	738.75	711	169.29	741	97.50	811	66.48	881	57.21	941	54.08
0.5	780	34.82	1,460	14.04	2,310	12.16	4,020	13.14	5,720	14.90	7,420	17.18
N.Y.C.	809	36.12	1,489	14.32	2,339	12.31	4,049	13.23	5,749	14.97	7,449	17.24
Denver	810	36.16	1,499	14.41	2,349	12.36	4,059	13.26	5,759	15.00	7,459	17.27
S.F.	851	37.99	1,531	14.72	2,381	12.53	4,091	13.37	5,791	15.08	7,491	17.34
1.0	1,280	14.32	4,020	10.01	7,420	9.74	14,410	11.73	21,400	13.91	28,240	16.29
N.Y.C.	1,309	14.64	4,049	10.08	7,449	9.78	14,462	11.78	21,504	13.98	28,344	16.35
Denver	1,319	14.75	4,059	10.11	7,459	9.79	14,487	11.80	21,555	14.01	28,395	16.38
S.F.	1,351	15.11	4,091	10.19	7,491	9.83	14,553	11.85	21,686	14.10	28,526	16.45
1.5	2,140	10.65	8,280	8.85	16,130	9.41	31,640	11.47	47,020	13.60	62,400	16.02
N.Y.C.	2,169	10.79	8,309	8.88	16,182	9.44	31,744	11.51	47,124	13.63	62,504	16.04
Denver	2,179	10.84	8,319	8.89	16,207	9.46	31,795	11.53	47,175	13.64	62,555	16.06
S.F.	2,211	11.00	8,351	8.92	16,273	9.49	31,926	11.58	48,306	13.97	62,686	16.09
2.0	3,320	9.33	14,410	8.67	28,240	9.28	55,560	11.35	82,900	13.50	110,220	15.94
N.Y.C.	3,349	9.41	14,462	8.70	28,344	9.32	55,664	11.37	83,004	13.52	110,324	15.95
Denver	3,359	9.44	14,487	8.72	28,395	9.33	55,715	11.38	83,055	13.53	110,375	15.96
S.F.	3,391	9.53	14,553	8.76	28,526	9.38	55,846	11.41	83,186	13.55	110,506	15.98
2.5	4,880	8.75	22,240	8.55	43,600	9.17	86,320	11.28	129,020	13.45	171,720	15.88
N.Y.C.	4,909	8.80	22,344	8.59	43,704	9.19	86,424	11.29	129,124	13.46	171,824	15.8
Denver	4,919	8.82	22,395	8.61	43,755	9.20	86,475	11.30	129,175	13.46	171,875	15.90
S.F.	4,951	8.87	22,526	8.66	43,886	9.23	86,606	11.32	129,306	13.47	172,006	15.91
3.0	6,760	8.41	31,640	8.46	62,400	9.11	123,720	11.23	185,400	13.42	246,880	15.86
N.Y.C.	6,789	8.44	31,744	8.48	62,504	9.13	123,824	11.24	185,504	13.43	246,984	15.86
Denver	6,799	8.46	31,795	8.50	62,555	9.14	123,875	11.24	185,555	13.43	247,035	15.87
S.F.	6,831	8.50	31,926	8.53	62,686	9.16	124,006	11.25	185,686	13.44	247,166	15.88

1136457

Table 9

Data for 1.0 cm diameter rod; cross sectional area = 0.7854
density of Co 60 is assumed to be 8.7 grams/cm^3

length cm	volume cm^3	total curies at various specific activities											fractional transmission
		1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g	
0.1	0.078	0.68	3.39	6.8	7.5	20.4	21.0	33.9	34.6	47	48	68	0.970
0.5	0.393	3.42	17.10	34.2	37.6	102.6	106.0	171.0	174.4	239	243	342	0.900
1	0.785	6.83	34.15	68.3	75.1	204.9	211.7	341.5	348.3	478	485	683	0.825
2	1.571	13.67	68.34	136.7	150.3	410.0	423.7	683.4	697.1	957	970	1367	0.664
3	2.356	20.50	102.49	205.0	225.5	614.9	635.4	1024.9	1045.4	1435	1455	2050	0.555
4	3.142	27.34	136.68	273.4	300.7	820.1	847.4	1366.8	1394.1	1913	1941	2734	0.469

length cm	rhm at various specific activities										
	1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g
0.1	0.9	4.4	8.9	9.8	26.7	27.5	44.4	45.3	61.5	62.8	89.0
0.5	4.2	20.8	41.6	45.7	124.6	128.8	207.8	211.9	290.4	295.2	415.5
1	7.6	38.0	76.1	83.6	228.2	235.8	380.3	387.9	532.4	540.2	760.7
2	12.2	61.2	122.5	134.7	367.5	379.8	612.6	624.9	857.8	869.5	1225.4
3	15.4	76.8	153.6	169.0	460.7	476.1	767.9	783.3	1075.2	1090.2	1536.0
4	17.3	86.5	173.1	190.4	519.2	536.5	865.4	882.7	1211.2	1228.9	1731.0

Table 10

Data for 1.5 cm diameter rod; cross sectional area = 1.7671
density of Co 60 is assumed to be 8.7 grams/cm^3

length cm	volume cm^3	total curies at various specific activities											fractional transmission
		1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g	
0.1	0.1767	1.54	7.69	15.37	16.91	46.1	47.6	76.9	78.4	107	109	154	.970
0.5	0.8836	7.69	38.44	76.87	84.56	230.6	238.3	384.4	392.0	538	546	769	.900
1	1.7672	15.37	76.87	153.75	169.12	461.2	476.6	768.7	784.1	1076	1092	1537	.825
2	3.5343	30.75	153.74	307.48	338.23	922.4	953.2	1537.4	1568.2	2152	2183	3075	.664
3	5.3015	46.12	230.62	461.23	507.35	1383.7	1429.8	2306.2	2352.3	3229	3275	4612	.555
4	7.0686	61.50	307.48	614.97	676.46	1844.9	1906.4	3074.8	3136.3	4305	4366	6150	.469

length cm	rhm at various specific activities										
	1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g
0.1	2.0	10.1	20.1	22.1	60.4	62.3	100.7	102.7	140.1	142.7	201.7
0.5	9.3	46.7	93.4	100.0	280.2	289.5	467.0	476.3	653.8	663.4	934.3
1	17.1	85.6	171.2	188.4	513.7	530.9	856.1	873.3	1198.4	1216.2	1711.8
2	27.6	137.8	275.6	303.2	826.8	854.4	1378.1	1405.7	1929.0	1956.8	2756.4
3	34.6	172.8	345.6	380.1	1036.7	1071.3	1727.9	1762.5	2419.3	2453.8	3677.5
4	38.9	194.7	389.4	428.3	1168.1	1207.0	1946.8	1985.7	2725.7	2764.3	3893.9

1136459

Table 11

Data for 2 cm diameter rod; cross sectional area = 3.1416 cm^2
density of Co 60 is assumed to be 8.7 grams/cm^3

length cm	volume cm^3	total curies at various specific activities											fractional transmission
		1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g	
0.1	0.314	2.73	13.66	27.3	30.5	82.0	84.7	137	139	191	194	273	.970
0.5	1.571	13.67	68.34	136.7	150.3	410.0	423.7	683	697	957	970	1367	.900
1	3.141	27.33	136.63	273.3	300.6	819.8	847.1	1366	1394	1913	1940	2733	.825
2	6.283	54.66	273.31	546.6	601.3	1639.9	1694.5	2733	2788	3826	3881	5466	.664
3	9.425	82.00	409.99	820.0	902.0	2459.9	2541.9	4100	4132	5740	5822	8200	.555
4	12.566	109.32	546.62	1093.2	1202.6	3279.7	3389.1	5466	5576	7653	7762	10932	.469

length cm	rhm at various specific activities										
	1 c/g	5 c/g	10 c/g	11 c/g	30 c/g	31 c/g	50 c/g	51 c/g	70 c/g	71 c/g	100 c/g
0.1	3.6	17.9	35.7	39.9	107	111	179	182	250	254	357
0.5	16.6	83.0	166	183	498	515	830	847	1163	1179	1661
1	30.4	152	305	335	913	943	1521	1553	2130	2161	3044
2	49.0	245	490	539	1470	1519	2450	2499	3430	3479	4900
3	61.4	307	614	676	1843	1905	3072	3133	4301	4362	6140
4	69.2	346	692	761	2077	2146	3461	3530	4845	4915	6922

1136460

Table 11A

Cost of 2 cm Diameter Rod*

length cm	specific activities - curies per gram										
	1c/g	5c/g	10c/g	11c/g	30c/g	31c/g	50c/g	51c/g	70c/g	71c/g	100c/g
0.1	105 554	160 609	230 679	367 816	750 1199	772 1221	1162 1611	1570 2019	2090 2539	2120 2569	2910 3359
0.5	160 609	435 884	775 1224	1267 1716	3210 3659	3315 3764	5257 5706	7150 7599	9750 10372	9880 10502	13850 14472
1	230 679	775 1224	1460 1909	2392 2841	6285 6907	6495 7117	10380 11002	14120 14742	19310 19932	19580 20202	27510 28334
2	365 814	1460 1909	2825 3274	4650 5099	12435 13057	12847 13469	20632 21456	28060 28884	38440 39264	38990 39814	54840 55664
3	500 949	2040 2489	4190 4812	6900 7522	18585 19409	19300 20124	30885 31709	42000 42824	57580 58404	58400 59224	82200 83024
4	640 1089	2825 3274	5560 6182	9157 9779	24735 25559	25560 26384	41130 41954	55940 56764	76710 77534	77800 78624	109500 110324

* Cost on top line is for source alone. Cost on second line is for encapsulated source delivered to New York City.

$/rhm

length cm	1c/g	5c/g	10c/g	11c/g	30c/g	31c/g	50c/g	51c/g	70c/g	71c/g	100c/g
0.1	153.89	34.02	19.02	20.45	11.21	11.00	9.00	11.09	10.16	10.11	9.41
0.5	36.69	10.65	7.37	9.38	7.35	7.31	6.87	8.97	8.92	8.91	8.71
1	22.34	8.05	6.26	8.48	7.57	7.54	7.23	9.49	9.36	9.35	9.31
2	16.61	7.79	6.68	9.46	8.88	8.87	8.76	11.56	11.45	11.44	11.36
3	15.46	8.11	7.84	11.13	10.53	10.56	10.32	13.67	13.58	13.58	13.52
4	15.74	9.46	8.93	12.84	12.31	12.29	12.12	16.08	16.00	16.00	15.94

curies

1-10 = $100 for first 2 curies plus $5 per curie for each additional curie or fraction thereof.

11-50 = $150 for first 2 curies plus $7.50 per curie for each additional curie or fraction thereof.

51-100 = $200 for first 2 curies plus $10.00 per curie for each additional curie or fraction thereof.

Handling charges include shipment to New York City
- $449 up to 750 curies
- $622 up to 2000 curies
- $824 over 2000 curies

1136461

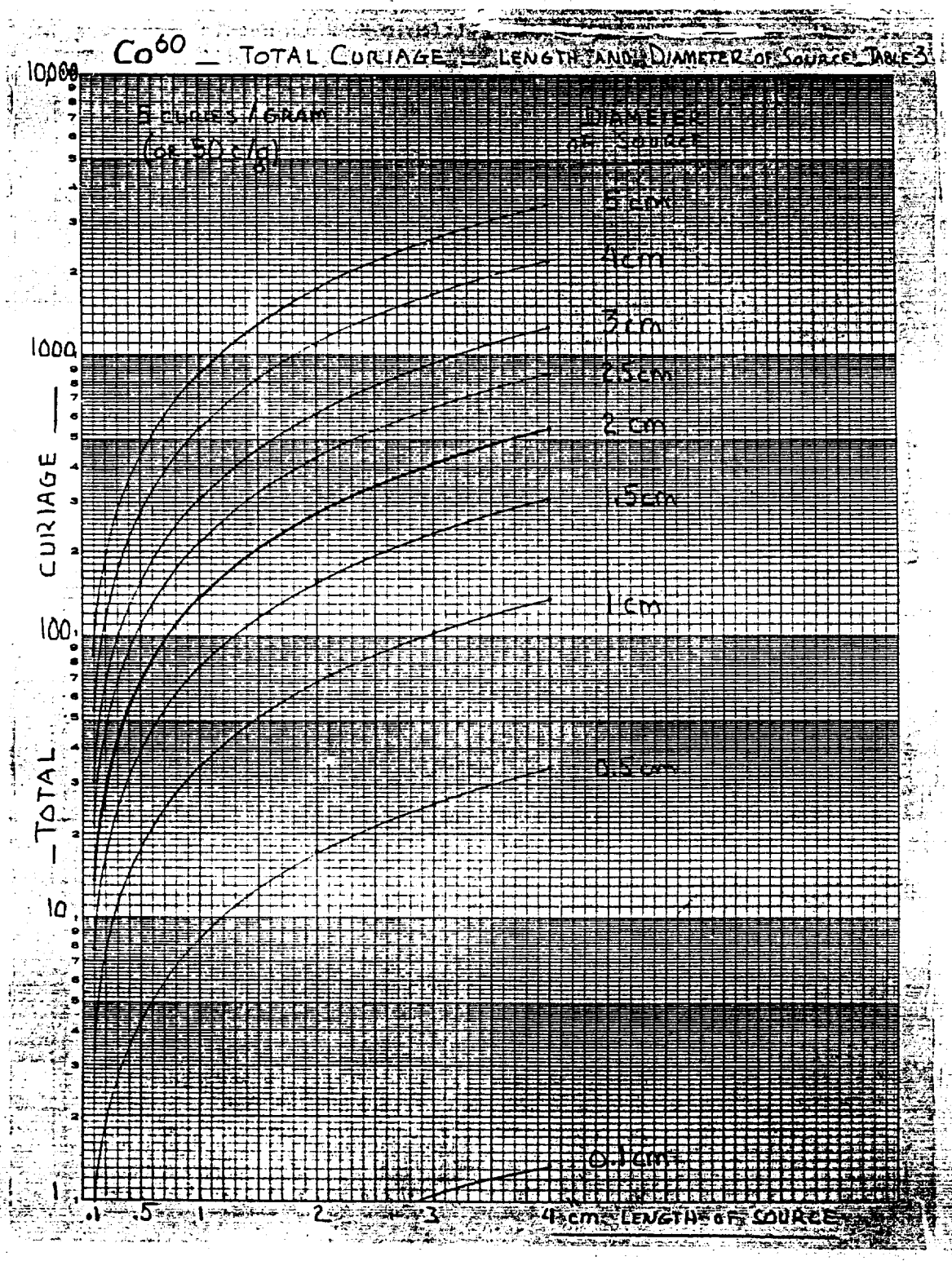


Figure 1

1136462

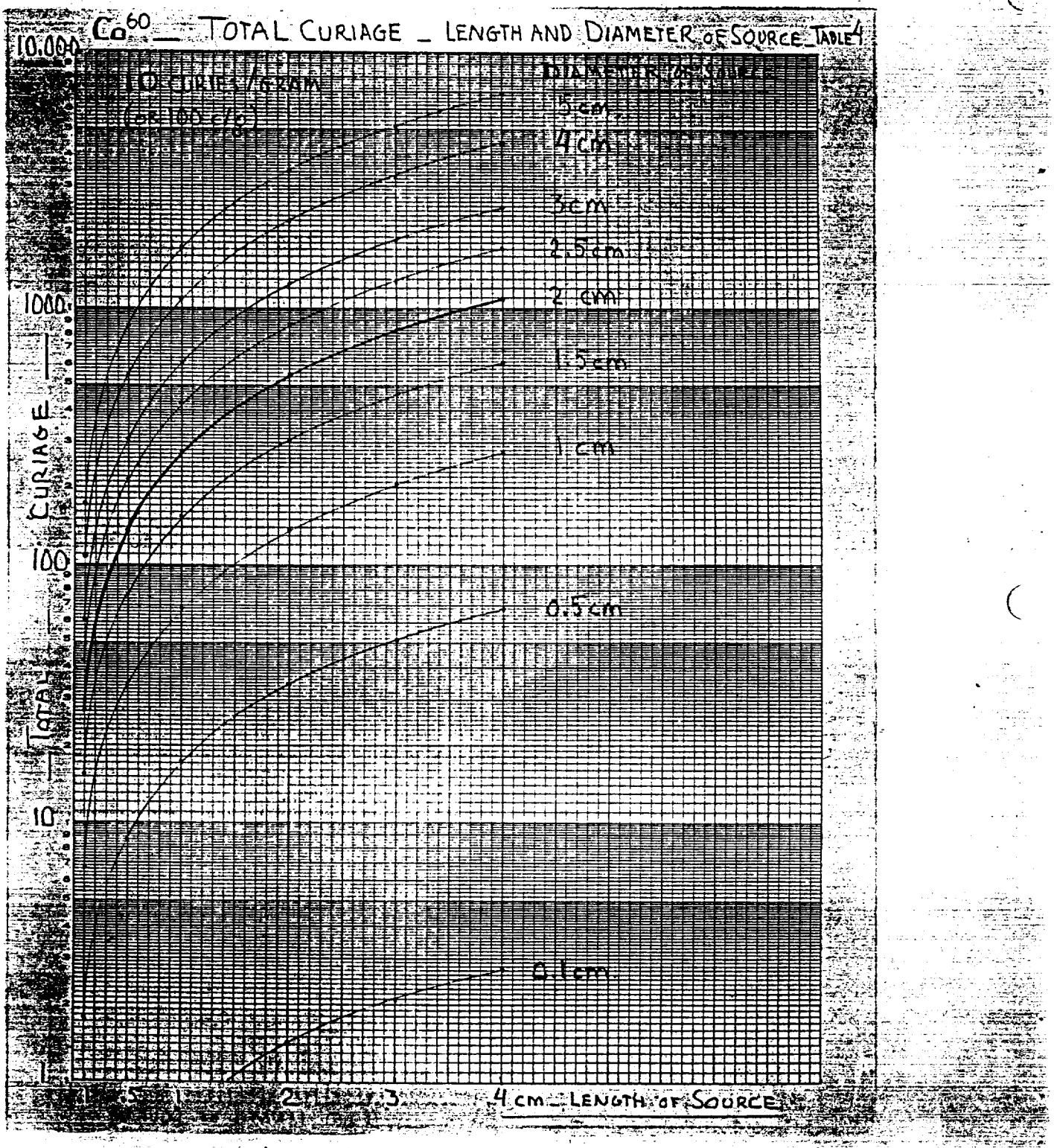

Co60 — TOTAL CURIAGE — LENGTH AND DIAMETER OF SOURCE TABLE 4
10 CURIES/GRAM
(OR 100 C/G)
DIAMETER OF SOURCE
5 cm
4 cm
3 cm
2.5 cm
2 cm
1.5 cm
1 cm
0.5 cm
0.1 cm
10,000
1000
100
10
1
TOTAL CURIAGE
1
2
3
4 cm — LENGTH OF SOURCE

Figure 2

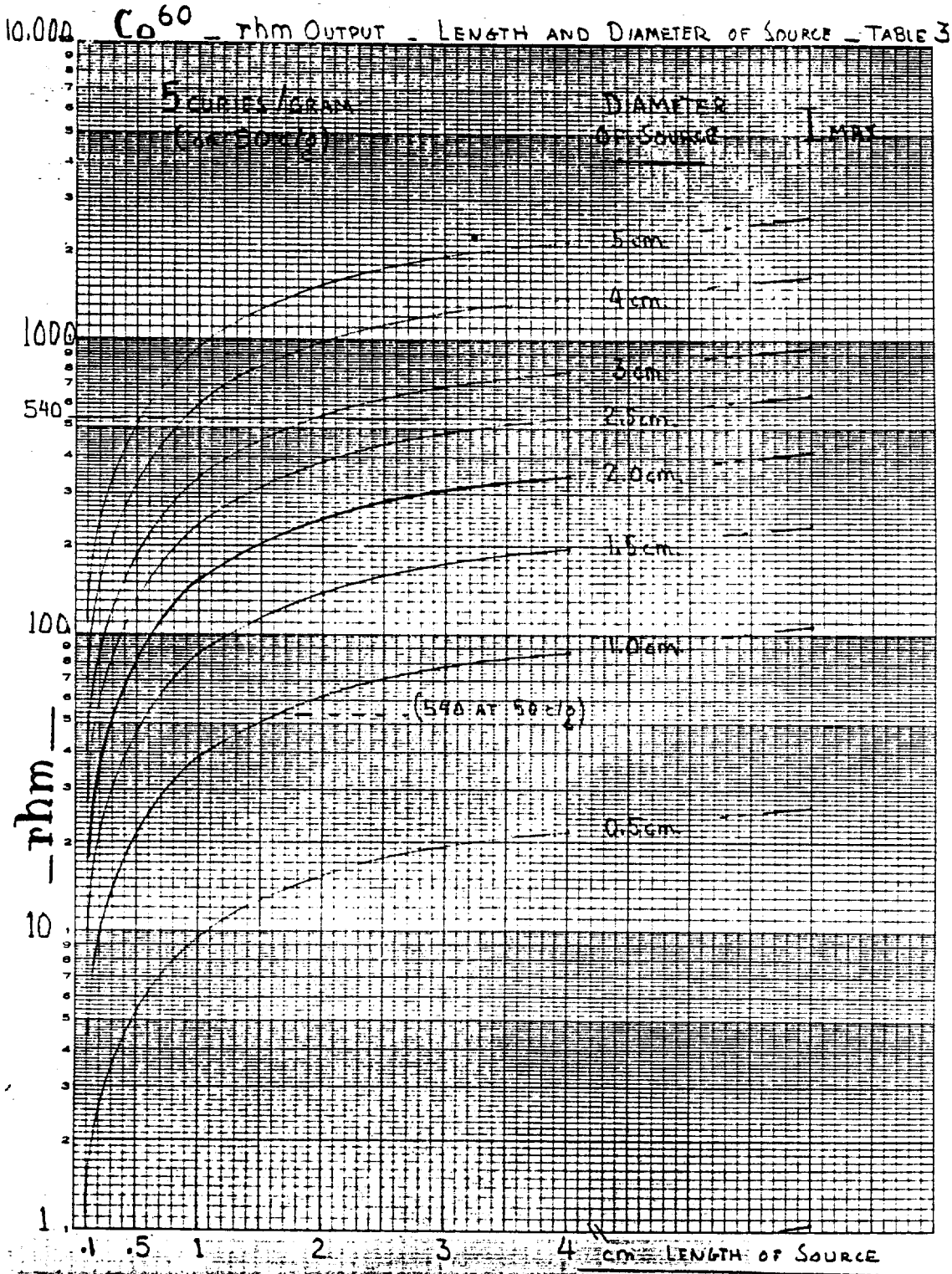


Figure 3

1136464

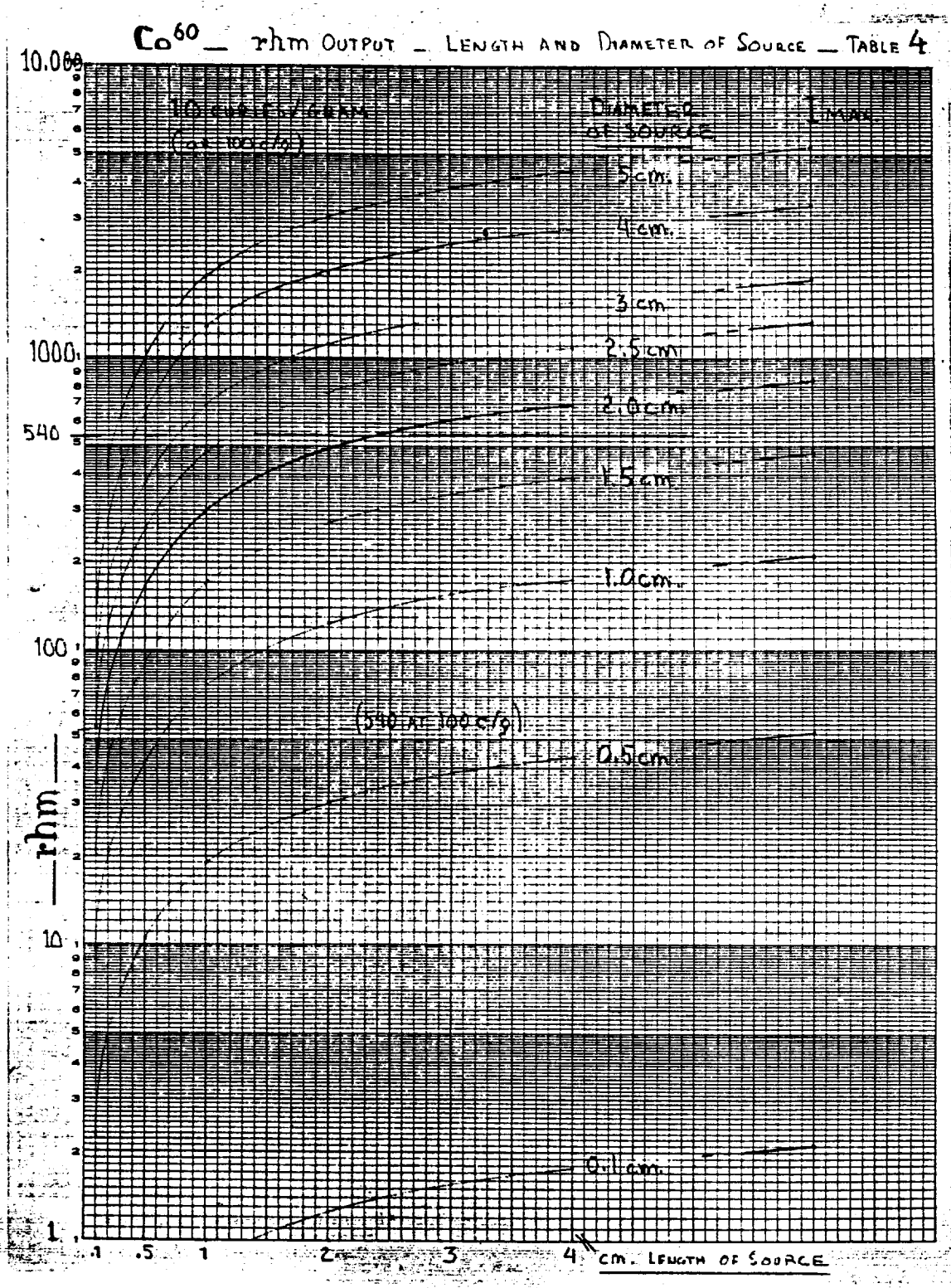
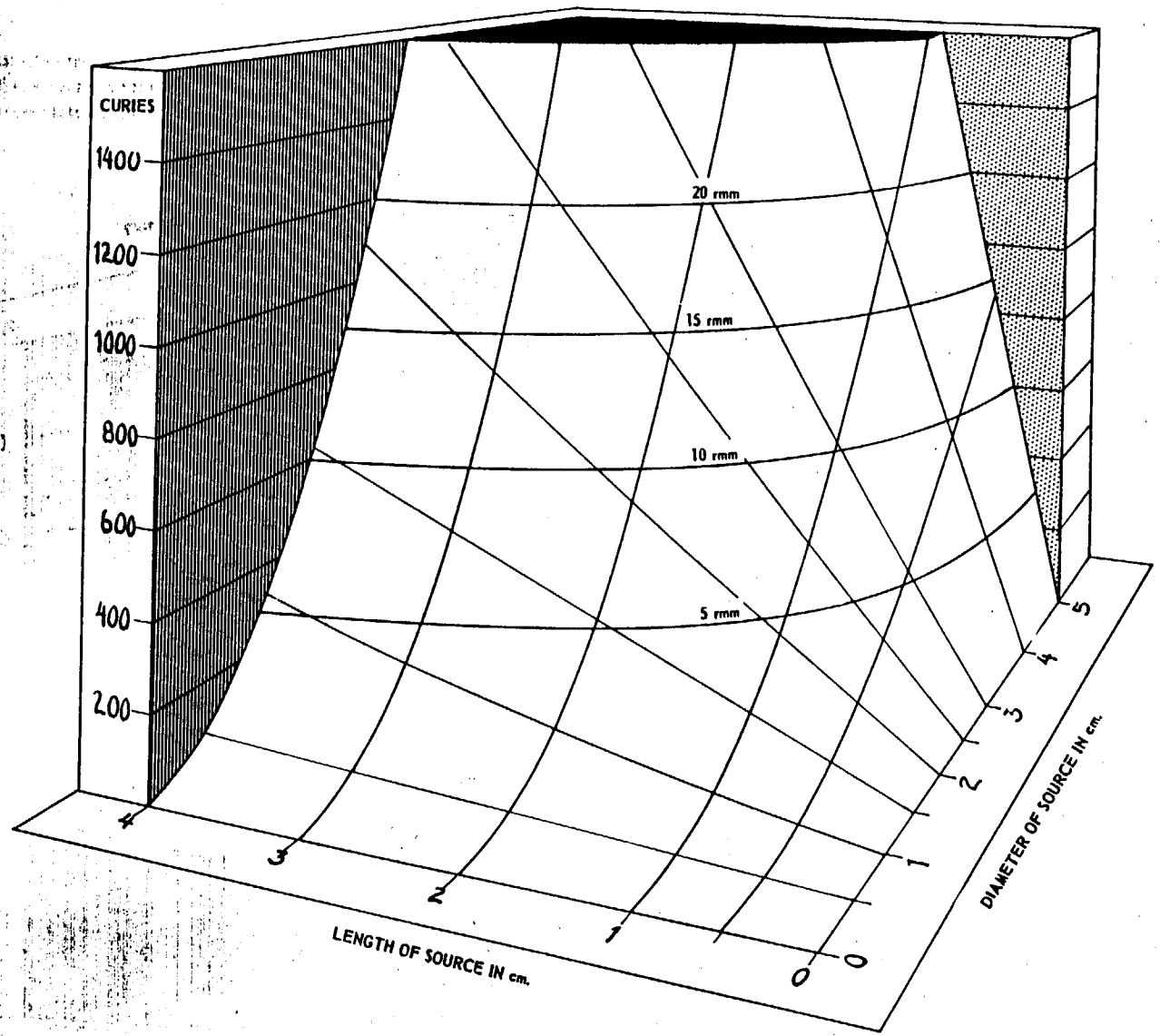


Figure 4

1136465



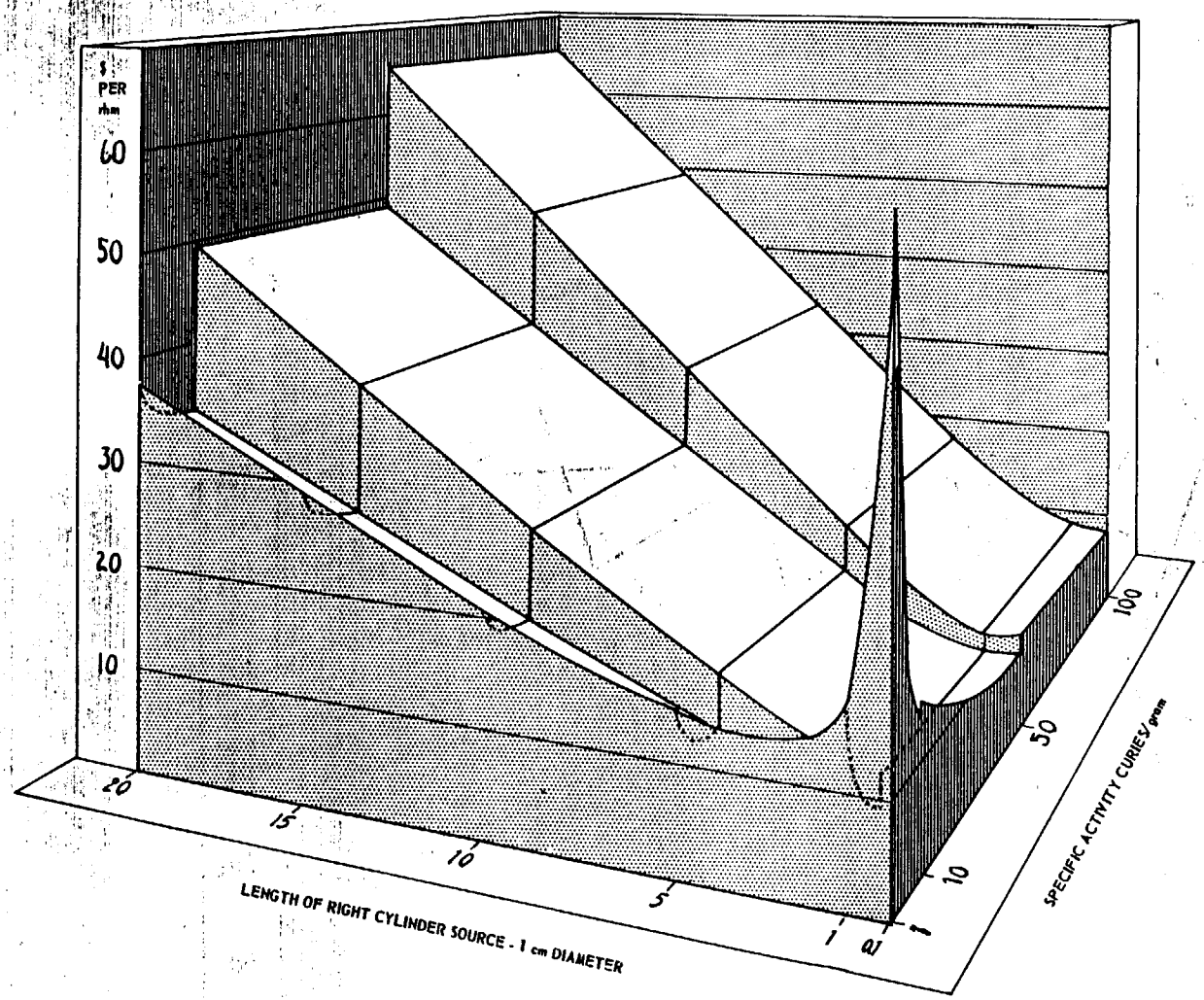
VOLUME. IN CURIES, OF CO^{60} IN A RIGHT CYLINDRICAL SOURCE WITH RADIATION OUTPUT LEVELS

Figure 5

1136466

Co^{60}

THE EFFECT OF SOURCE LENGTH AND SPECIFIC ACTIVITY ON THE COST OF RADIATION FROM Co^{60}



1-10 c/gm = $5.00/c-2 + $100
10-50 c/gm = $7.50/c-2 + $100
50-100 c/gm = $10.00/c-2 + $100

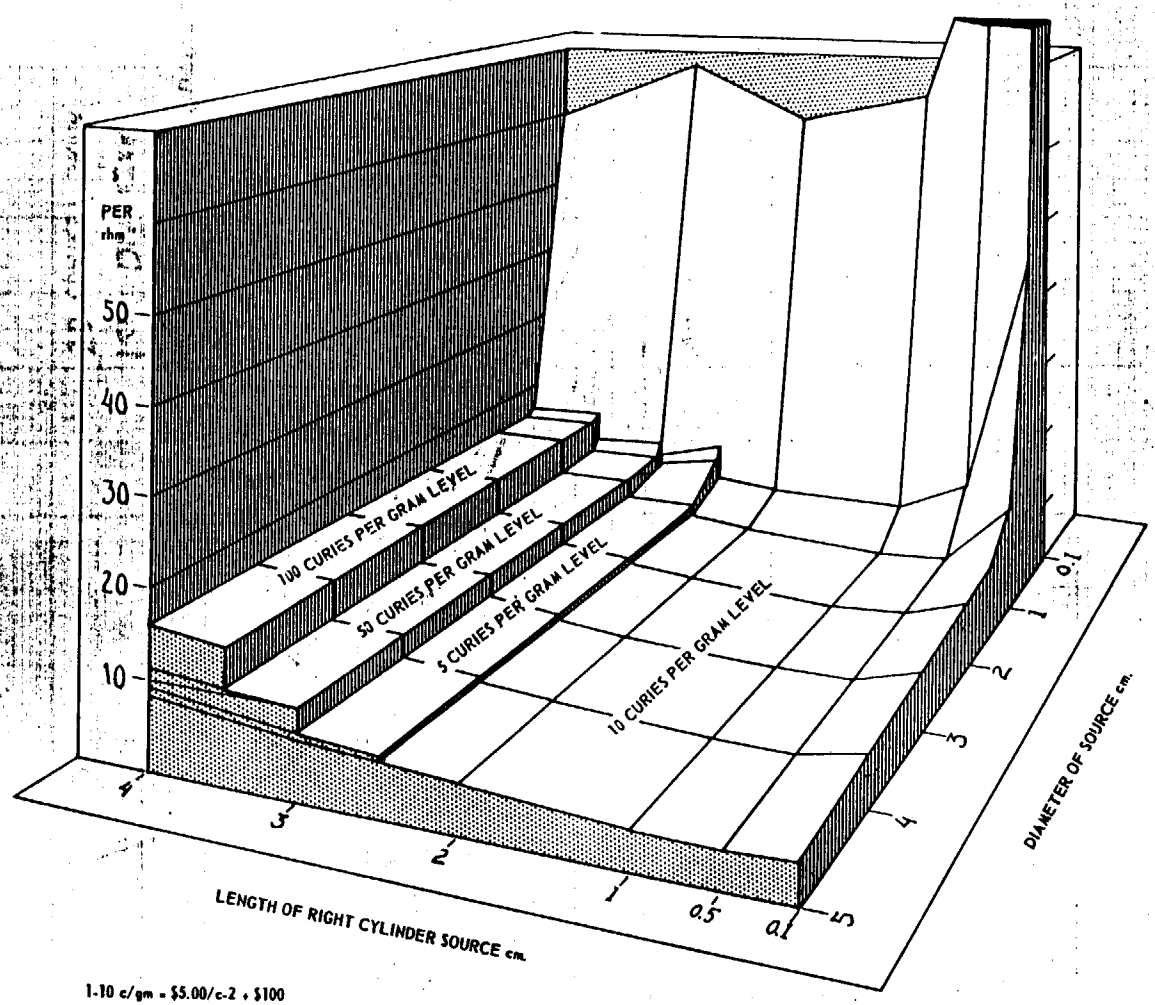
Figure 6

1136467

CO^{60}

THE EFFECT OF SOURCE DIAMETER AND LENGTH
ON THE COST OF RADIATION FROM CO^{60}

THE LEVEL FOR SPECIFIC ACTIVITY OF 10 CURIES PER GRAM IS SHOWN COMPLETE
THE LEVELS FOR SPECIFIC ACTIVITIES OF 5, 50 AND 100 CURIES PER GRAM IS SHOWN IN PART



1-10 c/gm = \$5.00/c-2 + \$100
10-50 c/gm = \$7.50/c-2 + \$100
50-100 c/gm = \$10.00/c-2 + \$100

Figure 7

1136468

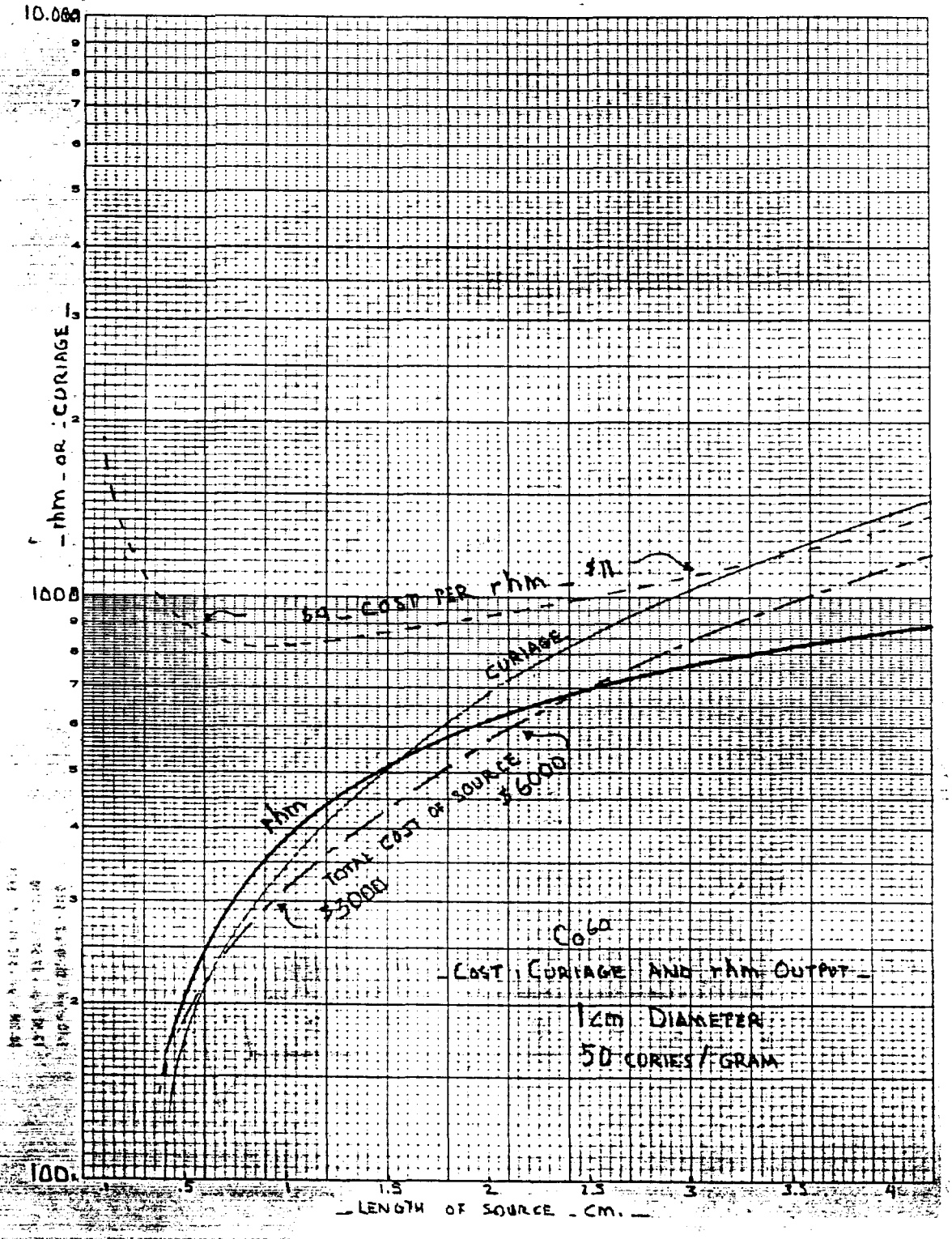


Figure 8

1136469

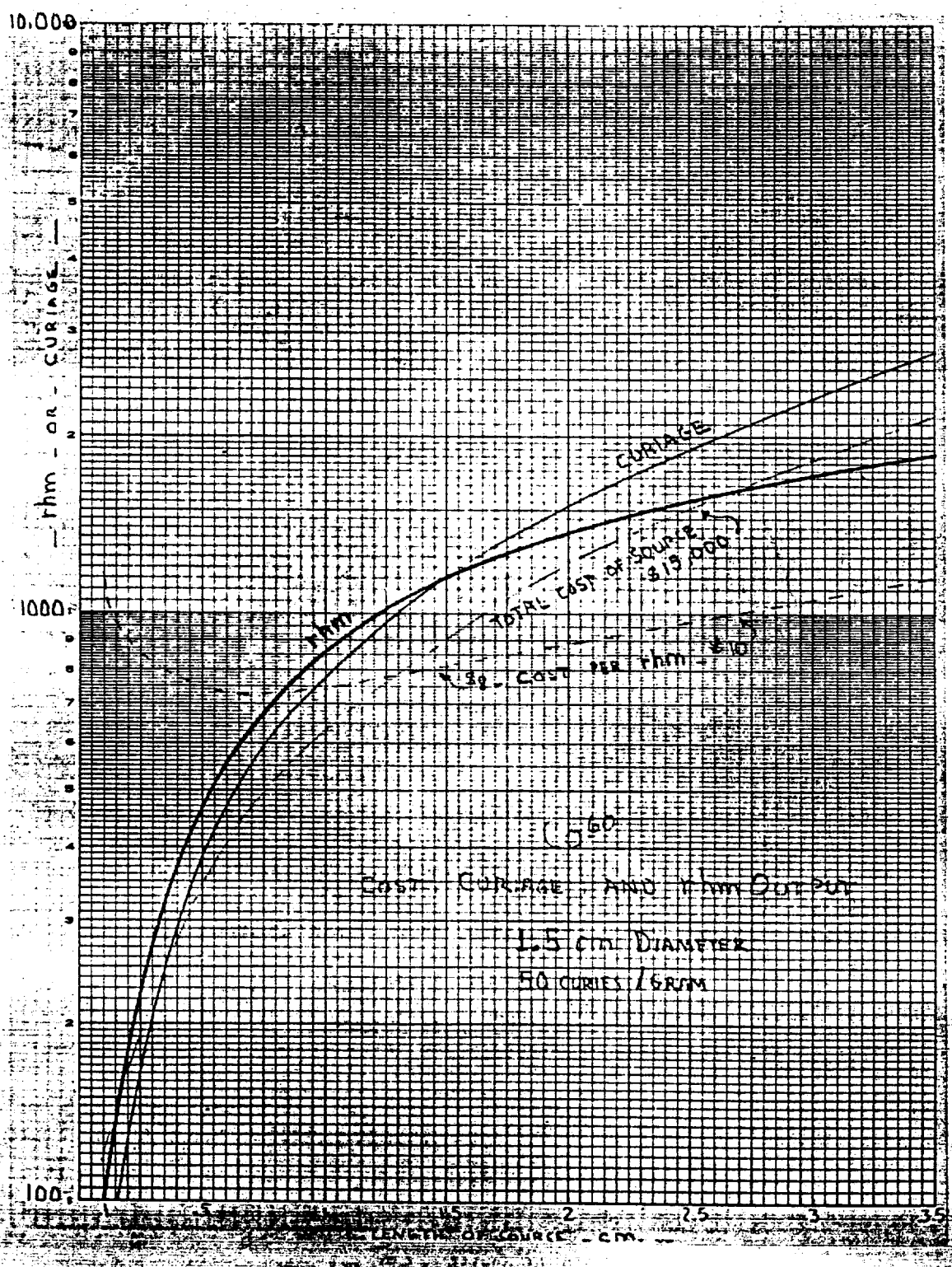


Figure 9

1136470

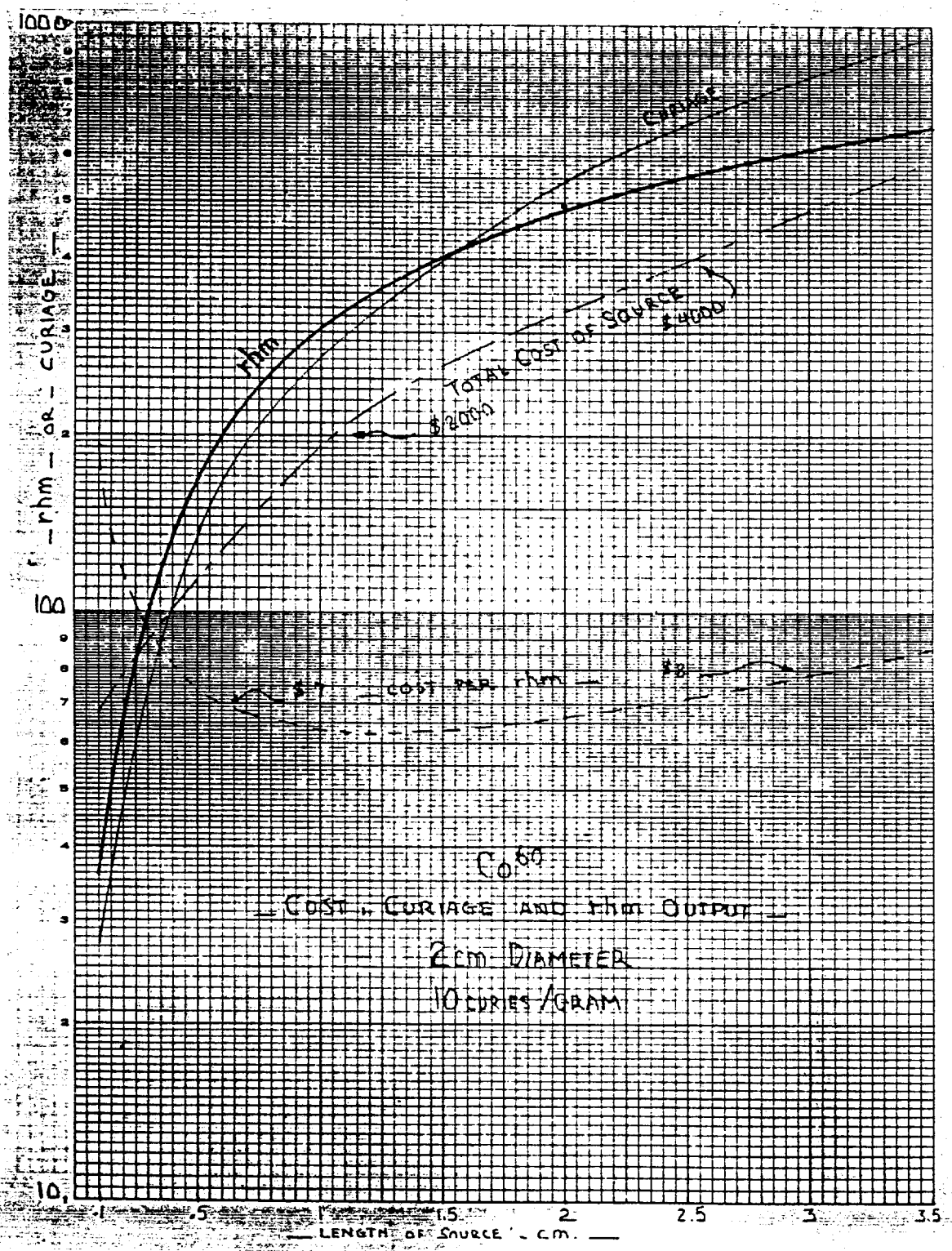

1000
100
10
r - rhm - or - CURIAGE
rhm
CURIAGE
TOTAL COST OF SOURCE
$4600
$2000
$7
COST PER rhm
$8
Co 60
COST - CURIAGE AND rhm OUTPUT
2 cm DIAMETER
10 CURIES/GRAM
.5
1
1.5
2
2.5
3
3.5
LENGTH OF SOURCE - cm.

Figure 10

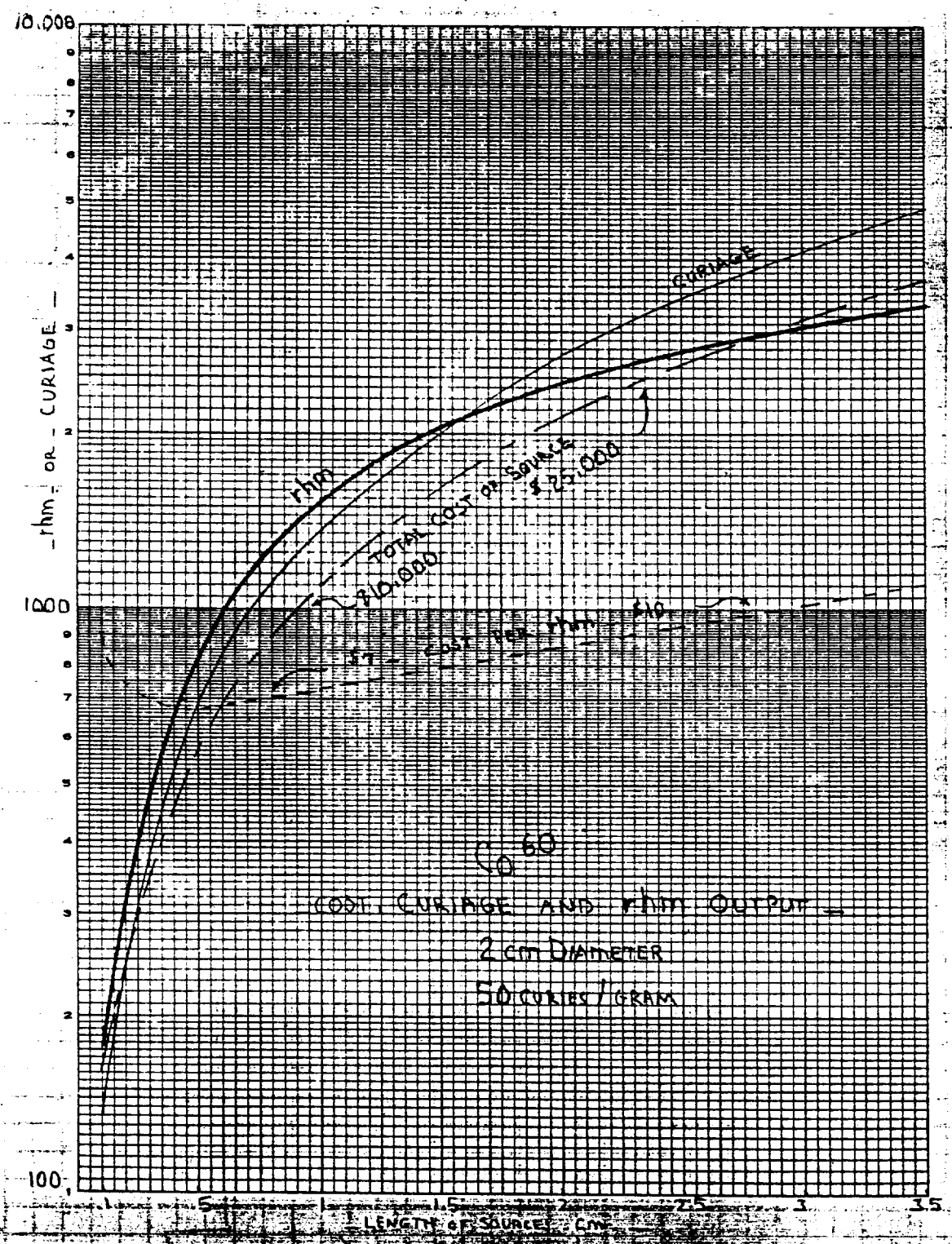


Figure 11

1136472

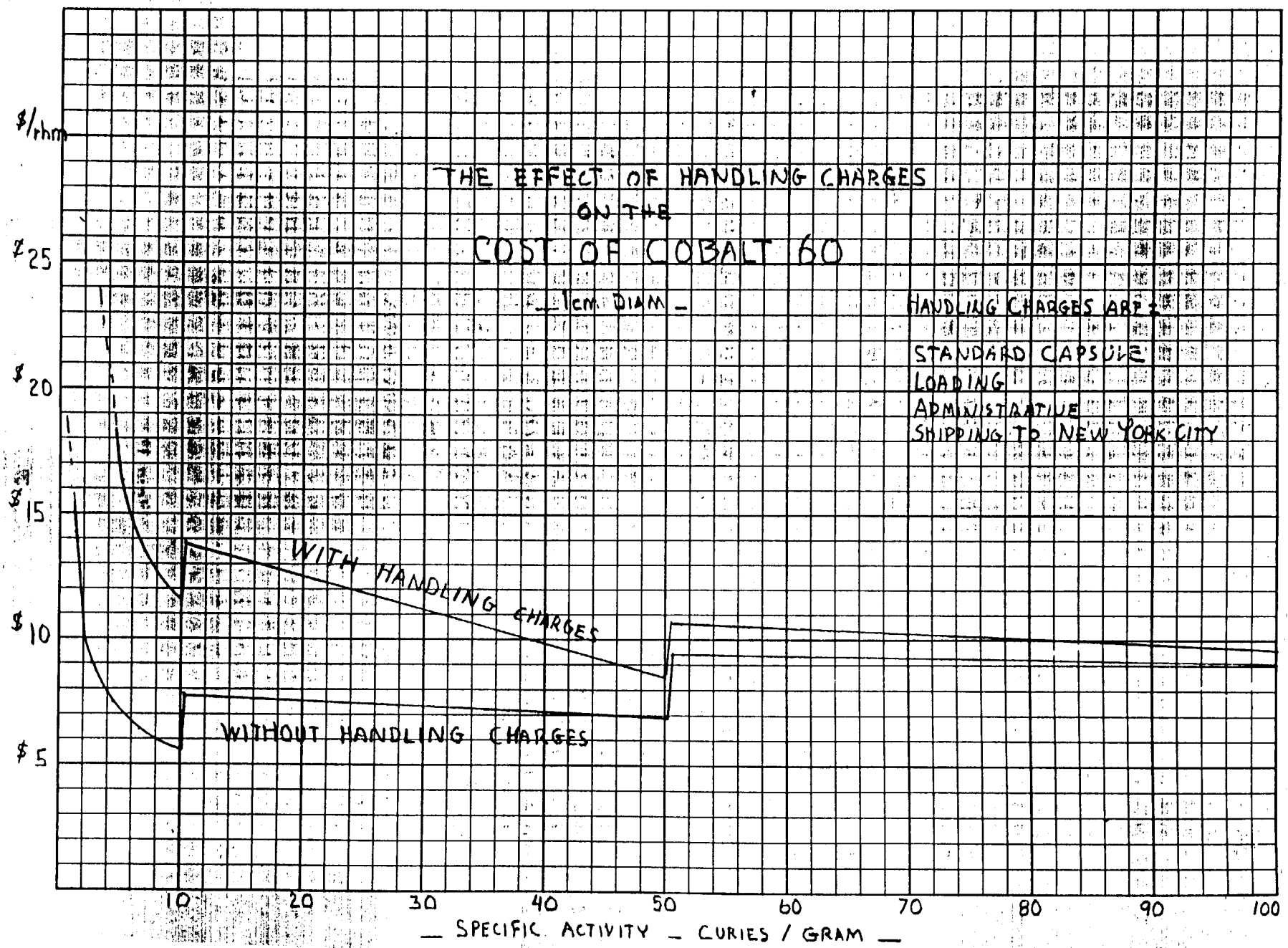


Figure 12

1136473

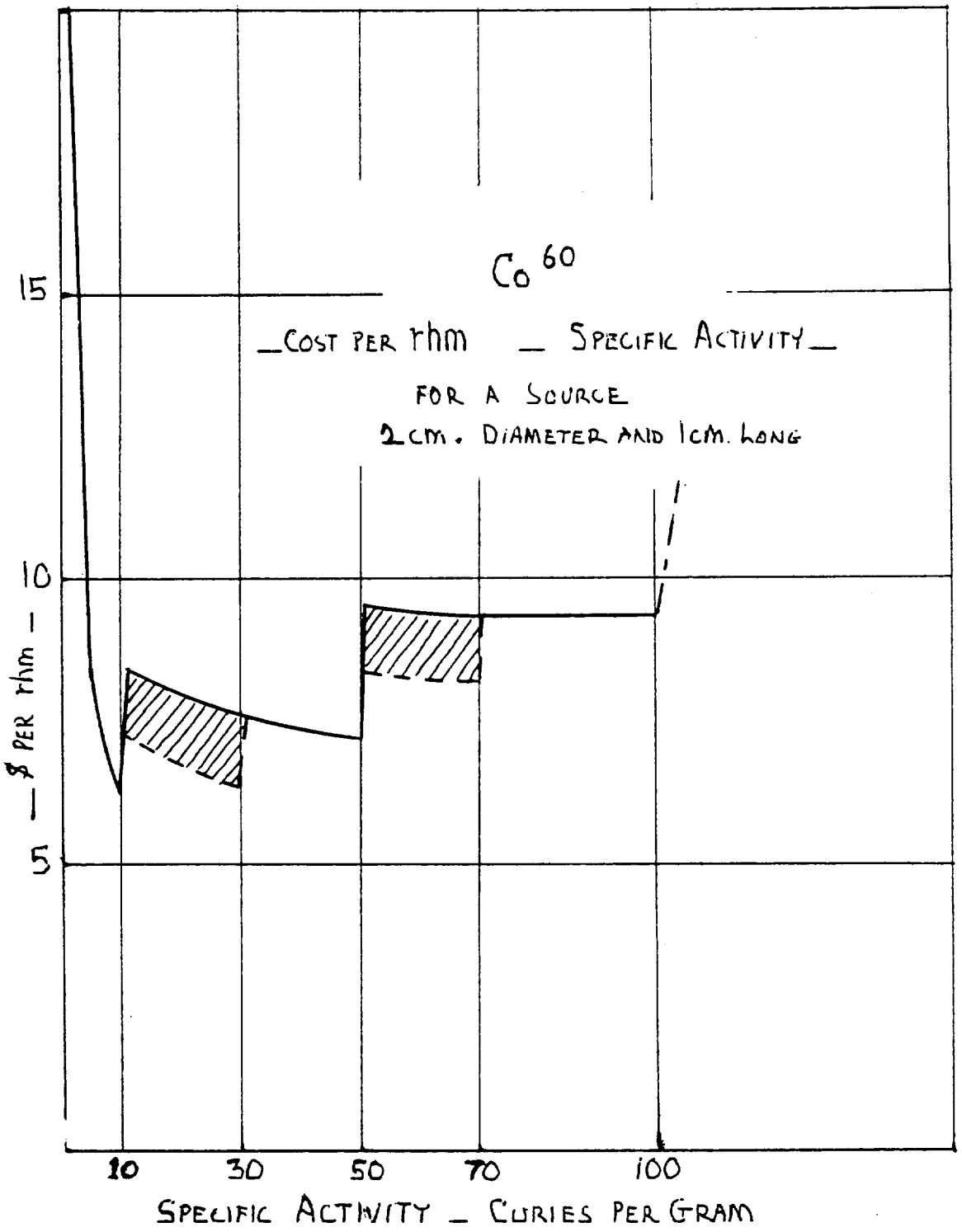


Figure 13

1136474

A STANDARD COBALT 60 TELETHERAPY SOURCE CAPSULE*

Prior to 1953, the design and construction of a cobalt 60 teletherapy machine was a highly individualized research project. The immediate and widespread recognition of the value of cobalt 60 has lead to many diversified and ingenious designs both here and in Europe. During the past year, several X-ray companies have selected designs for teletherapy machines suitable for commercial production. In each machine, whatever its design, there must be a source capsule to seal the raw cobalt 60, and the characteristics of this capsule are related to the economic problems of the source itself.

Cobalt 60 must be produced in a nuclear reactor. For multicurie sources relatively large volumes of cobalt are used, and if this cobalt is incorrectly placed in the reactor, it can stop the chain reaction. Although the shapes and sizes of cobalt 60 sources that can be used are manifold, the characteristics of neutron irradiation make small pieces essential. Since each source must stay in a reactor for a year or so, and since each separate piece comes out of the reactor with exceedingly high activity, the problems of production, handling, loading, sealing, and avoiding contamination make the manufacture of a cobalt 60 source a surprisingly complex technological problem. Because of the necessity for special remote handling tools, economy has dictated a small number of standard source sizes. For various reasons the two producers of high curiage cobalt 60 - Atomic Energy of Canada Limited and the United States Atomic Energy Commission - have chosen a limited variety of sizes ranging from small pellets to wafers 2 cm in diameter. With these standard sizes, it is possible to devise high activity sources of almost any required number of curies.

The problems of loading a series of pieces of cobalt 60 so that they can be used as a teletherapy source presents an additional serious problem requiring specialized tools and equipment. The National Committee on Radiation Protection, Subcommittee No. 9, has recently devised and will soon publish in Handbook 54 the results of its study on how cobalt 60 can be "safely" encapsulated. There is, therefore, an accepted standard for encapsulation of sources.

Since a cobalt 60 source decays to half its output in a little over five years, a therapist starting out with a kilocurie source will ultimately have a source too "cold" for his own machine but still containing a large number of curies. Since the capital investment is based upon the number of curies originally present, a partially decayed source that is no longer usable represents a sizable investment in wasted curies. Can such a source be re-irradiated in a reactor for half the original cost? The United States Atomic Energy Commission points out that reactors are designed to admit "cold" pieces and discharge "hot" pieces. A modification of the reactor to permit admission of "hot" pieces (and a partially decayed teletherapy source is still very "hot") limits the adaptability of the reactor and is exceedingly expensive. It is the United States Atomic Energy Commission's position that it is cheaper to start with inactive cobalt for each source even if it is necessary to discard many curies of cobalt 60. Since teletherapy is only a small part of the total benefit (and expense) of a high flux reactor, the therapist must accede to this judgment. It appears that in a few years there will be a problem of what to do with half-strength cobalt 60 sources.

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* The design presented here represents the combined efforts of many representatives of the organizations listed.

1136475

The Canadians, with a different set of priorities and for reasons just as valid, have demurred at this point and believe that it is possible to re-irradiate partially decayed sources.

When only very high curiage cobalt 60 machines were considered, the problem of the partially decayed source was an important factor in the economy of cobalt 60. One paid for twice as much as he could use. Recently, however, the Teletherapy Evaluation Board has developed a cobalt 60 machine that is designed for a maximum of 600 curies. This machine can use the sources that are no longer useful in kilocurie machines. The design of a 200 curie machine is also planned. A few machines in the 50 to 100 curie range have already been constructed. The possibility of the industrial use of lower curiage sources is as yet unexplored. If sources could be transferred conveniently from one machine to another, the cobalt 60 would maintain a decreasing but considerable value and the effective economic half life of the isotope could be extended from five years to 20 or 30 years.

For sources to be transferred from one machine to another, they must now be unloaded from a well-sealed capsule and reloaded. This is a technical problem of considerable magnitude and may easily cost more than it is worth. There is an easier and cheaper answer. The standardization of a capsule for all sources of cobalt 60 of all sizes and curiages would allow each one to be transferred in its capsule from machine to machine with no more than a handling charge. In October 1953, the representatives from 14 X-ray equipment manufacturers met with the Isotopes Division of the United States Atomic Energy Commission, Atomic Energy of Canada Limited, and the Oak Ridge National Laboratory at the ORINS Medical Division for a discussion of the current problems of teletherapy. It was decided at this meeting, after a review of the advantages and disadvantages of standardization, that it was to the best interests of the therapist, the industry, and the manufacturers of cobalt 60 that a source capsule for teletherapy machines be standardized. It was felt that there had been sufficient experience with encapsulation of high energy sources to permit design of a capsule that would meet every requirement of the therapist, the reactor technician, and the manufacturer. In November a special meeting was held, and by subsequent correspondence such a capsule was designed. The now accepted standard source capsule is shown in Figure 14, Page 46. It consists of five separate pieces: a tungsten alloy cap and plug, a stainless steel cup, and two lead wire seals. The over-all size of the capsule is a right cylinder 2 inches in diameter by 1 5/8 inches long. Detailed drawings of the capsule are shown in Figures 15-21, Pages 47-53. The standard cobalt 60 source capsule is designed to meet the following requirements:

1. Size of Source: The standard cobalt 60 source capsule must be adaptable to all projected source sizes of Canada and the United States. The largest Canadian source is a right cylinder 3 cm in diameter by 3 cm high. This maximum dimension fixed the inside dimensions of the capsule, since all sizes of projected cobalt 60 wafers of the United States can be accommodated within this space.

2. Activity of Source: The capsule must be able to contain the largest number of curies feasible for expected teletherapy use. Based upon material having a specific activity of 50 curies/gram, which is now obtainable, the design accommodates a total activity of more than 4,000 curies of cobalt 60.

3. Material of Capsule: The capsule must in itself be a part of the primary radiation shield since it is in the most economical position for shielding. All of the materials less dense and with lower atomic number than tungsten were discarded for obvious reasons. The platinum metals and gold were discarded because of high cost. Permission to use uranium was granted by the United States Atomic Energy Commission but this material was rejected by the industry. It was believed that the high cost and difficulties

in fabrication of uranium more than outweighed its slight advantage over tungsten alloy as a radiation shield. In the present design, tungsten alloy completely surrounds the source except in the direction of the primary beam. In the directions immediately adjacent to the primary beam, there is a particularly critical shielding problem, and the present design has a wide forward shoulder to give maximum shielding in this area. All of the screw threads are at the rear, in less critical areas.

4. Airtight Seals: The capsule must have a positive sealing system. This should be a double hermetic seal to prevent the leakage of particles of cobalt 60, which can flake and dust off of the raw cobalt 60 source material. The present design has two lead wire seals. The first large wire primary seal is partially pressure-welded into position by an incomplete seating of the plug. This will allow preassembly of the cap and cup as a single unit. The second small lead wire will be pre-fitted to the plug and upon final assembly the two preassembled pieces will be screwed into place under high torque; there will be a cold flow of lead into the screw threads and between the cap and cup to form a continuous airtight seal. Such a system has been in use for a number of years and there is sufficient experience to give confidence in its success. It will be difficult to break such a seal for removal of the cobalt 60. It is not intended in the United States, however, that such a source capsule will ever be unloaded and reloaded. If reloading is necessary, it will be possible with special tools to cut off the top window of the stainless steel cup.

5. Loading of Capsule: The capsule must be easily loaded with the cobalt 60 of both Canada and the United States. The problems of multicurie loading, which requires remote handling equipment behind thick shields, are not to be passed off lightly, and the designer of a special source container may easily find that the cost of loading exceeds the cost of cobalt 60. The present design is suitable for the methods of loading of both Canada and the United States, and only one set of jigs is necessary for all types of sources.

6. Manipulation of the Source Capsule: It should be possible to manipulate and position the source capsule without applying pressure to the movable and critical parts. The present design is such that the only movable part, the plug, is seated slightly below flush so that it need never be touched after loading. The only critical thickness is in the presenting face of the steel cup and this is protected by a shoulder of tungsten. The only part that need be handled by remote control equipment is the solid outer cap.

7. The Radiation Window: The presenting face of the source capsule, which makes up the window that the useful beam of cobalt 60 traverses, should be sufficiently strong to resist breakage but must be as thin as is feasible so that the attenuation of the beam will be minimal. A 2 per cent attenuation will cost from $100 to $400 in initial output and will add a few minutes to each treatment. Since even thin faces of metal will give attenuation of a few per cent, a poorly designed capsule for a high activity source can be expensive. The present design uses an 0.02 inch cover of stainless steel, which is regarded as the best compromise between strength and attenuation.

8. Emplacement of the Source Capsule: Some teletherapy machines will hold the source capsule in place by mechanical pressure, some will use a screw thread, and some will have a simple shelf arrangement. One design has visualized the capsule as a free floating bearing. The present design has had to allow any of these methods of emplacement.

The adoption of this standard source capsule by the manufacturers of cobalt 60 of both Canada and the United States does not preclude any person from designing or using

a cobalt 60 source and capsule of any size or shape he may wish. The increased cost of special loading facilities, however, must be borne by each purchaser and, in the United States, the capsule must meet the requirements of the National Committee on Radiation Protection. There have been many surprises arising out of the adaptation of cobalt 60 for teletherapy and in this field, which is fluid and highly competitive, it is to the credit of the X-ray industry that they have been able to cooperate on the one factor that might easily have led to a serious economic problem and waste of a significant amount of cobalt 60. They have adopted a standard source capsule with the aim of reducing the cost of cobalt 60 equipment. The manufacturers realize that such early standardization might easily be outmoded by the rapid development of new types of teletherapy machines. For this reason it has been agreed that the industry will meet about twice each year to discuss the current development problems of teletherapy equipment. During the next two years there will be an extensive study of the experience with the present standard source capsule, and late in 1955 the problem of a standardized source capsule will be reviewed by the entire industry. Criticisms of the present design and suggestions for its improvement will be welcomed.

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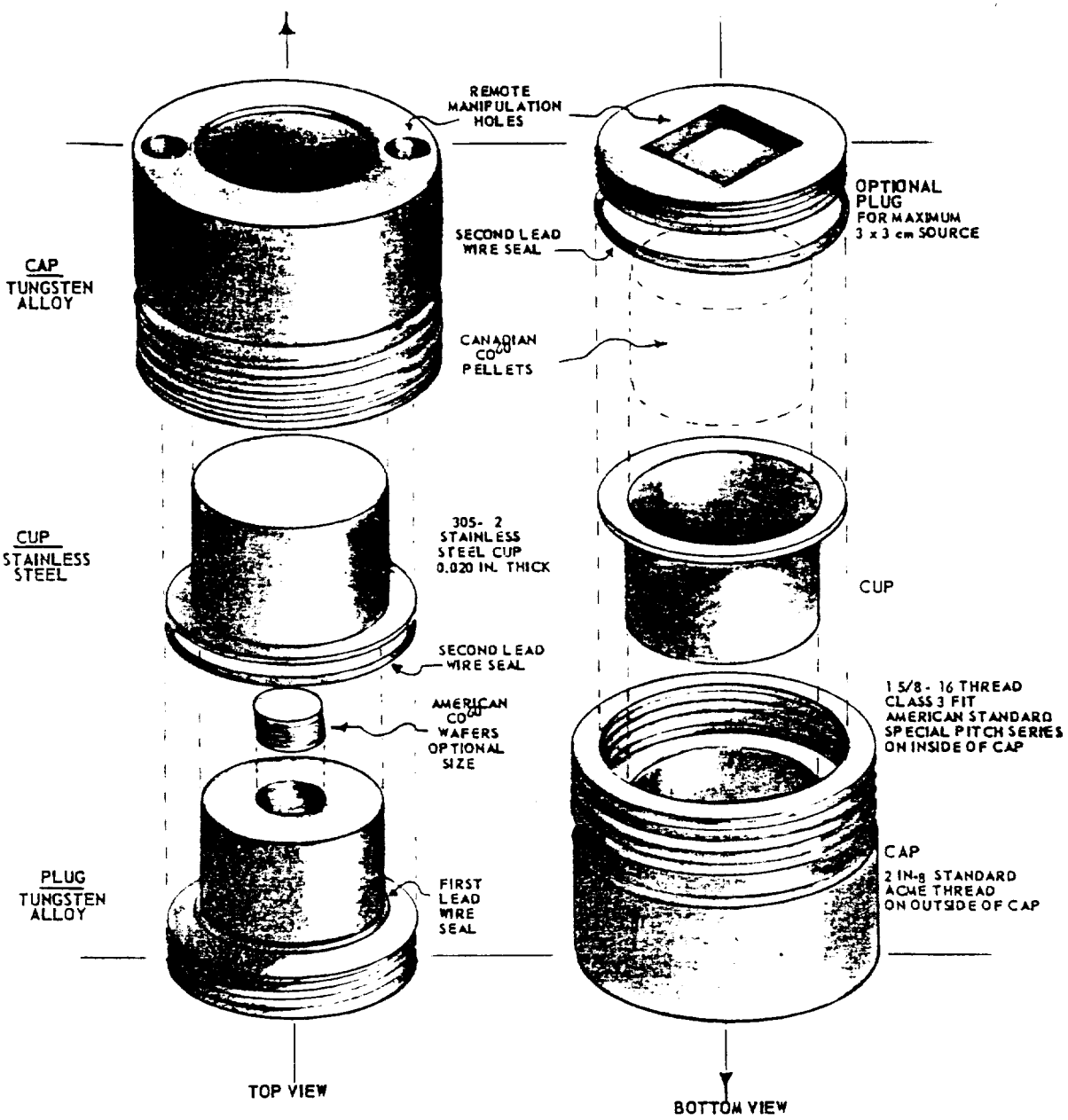
STANDARD CO^{60} SOURCE CAPSULE

TENTATIVE ADOPTION 6 NOV. 1953
BY MEMBERS OF
X-RAY INDUSTRY
CANADIAN AND U.S. AEC
AT ORINS. OAK RIDGE



DESIGNED FOR HECTOCURIE AND KILOCURIE TELETHERAPY UNITS

MAXIMUM SIZE OF CAPSULE 2 INCH DIAM x 1 7/8 INCH LENGTH

MAXIMUM SIZE OF SOURCE 3 cm. DIAM x 3 cm LENGTH

Figure 14

1136479

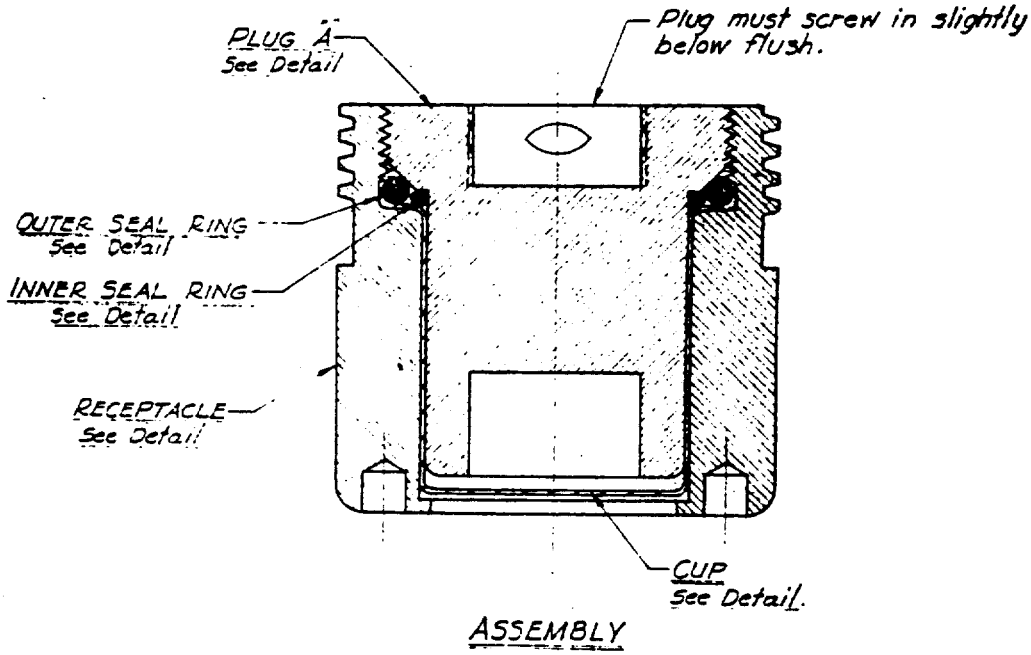


Figure 15

1136480

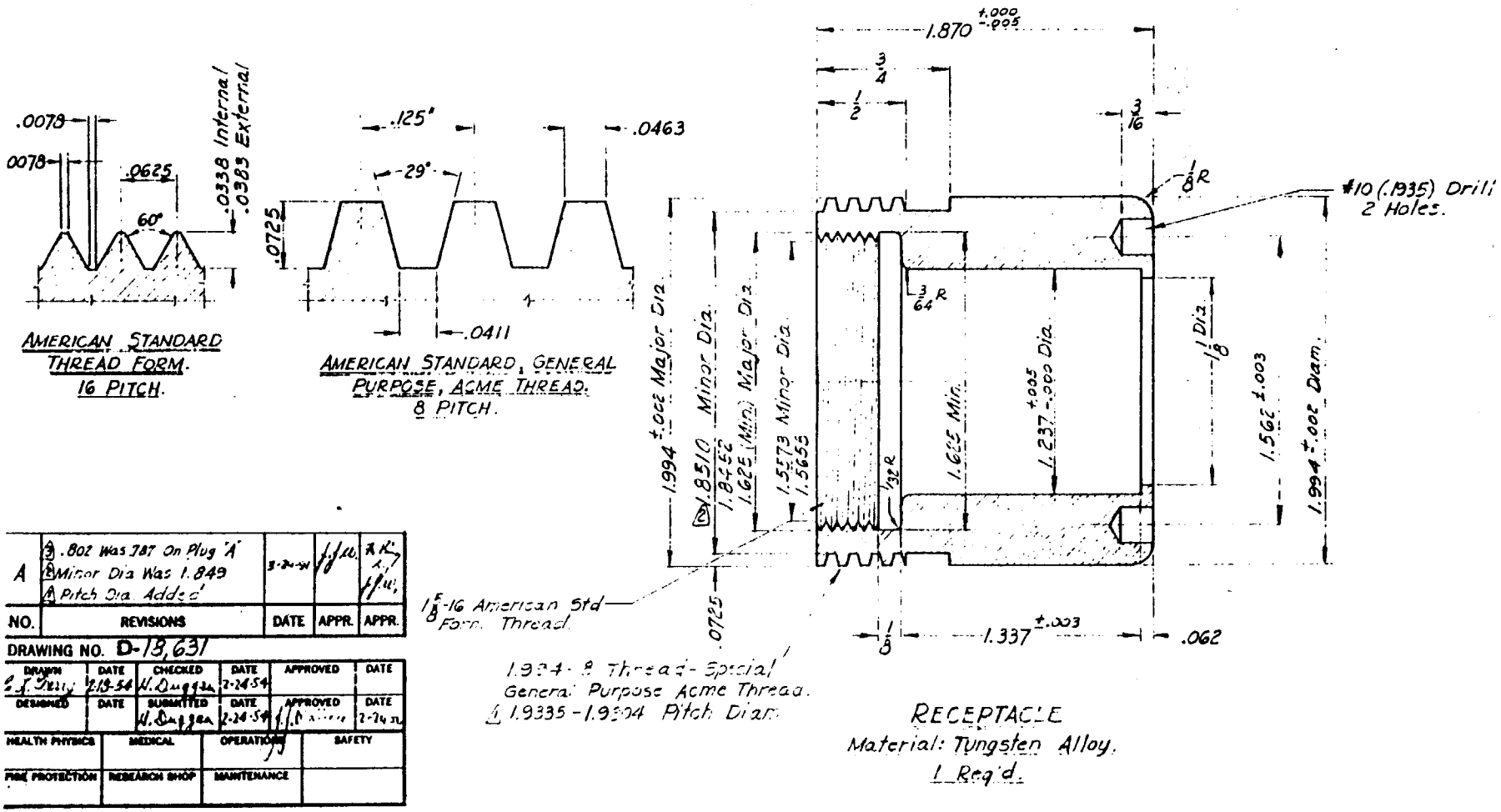
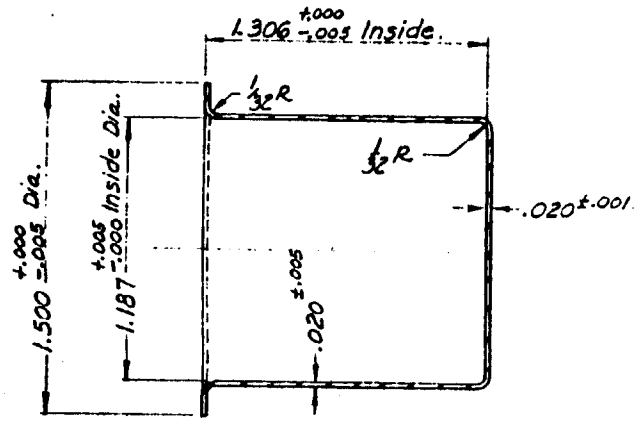


Figure 16

1136481

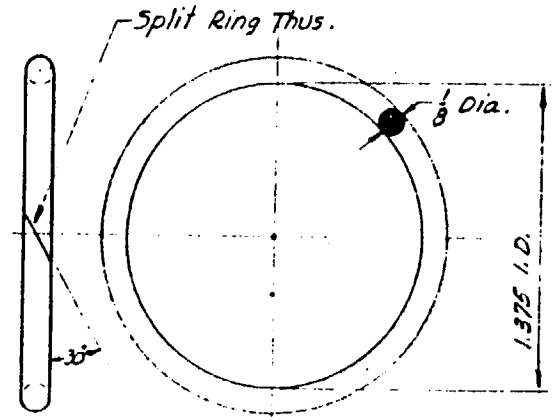


NOTE: Anneal at 2000°F & Air Cool before & after forming. Seamless Const. No Welding.

CUP.

Material: Stainless Steel, Type 305

1 Req'd.



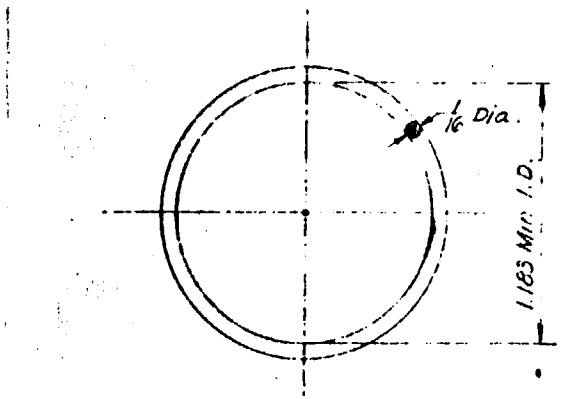
OUTER SEAL RING

Material: Soft Lead, Antimony Free

1 Req'd

Figure 17

1136482



INNER SEAL RING
Material: Soft Lead - Antimony Free
1 Req'd.

NOTES:

1- All dimensions on this dwg are in inches or decimal portions of an inch.

2- All material listed as tungsten alloy shall have an approximate composition of tungsten 90%, nickel 6%, copper 4% and shall have a density greater than 16.5 grams/cm³ and shall be equal to Carboloy Hevimet, Fansteel 77, or Mallory 1000.

3- Cup to be passivated after forming and to have 2D sheet finish according to ASTM specification A 167. Average profilometer reading to be 18 Microinches.

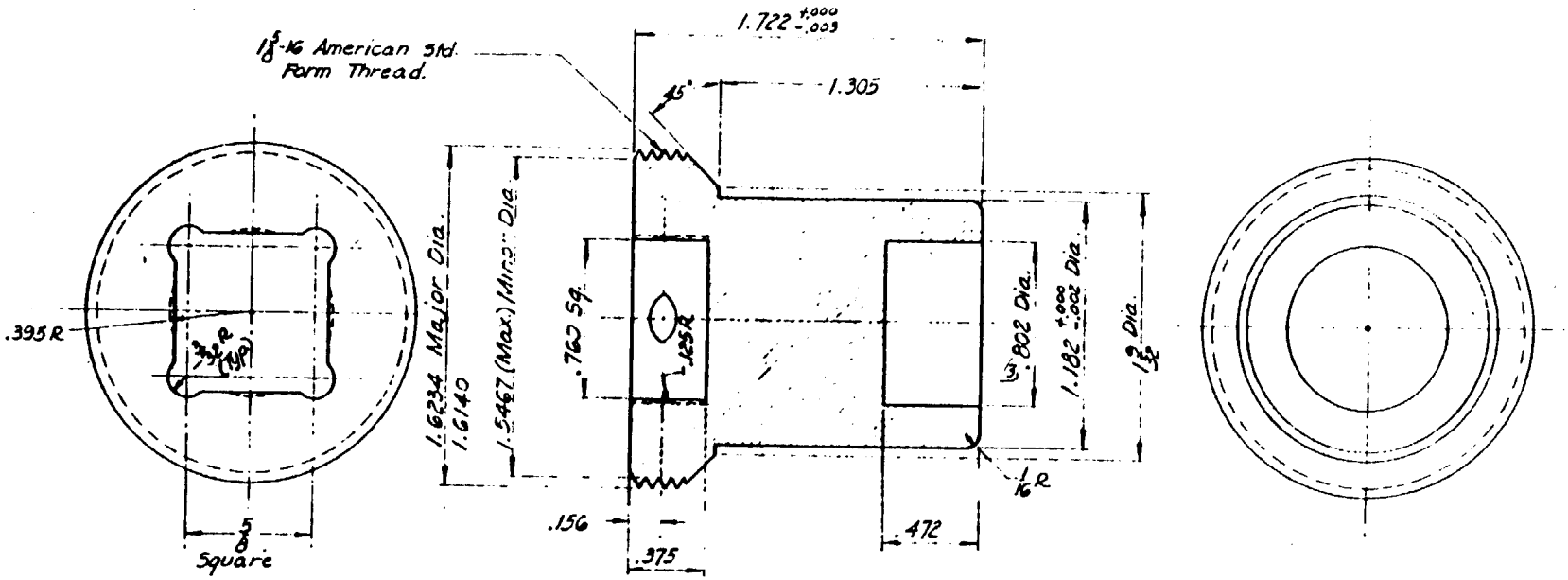
MACHINE FINISH SPECIFICATIONS:

1. Finish symbols are in accordance with ASA Standard B46.1 – 1947.
2. Roughness height values are the maximum arithmetical average deviation from the mean surface, expressed in microinches.
3. For surfaces not otherwise indicated, roughness height shall not exceed 32 √.

THIS DRAWING CLASSIFIED
AS NOT CLASSIFIED
PER [illegible]
LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS: ± 1/64
DECIMALS: ± .005
ANGLES: ± 2° - 30'
SCALE: 2" - 1"

Figure 18

1136483

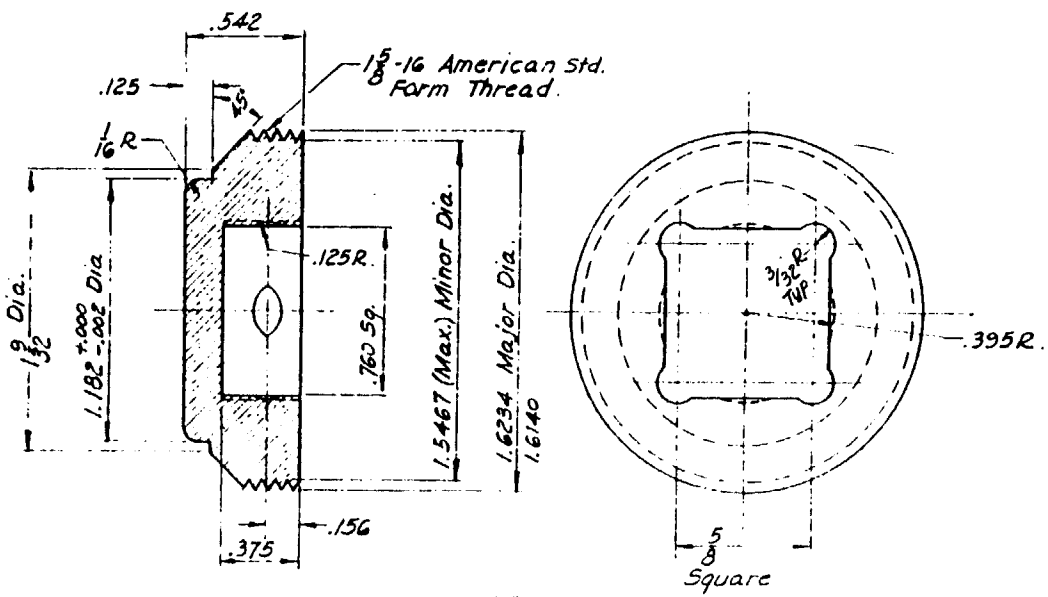


PLUG "A"

Material: Tungsten Alloy

Figure 19

1136484



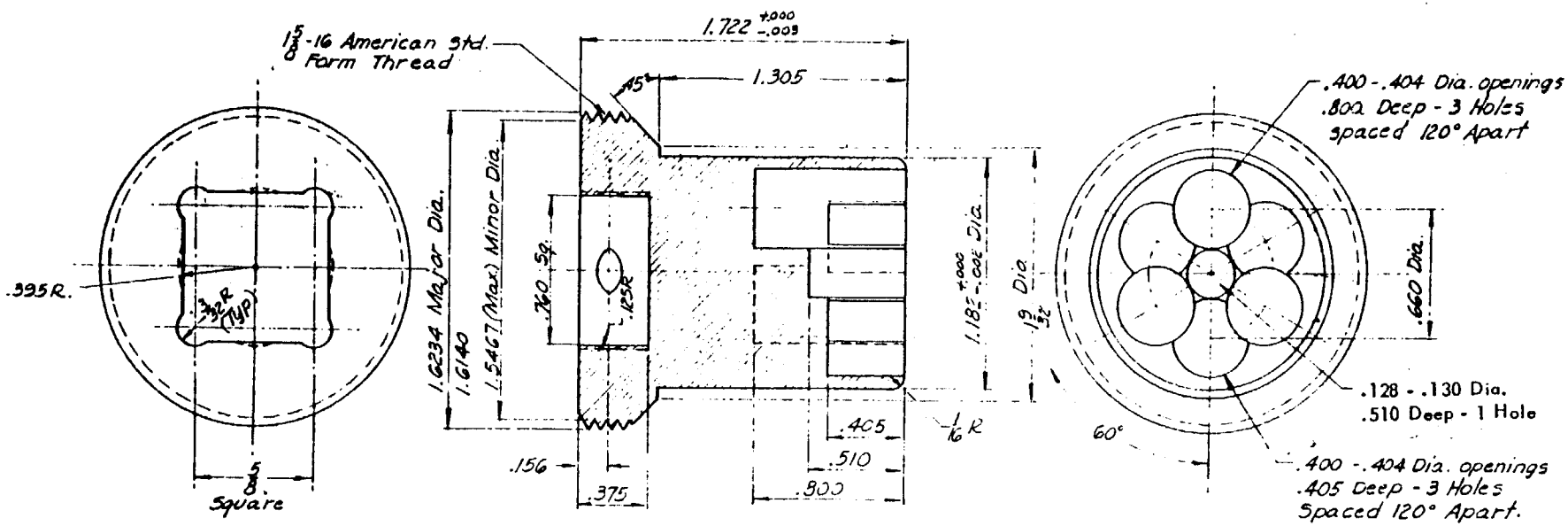
PLUG "B"

Material: Tungsten Alloy.

(Alternate for Canadian Co^{60} Pellets)

Figure 20

1136485



PLUG "C"

Material: Tungsten Alloy.

(Alternate for Cloverleaf Source)

Figure 21

1136486

AN AVAILABLE COBALT 60 SOURCE FOR TELETHERAPY

Marshall Brucer, M.D.

A double overlapping cloverleaf source was designed to make maximum use of the cobalt 60 currently in plentiful supply from one of the Oak Ridge facilities. Such source material is manufactured in serendipity and can almost be considered a use for "waste" neutrons. There are no foreseeable overriding priorities that would interfere with its production. This source material is now available as 1 cm diameter and 0.32 cm diameter rods. The rods are available in lengths up to 4 cm and with specific activities ranging from 7 to 11 curies per gram.

For teletherapy use, when sources in the multihectocurie range are used, it is an advantage to have a short SSD available. This will restrict the maximum allowable diameter of the source below that of a larger machine. Approximately 2 cm has been arbitrarily chosen as allowable. With this diameter, approximately 30 cm collimation distance will give penumbra relationships similar to those of the larger machines. After trials of many arrangements, the double overlapping cloverleaf, shown in Figure 22, Page 60, was chosen as a maximum compromise of economy, curiage, penumbra, and available materials.

The cloverleaf source consists of seven pieces of cobalt 60: six pieces are 1 cm diameter by 1 cm length, and one is 0.32 cm diameter by 1.27 cm length. The small piece is used as a central core and the larger pieces are grouped around this core in two layers. The top layer is in a cloverleaf pattern with three 1 cm rods arranged at 120° angles around the core; the bottom layer is similar but is 60° out of phase. Thus the total surface as presented to the patient contains cobalt 60 in three different depths. The depth of 6.3 per cent of the area, the central core, is 1.27 cm. The depth of 67.5 per cent of the area is 1 cm, but half of this area is at 1 cm greater SSD; the depth of 26.2 per cent of the area is 2 cm. The maximum diameter of the source is 2.3 cm; the minimum diameter is 1.9 cm.

The source capsule for the cloverleaf design has been drilled to fit; there is thus the possibility of maximum shielding in all except the forward direction where there is no unnecessary shielding. A jig has been made to allow for simple loading. The cloverleaf fits into the standard source capsule[1].

The characteristics of the first such source to be made can be used as an example of the advantages and disadvantages of the design. These characteristics are shown in Table 12, Page 57.

From Table 13, Page 58, a calculation has been made of the expected roentgens per hour at a meter (rhm) from such an overlapping cloverleaf design. The calculated measurement indicates that we should expect about 476 rhm or 7.9 roentgens per minute at a meter (rmm). The actual measurement was 381 rhm or 6.35 rmm. A number of corrections can partially explain the discrepancies. There was approximately 4 per cent absorption in the steel cap of a prototype source capsule and our measurement of the output was made about two months after the measurements of the individual pieces. The calculated value was reduced to an expected 7.4 rmm.

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The remaining discrepancy is probably due to the way in which the individual pieces were measured to give the original "paid-for-value" of 452 curies. These measurements are made by the Oak Ridge National Laboratory for the purpose of determining the price of the cobalt, and are made in a lead chamber with an inch of lead attenuation between the source and the detector in a very broad beam geometry. Although the instruments are calibrated accurately they were calibrated to measure total curies and the confidence level is not better than 20 per cent. The detector "sees" an aspect of each individual piece of cobalt which might be different from that used in a teletherapy machine. In the measurement of the output of the source in the teletherapy machine, we measure only a small fraction of the 4π geometry in air even with the largest cone in the teletherapy unit, and little of the scatter build-up is included. It appears that of all these possibilities for discrepancy, the use of a wide beam geometry in the calculation of curiage will give a constant bias; therefore, it is to be expected that the statement of curiage on the shipping ticket will be about 10 per cent higher than if it were measured under the conditions of teletherapy use. Although the proportional difference in expected to actual output is uniform at any curiage, the absolute value assumes considerable magnitude in high curie sources.

The cost of the cobalt 60 - adjusted to match the data in Table 14, Page 59 - for the cloverleaf source was $2,750 or $7.20 per rmm on delivery. It is not the most economical source, nor is it the most economical design. It is interesting to calculate the probable cost of what might be designed as a best possible source[2] when the same or even better production facilities are used. Such a source might be a 2 cm diameter disc irradiated in thin sections. To get an output of 381 rhm as measured for the cloverleaf, the length would have to be 1.4 cm and the cost per rhm would be $6.50, as shown in Table 14. Such a source could also be made of 50 curies/gram cobalt 60, in which case the source would be 0.25 cm long and cost $7.80 per rhm. If a 1.0 cm diameter source were used, the specific activity would have to be in the 50 curies/gram range and the cost would be higher. The 1 cm diameter source, with its better-than-necessary penumbra relationships, is already on the upswing of a rapidly rising curve of costs versus increasing specific activity. The 1.5 cm diameter source is still in the cost range comparable to the lower specific activity and appears to be an excellent source size. Since the hectocurie cobalt 60 machine is designed for a maximum of 600 rhm, Table 14 shows the cost relationships at maximum output. For comparison, similar data are shown for an 1800 rhm teletherapy machine.

A few other very important points must be considered. The higher curiage machines, which are especially valuable in rotational therapy, must use high specific activity cobalt 60 and cannot use lower specific activitites. Since the facilities for high specific activity production are limited, all of their production should be saved for those machines. High specific activity demands valuable reactor space, which must be allocated under a strict priority system. Further, the problems of handling the higher curie sources increase almost exponentially with increasing curiage. Costs in addition to those of the source shield must be taken into account. Until a few years ago there were no facilities for handling high curiage sources; even today these are new and handling experience is limited.

The 10 curies/gram specific activity material is produced in an AEC facility that produces neutrons for various purposes not related to teletherapy. As long as such neutron production is necessary, such a production of low specific activity cobalt 60 contains a hidden subsidy. Further, this type of low specific activity cobalt 60 need not be on a strict priority allocation. There can always be a guaranteed production and it is believed that there always will be sufficient amounts available, so that the low activity material can be exported without danger of affecting the American neutron economy.

The cloverleaf design has only one advantage to recommend it, and this advantage takes ultimate precedence over all other factors at the present time and probably for some time to come: it uses cobalt 60 that is available now.

References

[1] M. Brucer, submitted for publication in Nucleonics.

[2] M. Brucer, W. G. Pollard, H. Leiter, and H. Scarf, Nucleonics 11, No. 2, 38 (1953).

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Table 12

	1 cm rod		1/8 inch rod
Diameter	1.0 cm		0.3175 cm
Length	1.0 cm		1.27 cm
Area of Presenting Face	0.7854 cm^2		0.1008 cm^2
Volume	0.7854 cm^3		0.1280 cm^3
Weight (d = 8.9)	6.99 grams		1.14 grams
Total Weight of Source		43.08 grams	
Total Curiage (ORNL*)		452	
Average Specific Activity		10.5 cm/gram	
Average Curiage per piece	73.35 curies		12.0 curies

* Oak Ridge National Laboratory

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Table 13

Calculation of Expected Output of Cloverleaf Cobalt 60 Source

	per cent of large piece area	per cent of total area	curies	rhm without self-absorption	fractional transmission	rhm with self-absorption
1 cm deep area	72%	67.5%	316.8	427.8	0.825	352.9
2 cm deep area	28%	26.2%	123.2	166.3	0.664	110.4
1.27 cm deep area	--	6.3%	12.0	16.2	0.780	12.6
Total		100%	452		0.780	475.9 = 7.93 rmm
With corrections for decay and steel cap of prototype source capsule						445 = 7.4 rmm
Measured output						381 = 6.35 rmm

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Table 14

Cost of Cobalt 60 Sources

Cost includes cobalt 60, capsule, loading, handling, and shipment to New York City

Diameter	Length	Specific Activity	Curies	Total Cost	Cost per rhm
		6.3 rmm			
2.0 cm	1.4 cm	10 c/gm	370	$2,500	$6.50
2.0 cm	0.25 cm	50 c/gm	310	$2,900	$7.60
1.5 cm	0.4 cm	50 c/gm	320	$3,000	$7.80
1.0 cm	1.0 cm	50 c/gm	340	$3,140	$8.25
		10 rmm			
2.0 cm	2.85 cm	10 c/gm	780	$4,550	$7.60
2.0 cm	0.37 cm	50 c/gm	485	$4,250	$7.10
1.5 cm	0.65 cm	50 c/gm	515	$4,400	$7.30
1.0 cm	2.00 cm	50 c/gm	680	$5,700	$9.50
Canadian quotation	unknown sizes	?	500	$8,800	Reirradiation allowance
		30 rmm			
2.0 cm	impossible	10 c/gm	---	---	---
2.0 cm	1.23 cm	50 c/gm	1650	$13,250	$7.40
1.5 cm	3.25 cm	50 c/gm	2550	$20,000	$11.00
1.0 cm	impossible	50 c/gm	---	---	---
Canadian quotation	unknown sizes				
3 cm?	3 cm max.?	?	1800	$23,220	reirradiation allowance

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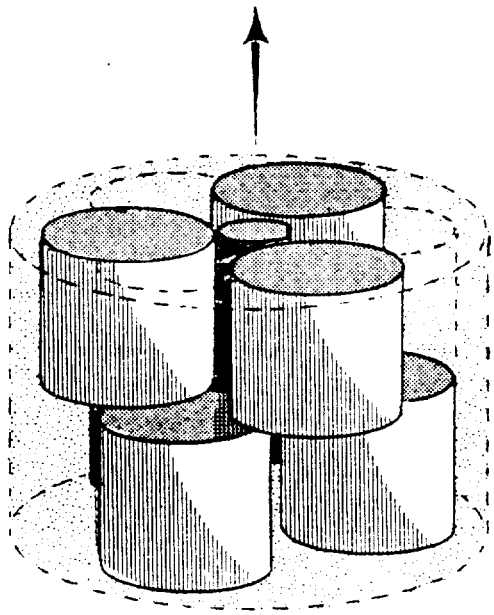

Figure 22

1136493

CHECK LIST OF REQUIREMENTS FOR TELETHERAPY MACHINES

Abstracted from the manuscript of Handbook 54, National Bureau of Standards

The following check list of requirements for teletherapy machines has been taken directly from the final copy of Handbook 54, "Protection Against Radiation from Radium, Cobalt 60, and Cesium 137 Encapsulated Sources," National Committee on Radiation Protection, National Bureau of Standards. On October 3, 1953, representatives of the Oak Ridge Institute of Nuclear Studies, the Isotopes Division of the United States Atomic Energy Commission, Atomic Energy of Canada, Limited, and the X-ray industry met to discuss teletherapy in human radiographic problems with isotopes. Most of the details from the new handbook are included in the copy of the minutes of this joint meeting. The handbook, however, will be published within the next few months and there is no need for a review of the material here. In this check list an attempt has been made to extract from the manuscript copy of Handbook 54 those features that are necessary for a manufacturer to consider in the design of a teletherapy machine. There is one important change from the document issued on October 3, 1953, and that change concerns the protection requirements for the primary teletherapy shield. The corrected version is given in the following list. Handbook 54 is concerned only with protection problems and has quasi-legal status in that it represents the current "best possible opinion." The use of shall and should in the NBS handbook recommendations are used in the check list and are defined as follows:

> Shall denotes that the ensuing recommendation is necessary or essential to meet the currently accepted standards of protection. Should indicates advisory recommendations that are to be applied when practicable.

Check List of Protection Requirements from Handbook 54

General

1. Foolproof Design. Teletherapy apparatus must be so designed as to be practically foolproof in operation and it must be improbable for any accidents to leave the source unshielded.

2. Kinds of Hazard. Hazards to be considered in the design of teletherapy machines are: (a.) Those harmful to human beings; (b.) those that interfere with function of equipment or damage to material sensitive to radiation (photographic films).

3. Isotopes are Monoergic. Unlike X-ray machines, radioisotope sources are always "on." Hence, protection requirements are different. With most isotopes, the radiation is not a continuous spectrum, but is from either single or multiple monoergic gamma energies. The protection requirements will be higher for a monoergic gamma energy than for a similar peak energy from an X-ray generator.

4. Definition of Permissible Dose. The permissible external radiation levels for long term occupational exposure will be reported in an NBS handbook soon to be published.

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The following is extracted from the manuscript:

A. For adults under 45 years of age whose entire body or major portions thereof is exposed solely to X rays with full time energies less than 3 Mev from external sources for an indefinite period of years, the maximum permissible total weekly dose shall be 300 mr measured in air at the point of highest weekly dose in the region occupied by the person, provided that the actual total weekly dose in the gonads does not exceed 300 mrad.

B. For persons 45 years or older similarly exposed, the corresponding maximum permissible total weekly doses shall be double the previously stated values, provided that the actual total weekly dose in the lenses of the eyes does not exceed 600 mrad.

C. For adults of any age whose hands and forearms (or feet and ankles) are exposed solely to X rays from external sources for an indefinite period of years, the maximum permissible weekly dose shall be 1500 mrad in the skin.

D. For adults of any age whose entire body or major portions thereof is exposed to ionizing radiation of very low penetrating power from external sources (half value layer less than 1 mm of soft tissue), the maximum permissible total weekly dose in the skin shall be 1500 mrad, provided that the total weekly dose in the lenses of the eyes does not exceed 300 mrad.

E. It is recommended that in cases in which minors may be exposed to radiation in the course of their normal activities, protective measures be taken to make sure that no minor actually receives radiation at a weekly rate higher than one-tenth respective basic permissible weekly doses for the critical organs.

F. Permissible dose shall be applied to the total dose to which a person is exposed throughout the week. This is an important consideration in cases of simultaneous and separate exposures to more than one source of ionizing radiation.

5. How to Furnish Protection. Protection from radiation can be achieved in any one, or a combination of the following factors: (a.) Increasing the working distance from the source of radiation; (b.) reducing the time of exposure; (c.) interposing attenuation (protective) barriers between the source of radiation and the person exposed.

6. Occupancy Factors. For use as a guide in planning shielding where complete occupancy data are not available, the following occupancy factors can be used:

(a.) Full occupancy (T=1). Control space, residencies, wards, office work rooms, dark rooms, corridors, and waiting space large enough to hold desks, rest rooms used by the radiological staff and others routinely exposed to radiation, and play areas.

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(b.) Partial occupancy ($T=\frac{1}{4}$). Corridors and X-ray departments too narrow for future desk space, rest rooms used by radiological personnel, parking lots, and utility rooms.

(c.) Occasional occupancy ($t=1/16$). Stairways, automatic elevators, streets, closets too small for future work rooms, rest rooms not used by radiological personnel.

7. The Use of Barriers. The thickness of barriers for protection against radiation can be computed in many different ways. Handbook 54 gives a detailed description of one useful method of calculating such barriers:

(a.) For reasons of economy, barriers should be placed as near to the source as possible. The thickness of the barrier is not reduced by this procedure but the area, and therefore the volume, is reduced.

(b.) Concrete, marble, and similar materials generally provide the most economical barrier, but lead may be required where the space is limited, or where it is desirable to reduce the total weight of the barrier.

(c.) All openings in barriers, such as for doors, windows, and pipes, shall be provided with at least the radiation protection required by the surrounding barrier.

(d.) Joints between the same or different kinds of protective materials shall be constructed to provide the same protection as that required of the adjacent material.

Transportation of Sources

8. Regulations on Transport. Proper transportation of radioactive materials is subject to federal, state, and local regulations. Those responsible for the shipment of sources should be familiar with the current regulations of the Interstate Commerce Commission, the Post Office Department, the Civil Aeronautics Board, and the Bureau of Explosives. Various local tunnel and bridge authorities may regulate or prohibit the shipment of dangerous material through vehicular tunnels or over major bridges.

9. ICC Regulations. The Interstate Commerce Commission does not permit shipment of over 2 curies of radium or 2.7 curies of cobalt 60 or cesium 137 in express packages. Complete ICC regulations are available from the Bureau of Explosives, Association of American Railroads, 30 Vesey Street, New York 7, New York (Current price:$3.50).

10. CAB Regulations. The Civil Aeronautics Board will, in general, prohibit the shipment of teletherapy sources by air, except with special permission. Since airlines are not required to accept shipments even if they meet CAB regulations, some airlines refuse all shipments of radioactive materials.

The Source and Its Capsule

11. Information to Buyer. Teletherapy sources are generally defined as those sources emitting gamma rays between 1 and 50 rmm. Complete information regarding construction of the capsule and shield shall be provided the buyer or user by the manufacturer.

12. Marking of the Capsule. Wherever size permits, the content of the capsule shall be clearly and permanently marked and be readily identifiable from a considerable distance. When sizes and shapes are not adequate, other means of identification should be employed. The standard source capsule meets all of the recommendations of the handbook, except that it does not provide for marking on the source. It is expected that on

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teletherapy machines the same characteristics will be plainly marked on the machine.

13. Removal of Source Material. Removal of radioactive material from permanently sealed sources should be done only by those persons particularly trained and equipped to do the job. Any dismantling shall be limited to the removal of the source in its capsule.

14. Design of Source Capsule. Containers for solid sources shall be designed to prevent the release of highly radioactive dusts. Containers for loose powders or liquids shall be especially designed to prevent accidental release of the material. These containers should be doubly protected against leakage.

15. Capsule Shall be Airtight. Sources shall be sealed in airtight capsules of suitable material.

16. Contamination on Capsule. After the isotope is loaded into its permanent capsule, the capsule shall be scrubbed clean of contaminating radioactivity. It shall not be released by the manufacturer until a reasonable test reveals no significant contamination.

17. Glass Prohibited. Isotopes used in teletherapy shall not be sealed in glass or other breakable containers.

18. Gas Production. Certain teletherapy sources, those subject to decomposition, should be sealed in a powdered source container and then resealed in a second safety capsule containing an air pocket.

The Teletherapy Apparatus

21. Protection Requirements for the Housing. The housing and collimating devices shall be so constructed that at one meter in any direction from the source in the "off" position, the maximum and average dose rates do not exceed 10 mr/hr and 2 mr/hr respectively. In order to reduce the integral dose to the patient, the leakage radiation in the "on" position should not exceed 1 per cent of the useful beam measured at one meter from the source. A reduction of the leakage radiation to 0.1 per cent or lower will result in a more economical secondary protective barrier.

22. Multiple Source Units. In multiple source units, each source should meet the protection requirements of a single source unit, except that the protection requirements for the entire apparatus shall in no situation be less than those recommended for a single source unit.

23. Diaphragms. Adjustable beam defining diaphragms when used shall allow transmission of not more than 5 per cent of the useful beam dose rate outside the useful beam.

24. Filters. Where filters to harden the radiation are considered necessary, the filters shall be a permanently affixed part of the housing.

25. Line-up of Source in "OFF" Position. The relationship of the source and the collimating openings shall be such that in the "off" position of the beam, the moving part shall always return to a position of shielding defined as safe.

26. Line-up of Source in "ON" Position. In the "on" position, the moving parts shall always come to rest with the source and the beam collimating device accurately aligned.

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27. Liquid Shutter. If a liquid "on"-"off" device is used, the liquid container shall be filled and emptied with less than a 5 per cent change in dose rate in the "on" position.

28. Mercury Shutter. If the liquid used in an "on"-"off" device is mercury, provisions should be made for periodic tests for leakage of mercury vapors, since they are toxic and may also affect the film badges used in monitoring personnel.

29. Beam Control Shutter. The beam control mechanism shall be of a positive design, capable of acting in any position of the housing, and shall shut off automatically. In addition to the automatic closing device, the apparatus shall be so designed that it can be manually turned off with a minimum risk of exposure.

30. Design of Moving Parts in Shutter. The moving parts shall be so designed that it is highly improbable for projections, breakages, loose screws, dirt, or failure of any part to impede the closing of the source.

31. "ON"-"OFF" Warning. There shall be at the housing and on the control panel a warning device that clearly indicates whether the apparatus is "on" or "off."

32. Shut-off Timer. The controls shall be provided with a timer that automatically terminates the exposure after a pre-set time.

33. Automatic Closing. The closing device shall be so designed as to return automatically to the "off" position in the event of any breakdown or interruption of the activating force, and shall stay in the "off" position when the force goes on again until activated from controls.

34. Control Lock. The beam controls shall be provided with a locking device to prevent unauthorized use.

The Teletherapy Room

35. Lead Barriers. Lead barriers, if used, shall be mounted in such a manner that they will not creep because of their own weight and shall be protected against mechanical damage.

36. Movable Barriers. Movable barriers should not be depended upon except for emergency procedures. The primary beam shield affixed to a rotational device should not be considered a movable barrier.

37. Computation of Direct Beam Protection. Protection for the useful beam shall be computed without a patient in the beam. Protection for scatter shall be computed with a patient in the beam.

38. Window and Maze Designs. In general, it is more economical to place the observation window out of the direct beam and to provide a maze rather than a heavy lead or steel door for access to the radiation room.

39. Size of Primary Barrier. Primary protective barriers shall be provided for any area that the useful beam may strike, with the largest possible diaphragm opening. These barriers shall extend at least six inches beyond the useful beam for any possible orientation.

40. Extent of Barrier. The barrier shall be such that at no place liable to

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uncontrolled habitation shall the radiation exceed the dose rate of 300 mr per week.

41. Position of Controls. The controls should be in a separate room or behind permanent structures.

42. Access Doors. All access doors to the treatment room and other hazardous areas shall be provided with electrical interlocks; warning lights, bells, or other devices should also be provided.

43. Secondary Barriers. Secondary protective barriers shall be provided for areas exposed to leakage and scattered radiation.

44. Only Patient Allowed in Room. The teletherapy machine and its position in the room should be so designed that only the patient should be allowed in the treatment room during irradiation.

Other Considerations Involving Nonmedical Applications

Generally, teletherapy-type machines used for nonmedical applications have less strict regulations and allow for monitoring of nonroutine use by a radiological safety officer. Some of the following recommendations are for sources of lower output, but are useful rules to observe even in teletherapy devices:

45. Deviations Allowed Radiation Safety Officer. In the event that a situation beyond the reasonable contemplation of these recommendations is believed to exist, any deviation shall be allowed only upon authorization by the radiological safety officer after thorough survey of the conditions.

46. Labels. Labels stating type of activity, amount, and danger range, shielded and unshielded, should be attached to the source shield. Lettering should be easily read at the danger range.

46. Label for Source. The presence of a radioactive source shall be clearly indicated by a suitable permanent legend on the face of the instrument stating the isotope and its curiage and date. The source shall be readily distinguishable upon dismantling the instrument.

47. Handling Sources. Special remote handling equipment shall be used with sources exceeding 30 mr/hr at the surface. Movement of the source from shielded position to any other position should be accomplished by mechanical linkage or other remote control methods.

49. Calculations Insufficient. It shall not be considered sufficient to calculate dose rates and danger ranges from multicurie sources from consideration only of the amount of activity present. For these sources, an actual survey of the radiation levels should be made. Consideration must be given both to primary and scattered radiation.

50. Research Apparatus. Teletherapy apparatus used for research shall be subject to the same design criteria and operational precautions as those recommended for medical teletherapy apparatus, except that considerations given to the protection of the patient against accidental overexposure shall not apply where animals, plants, or other experimental materials are being irradiated. Precautions, however, should be taken by means of door lock, or alternate means, to prevent unauthorized persons from entering the teletherapy room while the beam is in the "on" position. Interlocks

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need not be electrically operated.

Radiation Surveys and Personnel Monitoring

51. Initial Survey. An initial survey should be made of any facility to be used for the handling or storage of radioactive sources.

52. Repeat Surveys. If any changes are made in layout or shielding, or if there is a possibility of a fault developing through cold flow in metallic shielding, or through wear, the survey should be repeated at appropriate intervals.

53. Film Surveys. For conditions in which the dose rate is expected to be low, films may be used in making an approximate survey.

54. Chamber Surveys. Ionization chamber instruments are required only if a prior scanning with a suitably calibrated Geiger-Muller or scintillation type of instrument indicates occupied regions to have a radiation level of over one-fifth of the permissible dose rate.

55. Protection Survey. No teletherapy installation should be used routinely until its safety has been established by a protection survey.

56. Area Survey. A survey should also be made of all regions adjacent to the radiation room, with the beam on, and a patient or phantom in place.

57. Pinhole Leaks. Pinhole leaks shall be considered in terms of the possibility of a hazard to operator or patient, rather than in terms of specified exposure rates.

58. Warning Signs. Any restrictions on occupancy should be indicated by appropriate warning signs. The signs should be removed when the hazard is eliminated.

59. Personnel Monitoring. Personnel monitoring should be employed where the radiation safety depends upon proper operating procedures. A film badge, pocket dosimeter, or pocket chamber may be used.

60. Discontinued Personnel Monitoring. If a particular operation is routine or repetitive and the hazard is slight, the local exposure may be established initially without the necessity of wearing these devices continuously.

61. Instruction of Personnel. Before a person is allowed to handle radioactive sources, he should be informed of the hazards involved and how to guard against them. Such an employee should be required to read the sections of Handbook 54 pertaining to his work and the special safety rules.

62. Radiological Safety Officer. In every hospital, clinic, or laboratory handling radioactive sources, there shall be a radiological safety officer. The radiological safety officer shall be responsible for the establishment of satisfactory working conditions according to current standards, including those established in Handbook 54.

63. Warning Signs. Regions that are easily accessible, and that cannot be continuously occupied without exceeding the maximum permissible dose, should be posted to warn all concerned that this is a dangerous area.

64. Personnel Examinations. No special examinations other than those considered good medical and industrial practice should be required of personnel working with radioactivity. If there is any possibility of accidental heavy exposure to any person, a normal blood count series for any such individual would be useful as a later reference to indicate radiation damage or absence of significant radiation damage.

65. Vacation Policy. Vacations should not be considered protection against overexposure to radiation.

66. Accidents. Procedures are recommended for accidents with radioactive sources. The detailed statement of what to do in case of accident, which is a part of Handbook 54, should be read at least once by every person working with dangerous amounts of radioactive material. The handbook should be kept available near any location where these accidents could possibly occur.

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THE USE OF MARBLE AS A RADIATION SHIELD

Marshall Brucer, M.D.*

For many centuries, marble has been accepted as one of the most beautiful of building materials. Its structural characteristics - durability and strength - have kept it in the field of competitition with other not-so-naturally-beautiful construction materials, but cost of quarrying and cutting and expense of transportation have given it the reputation of being in the luxury class. Both the advantages and disadvantages of using marble are well known to architects. If there were not a cost factor involved, there would be no difficulty in choosing between a mud hut and a marble palace.

Today, we are going to consider one other characteristic of marble which has received little attention and which may add to the desirability of marble, not as a luxury item, but because under certain conditions it may be more economical than mud. Marble is an effective shield against radiation; when used to its best advantage, it may compete economically with other materials.

This discussion involves a relatively routine problem in the science of physics, but also includes some very serious and complicated problems in economics. The problem of shielding a person from the hazards of radiation is essentially simple. It is only when cost enters the picture that the problems multiply. The word "cost," for example, is used here to cover two distinct types of expense. First, there is the dollar expenditure to cover the purchase of materials and the fabrication out of these materials of a shield to absorb radiation. Second, there is the cost involved in the efficient use of space.

If we take, for instance, an intense source of high voltage gamma radiation such as is now being manufactured for use in cobalt 60 teletherapy machines, and place this source in an open field, it will not be hazardous (by any stretch of the imagination) to anyone who stays 1/5 mile away from the source. A fifth of a mile of air and the distance itself is a good radiation shield, but this is not necessarily cheap shielding. The rent on more than 1/2 acre of land must be considered if such a source of radiation is used. If only simple manipulation of the source is required, as shown in Figure 1, involving merely a raising and lowering of the source, there is a necessity for the erection of high poles, the use of telescopes and long fish lines for positioning; these operations are not free of cost. If a more complicated manipulation of the source were required, there would arise demands for mechanical gadgetry that could make "distance" an expensive shielding material.

A simple way to cut down on the distance would be to use another cheap material - water. Since water is about 1000 times more dense than air, only about six feet of water would give adequate shielding. Water is currently being used for high intensity sources of radiation such as nuclear reactors. It could also be used as a shield for a cobalt 60 source. The six feet of water, however, must be enclosed in a tank, which involves a considerable cost, and the manipulation of the source through

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* A talk delivered before the Marble Institute of America, Washington, D. C., March 2, 1954.

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six feet of water is almost as expensive as at greater distances in air.

If the use of space is a major consideration, one of the best ways to shield the source of radiation is to surround it with a high denisty material such as platinum. A few inches of platinum surrounding a high intensity cobalt 60 source are sufficient to reduce the radiation to negligible levels. The manipulation of a high intensity source of radiation inside a block of solid platinum is relatively simple and inexpensive. This is an economical use of space, but this saving must be balanced against the cost of the shielding material. Here lies the crux of the entire problem of shielding. Air is just as useful a radiation shield as platinum, but the former uses a great deal of space and the latter uses little space. When "space" is very expensive or impossible to obtain, platinum can be a cheaper shielding material than air.

The Maximum Permissible Dose of Radiation

The first problem in designing a radiation shield is to determine how much shielding is required. It is never possible to be free of all radiation, since we are living in a constantly present radiation field. A small amount of radiation does no appreciable damage to the body. There is a constant bombardment of the earth by cosmic rays from outer space. Mountaineers absorb more of this radiation than do lowlanders, yet this increase is not noticeably dangerous. There is a natural radioactivity in the earth and even the carbon making up the human body is partially radioactive, but this does not constitute a danger. Since it is impossible to shield ourselves from all radiation, some small but measurable amount can be considered nonhazardous. For the past 50 years it has been well known that too much radiation, however, is a distinct hazard. An international commission was set up many years ago and given the impossible task of determining how much radiation a person could absorb and still be "safe." By a judicious use of many types of information, they arrived at a workable answer: The human body can absorb 300 milliroentgens of gamma radiation each week during his adult life without measurable danger. All of our safety measures are based upon these figures, and radiation shields must be sufficient to give at least this minimum protection.

The Mechanism of Radiation Absorption

To explain how marble can be used to achieve this minimum protection, it is necessary to explain the mechanism of radiation absorption. When an X ray or gamma ray travels through empty space, it moves in a straight line at the speed of light, without losing any energy. Although it is not the kind of a thing which has size, it can be pictured in the mind as an object of very small size. The energy of the gamma ray can be pictured as the size factor. A low energy X ray from a diagnostic X-ray tube would, in this mental picture, be a large basket ball moving through a vacuum and a high energy gamma ray would be a small golf ball moving through a vacuum at the speed of light. Any piece of matter, such as a slab of marble, at these distorted dimensions would consist of atoms thought of as very large balls separated by many feet of vacuum in an orderly array. Most of the space in this slab of marble is just space. The atoms take up very little room; therefore, when a fairly large X ray moves into this slab of marble, it will very likely penetrate some distance before it collides with an atom of matter. It could go a considerable distance before a collision, and there is a theoretical possibility that it could go completely through a slab of marble without ever colliding.

A high energy gamma ray from cobalt 60, being a smaller ball to start with, can go even farther before it collides with an atom of matter, and it has a greater prob-

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ability of going a considerable distance. When it does collide, it loses some of its energy and bounces off in another direction. This means, by our distorted definition of energy and size, that it becomes a somewhat larger ball and then has a greater probability of making a second collision. If it hits a glancing blow, it continues at a small angle with little loss of energy and becomes only slightly larger. If it hits head-on, it bounces straight back with much loss of energy and becomes a much larger ball with a much greater probability of the next collision.

Without taking such a simplified picture too seriously, we can appreciate a number of important characteristics which determine how many gamma rays get through a slab of material.

First: If the moving ball is small, it is likely to go a long distance without collision. If it is large, it will not penetrate very far. Thus, low energy X rays are more easily stopped than are high energy gamma rays.

Second: If the wall of atoms stopping the rays is made up of very small atoms, they present poor targets to the moving gamma rays, which will then be able to penetrate deep into the wall before collision. If the atoms are very large, they are good targets and the rays will not penetrate far. Thus, a slab of material made up of small atoms of hydrogen, oxygen, aluminum, or magnesium does not stop gamma rays easily. A wall of large atoms of lead, gold, or uranium will have greater stopping power.

Third: If the wall is made up of atoms spaced close together, it will stop gamma rays more easily than if the atoms are spaced far apart. The spacing of atoms is what determines the density of the material. A loosely packed spongy filigree of brick will not have the same stopping power as a dense, tightly packed solid wall of clay.

In measuring the ability of any material to stop radiation, all three of these factors must be considered: the energy of the radiation, the atomic mass of the kind of material used, and the density of the material. It is interesting to see where marble stands in relation to other materials.

The Ability of Various Elements to Absorb Gamma Rays

In Figure 2 is a plot of the relative ability of each of the elements to stop three different energies of gamma rays. The top line shows the picture for 400,000 electron volt gamma rays from radioactive gold. An element with a high atomic number, such as lead with atomic number 82, is much more effective than an element such as calcium with atomic number 20. The middle line shows the ability of all the elements to stop the higher energy gamma ray from a radioactive isotope of cesium at 660,000 electron volts energy. The lower line is for the much higher, million volt energies of the cobalt 60 gamma ray. It is noticeable that calcium will stop the 400,000 volt gamma rays from radioactive gold more easily than lead can stop the million volt gamma rays from radioactive cobalt. It is also apparent that the relative difference between calcium and lead becomes less as the energy increases. Lead is much better than calcium at low energies. It is not so much better at high energies. This explains why the relative lead equivalence of various building materials depends so markedly upon the voltage of X-ray machines, as shown in Table 1.

At the energy of a low voltage diagnostic X-ray machine, 71 inches of marble or 80 inches of concrete are necessary to give the same protection as one inch of lead. But at the high energy of cobalt 60, only about four inches of marble or four and one-fourth inches of concrete are the equivalent of one inch of lead. Since only very thin protective walls of lead are necessary in low voltage diagnostic X-ray installations,

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marble can be used, but at some disadvantage. With high voltage teletherapy equipment where thick shielding walls are necessary, marble is in a position of advantage because of the difference in the cost of space and the cost of material.

The Half Value Layer

Before going on to the next relationship, we should explain the method of measuring the relative stopping power of any given material. Since the passage of gamma rays through a wall of material is hindered only by chance collisions with atoms, there can be no prediction of when and where one single gamma ray will be stopped. Since, however, so many gamma rays are involved with such a great number of atoms in even a thin wall, there is a definite predictable decrease in the number of gamma rays stopped with each added layer of material. For example, one-half of a beam of cesium gamma rays approaching a wall of marble are stopped by one and one-third inches of thickness. The next added one and one-third inches will stop half of what is left, or three-fourths of the total rays. The next added half value layer will stop half of what is now left, or seven-eighths of the total, etc. There is never a complete stoppage of all of the beam, but this, fortunately, is not necessary. It is necessary to insert only a sufficient number of half value layers to reduce the beam to a safe level of radiation. With a beam of cobalt 60 radiation, the half value layer is one and three-fourths inches. It would be just as easy to speak of a tenth value layer, and sometimes, with intense beams of radiation, it is more appropriate to speak in terms of the thickness required to reduce the beam to one-tenth of its original value. The two terms, "half value layer" and "tenth value layer," are mathematically interchangeable. The tenth value layer is three and one-third times the half value layer. Any other values could be used, but these two are the simplest and most commonly used.

The Effect of Density on the Absorption of Radiation

To show the relationship of the density of material to its stopping power, we use the half value layer method of calculating. In Figure 3, the half value layer (for cesium energies) of various building materials has been plotted. This shows the relative thickness of various building materials necessary to do the same job of stopping a relatively high energy radiation. It takes about 10 to 20 cm of wood to stop one-half of the cesium gamma rays. Less than half of 1 cm of uranium will do the same job. Though the exact shape and slope of this half value layer density plot will change with various energies, the relative positions of these various materials will stay about the same. Density is of great importance in radiation shielding and is the only essential difference between the various earth-type materials, since they are all made up of about the same kinds of low atomic number atoms.

One of the advantages of marble is its constant and reliable density. Concrete is not shown on the chart in Figure 3, since the density of concrete depends upon its formula, how it is mixed, poured, tamped, and since sizable holes in large pourings are to be expected. In the use of concrete, engineers have always insisted upon compression strength, whereas for radiation shielding constant density is essential. Instead of concrete, the graph shows sand and cement. When mixed, poured, and dried to a density of 2.35 grams/centimeter^3, this commonly used 147 pound concrete has a relative stopping power for high energy gamma rays about 0.87 times that of marble. The density of marble in 14 samples from quarries ranging from Missouri to Vermont were measured at 2.69 grams/centimeter^3 with a variation of less than 1 per cent. There were four exceptions. Napoleon Gray and Ozark Tavernelle had a slightly lower density of 2.63, or $2\frac{1}{2}$ per cent lower than the average. Alberene Soapstone and Neshobe Gray had a slightly higher density of 2.8, or 3 per cent higher than the average. Different samples of the same marble showed remarkably constant density. It is apparent that

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with this constant density, once a required thickness is determined, there is no necessity, as there is with concrete, to add a few inches for safety.

One of the reasons we use marble in the studies of radiation shielding, even for studying concrete, is that we can be sure of the density and a simple multiplication factor of 1.15 is all that is required to convert thickness of marble to that of concrete.

Measurements of Absorption of High Energy Gamma Rays in Marble

We have completed the absorption studies on the samples of marble submitted by 14 different quarries for the cesium 137 isotope gamma rays of 0.661 Mev energy. The cobalt 60 and other energy figures are incomplete. The data on 14 different kinds of marble are shown in Table 2. The first column shows the density. Although some differences are shown, the error of our measurement is at least a few per cent. For all practical purposes, there is no difference in density except that Alberene stone is perhaps slightly more dense than other marbles.

The second column shows the linear absorption coefficient. This is the absorption per unit thickness of material. The differences are insignificant, except that Blue Belge is slightly lower and Alberene is slightly higher.

The third column shows the half-value layer or the thickness in centimeters that will reduce a narrow beam of cesium radiation to one-half its original value. About 3 1/3 cm is the half-value layer at this high energy. The differences between various marbles can be exaggerated by using the fourth column, which shows the tenth-value layer. A little over 11 cm is the thickness necessary to cut the cesium radiation to one-tenth its original value. Such minor differences as that of a few per cent between our "large set" Etowah marble and Napoleon Gray are within the error of our measuring device and are insignificant. It does, however, take a slightly greater thickness of Blue Belge and somewhat less Alberene stone to accomplish the same radiation shielding. On a practical economic scale, even these differences are probably of little significance.

Tables 3 and 4 show a comparison of marble with other building and shielding materials. For both the cesium 137 gamma ray energy of 0.661 Mev and the cobalt 60 gamma ray energy of over a million and a quarter electron volts, marble stands in about the same position. The differences are significant from the physical point of view, but the significance in the economy of shielding radiation is not immediately visible from these facts alone.

For example, if the problem is to build a shielding head for teletherapy machines, such as is shown in Figure 4, it is necessary to use an 18 cm radius sphere of lead to give adequate protection. The treatment is to be done in the beam at 35 cm from the source; hence, lead can be used. Tungsten would take less space. Only a 13 cm radius of tungsten would be necessary, or only a 10 cm radius of gold. But there is no necessity for such a small diameter and, even though it would look pretty, at the cost per pound of tungsten and gold, it would be economically wasteful to use such materials in a teletherapy machine. On the other hand, it would take over 70 cm radius to give the same protection with marble. Since the treatment distance is to be at 35 cm, marble cannot be considered for this use.

Such a teletherapy machine must be contained inside a treatment room, and this treatment room must have adequate protection in its walls during the time that the beam is on. This problem of wall protection is a different story: If one were to

build the shielding wall of solid lead, a few inches of thickness would be required, and this would be exceedingly expensive. If one were using such a device for an experimental irradiation of test animals in an old barn on a vacant lot where concrete could be mixed from sand and gravel immediately at hand, no finish or cleanliness would be necessary. About 20 inches of cheap home-made concrete, or a few feet of packed dirt, would probably be the most economical method of building a shield.

Austerity, however, can easily be carried too far when such a machine is to be used in the treatment of patients. Here, cleanliness and a certain minimum of appearance is essential. It might be that marble with a polished finish would be cheaper to construct, would reduce the size of the room less, would be cheaper to maintain and keep clean than would any other material. By no means of least importance, it would have an attractive appearance, which can be one of the imponderable advantages in dealing with sick people. In situations such as this, marble has a distinct advantage and can compete with other shielding and construction materials, not as a luxury item, but as an economical method of giving radiation protection.

One particular type of cobalt 60 machine is currently receiving extensive investigation. It is the most economical of the isotope teletherapy machines and, fortunately, is the one that is immediately available. It will probably be a very popular machine in the near future. A big factor in the cost of this machine is the cost of building the protective walls in the room in which the machine is to be housed. One of the advantages of the machine is that it can be put into a relatively small room. The size is close to that of existing X-ray therapy rooms, and the few inches of difference between marble and concrete make it probable that marble could easily be the material of choice. For this reason, a series of charts has been prepared for the thickness of marble necessary to shield a hectocurie cobalt 60 machine. The measurements were made by using nests of marble boxes as shown in Figure 5. Scatter measurements were taken with the beam in various positions in an extra large teletherapy room, as shown in Figure 6. At points F-2, F-5, and F-8, full shielding measurements were made to determine how much marble was necessary at various angles from the beam. These measurements were plotted on polar coordinate paper, and from the graphs shown in Figures 7-1, 7-2, and 7-3 it is possible to determine the thickness of marble shielding necessary in various sized rooms. A complete chart of room protection measurements is given in the Appendix to this paper. From such information, it should be possible to compute the costs of using marble, concrete, or lead. If marble cannot compete economically with concrete or lead, then marble remains a luxury item that is an adequate shield and a beautiful wall. If marble can compete economically, it has a definite place as a radiation shield beyond its other architectural advantages.

The example of the teletherapy treatment room is not the only use of marble. In Figure 8 is shown the use of Alberene stone shielding bricks as a temporary shield around a chemical radioisotope preparation. These 4x4x8-inch and 4x8x8-inch bricks were purchased because they did the same job of protection as do our standard 2x4x8-inch steel and lead shielding bricks. They have been in use for about two years. There is less distortion of the corners and edges than we have found in our standard lead bricks. They are used interchangeably with lead bricks, and they can be decontaminated more easily than can lead. The purchase order bids for a number of lead, marble, and steel bricks, which would give about the same radiation protection, showed that marble was one-sixth as expensive as lead. This is another example of the use of marble as a radiation shield, which depends not on the ancient recognition of marble as a most beautiful and luxurious stone, but on the cold hard cash value of marble as a piece of equipment.

During the past 50 years, marble has been periodically suggested as a useful

radiation shield. Years ago, when low energy radiation was the only kind available for medical use, lead always kept its preferred position as the shielding material of choice. It used up little space and it was economical in that not much of it was required. With the rapid development of the use of higher energy radiation and the necessity for thicker shielding walls, the argument about the cost of the material versus the effective use of space has become an important issue. If a few inches of extra thickness make no difference, marble is economically superior to lead. If a few inches less space make a big difference, marble may be economically superior to concrete. There is need for a re-evaluation of the use of marble as an economical means of radiation protection.

Table 1. Lead Equivalent of Marble and Concrete at Various Energies

Kilovolts Energy	Lead d = 11.3	Marble d = 2.69	Concrete d = 2.35
75	1.0	71	80
150	1.0	67	75
200	1.0	58	65
300	1.0	25	28
400	1.0	16.5	18.5
Cs 137	1.0	5.74	6.80
Co 60	1.0	4.05	4.66

Table 2. Shielding Data on 14 Different Kinds of Marble

Name of Marble	Density gm/cm^3	μ cm^{-1}	HVL cm	TVL cm	Quarry
Escalette	2.70	.21	3.34	11.11	Gowan, New York
Blue Belge	2.67	.19	3.63	12.07	Gowan, New York
Termain Domestic Fleuri	2.69	.21	3.32	11.04	Tennessee
Alabama Veined A	2.68	.21	3.35	11.13	Gantts, Alabama
Alabama Grade A	2.69	.21	3.33	11.05	Gantts, Alabama
Etowah	2.70	.21	3.32	11.03	Georgia
Imperial Danby	2.69	.21	3.35	11.13	Vermont
Neshobe Gray	2.77	.21	3.34	11.10	Vermont
Rutland	2.70	.21	3.33	11.07	Vermont
Napoleon Gray	2.63	.20	3.42	11.38	Carthage, Mo.
Ozark Tavernelle	2.63	.21	3.37	11.19	Carthage, Mo.
Ozark Veined	2.70	.21	3.33	11.06	Carthage, Mo.
Large Set Etowah	2.70	.21	3.31	11.01	Georgia
Alberene Soapstone	2.80	.23	3.00	9.96	Virginia

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Table 3. Comparison of Marble with Other Building and Shielding Materials for Gamma Rays from Cesium 137. (0.661 Mev)

Material	Density gm/cm^3	1^{μ} cm^{-1}	HVL cm	TVL cm
Tungsten	16.50	1.53	0.45	1.50
Lead	11.26	1.20	0.58	1.92
High Density Glass	6.94	0.67	1.04	3.44
Brass	8.40	0.60	1.16	3.86
Steel, Cold Rolled	7.76	0.55	1.26	4.18
Alberene Soapstone	2.80	0.23	3.00	9.96
Typical Marble	2.69	0.21	3.33	11.05
Aluminum	2.44	0.18	3.81	12.65
Barytes Stone Brick	2.29	0.18	3.85	12.79
147 lb. Concrete	2.35	0.18	3.94	13.10
Berea Sandstone	1.76	0.16	4.32	14.36
Cement, Portland	2.12	0.16	4.35	14.46
Sand	2.12	0.16	4.38	14.54
Water	1.00	0.08	8.41	27.95
Wood, Fir	0.53	0.04	15.82	52.55

Table 4. Comparison of Marble with Other Building and Shielding Materials for Gamma Rays from Cobalt 60 (1.25 Mev)

Material	Density gm/cm^3	1^{μ} cm^{-1}	HVL cm	TVL cm
Tungsten	16.50	0.92	0.75	2.49
Lead	11.26	0.64	1.09	3.61
Brass	8.40	0.43	1.62	5.37
Steel, Cold Rolled	7.76	0.40	1.75	5.82
High Density Glass	6.94	0.37	1.86	6.17
Alberene Soapstone	2.80	0.18	3.78	12.55
Typical Marble	2.69	0.16	4.40	14.64
Berea Sandstone	1.76	0.14	4.85	16.11
Aluminum	2.44	0.13	5.25	17.44
147 lb. Concrete	2.35	0.13	5.41	17.98
Cement, Portland	2.12	0.12	5.88	19.53
Barytes Stone Brick	2.29	0.12	5.92	19.67
Sand	2.12	0.11	6.13	20.37
Water	1.00	0.06	10.83	35.98
Wood, Fir	0.53	0.03	22.58	75.03

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Appendix

ROOM PROTECTION CHART

Co 60 - HECTOCURIE TELETHERAPY MACHINE - 540 rhm

THICKNESS OF MARBLE NECESSARY TO SHIELD A POINT 3 FEET, 7½ FEET, AND 12 FEET FROM THE SOURCE

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Objective

To determine by direct measurement the thickness of marble required to reduce to predetermined levels the direct and scattered radiation from a cobalt 60 hectocurie teletherapy machine.

Source of Radiation

The prototype hectocurie teletherapy machine (Figure 4) was used as the source of radiation. This machine was loaded with a double cloverleaf source of about 452 curies of cobalt 60. A calibrated Victoreen rate meter with a 3 mm lucite cap on the chamber was placed one meter from the source on the central axis of the useful beam. With the largest possible cone in place, the instrument was 366 rhm on November 1, 1953.

The Teletherapy Room

The machine was placed in the teletherapy room at the Medical Division of the Oak Ridge Institute of Nuclear Studies. A plan of this room is shown in Figure 6. The room measures 14 feet by 24 feet, with an 11-foot ceiling height. The tile flooring allows for the ruling of the room into lettered and numbered points, which make a series of squares 18 inches on center with an 8-inch to 9-inch border around the sides. The entire room is surrounded by an earth fill. It is sunk into a hillside of clay with the roof covered and the control room projecting from the bank.

The source is almost directly over point F-10. The beam from the machine can be pointed in any direction from point F-16 through about 230° counter-clockwise to point J-7. For all of the measurements in this figure, the source and detector were one meter off the floor. There were no scattering objects in the room. The doors leading into the chamber are of wood.

Marble Absorbers

Since it was impractical to build a complete wall of each thickness of marble, three sets of nesting boxes were used as broad beam absorption shields, as shown in Figure 5. Each marble box consisted of five sides of uniform thickness and a cover with staggered joints. The side opposite the cover in each box was a single slab of

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marble without cracks and was always pointed toward the source of radiation.

The smallest box in each set was a 2 3/4-inch cube with a 1-cubic-inch cavity. The largest box was an 18-inch cube with a 13 3/4-cubic-inch cavity. There were six nesting boxes in each set. The thickness of the marble in one set of the boxes was as follows:

Box No. 1 = 48.8 mm - Largest box
Box No. 2 = 38.0 mm
Box No. 3 = 38.1 mm
Box No. 4 = 32.1 mm
Box No. 5 = 31.4 mm
Box No. 6 = 23.8 mm - Smallest box

One set of boxes was from marble quarried in Vermont, one set from marble quarried in Alabama, and one set from marble quarried in Georgia.* The density of the marble used in all these separate boxes was uniformly measured on various samples at 2.69 ± 0.02 grams/cm^3.

Radiation Instruments

The Victoreen rate meter calibrated for cobalt 60 energies with a 3 mm lucite cap could be inserted into the smallest box. To arrive at an attenuation coefficient, measurements were taken in the smallest box first and each succeeding larger box was added. Most of the scattered radiation measurements were at rates lower than the lowest scale on the Victoreen rate meter. At these positions a cobalt 60 calibrated cutie pie was inserted into the No. 4 box and surrounding boxes added. For some of the open beam and small angle scatter measurements, when the rate lay between the sensitivities of the Victoreen rate meter and the cutie pie, a cobalt 60 calibrated GE long probe cutie pie was used.

Each set of measurements was completed in a few hours. In all situations, the errors inherent in the measurements were sufficiently large and the measurement sufficiently rough that it was felt unnecessary to make corrections for temperature and pressure. Repetitions of the same procedure from week to week and with different measuring instruments gave direct reading results within a 5 to 10 per cent accuracy, except at some of the very low radiation levels where 25 per cent accuracy was considered sufficient on any single measurement.

Results

The results of the marble absorption measurements at various angles of the scatter are shown in the accompanying tables. Smooth curves were drawn from the attenuation data at six different angles, and the other angle readings were intrapolated. At the points with high radiation levels, it was occasionally necessary to extrapolate. The measurements were taken with the beam pointed at F-16, A-16, A-10, A-5, A-1, and in the direct beam. Measurements in the direct beam were taken without a water phantom in place since the NCRP requirements specify that such protection shall be calculated without a patient

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* Furnished through the courtesy of the Marble Institute of America by the following quarries:

Vermont Marble Company, Proctor, Vermont
Alabama Marble Company, Sylacauga, Alabama
Georgia Marble Company, Tate, Georgia

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in the beam. Measurements at all angles of scatter were taken with a 20 x 30 x 30 cm water phantom in place at a 50 cm SSD. All measurements were with the widest possible cone, which measured 12 cm in diameter, at 30 cm from the source.

In Table 1A is shown the measured mr/hr at points F-2, F-5, and F-8 which were at 0.91 meters (3 feet), 2.3 meters (7 1/2 feet), and 3.6 meters (12 feet) from the source. These measurements have been corrected from the 366 rhm source actually used to read as though they were from a 540 rhm source, which is the maximum for which the hectocurie machine is designed.

In Table 2A are shown intrapolations from the measurements of the thickness of marble necessary to reduce the radiation to 6.25 mr/hr. This is the required shielding for a "beam-on" time of 48 hours per week with a person in the field 100 per cent of 48 hours.

Tables 3A to 7A show similar intrapolations for various standard definitions of both 40 per cent and 100 per cent "beam-on" time and for occupancy factors of 1/4 and 1/16.

Figures 7-1, 7-2, and 7-3 show on polar coordinates the thickness of marble required at all positions around the teletherapy machine and are a graphic plot of the data shown in the tables.

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Table 1A

Angle from central axis of useful beam	mr/hr at		
	Point F-8 3 feet	Point F-5 $7\frac{1}{2}$ feet	Point F-2 12 feet
0-10° = widest cone without phantom	815,000	110,000	40,700
water with phantom in place			
20°	13,000	3,200	1,100
30°	3,800	1,300	410
40°	2,500	920	330
50°	1,900	710	270
60°	1,550	560	220
70°	1,250	450	190
80°	1,000	370	160
90°	800	310	140
100°	660	255	120
110°	550	220	105
120°	450	180	92
130°	370	155	81
140°	300	130	72
150°	250	110	63
160°	200	95	55
170°	160	82	49
180°	130	70	43

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Table 2A

Table 3A

Angle from central axis of useful beam	Beam "ON" 100% of 48 hr week Full occupancy factor Thickness of marble (centimeters) For reduction to 6.25 mr/hr			Beam "ON" 40% of 48 hr week Full occupancy factor Thickness of marble (centimeters) For reduction to 15.6 mr/hr		
	Point F-8 3 feet	Point F-5 7½ feet	Point F-2 12 feet	Point F-8 3 feet	Point F-5 7½ feet	Point F-2 12 feet
0-10° = widest cone without phantom	79.5 cm	66.9 cm	60.7 cm	74.5 cm	61.9 cm	55.7 cm
water with phantom in place						
20°	52	46	42	50	40	34
30°	42	40	37	38	33.5	29
40°	39	37.5	34.5	34.5	31	27
50°	37	35	32	32	29	25
60°	36	33	30	30	27	23
70°	34	31.5	28.5	28	25	21.5
80°	33	29.5	27	26	23.5	20
90°	32	28	25.5	24.5	21.5	18
100°	31	26.5	24	23	20	17
110°	30	25	22.5	21.5	18	15
120°	29	23.5	21	20	17	14
130°	28.5	22	20	18.5	15	12.5
140°	28	20.5	19	17	14	11
150°	27.5	19	18	16	12.5	10
160°	27	18	16.5	14.5	10.5	8.5
170°	26	16.5	15.5	13.5	9	7
180°	25	15	14.5	12.5	8	6

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Table 4A

Table 5A

Angle from central axis of useful beam	Beam "ON" 100% of 48 hr week 1/4 occupancy factor Thickness of marble (centimeters) For reduction to 25 mr/hr			Beam "ON" 100% of 48 hr week 1/16 occupancy factor Thickness of marble (centimeters) For reduction to 100 mr/hr		
	Point F-8 3 feet	Point f-5 7½ feet	Point F-2 12 feet	Point F-8 3 feet	Point F-5 7½ feet	Point F-2 12 feet
0-10° widest cone without phantom	70.9 cm	58.3 cm	52.1 cm	62.2 cm	49.6 cm	43.4 cm
water with phantom in place						
20°	43	36	31	35	30	22.5
30°	34	30	25.5	26	21	15
40°	29.5	27	23	22	18	12
50°	27	25	21	19	16	10
60°	25	23	19	17	13.5	8
70°	23	21	17	15	12	6
80°	21	19	15.5	13	10.5	5
90°	20	18	14	12	9	3
100°	18.5	16.5	13	10.5	8	2
110°	17.0	15	12	9	6.5	1
120°	16	13.5	10.5	8	5	-1
130°	14.5	12	9	6.5	4	-1
140°	13	11	8	5.5	3.5	-1
150°	12	10	7	4.5	2.5	-1
160°	10.5	8	6	3.5	1.5	-1
170°	9	7	5	1.5	1.0	-1
180°	8	6	4	1.0	1.0	-1

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Table 6A

Table 7A

Angle from central axis of useful beam	Beam "ON" 40% of 48 hr week 1/4 occupancy factor Thickness of marble (centimeters) For reduction to 62.5 mr/hr			Beam "ON" 40% of 48 hr week 1/16 occupancy factor Thickness of marble (centimeters) For reduction to 250 mr/hr		
	Point F-8 3 feet	Point F-5 7½ feet	Point F-2 12 feet	Point F-8 3 feet	Point F-5 7½ feet	Point F-2 12 feet
0-10° = widest cone without phantom	46.1 cm	52.3 cm	64.9 cm	56.5 cm	43.9 cm	37.7 cm
water with phantom in place						
20°	38	31.5	25	30	22	15
30°	29	24.5	20	20.5	16	9
40°	25	21.5	17	17	12.5	6
50°	22	19	14	14.5	10	4.5
60°	20	16	12	12	8	3
70°	18	14	10	10	6	2
80°	17	12	8	8	4.5	1.5
90°	15	11	7	6.5	3	1
100°	13	10	6	5.5	2	-1
110°	12	8.5	5	4.5	1.5	-1
120°	10.5	7.5	4	3.5	1	-1
130°	9.5	7	3.5	2.5	-1	-1
140°	8	6	3	2	-1	-1
150°	7	5	1.5	1.5	-1	-1
160°	6	4	1	1	-1	-1
170°	4.5	3	-1	-1	-1	-1
180°	4	2	-1	-1	-1	-1

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Figure 1. Open air measurement of a hectocurie Co 60 source in the high intensity gamma radiation field at Oak Ridge.

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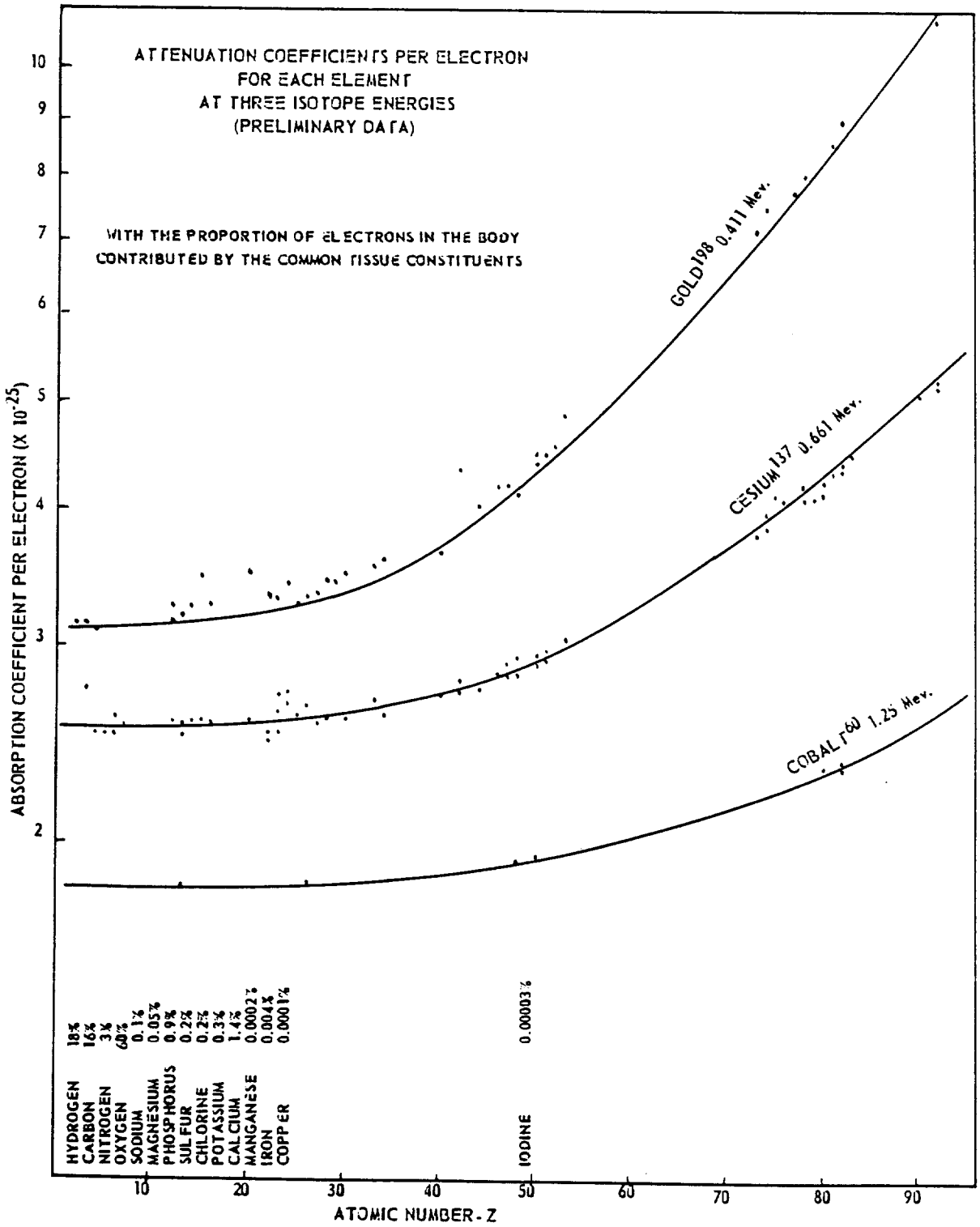

Figure 2. Plot of the relative ability of each of the elements to stop three different energies of gamma rays.

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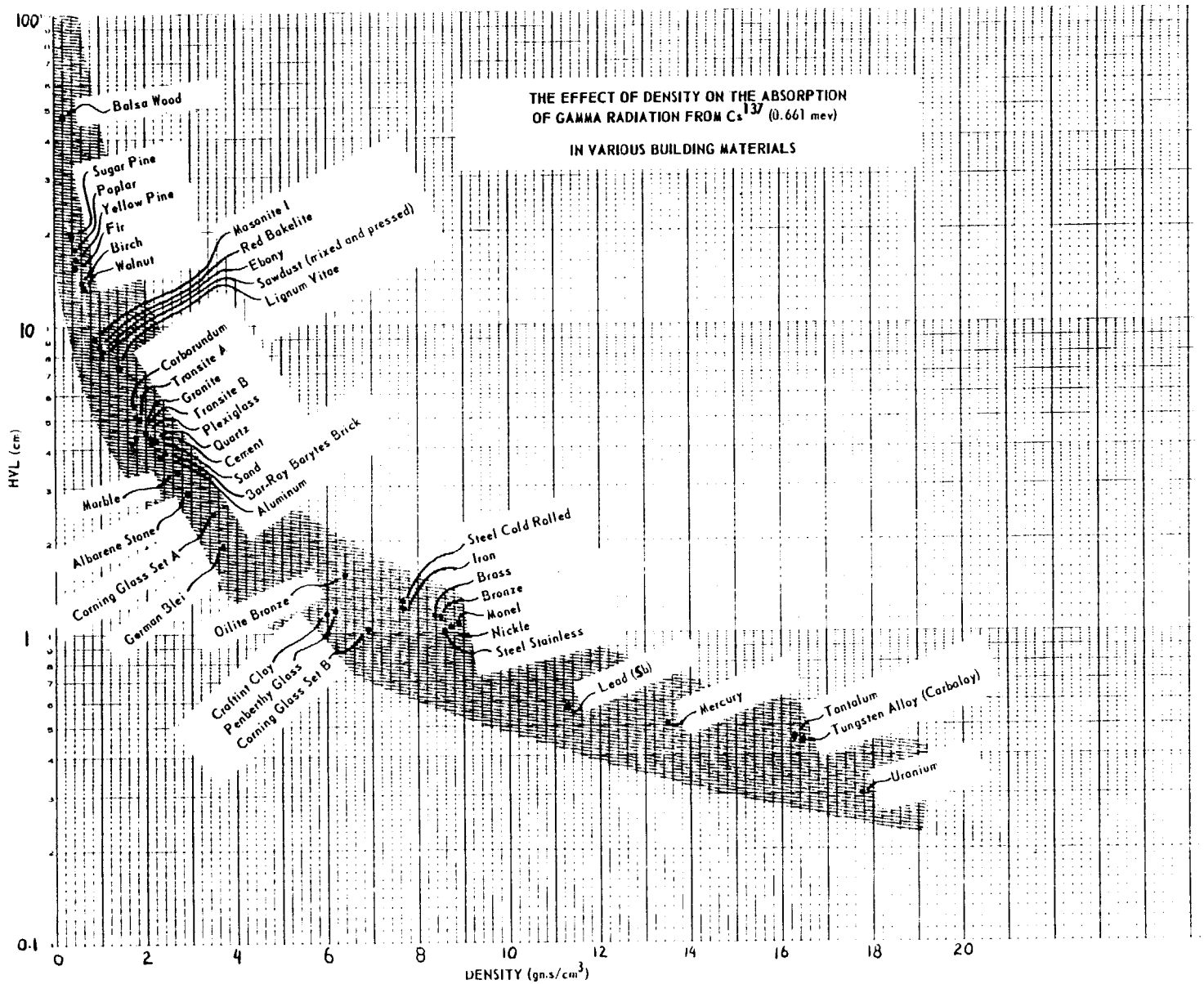

Figure 3. Plot of half value layer related to density (for cesium energies) of various building materials.

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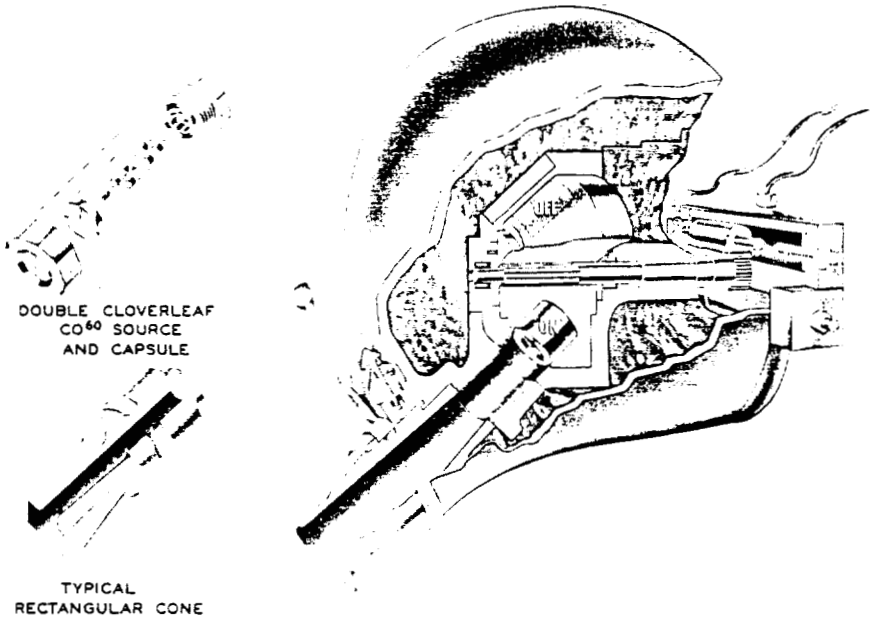

Figure 4. Hectocurie Co 60 teletherapy unit (up to 10r per minute at 1 meter).

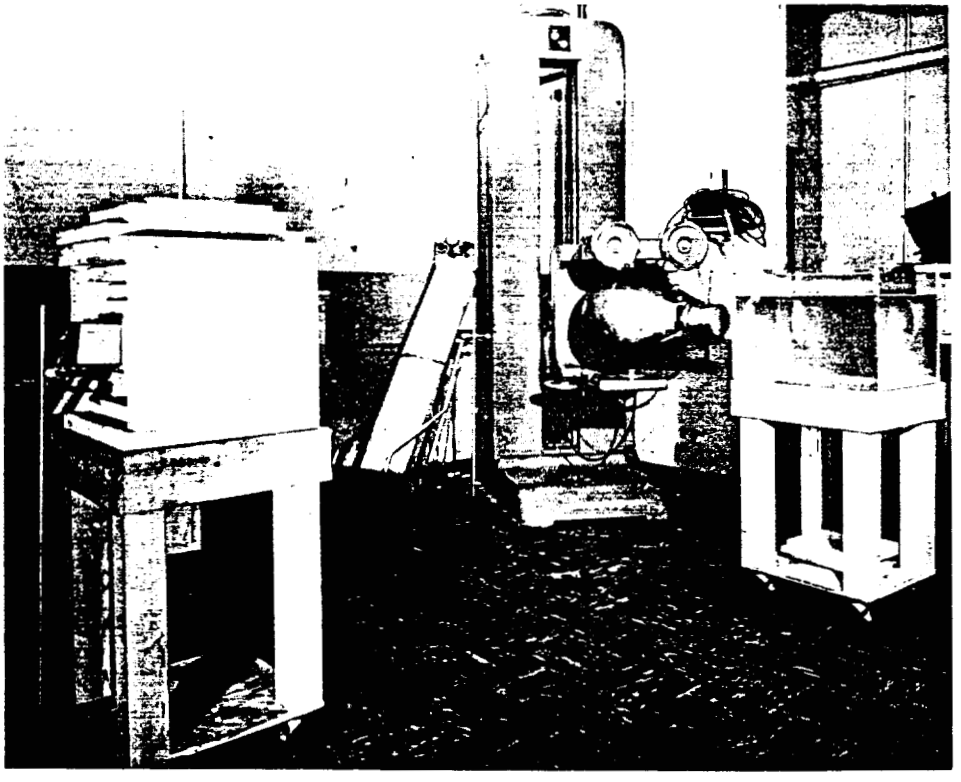

Figure 5. Nests of marble boxes for absorption study.

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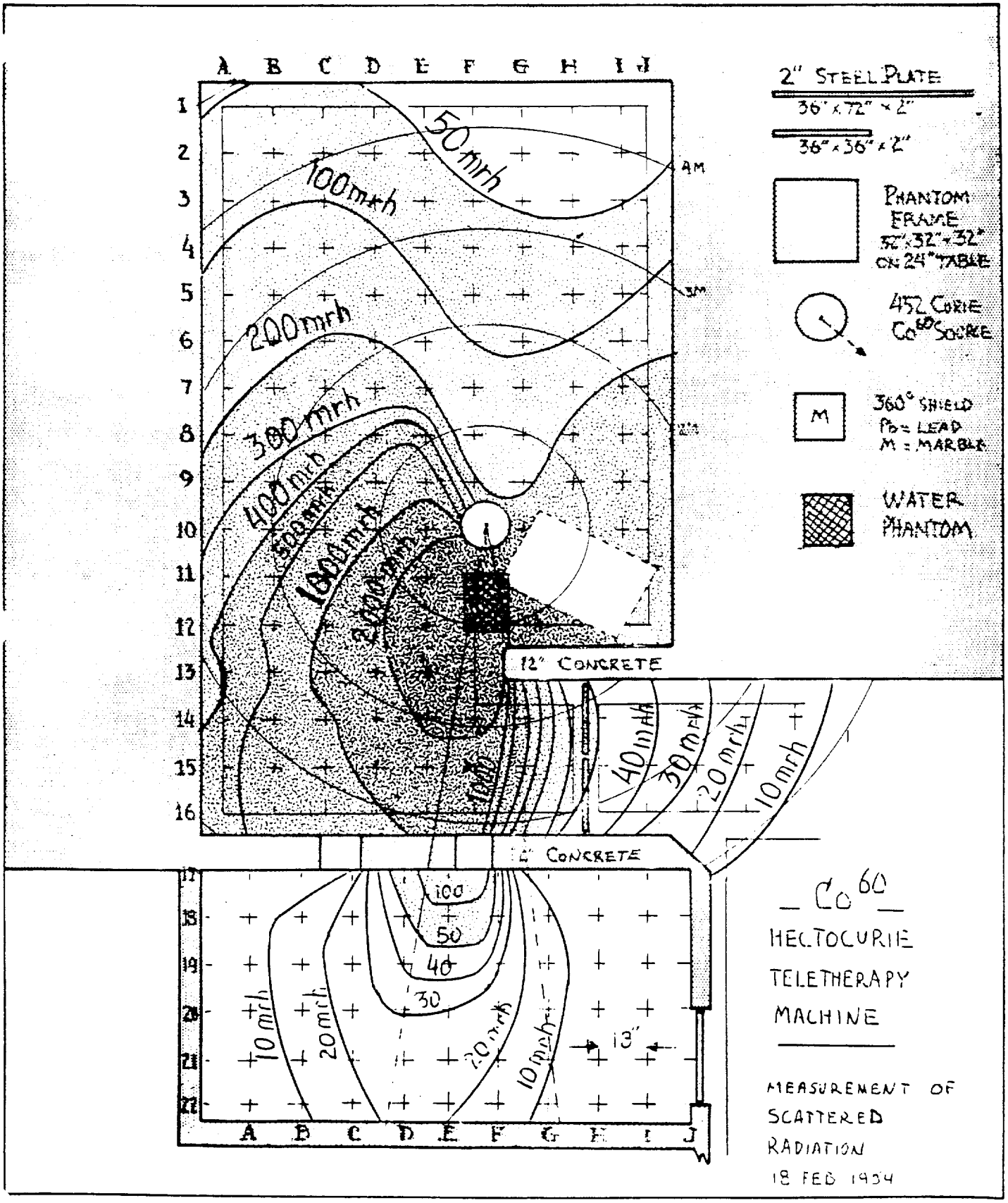

Figure 6. Arrangement of the hectocurie Co 60 machine in a well shielded teletherapy room.

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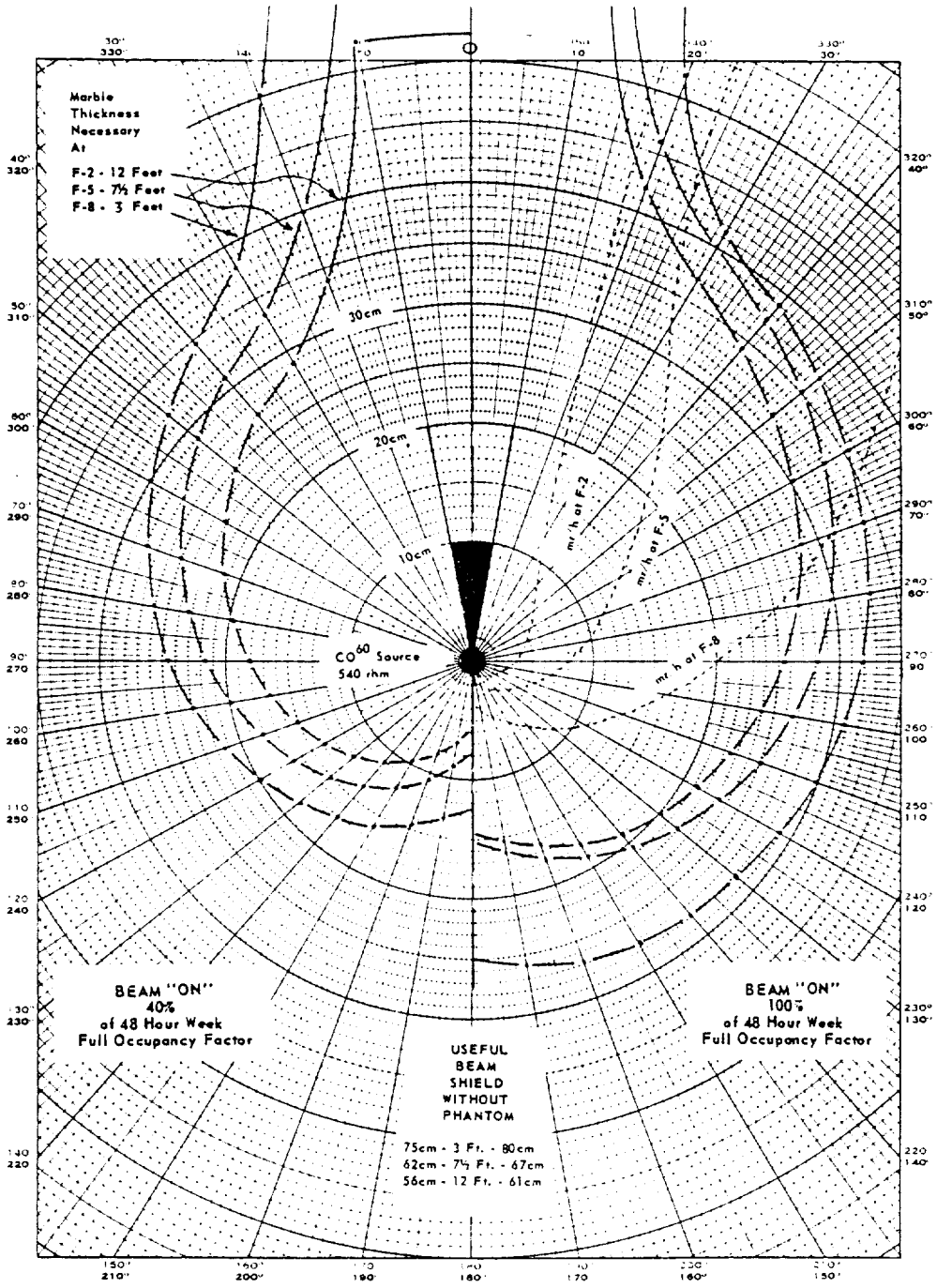

1.

ROOM PROTECTION

COBALT 60 - HECTOCURIE MACHINE - 540 rhm

Thickness of Marble Necessary to Shield a Point
3 Feet, 7½ Feet, and 12 Feet From Source
With a Full Occupancy Factor

Extrapolated from Direct Measurements of a 366 rhm Source
Water Phantom at 50 cm SSD for all Angle Measurements
No Phantom in Place for Useful Beam Measurement
Largest Possible Cone (10°); Marble Density is 2.69 g/cm^3

Figure 7-1. The thickness of marble necessary to shield a hectocurie Co 60 source with the beam "ON."

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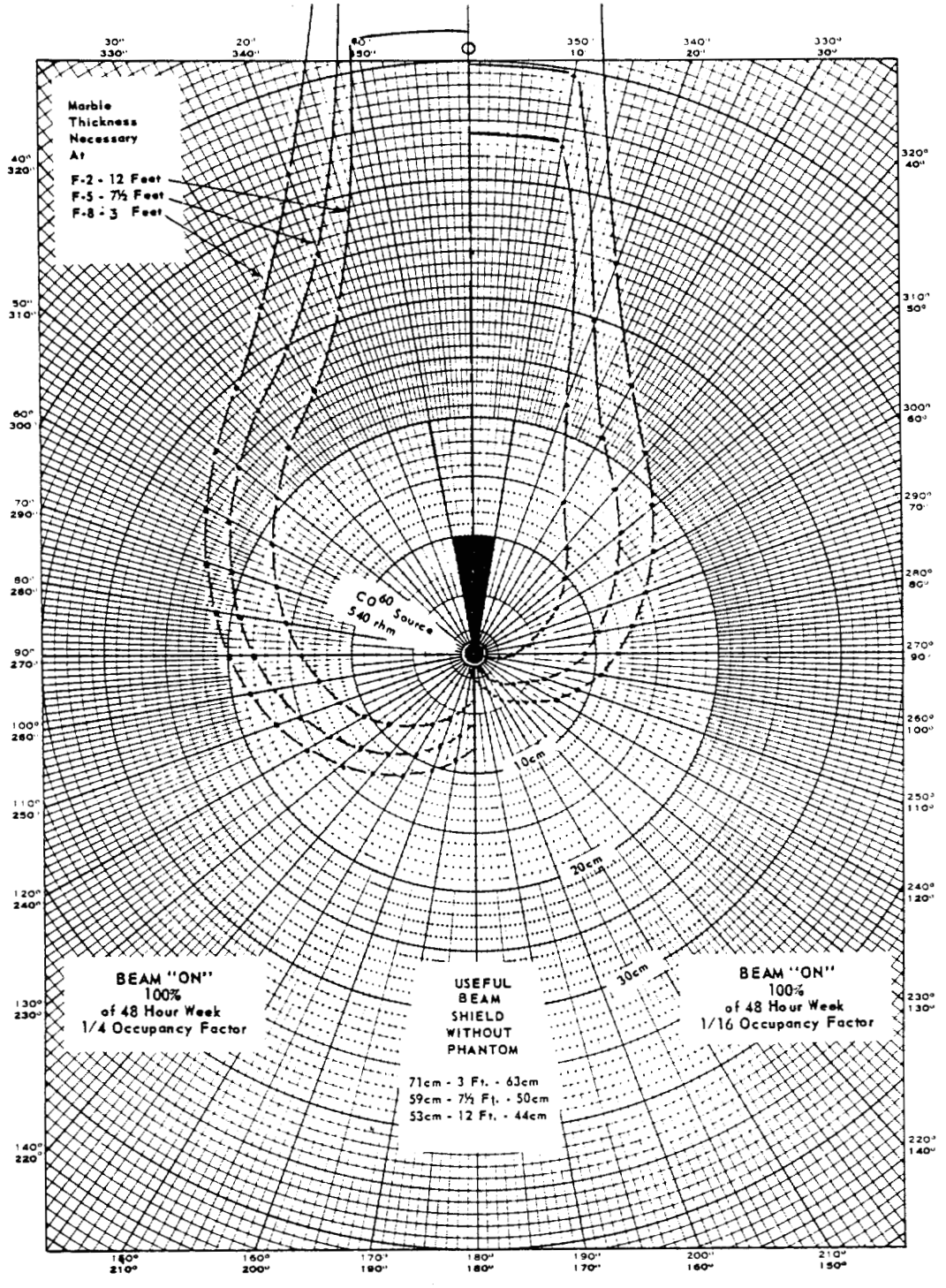

2.

ROOM PROTECTION

COBALT 60 - HECTOCURIE MACHINE - 540 rhm

Thickness of Marble Necessary to Shield a Point
3 Feet, 7½ Feet, and 12 Feet From Source

At 1/4 and 1/16 Occupancy Factors
With Beam "On" 100% of 48 Hour Week

Figure 7-2. The thickness of marble necessary to shield a hectocurie Co 60 source with the beam "ON."

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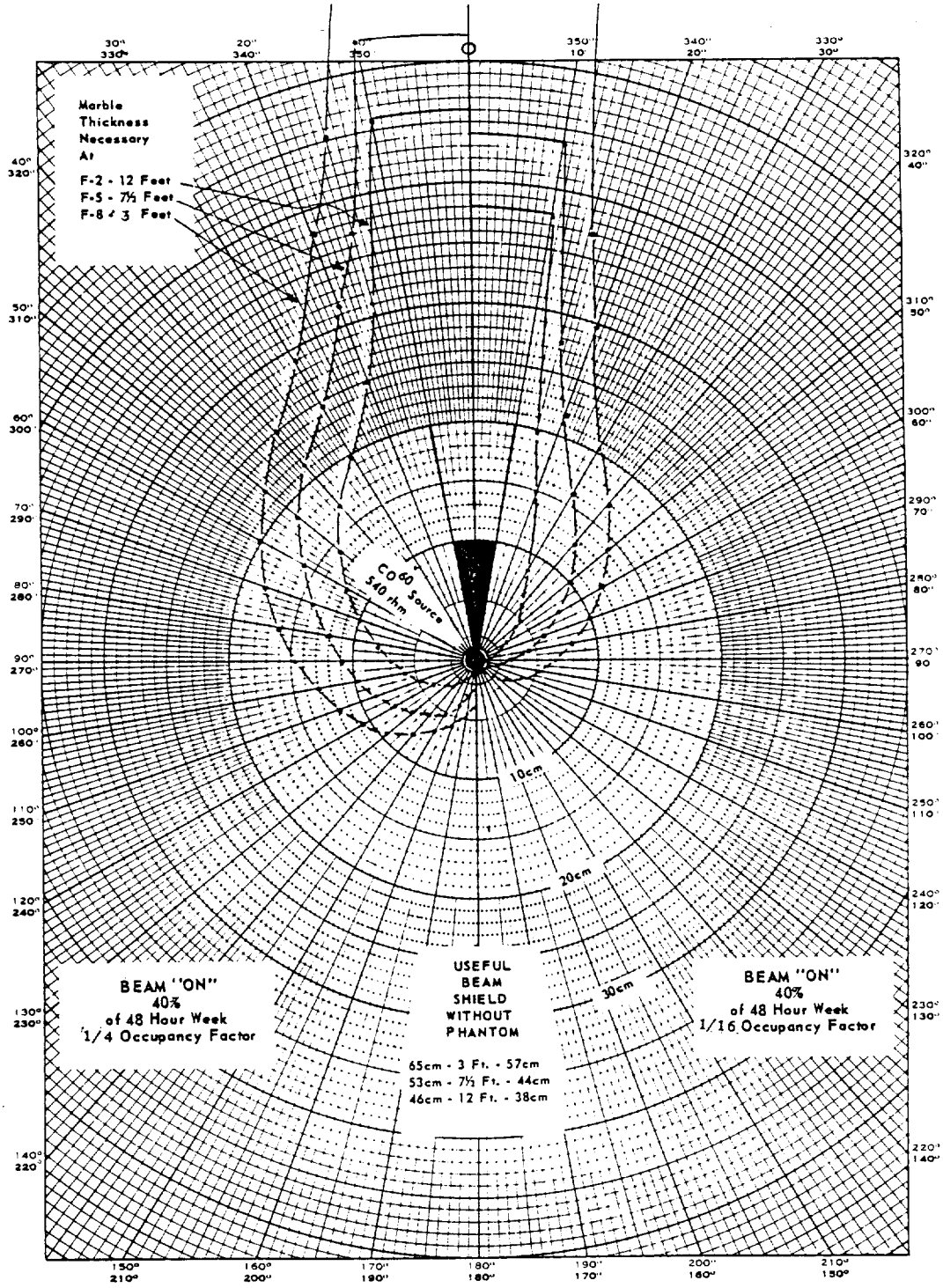

3.
ROOM PROTECTION
COBALT 60 - HECTOCURIE MACHINE - 540 rhm

Thickness of Marble Necessary to Shield a Point
3 Feet, 7½ Feet, and 12 Feet From Source

At 1/4 and 1/16 Occupancy Factors
With Beam "On" 40% of 48 Hour Week

Figure 7-3. The thickness of marble necessary to shield a hectocurie Co 60 source with the beam "ON."

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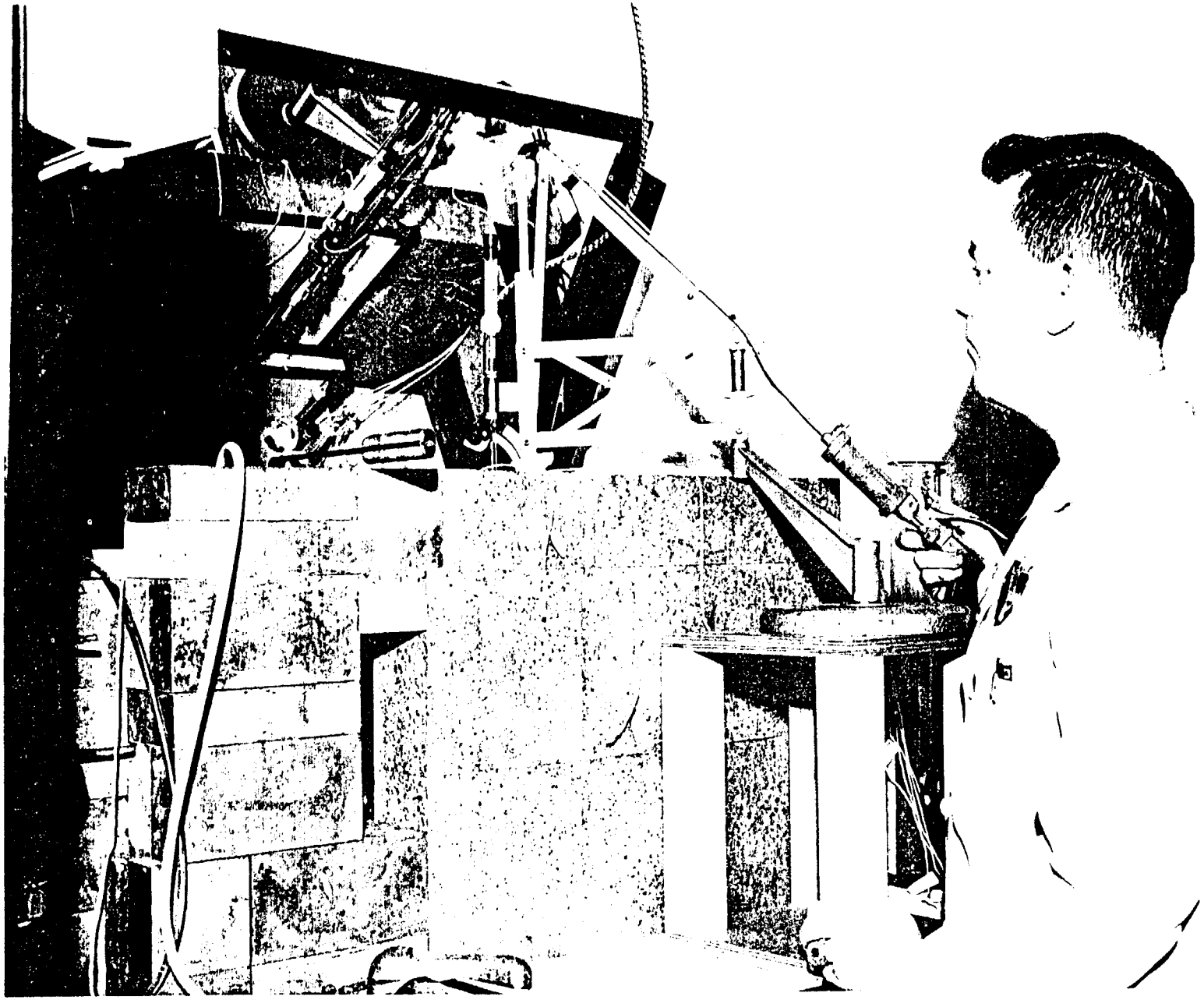

Figure 8. The use of Alberene stone in temporary shielding problem.

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FINAL REPORT ON THE L. G. GRIMMETT CO 60 TELETHERAPY UNIT*

Herbert D. Kerman, M.D. **

In preliminary reports [1,2,3,4,5], the essential features of construction and operation of a cobalt 60 teletherapy unit were described. This final report will amplify and describe further experiences in its design and construction. The unit, now completed, is in clinical operation at the M.D. Anderson Hospital, Houston, Texas. Additional reports covering specific topics are listed in the reference section of this paper [6,7,8,9,10,11,12].

Stray and Scattered Radiation

The unit loaded with a 200 curie source was subjected to preliminary stray radiation surveys with ionization chamber survey instruments. These measurements indicated an asymmetrical pattern of transmitted radiation about the head as demonstrated in the isodose contour model in Figure 1. At the point of maximal transmitted radiation, the measurement was approximately 50 mr/hr. The elliptical shape of radiation corresponded identically with the pattern of the cobalt source and container within the shielding head, and the contour suggested that the pattern of transmitted radiation was due, in part, to removal of small segments of tungsten alloy from the central rotating disk for the insertion of the source container. The factors of scattering along metal surfaces, and of multiple and right angle scattering, undoubtedly contributed to this pattern.

To correct this asymmetrical pattern, the source container was redesigned so that the soft steel ears of the source container box were replaced with the higher density material, tantalum, which effectively reduced the asymmetry of the transmitted radiation.

Measurements made after the loading of the unit with a 950 curie source indicated a maximum transmitted radiation at the surface of the unit with the source in the "off" position of approximately 170 mr/hr. At 1 meter from the source this was reduced to 6 mr/hr.

If a maximal permissible exposure level is required at the surface of the unit, the addition of lead blisters (Figures 2 and 3), each weighing 120 pounds and measuring 2 1/8 inches at the center of curvature, will reduce this transmitted radiation at the surface of the unit to 4 mr/hr. With the blisters in place, only minor rebalancing was required, and the same flexibility was maintained. At 1 meter from the source the radiation measured 0.2 mr/hr.

Subcommittee No. 9 of the National Bureau of Standards has recommended that with encapsulated sources the 10 mr/hr isodose line exposure be at 1 meter from the source,

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* This report summarizes work done during 1950-1953 by the principal investigators: Herbert D. Kerman, M.D., Jasper E. Richardson, Ph.D., Marshall Brucer, M.D., William C. Martin, William R. Buher, James H. Wilde, Harry E. Kimble, Nathaniel W. Hill.

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and since this unit meets this requirement without the blisters, they have been removed. At no point around the unit with the source in the "off" position is the maximal permissible exposure exceeded at 1 meter (Figure 4).

Personnel protection meters and radiation film badges of personnel working with the unit have revealed less than 10 mr/wk. These persons have been in relatively the same areas as will be personnel using the machine for treatment purposes.

With the beam directed at the control room and with the use of the widest possible fields (a condition that would never obtain during routine use), measurements were 4.4 r/hr behind the concrete barrier in the treatment room, 3.5 r/hr in the control room directly opposite the central axis of the beam, and 2.5 r/hr behind the zinc bromide viewing ports.

When the unit was in the usual position for therapy, with the widest possible beam 1.5 meters from the floor, less than 16 mr/hr was recorded behind the concrete barrier in the treatment room, and less than 1 mr/hr was recorded in the control room.

Scattered radiation from a unit density phantom with widest possible field at 1 meter from central axis of beam was recorded as 0.006 per cent of useful intensity of the central axis beam.

Leakage Tests

The unit was subjected to a reloading procedure which afforded an excellent opportunity to test for possible leakage of the radioactive source from the specially designed source container. Smear tests made from the source container and treatment head showed no evidence of radioactive contamination, which testified to the efficency of sealing and the integrity of the source container.

Measurement of the Gamma Ray Beam in Air

Measurements of the gamma ray beam in air were made at 50 cm SSD (source to skin distance) with a beam of approximately 20 x 20 cm at the point of measurement. The measurements were made with calibrated Victoreen condenser chambers and a Victoreen rate meter. With temperature and pressure corrections, a dose rate of 76.6 r/min was determined.

Determination of Effective Curtage

Using the relationship of 13.5 r/hr for 1 mc of cobalt 60 at 1 cm, the effective curie value was 851 at the time of measurement. Correcting for decay of the source since removal from the reactor, a value of 868 curies with an effective specific activity of 24.4 curies/gram was established.

The calculated expected activity of the source was said to be 1250 curies. If the loss because of self-absorption is considered to be approximately 20 per cent, the effective curie value of the source should have been approximately 1000 curies.

The apparent discrepancy in the calculated value and these measurements was 13.2 per cent. This discrepancy of calculated values and in actual measurements is not at all uncommon. The experiences of Johns [13] and Merewether [14], and the investigations of Rosenzweig [15], and Levin and Hughes [16] all report lower measurements than those expected based on the pile activation formula. It would seem that the expected

specific activity based upon calculations and the actual activity obtained under present reactor operating conditions are not coincidental when large activities are involved. Part of this is because of the fact that reactor measurements are taken and are calibrated with a broad beam geometry, whereas the teletherapy machine uses a narrow beam geometry. A correction factor for the relatively narrow beam geometry indicates that the actual curiage was about 950.

Other possible factors responsible for this discrepancy are:

1. Inaccuracy of cross section values for pile neutrons.
2. Inaccuracy of values for effective neutron flux in the immediate area of the target material.
3. Uncertainty of corrections for self-shielding of the target material, and values of optimum thickness for efficient radiation.
4. Dusting of the source and loss of activity and handling.
5. Complications of the scattering phenomena in measurements of high intensity sources.

Final Design of Treatment Cones

High energy gamma rays, collimated and defined by a master collimating and treatment cone, produce secondary forward scattered electrons by the interaction of these gamma rays with the high "Z" material of the cones. These secondary electrons are highly ionizing and have been shown to increase the skin dose when the collimating system is close (less than 30 cm) to the skin surface. Since one of the advantages of supervoltage radiation is the reduction of skin damage, every effort should be made to preserve this advantage.

A treatment cone used close to the skin (less than 30 cm) should not only serve its purpose of defining the beam, but should also be constructed to reduce, to a minimum, the emission of forward scattered electrons from the cone.

The treatment cones of the cobalt unit are not used to indicate the size of the beam, but are the absorbing materials that define the size of the beam. This material is the primary source of these scattered electrons.

Most designs for supervoltage units make use of diaphragming systems at some distance above the skin of the patient and utilize the air gap to dissipate the electrons. This method, however, usually permits large penumbra effects, which are also undesirable. In addition, when large SSD are used, extremely intense radioactive sources are necessary. Isotopes that have been made in very high specific activity sources are therefore necessary. Combinations of diaphragming systems and secondary "umbrella type" treatment cones can be designed to reduce penumbra effects, but these are usually somewhat complicated, expensive, and cumbersome.

The ORINS - M. D. Anderson unit was originally designed with the intention of using close SSD, and with the master collimating cone and treatment cones as the absorbing materials that would define the beam. It was then necessary to find a method that would minimize the secondary electron contamination of the gamma beam.

A possible solution to this problem was suggested by the work of several investigators [17] in which the forward scattered electron emission from radium and cobalt [18] was found to be reduced when screened by materials of intermediate atomic number, such as brass. Accordingly, experiments were undertaken to determine whether this finding might be applied to the design of treatment cones for the cobalt irradiator.

Preliminary measurements were made with untapered cones (Figure 5) having apertures of 2 cm, 5 cm, and 10 cm diameters. Brass and lucite sleeves were made to study the importance of the inner lining material, and several different materials were used as caps over the opening of the cones.

The electrons were observed through their effect on electron build-up curves. The instruments used for these measurements consisted of (1) a shallow ionization chamber, active volume 1 mm deep by 2 cm diameter (Figure 6); (2) a masonite phantom of infinite thickness (Figure 7); and (3) lucite and polystyrene foils of different thicknesses to supply unit-density material simulating the skin of a patient (Figure 8). The ionization chamber was modified from the design of Miller [19], and Trump and Cloud [20]. The vacuum tube electrometer circuit to measure current produced in its chamber, was a modification of a circuit developed by T. E. Bortner of the Oak Ridge National Laboratory. This circuit is a null indication bridge using a potentiometer for the balance and a galvanometer for the indicator. The masonite phantom was constructed so that the ionization chamber could easily be moved from the center to the edge of the field.

The effect of the inner lining of the cone can be seen from Curves A, B, and C of Figure 9. The absorber thickness is given in millimeters of polystyrene. The lucite absorbers, density of 1.18 gm/cm^3, have been converted into equivalent thickness of polystyrene, density 1.03 gm/cm^3. The curves have been normalized at 6 mm. As was anticipated, a material of intermediate atomic number proved to be best (Curve C).

To further minimize the electron emission, various materials were used to cap the opening of the cone. The materials used, all of equivalent thicknesses, for stopping 1 Mev electrons were lucite, pyrex, and brass.

Brass again proved to be the best material (Curve D of Figure 9). A 0.010-inch brass cap attenuated the beam by only 1 per cent. Greater thickness only increased the attenuation without altering the build-up curve.

Build-up curves taken at greater distances show that the electrons become a serious problem only for distances within 10 cm from the skin surfaces. With larger field sizes, greater effects were demonstrated.

The biological effect as demonstrated by erythema studies on the skin of rabbits corroborated the physical measurements.

The use of brass inner linings and a brass cap over the cone effectively reduced the electron contamination of the beam, but it was thought desirable to retain the usefulness of the light localizer if possible. This was accomplished by construction of a composite brass and lucite cap so that the margin of the light beam could be projected through the cap (Figure 10). The base was made of 1/16-inch lucite and 0.005-inch brass, the brass on the outer face. This is equivalent to about 0.010-inch of brass, necessary for stopping 1 Mev electrons. The brass covers the opening of the cone except for a narrow (1 mm) slit around its edge. Although this arrangement will show more improvement at the center of the field than at the edge, it is allowable since previous measurements with no cover showed a better build-up curve at the edge than at the center. The light localizer is adjusted so that the outer edge of the light beam coincides with the outer edge of the source penumbra, and a dark line showing the edge of the slit coincides with the beam from the source.

In this arrangement, the penumbra of the X-ray beam and of the light source are

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identified, and are readily visualized on the skin surface for any field or SSD. At the same time, the brass cap minimizes the secondary electron emission, making small skin-cone distances tolerable (Figure 11). The sharp dark lines are the edge of the primary beam. The penumbra is easily seen.

Reloading Unit with Large (851) Cobalt Source

The reloading procedure was carried out at the Oak Ridge National Laboratory, and in this instance the loading procedure was changed considerably so that a "hot cell" and remote-control slave manipulators were used to accomplish the loading procedure without resorting to the use of water as a shielding medium.

A practice loading procedure was rehearsed and the details were developed to satisfaction. The source was unloaded from the transfer container and removed from the aluminum irradiation cans. This procedure was done under water, by the usual techniques of handling intense sources of radiation. The source was then placed in a carrier and the carrier was transferred to the hot cell.

The cobalt wafers were removed from the carrier within the hot cell by use of the slave manipulator and transferred to the newly-devised source container. The source container was sealed in the manner developed by the previous loading, and the outside of the source container was decontaminated by a series of washings and scrubbings, all by use of the slave manipulator. The source container, into which the cobalt wafers had been loaded and sealed, was then transferred to an intermediary storage cell and the unloaded carrier was removed from the hot cell. The hot cell was then decontaminated and the treatment head was placed into the hot cell. The source container containing the cobalt wafers was then transferred again to the hot cell and loaded directly into the cobalt head. This transfer was accomplished by means of the slave manipulators and remote control handling screw driver. The rotating disk was then turned by means of the flexible shaft to the "off" position, and the loading procedure was complete.

Smears taken of the outside of the treatment head revealed minimal contamination, and the head was then scrubbed down and decontaminated until background radiation was observed. The entire procedure, using the hot cell was accomplished satisfactorily. The highest radiation any of the personnel received during the entire procedure was 65 mr.

The transfer procedure, under the direction of M. F. Tench, S. Dismuke, and J. Cox, of the Oak Ridge National Laboratory, was executed in a satisfactory manner. The procedure illustrated the fact that intense sources could be handled by using proper equipment, and served as a test of the shielding qualities of the hot cell, and the capabilities of the slave manipulator. This was the strongest single source handled in this area.

Depth Dose Data

Depth dose data obtained in a water phantom with identical instrumentation as that used by the Saskatchewan group [20] revealed isodose curves for various field sizes and SSD to be almost identical to those published by this group. These curves also closely parallel the measurements obtained by Dixon [21] on the Eldorado Co 60 teletherapy unit. The entire set of isodose curves is published as an appendix to the ORINS Quarterly Report for the period ending September 30, 1953 [5].

Summary and Conclusions

Telecobalt therapy units containing multicurie sources of several different designs have been constructed, loaded, and are now in clinical operation. Several designs used appear to be eminently satisfactory with minor advantages and disadvantages inherent in each. All units were loaded differently without difficulty or undue hazard to personnel. The use of radiocobalt as a source for the teletherapy unit in the supervoltage range is certainly definitely established. The use of an isotope also demonstrates the flexibility of design possible, so that both conventional single source design and units capable of "moving field therapy" are quite possible.

Radiocobalt teletherapy units should prove to be excellent, flexible, and practical sources of beam therapy devices in the supervoltage range and compare quite favorably with X-ray generators in the same range.

Experiences in the design and construction of a multicurie cobalt teletherapy unit have been described. It should be exphasized that this design is certainly not fixed and that further changes undoubtedly will be made as indicated by future clinical experience with the unit.

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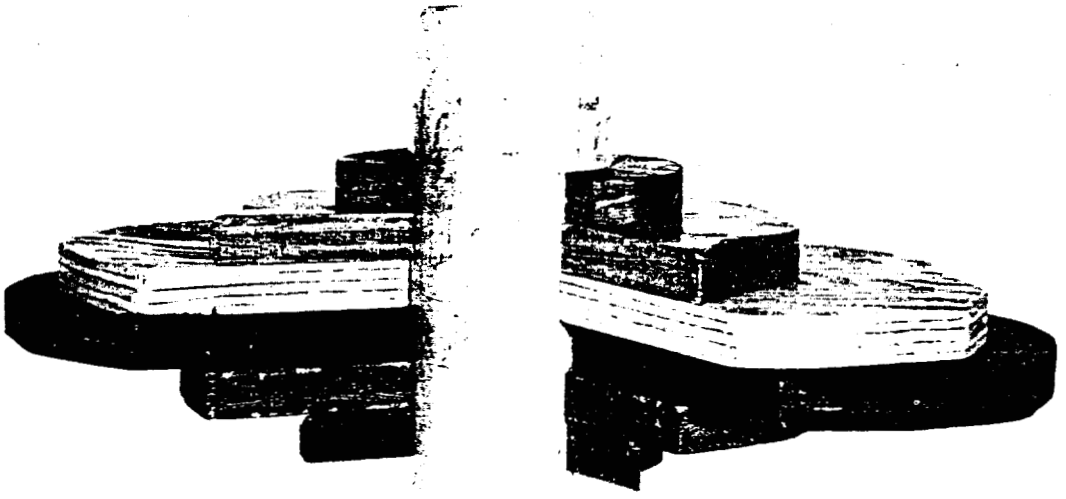

Figure 1. Isodose contour model.

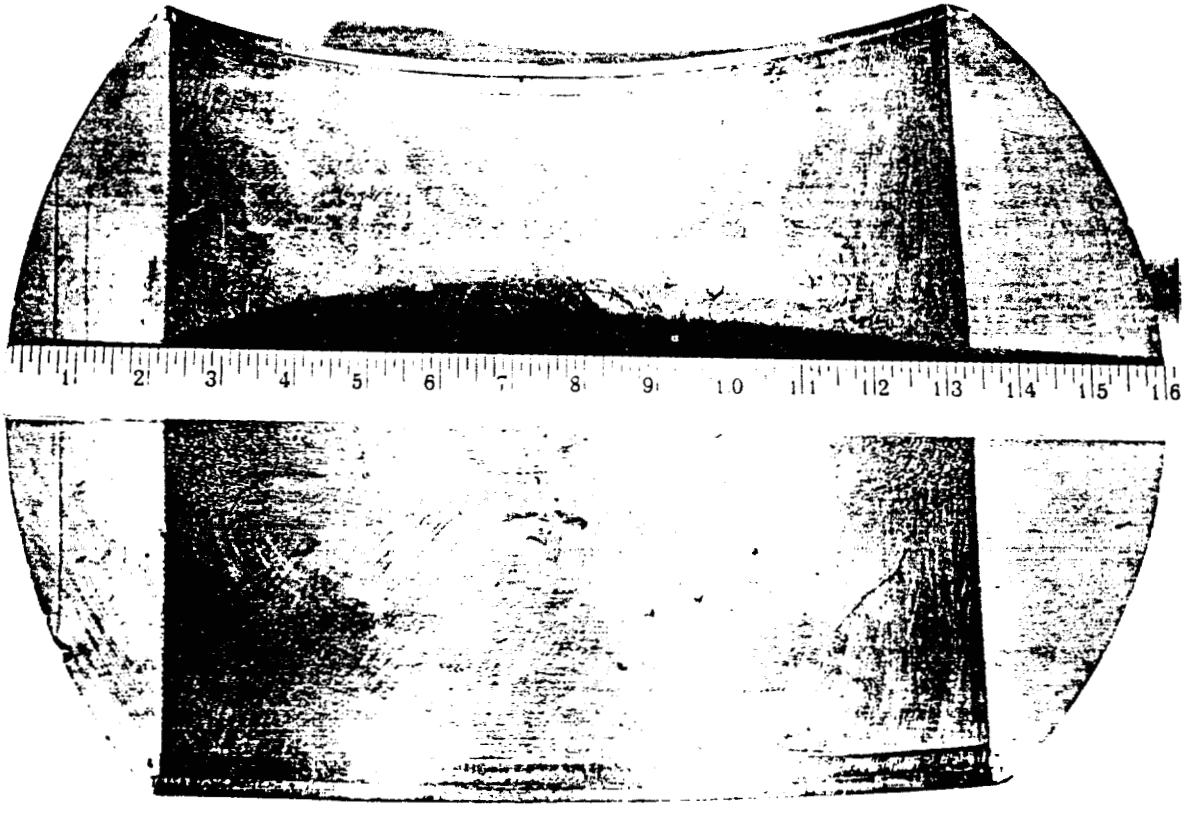

Figure 2. Lead blisters to reduce transmitted radiation.

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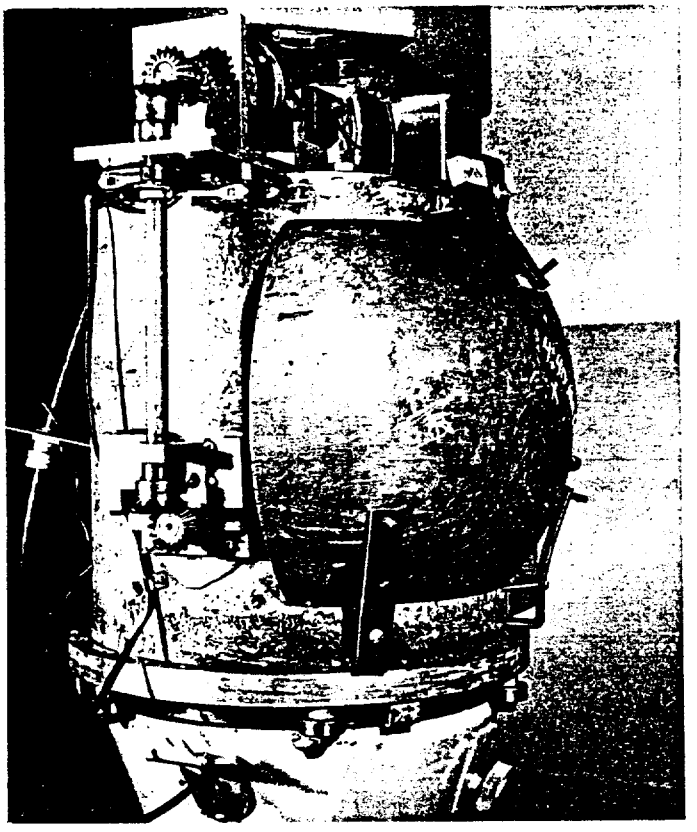

Figure 3. Lead blisters to reduce transmitted radiation.

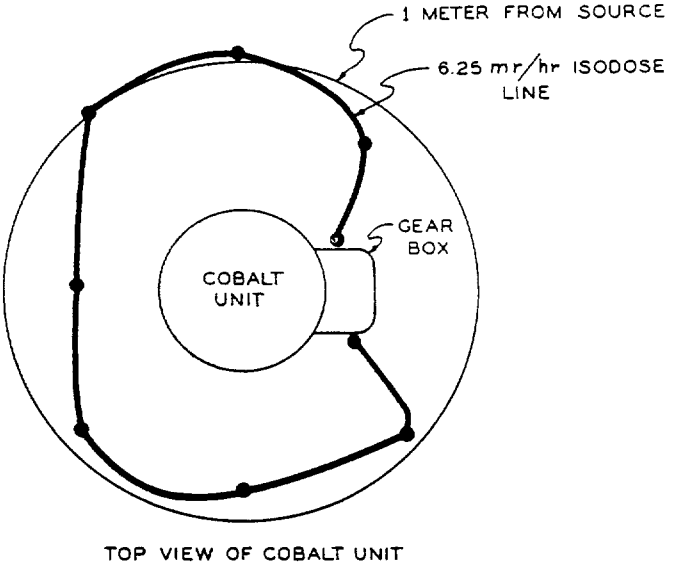

Figure 4. Isodose line for maximum permissible dose around cobalt unit through level of maximum radiation leakage (900 curie source in "OFF" position).

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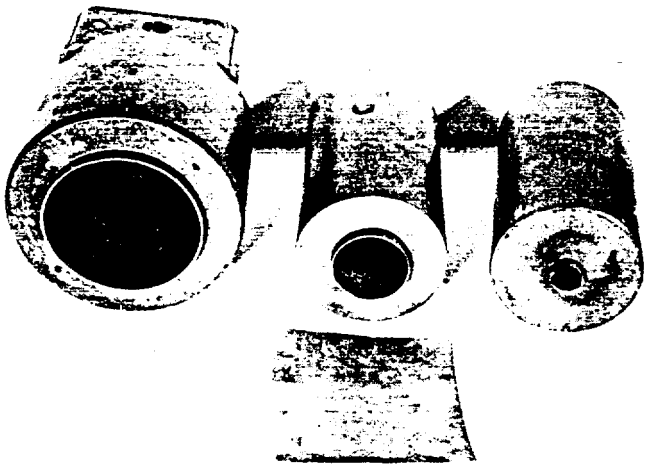

Figure 5. Untapered experimental cones.

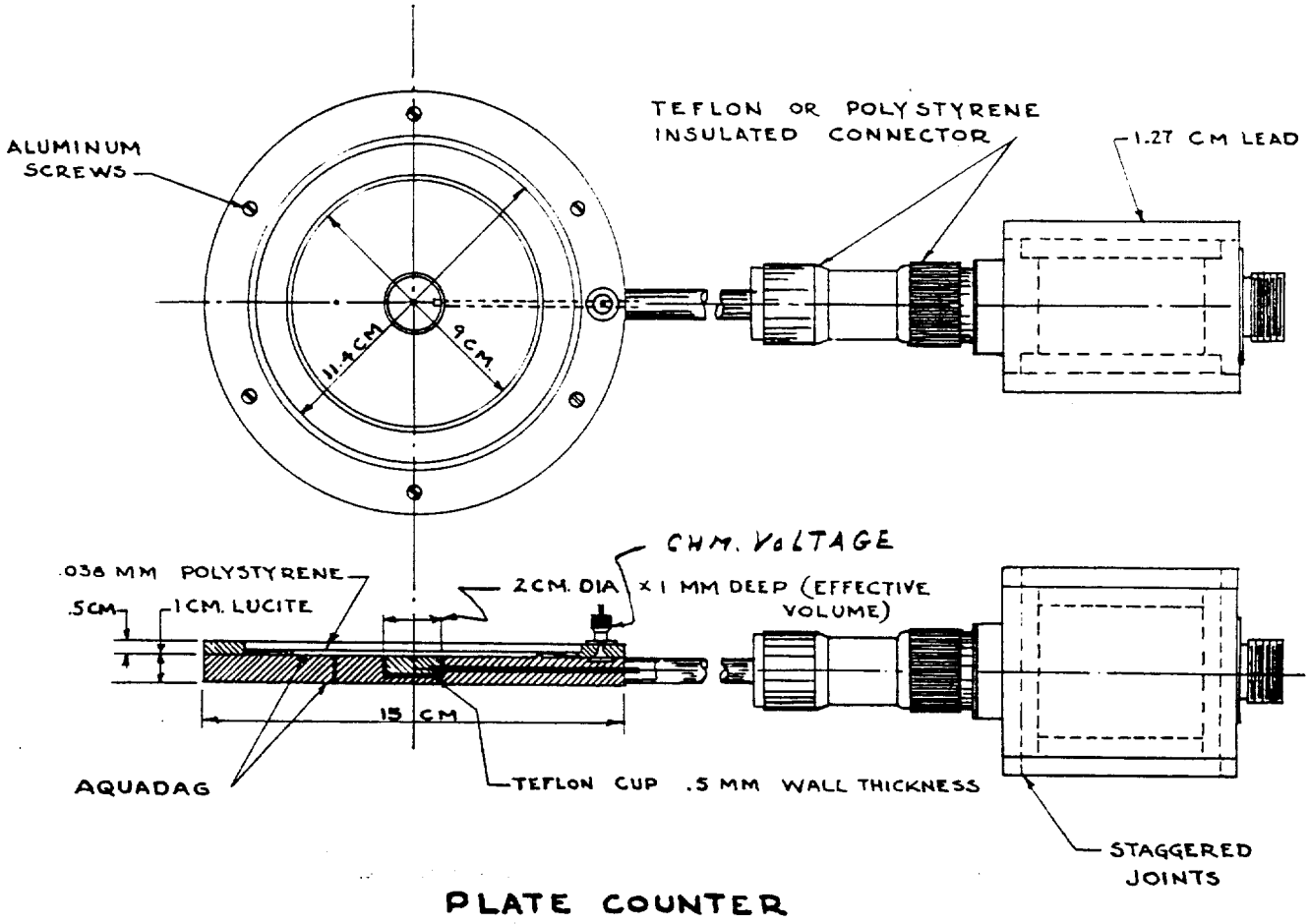

Figure 6. Shallow ionization chamber.

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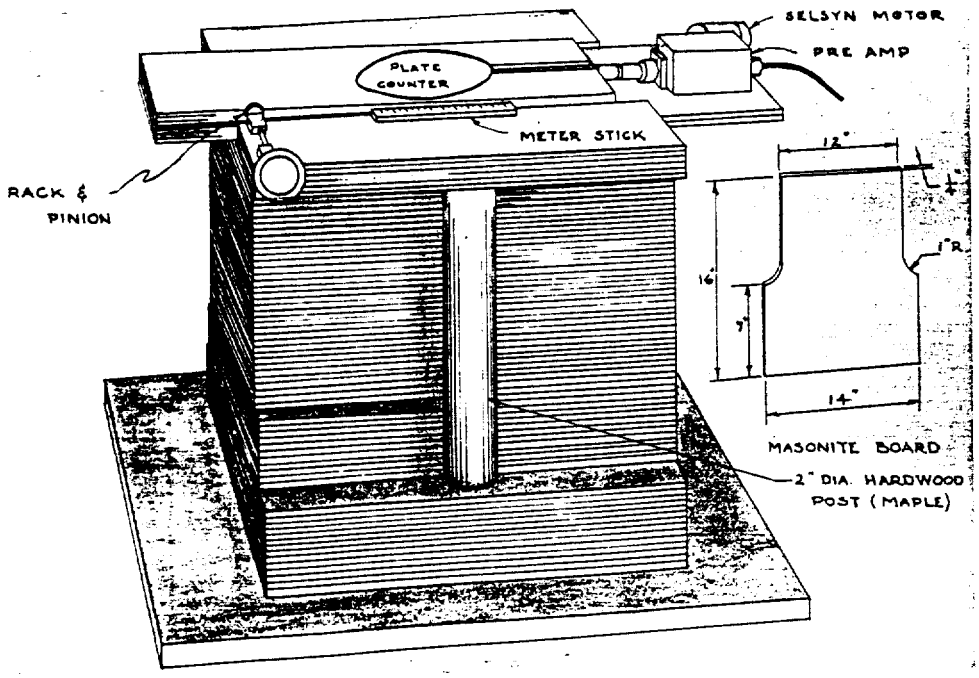

Figure 7. Masonite phantom.

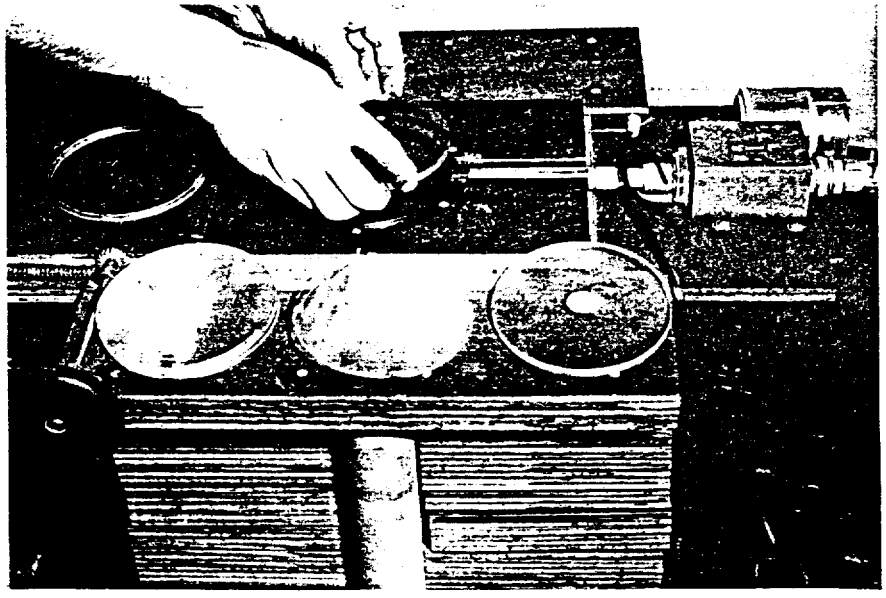

Figure 8. Phantom in use showing lucite and polystyrene foils.

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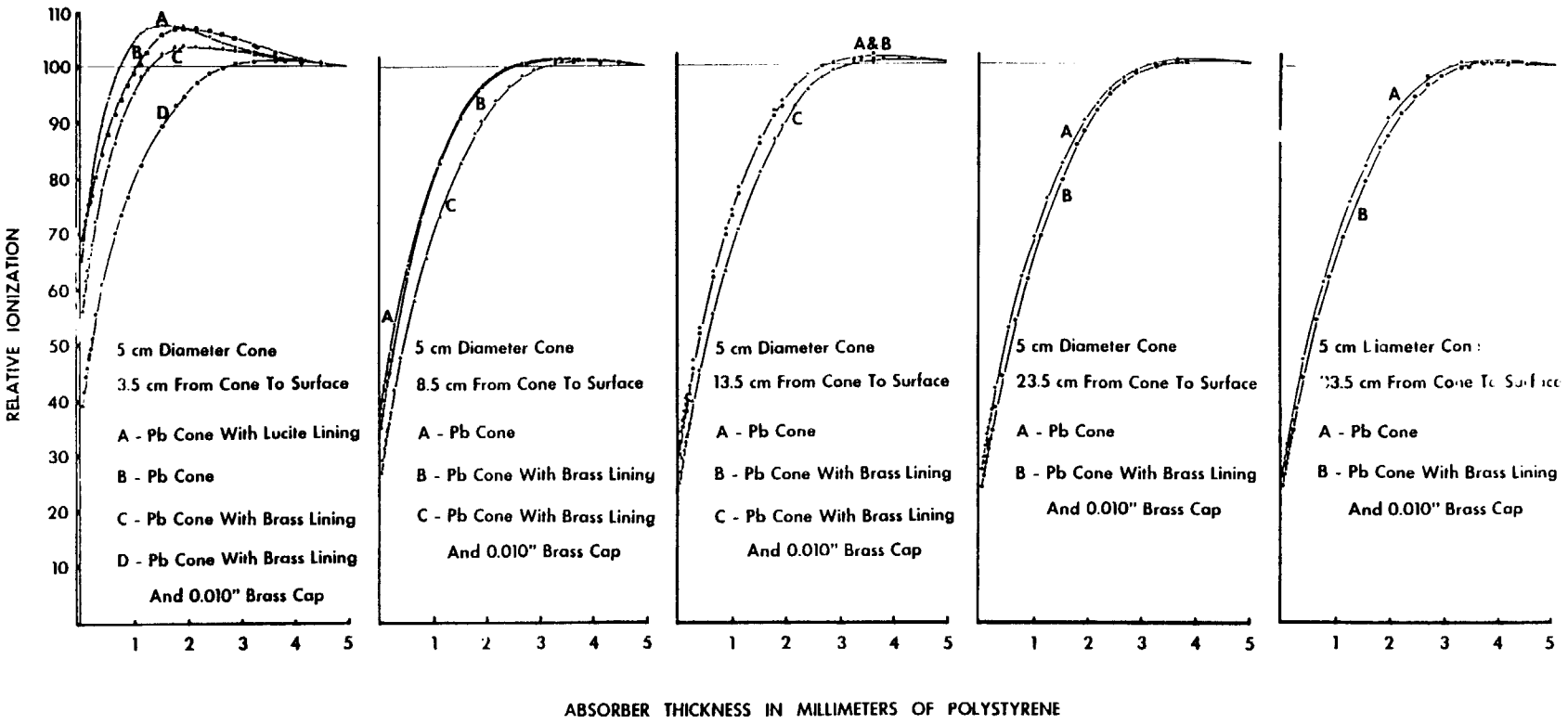

Figure 9. Electron build-up curves with experimental cones.

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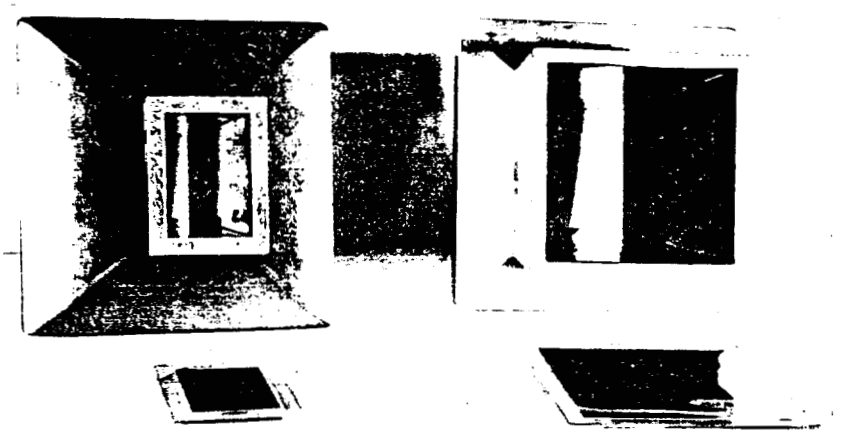

Figure 10. Photograph of lucite and brass cap.

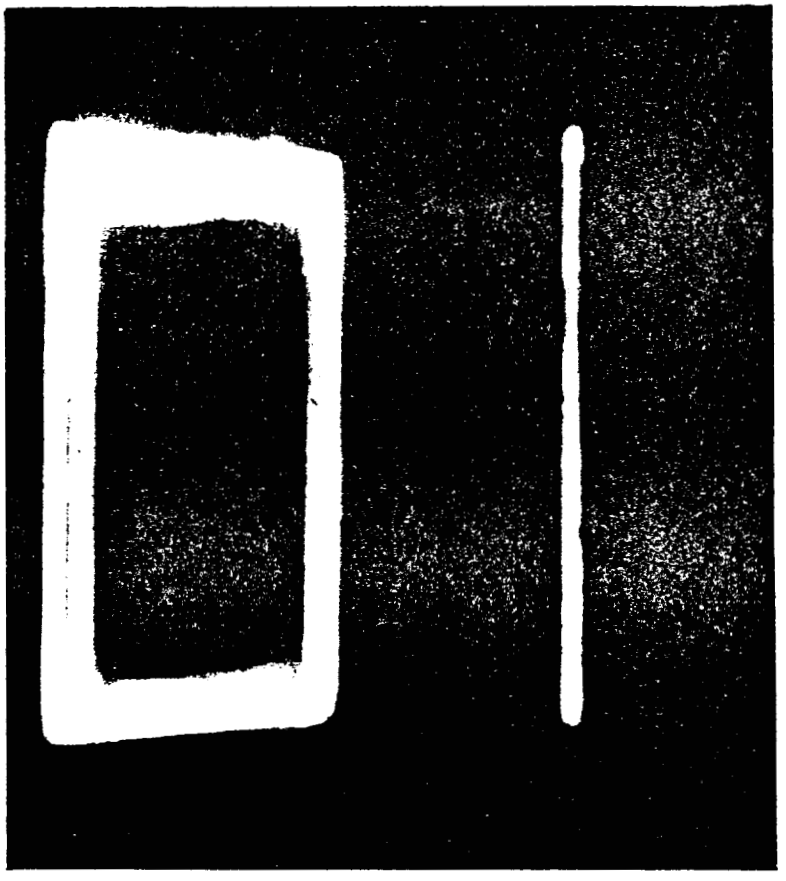

Figure 11. Light beam projected through cap.

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Billy Hudson

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INSTITUTE of NUCLEAR STUDIES

Medical Division

Quarterly Progress Report

Teletherapy Design Problems III
Supplement

January 1 - March 31, 1954

Operating Under Contract AT-40-1-Gen-33
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PROCEEDINGS OF THE THIRD INDUSTRIAL CONFERENCE ON TELETHERAPY

May 14 & 15, 1954

An informal information conference jointly sponsored by the United States Atomic Energy Commission, Atomic Energy of Canada Limited, and the Oak Ridge Institute of Nuclear Studies. The meeting was held at ORINS Medical Division, Oak Ridge, Tennessee.

ACTING CHAIRMAN

J. R. Mason, Chief
Radioisotopes Branch
Isotopes Division, U.S.-A.E.C.

EDITORS

Marshall Brucer, Chairman, Medical Division, ORINS
J. H. Harmon, Administrative Officer, ORINS Medical Division
Elizabeth B. Anderson, Technical Editor, ORINS Medical Division

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Supplement to Quarterly Progress Report, January 1, March 31, 1954, The Medical Division, Oak Ridge Institute of Nuclear Studies.

This supplement to the Quarterly Progress Report serves two purposes. It supplements material that was prepared and has been published in the last Quarterly Progress Report. It also constitutes the minutes of the Third Industrial Conference on Teletherapy. Since a portion of the material presented to the Third Industrial Conference is published in the regular Quarterly Progress Report, we can see no reason for republishing this in the minutes of the conference. The combined material from the Quarterly Progress Report of March 1954 and these minutes constitute the proceedings of the Third Industrial Conference on Teletherapy.

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STATEMENT OF POSITION OF THE UNITED STATES ATOMIC ENERGY COMMISSION, WITH RESPECT TO THE INDUSTRIAL CONFERENCES ON TELETHERAPY

Chairman Mason

It has been called to the attention of the Chairman that, in the past, anti-trust questions have arisen in connection with the activities of so-called "Industry Advisory Committee" to Government agencies. It is not the position of the AEC that this group is an "Industry Advisory Committee". It is, more characteristically, an informal conference for the purpose of considering or obtaining advice or information on specialized technical problems, and for preliminary discussions, relative to the distribution and use of cobalt 60 for teletherapy.

To the end that no such questions are raised in connection with this conference, the following rules are being observed:

1. All sessions shall be under the chairmanship of a full-time employee of the AEC.
2. Complete minutes of the conference shall be kept.
3. All sessions shall be open to the public, and information discussed at the conference may be made public.
4. The group shall act in an advisory capacity only, and all determinations as to actions or decisions concerning the functions of the AEC will be made by the proper officials of the AEC.

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See Quarterly Progress Report - Teletherapy Design Problems III, January 1 - March 31, 1954, for the following two papers presented at this meeting by Dr. Marshall Brucer, Chairman, Medical Division, Oak Ridge Institute of Nuclear Studies:

1. Cobalt 60: Cost, Curiage, and rhm Output.

2. Review of Final Requirements for Teletherapy Protection (check list).

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COST OF RADIATION IN HOSPITALS

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The economics of a medical specialty must take into consideration the geographic distribution of the specialists and the populations served, the type of private or institutional practice, the cost of service to the patient, and who pays. A new and significant factor in the field of radiation is that various forms of health insurance are being offered to the public for the purpose of providing funds for medical and hospital care. Only in rare instances do any of these contracts indemnify the subscriber against the expense incident to treatment by irradiation.

Radiation therapy is a highly specialized branch of medicine and until within recent years it has been limited to radium and X rays. With the advent of isotopes the field broadened and radioactive cobalt is now available for the treatment of deep seated malignancy. The cost of cobalt 60 therapy must be determined in order to compare such a method with conventional agencies.

At the present time there are probably less than 50 radiologists who devote their full time to therapy and less than that number outside of the radiotherapists who have a particular interest in the treatment of cancer. Patients for external radiation therapy (200 PKV and higher) are generally referred to the radiologist from other physicians. Patients for radium therapy are not all treated under the supervision of a radiologist and many have such treatment administered by surgeons, gynecologists and other specialists.

There are at the present time approximately 4000 American Board of Radiology certified radiologists devoting full time to their specialty. There are 156,000 practicing physicians (about one half of them are general practitioners) rendering over 2,500,000 medical services daily. One patient out of every 30 seen by a physician is referred to a radiologist and of those referred 16.2 per cent are for therapy. The therapy patients can be further divided into 80 per cent for high voltage, 19 per cent for low voltage or superficial therapy, and 1 per cent for contact therapy.

The practicing physicians who attend the general public in the United States are fairly uniformly distributed according to the population except in the sparsely settled areas. The radiologists are likewise distributed according to population but more closely in relation to the number of physicians than are other specialists. Both east and west of the Mississippi River the ratio of radiologists to physicians is one radiologist to every 57 physicians.

A total of 5,386 of 6,572 registered hospitals have X-ray equipment, and 4,000 of the 4,761 general hospitals have some form of equipment. Therapy installations are in a few of the less than 100-bed hospitals, and also in some of the 900 clinics in this country. The most recent survey showed that there are 1,850 therapy installations available to the general public and exclusive of those in governmental hospitals. As an example a recent check has revealed that there are at least 80 installations of 200 PKV or higher in the State of Michigan.

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To supervise and operate these units there are certified radiologists in all of these hospitals and full time radiologists in all of over 300 beds capacity. In a number of the large teaching hospitals a radiation physicist is a member of the radiology department staff. Forty-eight per cent of all physicians and 57 per cent of all radiologists are located in cities of 100,000 population or over. If all cities of 50,000 population or over are included, it is found that 69 per cent of the radiologists and 56.6 per cent of all physicians reside in these cities. Fifty thousand daily admissions furnish a daily hospital census of 430,000 patients, or 14.3 admissions per hospital radiologist per day. Considering the fact that 23 per cent of the hospitals (mostly small institutions) do not have X-ray equipment and that 16.2 per cent of all patients referred to a radiologist are for therapy, it can be assumed that there is an admission of at least one therapy patient per hospital radiologist per day. Practically all radiation therapy patients are at some time during their course of therapy treated as in-patients, usually at the beginning of the series of treatments.

It has been more or less a business axiom in industry that any piece of equipment should earn an annual gross return of 120 per cent of its cost to justify its purchase. Applying this business axiom and disregarding the humanitarian aspect of X-ray therapy it is apparent that many hospitals do not have a sufficient demand for therapy to justify equipping one or more rooms for that purpose. On the other hand, the cost of operation of a therapy department has always been a subject of controversy. Hospital staff members in some way seem to resent the fact that for lack of equipment their patients must be sent to another institution for special treatment. Hospital administrators and hospital Boards of Directors, realizing that the volume of therapy patients would not be great enough to justify the expenditure of money to buy equipment, are often reluctant to provide the space, equipment and personnel if such service is available nearby.

The cost of operation of a hospital therapy department should include every item of expense which is to be charged against the income. The most recent cost figures have been obtained from private offices and these are not applicable to all hospital radiology therapy departments. Many of the large hospitals have a sufficient number of therapy patients to warrant a separate therapy department with full time technical and medical personnel. The smaller hospitals must pro rate expenses and salaries between the radiographic department and the therapy department

In distributing costs common to both departments some accounting methods have used a percentage factor based on relation of square footage in each department to the total square footage in use. Some private office accounting systems use a percentage factor based on the relation of departmental collections to total collections. The square footage system appears to be the best method for prorating such expenses as space, heat, light and janitor service in keeping the ordinary method of calculating office or store room space rental. When operating an office for the private practice of radiology, either as a partnership or as a group, every item of business expense is usually included, such as entertainment for business purposes, travel expense to medical meetings, donations made in the name of the firm, insurance and any other expense the partnership has which is to be charged against the gross income. The hospital radiologists' income is derived from a salary, a percentage of the department income, or he operates the department on a space rental agreement with the hospital. Many of the items considered as a business expense for group private office operation, such as expense of attendance to medical meetings, are for taxation purposes deductible items from the radiologist's personal income.

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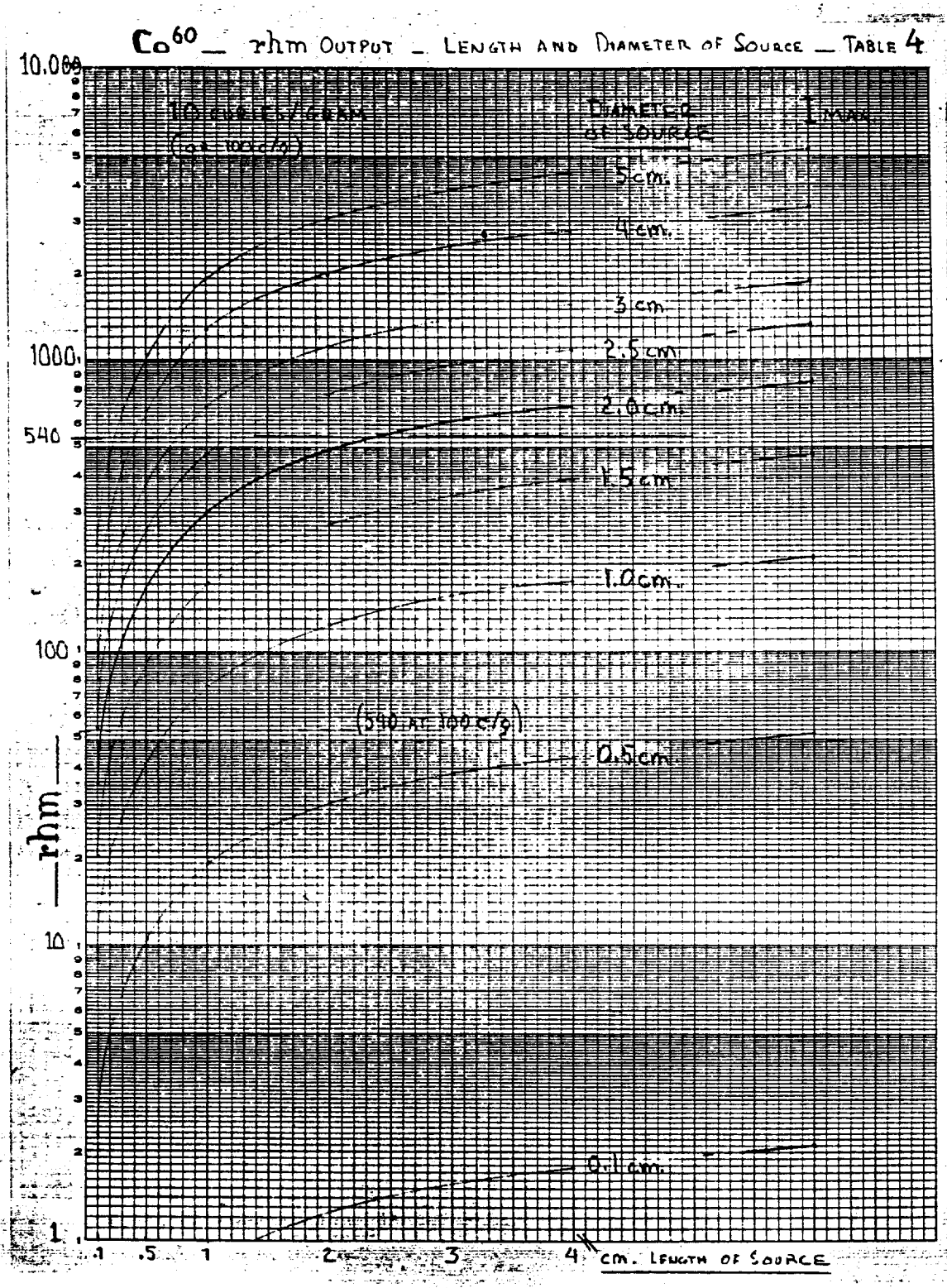

Figure 4

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All of the fixed charges such as space, depreciation, interest on the equipment investment, and insurance vary greatly dependent upon the extent of the therapy installation. Salaries, laundry expendible supplies, and administrative costs are fairly constant in those therapy departments which operate full time. Maintenance, repair, and replacements may vary tremendously in studies covering only a short period of time, but in studies over longer periods these costs usually show a comparable average per installation. It has been estimated that .04 per cent of income be allowed as the cost of the electrical energy for operation of the equipment per treatment.

If one accepts the manufacturers guarantee of tube life as a base line, it will be found that $1.00 per hour for 200 PKV machine and $2.50 per hour for 400 PKV equipment can be considered as the tube operational cost. The guarantee is necessarily low in order to provide a profit for the tube manufacturer and under ordinary conditions most tubes will exceed the guaranteed number of running time in hours. The gain from the additional usefulness above the guarantee of the tube will be sufficient to take care of cable and valve tube replacements. Linen or laundry expense in a therapy department is an item usually completely disregarded as negligible, but may prove to be far in excess of tube and maintenance cost. Sheets suitable for a treatment table cost as much as $30.00 per dozen and the life of a hospital sheet has been determined as 80 washings. The average over-all need of a general hospital is 17-18 lbs. of fresh linen per patient per day, and that of a department of radiology is 1-2 lbs. per patient per day.

The actual cost of radium therapy can be disposed of more easily than cost of X ray or cobalt 60. The major expenses attendant to the application of radium is, from a cost accounting point of view, allotted to the department of surgery in the form of a set charge for the use of the operating room and to the department of anaesthesiology as a fee for the anaesthesiologist. If hospital owned radium is regarded in the same manner as X-ray equipment, then everything which has been purchased and has any relationship to radium therapy, as well as standby radium not in use during a particular treatment must be considered as an investment and treated as such. For the physician using radium there is the additional expense of a higher premium for malpractice insurance.

If it were not for the hidden subsidy in the production of radioactive cobalt, the cost of obtaining it from private industry would not be competitive with X ray. The cost of X-ray therapy equipment is within the financial possibilities of both small hospitals and radiologist's private offices, and for that reason 200 PKV therapy is accessible to every community. More than 90 per cent of all X-ray therapy in the United States is administered by the general practitioner radiologist. Several factors are involved in such a situation: 1. Cost of equipment is not prohibitive; 2. Distances in this country are not comparable to those in Europe where large treatment centers have been developed; 3. An adequate supply of radiologists with training in therapy are available; 4. The demand of the medical profession is that equipment be available to treat patients locally.

The recently trained radiologist has received as thorough a training and possibly more complete training in some instances, then the young trainee of some of the other medical specialties. For that reason he is in most instances competent to serve his community as a therapist. Most of them do not like therapy but accept it as a necessary part of their specialty. They recognize the fact that 1/3 as much time is required to earn X dollars in therapy as in diagnosis and that

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funds for the medical care of the patient have often been depleted before he was referred to the radiologist. They also know that, except in few instances, therapy is not a benefit in the same manner as diagnostic services under any of the prepayment insurance plans, and that therapy patients are all potential malpractice cases.

In 1929 there were 400 medical malpractice claims filed in the United States. In 1952 there were 4,000 such claims, or one for every 39 of the 156,000 practicing physicians. The 4,000 certified radiologists were not the leading target for these claims, but damage due to therapy was the most frequent allegation against radiologists. It has long been a recognized fact that malpractice insurance rates are higher for radiologists than for any other physician. Fear of the court room may influence some radiologists to under treat their patients. The absence of extensive skin reactions following cobalt 60 therapy in the conventional manner may also tend to overcome this timidity, and result in better treatment of patients.

An additional expense to the operation cost of X-ray therapy has occurred in the larger medical centers since the introduction of so-called super voltage. This added expense is the remuneration for a radiation physicist who is necessary if high voltage or the rotational method of administration is used. Even though the expense of a physicist is usually borne by one institution the benefits of his knowledge and investigation is eventually passed along through publications and attendance to meetings to those who are doing therapy in more or less isolated communities.

One recently published compilation of cost figures set each 200 PKV treatment in a private office practice at $4.99. Of this amount $1.10 was the cost of the technician per treatment and the cost of the treatment was 67 per cent of the charge to the patient. This same study in the diagnostic department of the same office on the west coast showed the cost of each radiographic examination to be $10.04, which was 75.8 per cent of the charge to the patient.

Another study in the midwest had shown the general over-all expenses including both diagnostic and therapy departments in hospitals was 55 per cent of the income. In another study of a private office in New England with diagnostic work only, the cost per examination was 60 per cent of the charge, or, in other words, overhead was 60 per cent of income.

Not only do the available figures on cost accounting show a wide variation in the cost per treatment for radiation therapy, but there also appears to be several methods on which charges are based. The most common basis for charges is a flat fee for a series of treatments according to the anatomical location of the tumor with post irradiation check-up examinations included in the original charge. Other fee schedules may be based upon a unit charge per 100 r administered or a charge for each area or portal to which radiation is applied.

Inasmuch as therapy is on a strictly time basis for both medical and lay personnel who participate in the treatment of patients it seems more logical to calculate costs on a time for the "job" basis rather than according to square footage or a percentage of collections as has been done by some offices and hospitals. The fixed charges such as rental allowance for space, interest on equipment investment, depreciation and obsolesence, etc., would be constant and comparable among similar installations. The variable factors would be salaries of technicians, laundry, clerical help, nurses, orderlies and expendible supplies. Even though

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therapy cases should be individualized the fact remains that certain routine procedures have been set up and are followed in most departments of therapy. The majority of patients with like conditions are treated in the same manner in order to obtain the same tumor dose in each patient. A known number of portals of known dimensions will receive a known number of r-units in a known number of days and a known amount of time will be consumed at each visit. The actual cost of administering a complete series of treatments to two separate individuals with the same pathological condition located in the same anatomical part would be the same irrespective of the income received for administering the treatments. The physical condition of the patient during treatments or the skin reaction would probably be the only reasons for deviating from the prescribed formula.

With each set of cost figures which has been released for publication there has been a plea for a uniform system of cost accounting in order that factual data which would be of advantage to others could be obtained. In none of these has there been a suggestion that therapy cost be computed on a time basis and stated in dollars and cents in the same manner as the fee charged is stated to the patient rather than in vague percentages of income according to square footage occupied by the therapy department or of departmental collections. The information radiologists, manufacturers of equipment, hospital administrators and the patient want to know is - how much does it cost to treat what?

HOSPITAL CAPACITIES, FACILITIES, AND SERVICES

4761 - General Hospitals
2257, 50 beds or less - 77% have X-ray equipment
991, 50 to 100 beds
786, 100 to 200 beds
357, 200 to 300 beds
370, 300 or more beds
} All have X-ray equipment

15,000,000 Hospital admissions per year
50,000 Admissions daily
430,000 Hospital patient daily census
4,000 General Hospitals diagnostic equipment
10,000 Diagnostic units 2.5 each
1 Unit per 5 daily admissions

150,000 Physicians render 2,500,000 medical services daily
16 Services per physician per day
3,500 Radiologists and 600 residents - 20 patients per day - 82,000
610 Physician patient services per radiologist
20 Patients per radiologist per day - 1:30
1:30 Refer to radiologist of 2,500,000 services equals 83,333
(57) Physicians at 16 patients per day - 912 services
18,000 X-ray units-hospitals, radiologists, clinics
140 Physician patient service per X-ray unit

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3,000	Radiologists full specialty or certified
500	Part specialty or non-certified
3,500	Full or part specialty services 4,000 hospital X-ray departments
14.3	Hospital admissions per hospital radiologist per day

X-RAY EQUIPMENT UNITS

20,000	Gen. Pract.	1 unit each
3,000	Radiologists	2.5 units each
12,000	Specialists	1 unit each
2,000	Clinics	2 units each
13,000	Hospitals	3 units each
50,000	(1,800 therapy duplicated)	

1 X-ray unit per 3,000 population

OWNERSHIP OF MEDICAL X-RAY EQUIPMENT

Diagnostic and Therapeutic Installations in U. S. Hospitals
Diagnostic 5,170
Therapeutic (Duplicated) 1,850
X-ray Installations Owned by Private Physicians (under 65 years of age) in the U. S. 32,250
Total Medical X-ray Installations 37,420

	RADIOLOGISTS			PHYSICIANS			
	Full Specialists	Att. to Spec.	Total	G.P.	Full Specialists	Att. to Spec.	Total
EAST	1,828	326	2,154	49,306	38,169 (57)	16,271	103,746
WEST	788	101	889	22,613	5,209 (57)	6,662	45,208

RATIO OF RADIOLOGISTS TO POPULATION IN U. S.

Year	Population	Radiologists	Pop. per Radiologist
1931	122,775,041	1,005	122,164
1938	128,877,000 (est.)	2,191	58,821
1950	150,697,361	3,559	42,342

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PERCENTAGE DISTRIBUTION OF RADIOLOGISTS IN THE UNITED STATES

City Size	Radiologists	Physicians
Under 5,000	3%	17.1%
5,000 - 25,000	16%	16.9%
25,000 - 50,000	12%	9.4%
50,000 - 100,000	12%	8.4%
Over 100,000	57%	48.2%

Geographic Area		
New England	8%	7.9%
Middle Atlantic	27%	28.4%
Central	32%	27.4%
South and Southwest	20%	21.9%
Mountain and Pacific	13%	14.4%

ESTIMATED DISTRIBUTION OF DOCTORS OWNING X RAY

By City Size

City Size	General Practice	Specialist	Total
Under 5,000	6,490	--	6,490
5,000 - 25,000	4,530	1,890	6,420
25,000 - 50,000	980	2,150	3,130
50,000 - 100,000	1,770	1,740	3,510
Over 100,000	5,910	6,790	12,700
Total	19,680	12,570	32,250

By Geographic Area

Geographic Area	General Practice	Specialist	Total
New England	1,260	920	2,180
Middle Atlantic	5,150	4,230	9,380
Central	6,200	2,610	8,810
South and Southwest	4,310	2,620	6,930
Mountain and Pacific	2,760	2,190	4,950
Total	19,680	12,570	32,250

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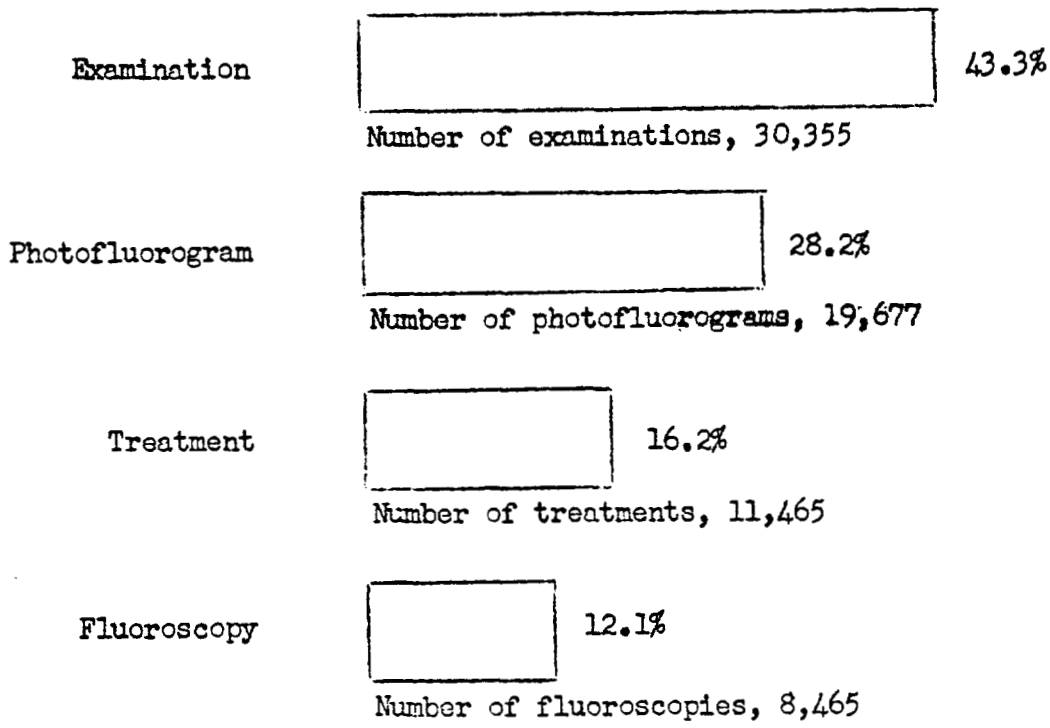
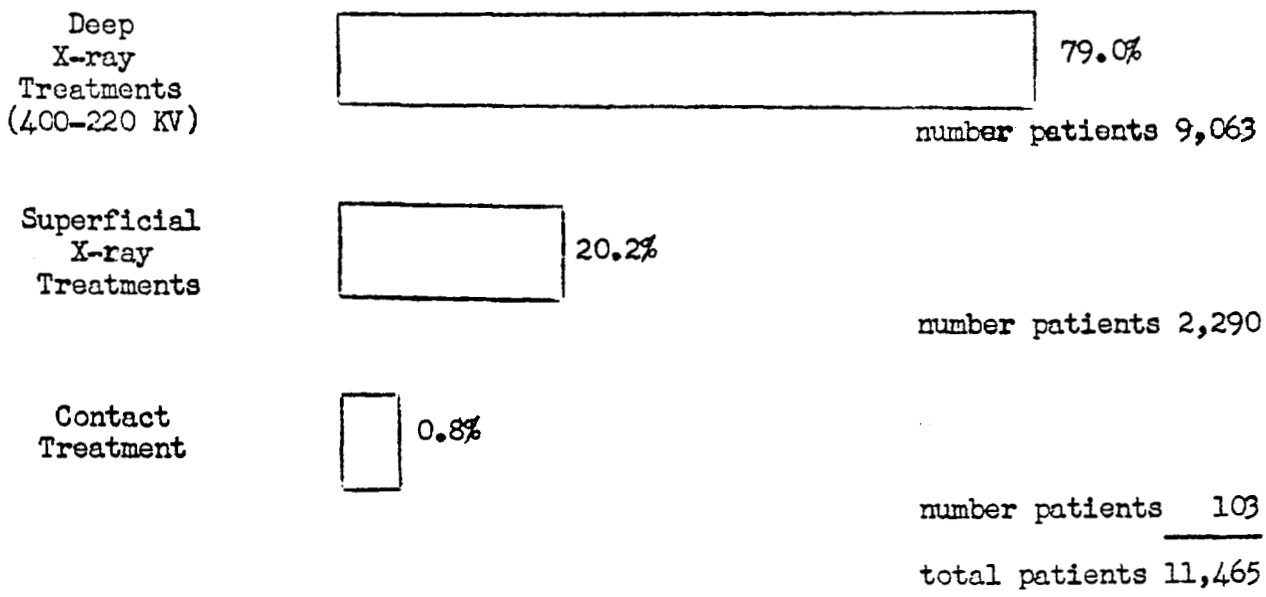
DISTRIBUTION OF X-RAY USE



(X-ray Department, University of Minnesota Hospitals. 1947-1948)

COMPARATIVE DISTRIBUTION OF X-RAY THERAPY



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CURRENT PRODUCTION, SCHEDULES, AND PROBLEMS OF COBALT PRODUCTION IN THE UNITED STATES

Dr. Paul Aebersold
Isotopes Division
United States Atomic Energy Commission

and

Mr. John Gillette
Radioisotopes Sales Department
Oak Ridge National Laboratory

Dr. Aebersold: It is generally known that the production and cost problems of cobalt 60 are dependent upon the availability of neutron fluxes. In the various reactors operated by the Commission there are at the present time excess neutrons as a by-product. The initial production and cost estimates of cobalt 60 were undertaken with the concept that these excess neutrons would be used.

Other factors for consideration are the period of irradiation and the flux of the reactor. If you were to bombard a cobalt sample for one year at flux F, you could do almost the same thing by bombarding it for five years at flux F/5.

If you attempt maximum irradiation in a period of one year, or that order of magnitude, the availability of space in high flux reactors becomes critical. The most economical approach would be to leave the cobalt in a reactor for five years or longer, permitting the AEC to use lower level fluxes without competing for the maximum fluxes that are available in the MTR reactor. If the productions program does not require speed and high specific activity cobalt, then the AEC could use a lot of excess neutrons that are available in lower flux reactors and the production of cobalt could be done much cheaper.

The AEC must consider that the primary purpose of a production reactor is to produce fissionable materials. The production of cobalt 60 would be secondary. If you have to produce so much cobalt 60 that you are competing with the production of plutonium or uranium then you need to base the cost of cobalt upon its competition with the production of essential fissionable material. The present production rate of cobalt 60 is between 30 and 50 thousand curies a year. If this is to be the total demand for cobalt, you can produce it as a by-product; however, to make many more times this amount may cut into the production of fissionable material.*

Another difficulty in the production of cobalt is that a sample depresses the flux in its region. This has two results. One is to cut down the neutrons available for the cobalt itself with the result that you end up with a lower specific activity cobalt than you would calculate for an undepressed flux. The second result, which annoys other people, is that the cobalt depresses the flux where other samples are placed. For example, when the AEC puts a lot of cobalt into the MTR reactor, there are other research samples nearby; and the depressed

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* The ultimate demand based on Donaldson's figures, assuming only cobalt 60 would be used, is that there must be produced 100,000 curies per year for teletherapy machines alone..... Editor's note (Brucer).

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flux interferes with the experiments. It is a constant problem to find a way to place the cobalt in the reactor so that it will not compete with its own self-absorption of neutrons, and not take neutrons away from research samples.

To supply replacement sources every five years, or x number of years, requires the production of new cobalt, or the reirradiation of old cobalt sources. In the United States there are no facilities for the reirradiation of cobalt, and the current production and pricing philosophy of the AEC is based upon supplying fresh cobalt. It is possible to reirradiate cobalt and the Canadians have a production and pricing schedule based upon reirradiation.

If one makes a long-term study of the future availability of cobalt 60, one must consider cobalt as a by-product of the power industry. If private industry or the government continue plans for development of reactors for power production, then certain kinds of reactors will have excess neutrons as by-products. Whatever the management of a power reactor decides to do with the excess neutrons will depend upon the market value of the by-products. If the government is buying plutonium 239 or uranium 233, then management will produce these fissionable materials as the primary by-product. However, if cobalt 60 is the big business, then the management might decide that the operating economics would favor cobalt 60 as a by-product. Whatever balance the economics comes out to be is undetermined at the present.

The original idea of a small curiage teletherapy unit was to use cobalt that the AEC now has on hand. We have tried on many occasions to encourage the design of teletherapy units that would use low specific activity cobalt because, it is easier to made and, we have quite a bit on hand; but no sooner does somebody build such a unit, than he conceives the wonderful idea of using high specific activity cobalt. The AEC has enough production problems in supplying high specific cobalt for kilocurie units without additional demands from low curiage units. I wish to emphasize that the AEC appreciates a radiologist's desire for a high specific activity source with a long useful life and a shorter treatment time.

Mr. Gillette: The Oak Ridge National Laboratory has about one hundred and forty pieces of cobalt, 3 cm by 1 cm, in the 50-55 curie range. This cobalt is available and the laboratory can load cloverleaf units as soon as they receive the standard source capsules.

The program for providing high specific activity cobalt was started by putting cobalt into the MTR in January 1953. The cobalt under radiation should amount to about 30 or 40 thousand curies at a specific activity of 50 curies per gram. We have one can back from the MTR and according to some very good estimates the activity may be up to 50 curies per gram. If the cobalt is at this specific activity, the laboratory should within three or four months get three additional cans, or an additional 10 thousand curies. The immediate availability of cobalt 60 is dependent upon what the laboratory finds out about the can we now have. If this material is up to 50 curies per gram, MTR people will be able to move into a higher flux some of the cobalt that is in a low flux. If this procedure becomes possible an additional 17 thousand curies of cobalt will be available by the end of this year.

In November of last year, 30 more cans of cobalt were sent to the MTR.

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These cans are being irradiated in a very low zone and, if ORNL can maintain the available high flux they now have and can keep feeding these 30 cans into higher zones, the specific activity of the material should reach 30 curies per gram sometime next year. If the specific activity of these cans should reach 50 curies per gram, there will be another 60 thousand curies of cobalt. At 30 curies per gram there will be less activity but, of course, the cobalt will be available faster.

There are two immediate problems in the loading of cobalt. First is the availability of the standard source capsule. ORNL has on order 15 cloverleaf designs and 15 wafer stack design capsules, and we have a promised delivery date of May 31st. The second problem is one of actually loading the cobalt into the standard capsule. The first few capsules will be loaded in cells that do not have adequate shielding for large sources; however, they have another loading facility that should be available for use this fall.

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CURRENT PRODUCTION, SCHEDULES, AND PROBLEMS OF CANADA

Mr. C. H. Hetherington
Atomic Energy of Canada Limited

Dr. Aebersold and others have already covered most of the problems that the Canadians are faced with but there is a slight difference. Whereas the US-AEC has a number of reactors, the Canadians have one reactor, and up until a few months ago, we did not have the one. The leak in the NRX reactor put the production program of the Atomic Energy of Canada back 1 year to 18 months. NRX is primarily a research reactor and during the 18 months there has accumulated a large backlog of research programs which will require a fair number of the available high flux positions. These factors put the Atomic Energy of Canada Limited into a position of not being able to say definitely how much cobalt 60 will be available at any future date.

As far as the use of excess neutrons go, if you put a few capsules of cobalt in the high flux position, you will get speed-up production but very small production. On the other hand, with a small number of sources in the high flux positions, and a large number in low flux positions, we would tend to meet present commitments. If Atomic Energy of Canada should start moving these positions it would seriously effect the long-term production program, so one has to necessarily reach a compromise.

The NRX reactor is basically a research reactor, operating at various power levels for various times during the year, and hence it is more difficult to forecast the exact production schedule as compared with a production reactor operating at a definite power level. The variations, however, would tend to average out over a period of 1 year to 18 months.

The Canadians do not expect to have a supply of cobalt in the region of 35 curies per gram until late 1955, or early 1956, because we are starting from scratch by putting in cold cobalt. As Dr. Aebersold has mentioned, it takes about a year to 18 months to start getting production in large quantities.

One other problem in the production of cobalt is the availability of adequate handling facilities. It is a simple matter to build a handling facility for one type of transfer case and one type of loading; it is quite a different problem to build equipment to handle various designs of containers and transportation facilities. The available handling facilities are presently working for the low curiage cobalt. Additional ones will probably be ready late this year or early next year.

Canada hopes to have a plentiful supply of very high specific activity cobalt when NRU begins operation. It is a guess as to when NRU will begin operations, but it is estimated as late as 1956 though it may be 1957 before any cobalt will be available from the reactor.

The Canadians have a pricing philosophy of offering replacement service with each source. The basic price includes the charges necessary to take the cobalt from its capsule and place it back into the pile for reactivation. At the present time the prices are a bit different from those of the US-AEC.

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Between now and the fall of 1955, there may be odd sources available but the Atomic Energy of Canada cannot predict the availability. If the pile flux is a little higher than is anticipated, there may soon be a few sources available. The Canadians cannot guarantee anything at the present time, but do invite inquiries, and the X-ray Industry will be kept informed about how things are coming along.

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DISCUSSION OF PAPERS ON CURRENT PRODUCTION SCHEDULING
AND COST OF RADIATION THERAPY

Mr. Stickney: Mr. Beauchamp described a standard device for measuring the rhm values of all sources; however, if the rhm values should differ from what the customer's physicist should find, it would probably make the customer unhappy.

Mr. Beauchamp: ORNL does not want to make such a measurement unless the customer or manufacturer definitely requests it.

Dr. Aebersold: Does your statement about the plus or minus 10 per cent have reference to the absolute value of a given source, and not from one cobalt source to another?

Mr. Beauchamp: I mean variations from the absolute and it remains constant from source to source.

Chairman Mason: What does this group think about the ORNL calibration? Will the manufacturers and radiologists want to receive the rhm values measured by ORNL?

Mr. Stickney: Picker X-ray would like to receive the data.

Mr. Stober: I cannot express an opinion. The Keleket Company will probably have their physicists measure the source after the installation is completed. As long as there may be a discrepancy between the ORNL method of measuring, I am not inclined to get involved in the argument. The ORNL source would have to come out very close to what the customer's measurement of rhm is.

Dr. Aebersold: The rhm may vary depending upon the port of the machine and the collimating device. You can not have a fixed rhm without defining the conditions under which the measurement was taken.

Dr. Lofstrom: Dr. Donaldson, how did you arrive at that average cost per patient treatment per portal?

Dr. Donaldson: In reply to survey questions I usually get on an average estimate between $3.00 and $4.00, probably about $3.50. The estimate depends upon the department organization. The man with one technician will handle everything himself, whereas in a large radiology department the work may be distributed among residents and a physicist.

Dr. Brucer: When Dr. Donaldson talks about the cost of X ray being cheaper than the cost of cobalt, I would like to say that we made a calculation at the Institute based upon all of the hedging that you must put into such a study. We took the cost of cobalt itself, based on figures previously presented, and made the poor assumptions that the machine is used eight hours a day, five days a week, twenty patients per day receiving 200 r in each patient. If the cobalt is used for five years, then the cost of the cobalt energy encapsulated and loaded into the machine, and shipped to New York, comes out at twelve cents per treatment. I wish to emphasize that this is just the cost of the energy.

Dr. Donaldson: In a similar study, I came out with ten cents per treatment energy cost. With the over-all cost of the machine, the housing, the depreciation, the interest on investment, the cost will come out slightly higher than conventional

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X ray. Once the cobalt machine gets on a production basis, the actual cost of the cobalt may compare more favorably with X-ray equipment and considering tube replacements and other repair and maintenance costs, the cobalt will probably be cheaper in the long run.

Dr. Lofstrom: Dr. Aebersold, if an individual places an order for a low specific activity source and later decides upon a high specific activity source, will that limit him or another customer in getting a source?

Dr. Aebersold: No, each would have to take his place on the respective priority lists and await the availability of a source.

Dr. Brucer: The customers would like to purchase the maximum rhm that can be placed in the hectocurie teletherapy unit. The 600 rhm with high specific activity is cheaper cobalt per roentgen delivered than low specific activity material. If a 2 centimeter diameter source were produced in the same reactor that produced the present cloverleaf source, then you could have a 600 rhm source, at a cost of approximately $4,550.

Dr. Aebersold: The AEC is trying to find the answer to the demand for high specific cobalt for the hectocurie unit, and I am wondering if rather than trying to make cobalt that is needed for the 1200 curie unit, should the AEC pull some cans from the reactor before they get to 50 curies per gram?

Chairman Mason: There is some advantage in an early delivery date, and perhaps 50 curies per gram for everybody is a possibility only in the future. A number of cans having specific activities of less than 50 curies per gram are in the reactor; and the production capacities of the MTR are greater for 30 curies per gram. I would like Mr. Gillette to explain this factor.

Mr. Gillette: It's true that you can get the cobalt out at 30 curies per gram but under present schedules the production is slow even at 30 curies per gram. Most of the cobalt is in a zone where the production rate is very slow although there are a very few cans in an extremely high flux. Dr. Aebersold, if the AEC attempts to increase the availability of 30 curies per gram cobalt, it can be done to a certain extent but for the benefit of only a few people. The radiologists who are purchasing hectocurie units want 600 curies because that's the maximum for which the machine was designed. Most people want 600 rhm, and it doesn't matter where it comes from, what shape or what specific activity it is; therefore, whenever possible industry and radiologists should demand high specific activity only for kilocurie therapy units. Support the AEC cannot supply the demands for high specific activity activity cobalt, what's the next best thing? What is the maximal capacity of the large unit at the present?

Dr. Brucer: It should be about 30 rhm.

Dr. Aebersold: People can't use that in the hectocurie unit and they will have to wait quite a while for high specific activities.

Dr. Brucer: The hectocurie machine was originally designed for the cobalt we now have; but with the idea that there might be better cobalt available in the future, the design was increased to permit the unit to shield 600 rhm.

Dr. Aebersold: I do not disagree with that planning; but unfortunately radiologists

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now think they can get high specific cobalt and that was not the concept we began with.

Mr. Hetherington: I probably should have added that the Canadian replacement schedule is based on the reirradiation of cobalt 60 in the form of very small pellets; consequently, sources of various diameters can be made up very easily. Also, in my earlier remarks regarding the supply problem, I was thinking mainly of the 30 to 35 curie per gram cobalt. When you get down to lower specific activities, 5 or 10 curies per gram, then the supply may be quite different. It has been pointed out that low specific activity cobalt is easier to produce, but if you try to produce a lot of material at 10 or 20 curies per gram, you very seriously affect the long range program for high specific material.

Dr. Aebersold: Don't you have cobalt coming along on a four or five year program?

Mr. Hetherington: Yes, but the production becomes quite a problem because of a large backlog of research. We can easily get it up to 5 or 10 curies per gram, but in order to bring that on up to a higher specific activity, we would have to allocate the center positions to the production of cobalt.

Dr. Brucer: With the use of a standard source capsule, this picture will ultimately change again. A standard source capsule with a high specific activity source not only can be used in the big machine but it can then be transferred from one machine to another until it decays from a 1200,to a 600, and eventually to a 300 curie source. These original very high specific activity sources will eventually reduce the requests for low specific activity sources, but right now there is a demand for the low specific activity source because a number of people are in a hurry.

Mr. Gillette: Low specific activity material is now ready, and the quantity will increase before 1200 curie sources decay down to the 600 or 300 curies per source.

Dr. Brucer: Instead of making the sources 1 centimeter in diameter, why not make 2 centimeter in diameter sources from the lowest specific activity? The cloverleaf design should be considered as a stopgap design, and is not an efficient design.

Dr. Aebersold: What is the cost of the cloverleaf source with the cobalt now available from the Commission?

Dr. Brucer: With the present available cobalt you can get up to 6.3 rmm. This means that the cost is approximately $2,500.

Dr. Aebersold: This is with the capsule loaded and everything?

Dr. Brucer: That price includes the loaded capsule. If, at the present pricing policy, we make a 2 centimeter diameter source it would cost the same as a 1 centimeter source because the pricing is based upon the amount of cobalt 60. If you make this 2 centimeter diameter wafer of the 50 curie per gram cobalt, then by the present pricing policy we get the same 6.3 rmm source for $3,000. The essential point is that the whole problem will change once the very high intensity sources have decayed one or two half lives and can be transferred from a big machine to a small machine. But that's not going to be true for a long time because it looks as though more small machines than big machines are being made. Mr. Stober says that his factory believes the ratio of hectocurie to kilocurie units will be five to one.

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Dr. Aebersold: If there are going to be fewer kilocurie units bought, then there is going to be more high specific activity cobalt available for the hectocurie units, but you'll never know this until the early sources have been delivered. The first to buy the hectocurie unit will have to accept immediate delivery of a low specific activity source, or wait until the first of next year, hoping to get high energy cobalt.

Mr. Gillette: How many people have changed their minds and are going from the 1500 curie down to small sources?

Dr. Brucer: I personally know of three people who have changed their minds.

Dr. Aebersold: This means that twice as many sources are available from the same stock pile of high specific activity cobalt. I again wish to emphasize that I am not against the hectocurie units; it's just the problem that they are competing for high specific activity cobalt.

Mr. Reynolds: Suppose a customer has an authorization for a 1200 curie source and decides to buy a 600 curie source. Will he have to give up a priority position on one list and become the low man on another list?

Dr. Aebersold: There's cobalt available and the people who requested it first requested kilocurie sources. If they don't pick up the kilocurie units, it's not going to confuse the situation on the priority list if they take a 600 curie source. The AEC doesn't know whether a customer is going to take 1200 or 600 curies of cobalt; however, it's all right with the Commission if he takes 600 instead of 1200 curies.

Mr. Gillette: The Oak Ridge National Laboratory would like to know those people who are interested in taking 600 curies instead of 1200 curies of cobalt. The AEC can see the advantage to the customer in doing this but, if a prospective customer hasn't put in an order, then the AEC can't give a delivery date for a source because they don't know how many hectocurie units are going to be bought by individuals who hold a kilocurie authorization.

Mr. Green: What would be the time required to build the 1 cm and the 2 cm diameter source to 50 curies per gram?

Mr. Gillette: Two years. Much the same for each diameter.

Dr. Brucer: If the diameter goes down to one centimeter, it means that the source is made only for the hectocurie unit. When you get down below 35 centimeters SSD, you can't use a 2 centimeter diameter source unless you start putting in a very fancy pinhole collimator, which could be done but won't be quite as satisfactory.

Dr. Blatz: Is there not a general agreement that a 2 centimeter diameter source is more effective than a 1 centimeter diameter source?

Dr. Brucer: I don't think there is such agreement. This argument comes from a very few persons who would much rather have a wide penumbra to work with. Almost everybody that I have ever talked with say that this is ridiculous. Most therapists agree that they don't want a penumbra and if they didn't agree penumbra can always be added by sawing off the cone. A comparison of penumbra has been made with the

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betatron and a 250 kv X-ray machine. If you compare the hectocurie cobalt 60 penumbra with the 250 kv machine then we can use a 3 centimeter source at 35 centimeters very easily. But people arn't comparing cobalt 60 with 250 kvp, they are comparing it with the beautiful curves from Johns' betatron.

Chairman Mason: The allocation of kilocurie sources was started by people wanting sources of about 100 curies. Then somebody thought he wanted 1200 curies to go into his machine. I think these people who are holding out for a 1500 curie source are on the optimistic side at this stage of the game and they ought to be thinking more of the 1000 curie sources for the initial units.

Mr. Stickney: My company is subject to just what the customers want, and without exception the customer asks for the biggest source that they can get.

Dr. Brucer: That is because of the publicity there has been concerning the bigger sources.

Mr. Stickney: No, it is a concept of the cost and .....

Dr. Lofstrom: It also reduces the treatment time.

Chairman Mason: It is just human nature to get the best you can get for the given situation or given dollar. Dr. Brucer, on your charts for a given specific activity, is it cheaper on a dollar per rhm to put 1500 than to put 1000 curies into a machine?

Dr. Brucer: Yes, but not because of the way the chart is drawn but because of the way Stickney calculates his costs. To calculate only on the basis of rhm on delivery has become argumentive. If you speak of dollars per total roentgens, a low source soon gets down to a rock bottom level. If you start out with a higher source, then you can use the source that much longer before it gets down to the rock bottom usefulness. Therefore, under these conditions, it's always better to get a higher intensity source.

Chairman Mason: It is just human nature to ask for the best of anything. I am wondering if teletherapy customers are to a large extent asking for maximum sized sources because they have been instructed to do so by some salesman.

Dr. Brucer: When people ask what size source they sould order, I always tell them to order 600 curies for the hectocurie unit, but to be perfectly willing to take what they can get.

Dr. Aebersold: The customer who saw the need for 1200 curies, and placed his order has acquired a priority for 1200 curies of cobalt 60. He may change the order to 600, but he can't get two sources of 600 curies.

Chairman Mason: If a manufacturer holds priority for seven 1500 curie sources, the first six people may purchase 1500 curies each; the seventh person may purchase a 600 curie source and the Commission can make available an eighth source of 600 curies to another user.

Mr. Reynolds: When this question was first brought to the attention of my company, our customers were putting in orders for 1300 or 1500 curies, and were thinking of floor instead of ceiling limitations on size. Apparently we should now specify both.

PROBLEMS OF SOURCE STRENGTH, CALIBRATION, AND LOADING

E. E. Beauchamp
Radioisotope Development Department
Oak Ridge National Laboratory

A number of the people present at this meeting have previously visited the Oak Ridge National Laboratory and have observed the remote handling cells with the slave manipulator. The present cell operates for sources up to 800 curie level, and the lab has a new cell design for higher levels. A source containing up to 800 curies can be loaded on a fairly routine basis; anything above this level requires special procedures. The high level cell will not be completed until late 1954; however, if Mr. Gillette has made a commitment to someone for loading a source above the 800 curie range, and if he has not made too many commitments, the Oak Ridge National Laboratory will load the source on a special basis. The people involved in the loading will have to take a measured dose of radiation, and this is not the sort of thing we like to do. The Division has only so many people, and each is allowed only so much exposure to radiation. The manufacturers should realize that this is not the type of procedure that ORNL could consider doing on a routine basis.

The new high level cell has been delayed for the approval of funds, which finally came through in March of this year. The preliminary designs are ready and final specifications are about completed. Very shortly we should let the contract for constructing the cell, and by the end of September, the large cell should be completed.

Until recently cobalt 60 has been stored under water in the canal in the pile building, and the measurements have been made there. This procedure proved to be an unsatisfactory storage condition and ORNL has gone to dry storage. For the past several months we have been setting up a new calibration method. The new method uses the manipulator cell to take one piece of cobalt at a time. Inside the calibration cell there is an air filled ionization chamber connected to an electrometer; and with this equipment, each piece of cobalt is measured. There was some difficulty in calibrating this gadget. First, the health physics group who routinely calibrate all health physics instruments, calibrated pieces of cobalt 60 in each range of specific activity and calibrated them. These pieces were then put into the new chamber and the appropriate readings were plotted for each range. In order to feel even more certain that these were accurate readings, the pieces of cobalt were dissolved, and aliquots of the solution were sent to the laboratory for assay. The two methods of calibration compared within 1 per cent. The electrometer is called Q826 and was constructed by the Oak Ridge National Laboratory. A paper describing this unit was delivered at the Atomic Instrument Society of American, September 12, 1946, in the Municipal Auditorium in St. Louis. If anyone is interested he may purchase a copy of the paper from the Instrument Society of America, 921 Rich Avenue, Pittsburgh. This instrument is mentioned here, just in case a customer might want to double check ORNL's calibration method. Mr. Gillette will probably be guaranteeing an accuracy of within 10 per cent and the instrument may be even more accurate than that. Instruments are constantly being improved, however, even laboratory counting instruments have some errors running that high. The error in laboratory counting equipment will run from 1 to 5 per cent; therefore, this electrometer is probably a very good instrument for calibrating cobalt.

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The ORNL had the privilege of having their Canadian friends visit them this week and to talk about cells and instruments, which they are building. During these visits one problem came up concerning the standard source capsule. They would have to make a minor change inside the capsule and ORNL can make the necessary changes.

From a previous meeting of this group, I got the impression that radiologists may request a guarantee of the rhm from the source. However, Dr. Brucer has mentioned that each head is going to be somewhat different in geometry and will give a different rhm value, therefore, ORNL's rhm factor would differ from that of each instrument. However, ORNL will make a standard setup and will measure the rhm of each source. Our measuring device will consist of a standard pig, with seven or eight inches of lead and with a well in it, with a collimating lead sleeve. A Victoreen r meter or chamber electrometer will be held in a fixed position from the source. This setup could be made without too great a cost, and might give something that is suitable for a customer buying a hectocurie unit.

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ALLOCATION POLICY FOR TELETHERAPY SOURCE UNITS

Dr. Paul Aebersold
Radioisotopes Division
United States Atomic Energy Commission

There are two separate problems in the allocation and distribution of cobalt 60 for teletherapy units. The first problem is the allocation criterion. The following allocation criteria have been recommended to the Isotopes Division by the Subcommittee on Human Application. This document recommends certain requirements for radiological safety and ties in with a later discussion on the agenda of this meeting.

You will note that the allocation policy makes it possible for the radiologist to arrange for the radiological safety to be taken care of by consultants, and it would be possible for this consultant to be a qualified physicist from the manufacturer.

A. The manufacturer of teletherapy equipment shall:

1. Provide for adherence of the prototype design of the equipment to the requirements and recommendations of the National Bureau of Standards Handbook 54.

2. Provide a program to test the critical shielding components of each unit.

The user shall be a physician qualified in therapeutic roentgenology with at least three years experience in this specialty. (A diploma of the American Board of Radiology may be presented as evidence of such qualification.)

B. The user shall do the following or shall be responsible for having them done by a qualified consultant:

1. Plan for the installation site and control of radiological safety in the surrounding area.

2. Make a radiation survey of each completed source and unit in its permanent location to comply with the requirements of the National Bureau of Standards Handbook 54.

3. Calibrate the radiation output of the unit. Information should be provided regarding the type of instrumentation to be used for the calibration and the pertinent experience of the user or consultant.

4. Describe an adequate program for radiological safety including a program of action in the event of a breakdown or need for adjustment of any part of the head, source, or mechanism involving the source. The pertinent qualifications and experience in radiological safety of the physicist or other individual assuming this responsibility should be included.

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5. Indicate his familiarity with, and intent to comply with the requirements of the National Bureau of Standards Handbook 54.

DISCUSSION

Mr. Reynolds*: Did you say that it was all right for the manufacturer to hire a consultant to have the survey made?

Dr. Aebersold: The AEC does not care who pays the salary of the man who makes the measurements so long as he is qualified to make them.

Mr. Reynolds: I want to be sure that this statement does not say that the manufacturer shall make a radiation survey. Such a statement would do violence to what has been the practice in X-ray industry. I am sure that our insurance coverer would have a great deal to say about my company's being held responsible for the radiation survey.

Dr. Aebersold: The radiologist purchasing the unit has the ultimate responsibility for the radiological safety of his unit. The manufacturer, however, has a responsibility before he turns the equipment over to the radiologist.

Chairman Mason: I think that Mr. Reynolds' question refers to B-3. Mr. Reynolds wants to know if the manufacturer shall actually make the survey, or is it acceptable for a qualified consultant to make the survey. Is that your question?

Mr. Reynolds: We should stay away from the implication that the X-ray company would guarantee the radiological safety of the machine and its installation.

Dr. Aebersold: I don't know the practice in the X-ray industry, but when you buy anything that is hazardous, the title must change from the manufacturer to the user, and the manufacturer must ascertain that everything is satisfactory before he passes the title to the radiologist.

Mr. Reynolds: I suggest that since we are not sure of all the facts, we maintain an open mind until legal counsel or the Electrical Manufacturers Association expresses an opinion.

Chairman Mason: In the X-ray industry, who arranges for the certified physicists to calibrate a 250 kv unit?

Mr. Reynolds: A radiologist may do it or they may request the manufacturer to do it as a service.

Dr. Lofstrom: Does this policy imply that the certification will be submitted to the allocation committee by the manufacturer or the user before the unit can be purchased?

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* Mr. Reynolds is referring to the original inclusion of B-3 as A-3. The AEC has revised the request. We use the final version to save space but include Mr. Reynolds discussion because it is pertinent to the entire problem. (Editor's note - Harmon)

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Chairman Mason: An agreement that it shall be done will be satisfactory. The Commission would expect the agreement to be met.

Dr. Aebersold: It seems to be a matter of record that having one of the machines you would want to make a record of all the survey. I don't think it is necessary to make the survey twice. In respect to the legal angle that is worrying the manufacturers, I believe that radiologists buying the equipment would want to know that it meets the minimum standards set forth in Handbook 54. In filling out AEC Form 313 there must be a positive statement that a radiation survey will be made and by whom.

Mr. Reynolds: This sheet, perhaps, is a guide for the preparation of Form 313.

Dr. Aebersold: Yes, I would think so. I wish to call your attention to the following statement on the distribution policy for high specific activity cobalt 60 sources:

(A discussion of the policy statement, distributed at the meeting, showed the necessity of further clarification on priorities held by commercial suppliers. At the suggestion of the US-AEC the following revised statement replaces the policy statement distributed at the meeting.....M. Brucer)

DISTRIBUTION POLICY FOR HIGH SPECIFIC ACTIVITY COBALT 60 SOURCES

Subject to availability, cobalt 60 teletherapy sources will be supplied to meet the demand of individual domestic users (commercial suppliers see below) who possess authorizations dated prior to July 1, 1954, and who purchase the source and indicate that they are prepared to take delivery within six months after notification by ORNL of availability. Should a source be purchased but not delivered within the specified six months period, the AEC reserves the right to direct ORNL to repurchase the source at the decayed level and redistribute it.

All orders for export to foreign countries whose nationals hold authorizations dated prior to July 1, 1954, will be filled (subject to availability) after orders from individual domestic users holding authorizations prior to July 1, 1954, but prior to filling domestic orders from customers authorized after July 1, 1954. At such a time as a source is purchased for export, shipment must be arranged within three months of date of notification of availability. If shipping arrangements are not made within this period, the AEC reserves the right to direct ORNL to repurchase the source at the decayed level and redistribute it.

Commercial suppliers holding priority on five sources, in order to obtain delivery of such sources, must have individual domestic users who hold an authorization dated prior to July 1, 1954, and who have purchased and indicated to ORNL that they are prepared to take delivery of the source within six months after notification of availability. Between July 1 and October 1 commercial suppliers of teletherapy equipment will have a final opportunity to secure firm customer purchase orders and authorizations for those remaining sources (of the five).

After October 1, 1954, all orders for high specific activity cobalt 60 will be filled according to the date on which ORNL received the user's authorization and purchase order, provided that such customer shall purchase and take

delivery of the source upon its availability.

Commercial suppliers will depend upon the authorization of individual customers for the availability of high specific activity cobalt for their devices.

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ESSENTIAL DATA A MANUFACTURER MUST SUPPLY TO THE RADIOLOGIST

J. B. Stickney
Engineering Department
Picker X-ray Corporation

I believe I can be quite brief in stating our views in the matter of data supplied with a cobalt unit. Some data is, of course, standard with any machine, and for the benefit of those present who are not familiar with the general practices of the x-ray industry, I might just list these standard items.

A. Installation Data

1. Physical dimensions of the equipment and recommended room size.
2. Floor loading and any other unusual mechanical problems such as minimum door size. There may perhaps be a problem of getting long members around corners or through narrow passageways. Weight is quite a problem with kilocurie cobalt units.
3. The electrical requirements will have to be listed in some detail. We customarily specify type and location of service inlet, fuse sizes, junction box sizes and locations, location and size of conduit number and size of wires in conduit between the treatment room and the control room, specifications for door interlock switches, warning lights or buzzers.
4. We will suggest the room protection which should be installed. I will comment in detail on this point later, but I should like to emphasize that this data is merely a suggestion, and it is not expected that the customer will use it without modification.
5. On request we will also go so far as to lay out a complete x-ray department or section showing the location and sizes of waiting rooms, dressing rooms, offices, etc.

B. Operating Data

1. We will supply the necessary warning literature. This includes a statement that the equipment is for use by or on the prescription of a physician, and also such special warnings as may be necessary for a particular machine. For the cobalt machine we will include a special statement regarding the hazard in using radioactive materials. We will also include the entire Handbook 54 when it is published.
2. Details of source capsule and shield, as required by Handbook 54.
3. Operating Instructions.
4. Lubrication, routine maintenance data, and routine safety inspection.
5. Emergency procedures. Most of this is already in HB 54, but we will repeat it.
6. Repair data is also included in our instruction manual, but it is generally not expected that the customer will make use of this himself, but will rather employ the services of a regular repair man.

We come now to the debatable part — the radiation data. I should begin by pointing out a policy of ours. A policy, which I believe is widely accepted in the x-ray industry. We believe that the responsibility for the administration of

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a safe dose rests entirely on the radiologist. It is his responsibility to find out what comes out of his machine, and to check it periodically. The manufacturer may run calibration data on output, depth dose, and isodose curves for his own information, for use in advertising or sales promotion; however, it is recognized that such data is merely typical, and is not to be used in connection with the treatment of a patient. We will, therefore, not furnish our data with the machine, because to do so would be to encourage its use without further checking, and this seems very risky.

Our position here is somewhat analagous to that of a drug manufacturer. In administering drugs, a physician almost always makes sure that the exact measurement of the size of the dose is carried out by a registered pharmacist or other qualified expert. Most state laws require that drugs be handled in this fashion to insure against accident through administration of improper dose. Similarly, we feel that the physician should employ the services of a registered physicist or other independent expert to measure the output of his x-ray equipment. Needless to say, we will argue with a physicist who gets output readings substantially different from ours; nevertheless, we will accept his findings as the final word. The medical profession apparently agrees with this policy. Their attitude is exemplified in the prohibition against members of commercial firms becoming registered calibration physicists. This prohibition is undoubtedly based on the feeling that manufacturers calibration data may be biased in favor of making the equipment look good. This is hard to swallow, but when one is dealing with human life, the attitude is probably justified. As in the case of the pharmacist who determines not only the quantity, but also the quality of the drug being dispensed, we feel that the physicist calibrating our equipment should determine not only the roentgen output, but also the half-value-layer and such other pertinent data as depth dose, isodose curves, and variation of the output with field size. In the case of the isodose curves, I expect to get some argument from the medical profession since every manufacturer's machine will be different, and it will be impossible to use standard published handbook data. It is apparent how much variation there will be when one considers the multiplicity of source diameters and collimating devices which are already in use. The associated variations in penumbra will make considerable differences in the shape of the isodose curves; and, therefore, some will think that the manufacturer ought to supply such curves with his particular unit. I think this argument is not sufficiently convincing though, and we will even here avoid sending out our own data. We will, of course, make an effort to supply typical data obtained independently by recognized authorities.

I think it will now be evident why we will not specify room protection design. We will, as I said, show typical installations with typical wall thicknesses, but we will always ask that the actual thicknesses and window thickness be specified by the radiologist or physicist in charge. On completion of an installation, we will make an abbreviated survey of the radiation protection, and will caution the radiologist if we find anything wrong; but, we will not put ourselves in the position of approving the radiation safety of the installation.

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ESSENTIAL DATA A RADIOLOGIST MUST GET FROM THE MANUFACTURER OF COBALT THERAPY UNITS

James E. Lofstrom, M.D.
Wayne University

I find myself in a very interesting position in appearing at this particular point. Certainly this task is going to be very easy after all the discussion today; and perhaps I should say amen to what Mr. Stickney has delivered to this group; but never let it be said that a radiologist would take it lying down without asking for something in addition to what industry would like to supply.

I was rather bemused when Dr. Brucer asked me to present the radiologist's point of view, because he outlined by implication about how far I should go. Dr. Brucer seemed to feel that I would not be too demanding on industry. On the other hand Dr. Brucer realized that he would probably need all the help he could get; therefore, I shall at least ask for quite a few things and precipitate some discussions.

We must bear in mind that all of the purchasers of teletherapy equipment are not going to be blessed with the full time services of a first class physicist. Some will have well trained individuals to carry out tests and surveys; others will have to employ a physicist, and others will use moderately trained physicists who will attempt to do an adequate job. It is readily seen that it becomes hard to draw a line in determining all the data that one should have. Certainly, the radiologists, in purchasing any radiotherapeutic equipment, are accustomed to accepting the basic information that Mr. Stickney outlined, and I would not want to go into that any further. However, I would like to bring up some of the aspects of Mr. Stickney's recommendations, and state my own personal point of view.

Suppose I have placed an order for a teletherapy unit and am anticipating its clinical application. I would like to be very certain that the manufacturer has met the protection standards of Handbook 54 and that the source material also meets all of those specifications. Radiologists certainly are not in a position to break down the unit to determine the primary aspects of this source capsule. The radiologist also must have a certification of the unit assuring its conformance to the minimum standard.

As a radiologist I would like to have available a set of isodose curves around the machine so that greater protection could be given to personnel at the outset. If there is an interval between the arrival of a physicist and personnel working around the machine, I think it would be worth while to have some fundamental knowledge of the radiation around the unit. The radiologist may have to accept the fact that the curiage and roentgenage does not constitute a final guarantee by the manufacturer.

I want to go back to this morning when there was a very generous offer of the rhm information, and which was immediately turned down. The radiologist is entitled to this information just as much as is the manufacturer; and certainly if he is presumed to be intelligent enough to operate his piece of equipment, he must also be presumed to have the knowledge that the rhm values are not the final authoritative rating which he is going to be using clinically. However the ORNL rhm values would certainly be of tremendous assistance and would add to the confidence of the radiologist if he calibrates the equipment himself, or if he has

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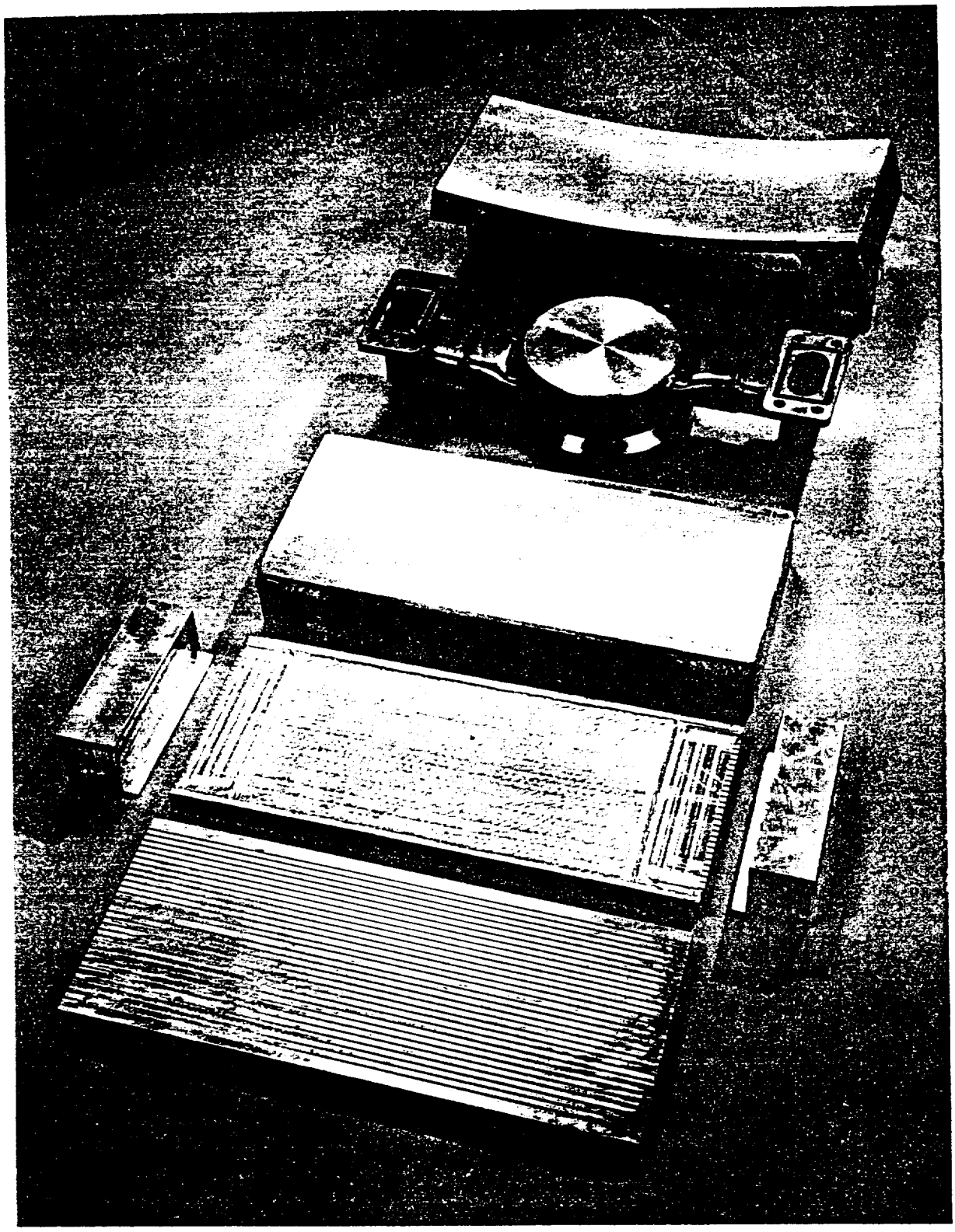

Fig. 7

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Presently existing data do not show whether the (p,α) cross sections or the sum of (p,2n) and (p,pn) cross sections is greater. Almost surely one will be found n current studies to be greater and in that event the use of enriched target material will be economical for the production of decacurie quantities of Co 57.* The use of isotopically enriched nickel for target material will then increase production rates of Co 57 and lower the ultimate cost.

The third step, fabricating targets for dissipation of much heat, has involved many man-hours of research and development by the cyclotron staff. There has been significant progress in target development under the direction of John A. Martin. Cyclotron targets have been fabricated which dissipate as much as 66 kilowatts of heat.

A typical target base is prepared in steps as shown (Figure 7). Rectangular slots 3/32-inch wide are cut to within 3/32 inch of the opposite surface of 2S aluminum plate 6 inches wide, 10 inches long, and 0.5 inches thick. A Heliarc-welded bead closes each slot to provide a water-cooling channel. Surfaces are machined near the ends of the channels for blocks which fit against gaskets on the target water header. These blocks are Heliarc welded in place and have water passage holes drilled in them. This flat assembly is bent to the radius of curvature of the proton beam and the blocks are machined to parallel surfaces. The target base is then ready for application of the cyclotron target material.

Various target materials have been applied by electroplating, chemical plating, flame spraying, and by casting in a shallow recessed area. In general, where the technique of electroplating has been developed, an electroplated surface is preferable.

In preparation of a Co 57 target, the target base is first electroplated with silver, so that the aluminum base will be protected from the hydrochloric acid used in the stripping solution during chemical processing. High purity natural nickel is then plated onto the silver by a standard plating process.

After assembly on the water header, the target is placed in the cyclotron for bombardment by 22-Mev protons. In order to dissipate a maximum of 33 kilowatts of heat for a beam of 1500 microamperes, the coolant water is under a pressure of 140 psi. It is necessary that there be a good mechanical bond of target material to the base, a good heat transfer bond, and sufficient water flow. If any one of these fails, target material is vaporized or melted away, requiring the machine to be shut down for installation of a new target and possibly a major clean-up of the machine.

After the target is bombarded in the cyclotron, it is highly radioactive because of both the desired and the unwanted shorter-lived activities. The target is removed from the machine by special remote handling equipment and stored in a shielded pit for decay of short-lived activities, in the case of Co 57 production for the decay of 36-hour Ni 57, 12-hour Cu 64, and others.

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* Study conducted with the Stable Isotopes Research and Development Division of the Oak Ridge National Laboratory.

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CYCLOTRON-PRODUCED Co57

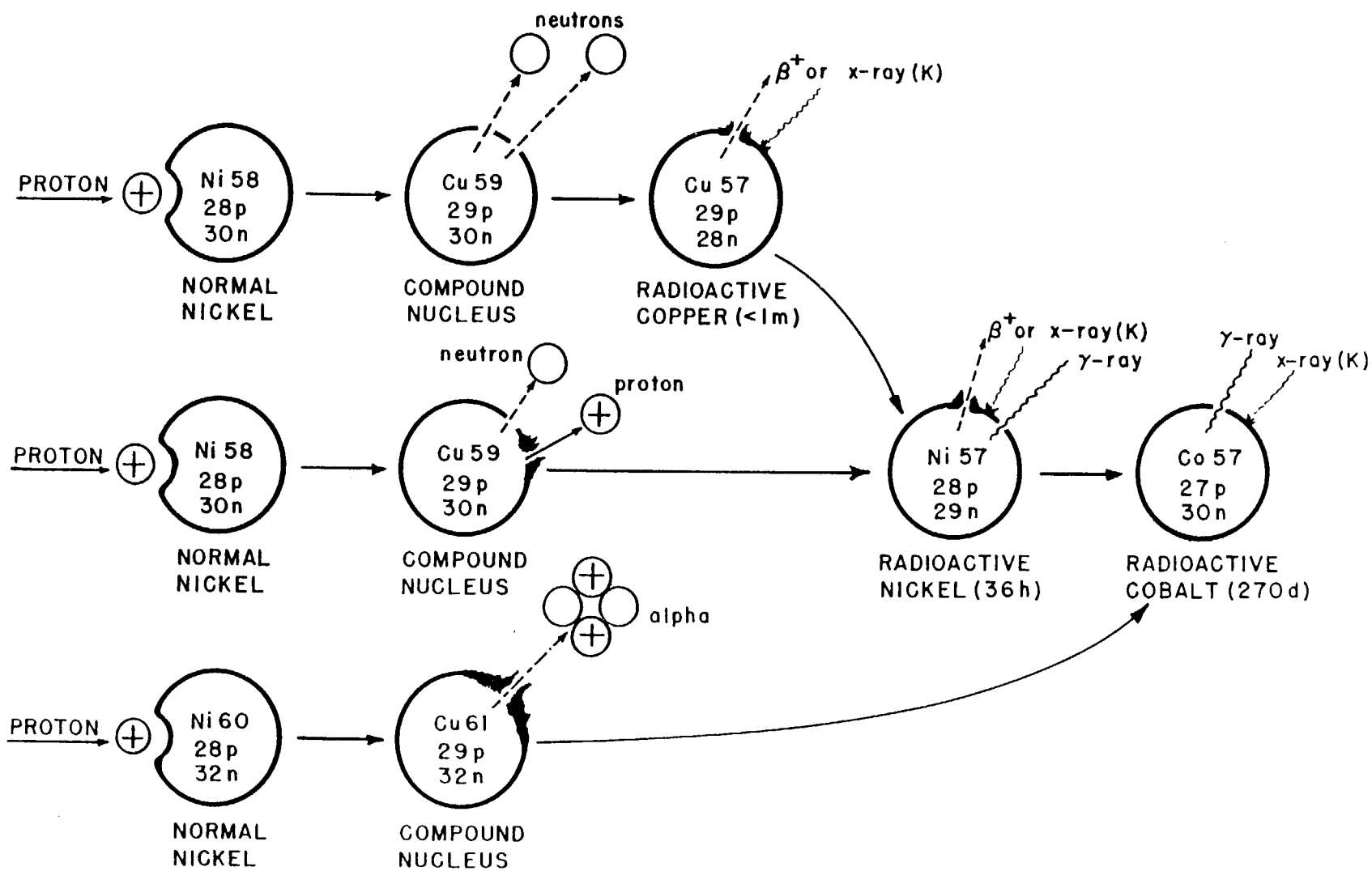

Fig. 6

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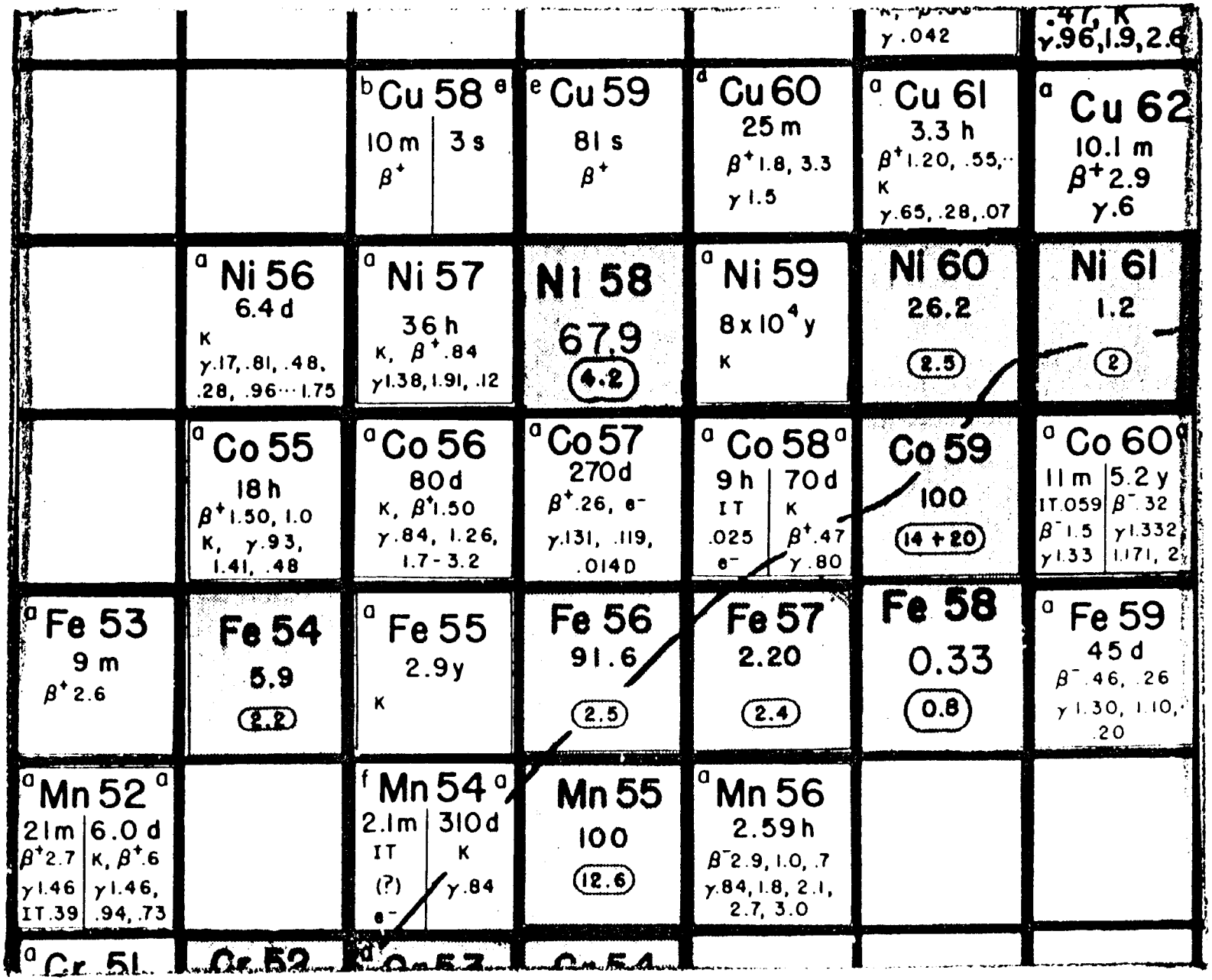

Fig. 5

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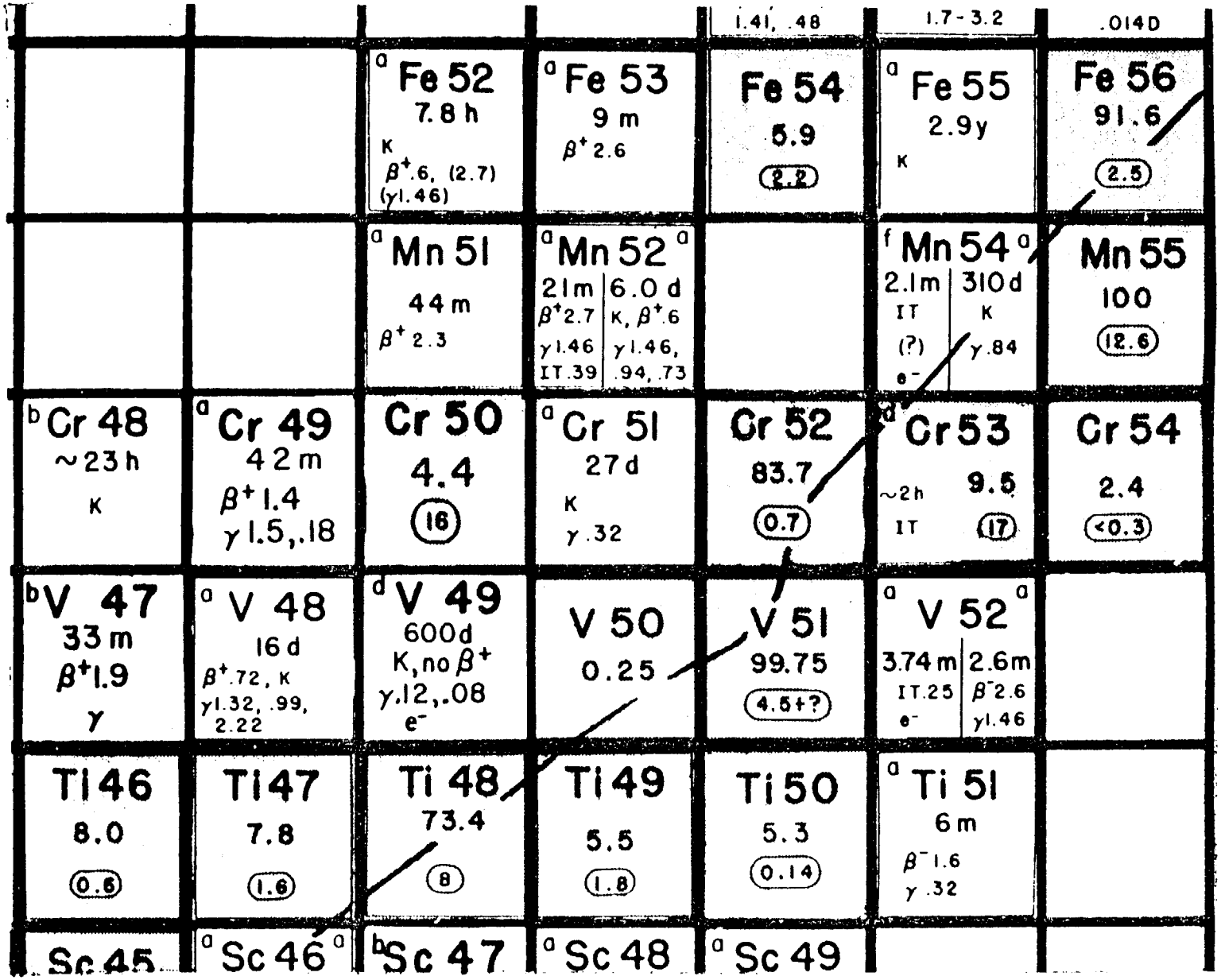

Fig. 4

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2) Determining process(es) by which the isotope may be made most efficiently, e.g., (p,n), (p,2n), (p,pn), (p,α).
3) Fabricating target for dissipation of much heat.
4) Bombarding target in cyclotron.
5) Handling hot target prior to chemical processing.
6) Chemical processing.
7) Designing and fabricating source.

Recent interest in considering certain radioisotopes for large-yield production on the 86-inch cyclotron has demonstrated that the first step is to carefully check existing nuclear data. Some data are subtly in error; some are grossly in error. There are numerous ommissions.

An example of gross error is data shown for V 49 on the General Electric Chart of the Nuclides (Figure 4) and in available literature. For teleradiation, V 49 on the chart looks promising; it has a good half life, is a soft-gamma emitter, should be made with high yield by protons on natural chromium, and could be produced simultaneously with regular production runs of Mn 52, Mn 54, and Cr 51 to share production costs with them. We believe, however, that we have preliminary evidence that 1) there is no soft-gamma radiation at all in V 49, 2) there probably are characteristic X rays from K-electron capture, and 3) the half life is not necessarily 600 days. Therefore, V 49 must be discounted until more reliable information is obtained.

An example of subtle error is Co 57. Our group was interested in Co 57 (Figure 5) as a positron emitter for possible medical usage. The literature shows the positron to be only 3 per cent abundant per disintegration. However, closer study in Oak Ridge National Laboratory by W. S. Lyon has shown the positron to be 0.3 per cent per disintegration. The discovery of this low percentage of positron emission destroyed our interest in Co 57 for its positron value, but opened new areas of possibility for application, teleradiation and soft-gamma radiography.

Similar examples of error and ommission and possible new applications could be given for holmium, terbium, gold, platinum, and other isotopes on the neutron deficient side of the stability line shown on the General Electric Chart of the Nuclides.

These examples emphasize a note of optimism; when all cyclotron-produced radioisotopes are re-examined for half life, emitted radiation, and decay scheme, surely other interesting possibilities for teleradiation will be found.

The second step in production of a given radioisotope in curie quantities is determination of the most efficient production method, which involves accurate experimental values of proton cross sections. Co 57, for example, can be made by at least four processes (continued use of Figure 5): (p, 2n) and (p,pn) on Ni 58, (p,α) on Ni 60, and (p,n) on Fe 57. The latter is undesirable for three reasons: 1) the (p,n) cross section on Fe 57 is less than the sum of other possible reactions, 2) the natural abundance of Fe 57 is low, and 3) Co 56 with hard gammas would be produced along with Co 57. Co 57 is most economically produced simultaneously by the three former reactions (Figure 6). Production rates in this discussion are based on experimental yield from these three reactions.

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Figure 3

COMPARATIVE TERMINOLOGY FOR RADIOISOTOPE PRODUCTION

	Reactor	Cyclotron
Activity proportional to	Neutron flux (n/cm^2-sec)	Proton current (μa)
Principle reactions producing radioisotopes	(n,γ), (n,p), (n,α) Fission	(p,n), $(p,2n)$, (p,pn), (p,α)
Cross sections	Listed frequently for (n,γ) reactions.	Not generally available for proton reactions.
Principle radiations	β^-, γ	β^+, characteristic X ray (electron capture), γ
Usual specific activity	Medium and low (n,γ); very high (n,p), (n,α); very high daughter products.	Very high (p,n), $(p,2n)$, (p,α); low (p,pn); very high daughter products.
Target fabrication	Nominal problem	Of major importance for high yield.
Chemical processing and handling	Comparable	Comparable

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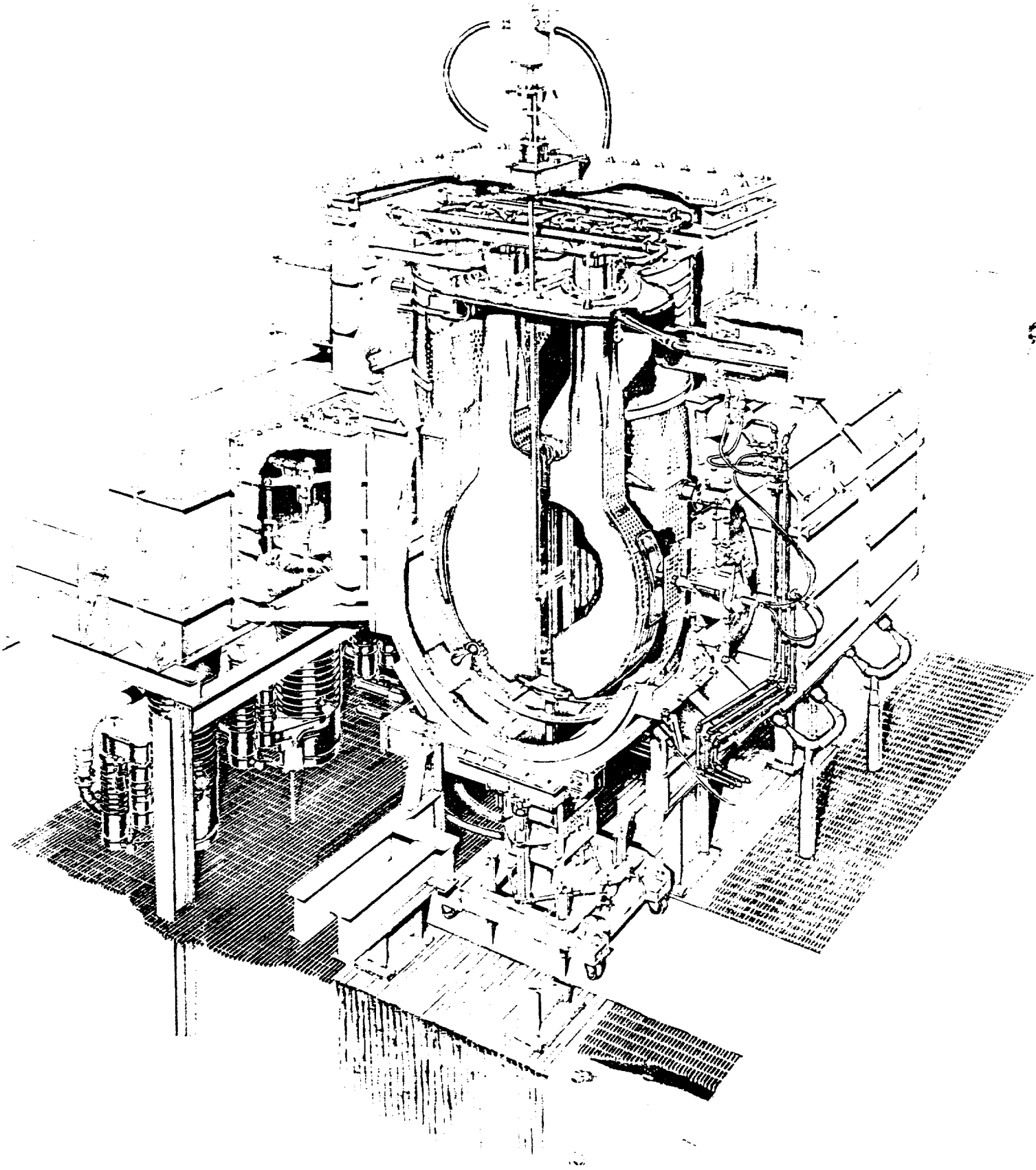

Fig. 2

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The first radioisotope production from a nuclear reactor in the 1940's gave early indication that the nuclear reactor would become the major producer of radioisotopes where large quantities of activity are required. Biological and medical scientists soon turned to reactor-produced radioisotopes, substituting them for cyclotron products.

The cyclotron in subsequent years became known, by comparison, as an exceedingly difficult means of producing radioisotopes. Two very important advantages of the cyclotron were virtually overlooked: 1) that the cyclotron can produce radioisotopes with certain important half lives and radiation characteristics which cannot be reactor-produced, and 2) that a cyclotron can in many cases produce a much higher specific activity than the reactor for radioisotopes of similar characteristics.

In 1949, plans were intiated at the Oak Ridge National Laboratory for development and construction of a high current proton cyclotron which could produce radioisotopes of long half life in more reasonable irradiation times than machines then in existence. These plans were achieved under the direction of Robert S. Livingston of ORNL in the 86-inch cyclotron which was put into operation in 1950. In very recent months it has become apparent that the Oak Ridge National Laboratory's 86-inch cyclotron, with present-day operation, forecasts certain cyclotron-produced radioisotopes which may become economically useful for teleradiation. The field of teleradiation (with that of industrial radiography), requiring decacurie and possible hectocurie sources, is the most difficult of all for the cyclotron to serve. Yet, today, the outlook is quite optimistic if there should develop sufficient demand for certain radioisotopes.

The ORNL 86-inch cyclotron is the only known cyclotron in the world designed and developed to be a high-current proton accelerator for large production capacity of radioisotopes as well as to be a basic research tool. This fixed-frequency machine accelerates protons to over 22 million electron volts with beams on the target consistenly averaging 1000 microamperes on production runs of 20-50 hours. Currents of 1400 microamperes have been achieved for several hours duration. Thickness of the dees and intensity of the magnetic field in this machine are more favorable than in most other machines for the generation of large proton currents and for the installation of targets suitably designed for the dissipation of large amounts of heat. Targets and heat dissipation will be discussed later in more detail.

The 86-inch cyclotron uses a U-shaped magnet yoke with a horizontally oriented magnetic field. An artist's cutaway sketch (Figure 2) shows the machine's ion source, vertically suspended dees, target in position at the bottom of the dees, vacuum pumps and other components.

Procedures used with the cyclotron for producing a new source for teleradiation will be discussed so that you will not only appreciate cyclotron problems but also so that you may use them as guide for future reference. A chart (Figure 3) may give assistance in cyclotron terminology by comparison with that for a reactor. Steps in producing a new radioisotope on the 86-inch cyclotron are:

1) Checking of existing and/or obtaining new nuclear data, e.g., half life, radiations emitted, decay scheme.

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Figure 1

ORNL 86-INCH CYCLOTRON PRODUCED GAMMA EMITTERS

	Co 57		Co 56					
Half life	270 days		80 days					
γ Energy, Mev	0.120	0.130	0.85	0.126	1.74	2.01	2.55	3.25
Abundance, %/dis.	65	low	100	50	20	10	20	20
β^+ Energy, Mev	0.26		3.25					
Abundance, %/dis.	0.3		23					
Electron capture (K) %/dis.	100		Not important					
Specific activity, curies/gram	~1000		~1000					
Activity produced curies	1.8* (3/26/54)		2.2 (12/4/53)					
Irradiation time, hrs	36		30					
Production rate, mc/hr	50		73.3					

* Estimated activity based on previous run.

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NEW SOURCES FOR TELERADIATION - CYCLOTRON PRODUCED

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Electronuclear Research Division
Oak Ridge National Laboratory

All previous discussions in this conference and prior conferences on teletherapy have been on reactor-produced radioisotopes used in teleradiation sources. We have been invited to describe several available cyclotron-produced radioisotopes, to discuss the background and problems of cyclotron radioisotope production and to predict the possibilities of making other source isotopes with the cyclotron.

Two gamma emitters which may extend the energy range of teleradiation have been produced with the Oak Ridge National Laboratory's 86-inch cyclotron. These are: Co 57 (half life 270 days) which emits 120-kev gammas at a rate of $\sim$ 65 per cent per disintegration and has no other radiation of importance; and Co 56 (half life 80 days) which has a high energy gamma spectrum with significant abundances of 2.5 - 3.25-Mev gammas (Figure 1). These two cobalt isotopes can be produced with specific activities of approximately 1000 curies per gram. Curie quantities have been produced in less than 25 hours of cyclotron irradiation time. These short production times are recent cyclotron achievements. In 1940, it would have been virtually impossible to produce curie quantities of Co 57 and Co 56 with any cyclotron in existence. Even in 1950, before the 86-inch cyclotron was available for such productions, these quantities would probably have required continuous cyclotron operation day and night for weeks. This discussion today will use Co 57 and Co 56 for illustration of typical procedures involved in cyclotron production of radioisotopes, and will indicate how additional basic scientific data and improved design and technology may provide radioisotopes for new teleradiation sources within the next few years.

A sketch of cyclotron history and radioisotope production may be of interest. In 1930 the cyclotron principle of accelerating protons was announced by E. O. Lawrence to be of importance for studying nuclear properties of atoms. During the next decade many radioactive nuclear species were produced by cyclotrons and other machines which accelerated protons, deuterons, and alpha particles. These radioactive nuclei (radioisotopes) yielded theoretical information and were immediately found to be practical for application in the fields of biology and medicine. By 1939 at least two out of a number of existing cyclotrons, the Berkeley 60-inch cyclotron and the cyclotron of the Biochemical Research Foundation, were producing radioisotopes for aid to these two fields.

Three principle techniques for application of radioisotopes to biological and medical problems were in use during 1942: 1) administration of suitable chemical compounds as tracers, 2) autoradiography, and 3) the "in vivo" irradiation of tissues. A few radioisotopes such as radiophosphorus, radiocalcium, and radiostrontium, were being investigated as possible therapeutic agents for cancer in various animal systems, including the human, by selective uptake of radiochemicals. Examples of encouraging results were those of radiophosphorus uptake and therapy in cases of chronic myelogenous leukemia and chronic lymphatic leukemia. However, all studies which were being pursued with cyclotron-produced radioisotopes were exceedingly difficult because cyclotron bombardments of many hours duration produced only microcurie and millicurie quantities of usable radioactive products.

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The neutron activation of natural europium, composed of the two isotopes 151 and 153, to yield the radioisotopes 152 and 154, appeared to be very promising for the preparation of teletherapy sources. However, recent data on the thermal neutron capture cross sections of europium isotopes have been used to make calculations which show that the maximum specific activity obtainable is relatively low. The decay schemes of europium 152 and 154 are not well established and the other nuclear data are likewise in doubt; therefore, these calculations are subject to revision. The average half-life for the two isotopes is reported to be between 12 and 16 years. With a thermal neutron flux of 10^{13}, the maximum specific activity of 27 curies per gram of europium metal occurs at 0.86 years; at a flux of 10^{14}, the maximum specific activity of 28.6 curies per gram occurs at 0.088 years. The calculations also showed the neutron economy to be low. For example, europium requires about 8.5 times as many neutrons as is needed to produce the same number of curies of cobalt 60. An experimental program is in progress to check these calculated values.

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NEW SOURCES FOR TELERADIATION
PILE-PRODUCED

T. A. Butler
Radioisotope Department
Oak Ridge National Laboratory

Dr. Brucer: We have been exceedingly practical all the way through this meeting so far. The next two talks and discussions will begin to speculate, and I think some of the speculation is very useful to us and to some of the ORNL people who are thinking up possibilities for producing some newer sources. There are still two main places to get radioactive isotopes. The pile is the No. 1 source of sources; in second place is the cyclotron. Some of us in Oak Ridge are following the principle that if we have both of these groups competing with each other we might get some place. In order to start these discussions, we asked Mr. Butler of ORNL to talk about some of the problems of pile-produced isotopes. Mr. Green is going to talk about some of the problems associated with cyclotron-produced isotopes.

Mr. Butler: Tuesday of this week, the Oak Ridge National Laboratory released a news item concerning the completion of a cesium 137 teletherapy source by the Radioisotope Department. The source can hardly be classified as a new teletherapy material; however, this is by far the largest source prepared and will permit an evaluation of cesium 137 as a deep therapy gamma source. We are now holding this 1540-curie unit for observation before transferring it to Dr. Brucer sometime in July for his rotational teletherapy unit.

Another fission-product isotope which we are working on is cerium 144. In the fission process, cerium isotopes 140, 141, 142, and 144 are produced. Of these isotopes, 140 and 142 are stable; 141 has a half life of 30 days and 144 has a half life of 275 days. The predominate gamma emission from both isotopes is in the energy range of 34 to 145 kev. It is reported that the praseodymium 144 daughter of cerium 144 has three strong gamma rays of 0.695, 1.48 and 2.19 Mev energy, but these amount to two per cent or less of the total disintegrations. It seems improbable that fission-produced cerium will be useful for deep therapy applications, but high specific activity sources could be prepared which would utilize the weak gamma radiation for other purposes.

Another radioisotope produced in fission which may be of interest is ruthenium 106, which has a half life of one year, and ruthenium 103, which has a half life of 40 days. In addition to these active isotopes, stable ruthenium isotopes 99, 101, 102, and 104 are obtained. Ruthenium 103 and the rhodium 106 daughter of ruthenium 106 have gamma emissions ranging in energy from 0.5 to 2.4 Mev. Experimental sources are being prepared at ORNL.

Some interest has been expressed in obtaining sources prepared from weak gamma ray emitters for use as portable X-ray devices. Among the radioisotopes we are considering for such use are zenon 133, europium 155 and americium 241, all products of fission, and thulium 170 obtained by thermal neutron activation of natural thulium 169. Thulium 170, which has been mentioned earlier in this conference, has received the most attention and we expect to make such sources available to industry and to the medical profession if there is sufficient interest in them.

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be worked out in connection with the calorimetric calibration of radiation beams and calorimetric calibration of ion chamber dose meters in rads, it does appear that practical dose measurements will still be made with air ionization chambers.

The future of this field calls for increasing use of radiation physicists and rightly so. It does pose a severe problem to the instrument manufacturer who finds the radiation physicist spending most of his time designing and building instruments.

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pressure variations, humidity, etc. For work in a water phantom, or in the humid tropics, or at high altitudes it is particularly desirable to have hermetically sealed probes.

The shortcomings of some available instruments may be summarized:

1. Radiation induced leakage of condenser dielectrics.

2. Size is too large for some applications, especially the probe or condenser stem which is attached to the active volume.

3. Accuracy. The problems on accuracy are many. The fundamental difficulty is that the standard for cobalt 60 and radium gamma rays is not well defined from the standpoint of absolute accuracy.

4. Reliability. A preference has developed for dependable day to day operation and ease of servicing at the sacrifice of accuracy. The manufacturer who has tried to incorporate laboratory accuracy and versatility in his instruments has often found this reduced the day to day reliability of the instrument. A high degree of reliability is essential in instruments as well as in the equipment of a teletherapy unit.

D. Future Instrumentation.

Future instrumentation will be based on changing needs not met by currently available and older equipment. These were generally too large, insensitive, and unreliable.

New equipment will tend to be more reliable and smaller. With increased reliability, prices will probably stay high or increase unless there is a large increase in demand. Future instrumentation will be aimed at radioisotope teletherapy needs and at the needs for betatron and higher energy therapy. In connection with teletherapy, very small diameter probes(1/8" or less) will be required for measuring isodose curves in air and in phantom. It may prove desirable to use a scintillation detector for this. Because of their size these small probes will be suitable only for very intense beams. For water phantoms it is particularly desirable to have hermetically sealed probes. The hermetically sealed probe also has advantages for use at all altitudes and in the tropics. It appears quite feasible to manufacture an aluminum-bodied, hermetically sealed probe with a beryllium thimble. The beryllium is particularly suited to this application since it will transmit the soft scattered radiation quite well even in thicknesses required for electronic equilibrium.

Such a probe will be offered with a new rate meter instrument which indicates the instantaneous dose rate in r/minute and at the same time integrates the rate until a preset dose in roentgens is reached. This instrument thus avoids the disadvantages of present condenser type integrating instruments, and presents both rate and total dose.

Future instrumentation will reflect the adoption of the physical basis of dose measurement (Fig. 5) in rads or ergs per gram. While many problems remain to

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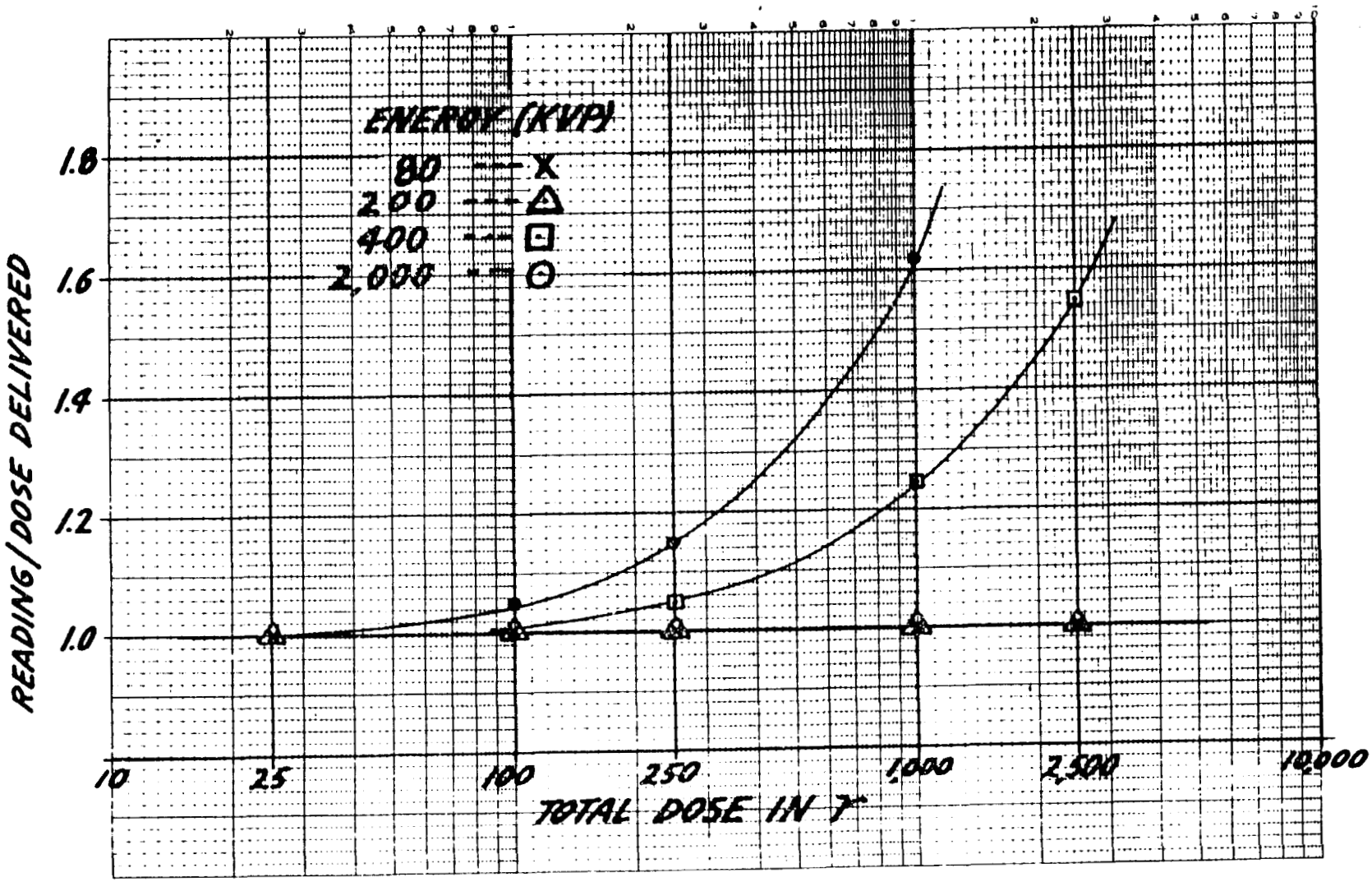

THE READING OF A CONDENSER TYPE ION CHAMBER IS SHOWN TO HAVE AN ERROR FOR RADIATION ABOVE 200 KVP DEPENDING ON THE RADIATION ENERGY AND ON THE TOTAL DOSE.

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The major shortcoming of the condenser type integrating dose meters is that the dielectric insulation of the condenser becomes conducting during and after exposure to gamma rays. The nature of this effect is not fully understood, though some work is being done in different laboratories and some progress is being made. The effect is noted to exhibit a threshold (Fig. 4) and to be proportional to the total dose. The threshold is related to the thickness of the dielectric and to the highest energy present in the gamma radiation. The threshold occurs at lower energies as the dielectric thickness is reduced and at higher energies as the thickness of the dielectric is increased. This effect in the chambers used with the Model 70 has been studied by Morgan and Chambers, REVIEW OF SCIENTIFIC INSTRUMENTS, page 938, October 1953, for X-ray energies of 80, 200, 400, 1000, and 2000 kilovolts and for total doses ranging from 25 to 2500 roentgens. They found no leakage from 200 kilovolts or less for a dielectric thickness of 1/16 inch. They found leakage from energies of 400 kilovolts and above and the leakage increased with total dose. This indicates that the threshold occurs at the energy for which the photo and Compton electrons just begin to penetrate the dielectric.

Similar effects have been noted in the case of radioactive batteries in which strontium 90 beta rays pass through a polystyrene dielectric and has been studied by Warner of the Federal Telecommunications Laboratory using cobalt 60 gamma rays on thin films of plastic. In these studies it is found that the resistivity of the plastic decreases rapidly on exposure to radiation, reaches a plateau, and finally increases if the dosage is continued long enough. Physical deterioration by radiation damage sets in, limiting the usefulness of this treatment. There does appear to be a definite promise of obtaining high performance insulators which will have a long life under radiation by carefully controlling the chemical composition and by subjecting the material to irradiation aging. It may even be possible to eliminate the need for the radiation aging.

To sum up the situation, it is important when using condenser type chambers with million volt radiation to keep the total dose low in order to avoid errors due to radiation induced leakage. A rule of thumb limit for cumulative exposures would lie somewhere around 1,000 roentgens within a period of one hour. This indicates the use of chambers having full scale ranges of 25 r or less. Higher range chambers may be used, but they should be checked very carefully for leakage. Instruments which use rolled foil condensers are not recommended above 100 kilovolts.

Until newer developments in plastic foils have been proven it is doubtful that rolled foil condensers can be used in condenser type integrating dose meters for teletherapy work. The rate meters which have resistance input rather than condensers do not suffer from this effect. Hence, where high intensities and high total doses are required, it is recommended that a rate meter be used. The constancy of the radiation intensity from teletherapy units lends itself to the use of ratemeters. From the rate the total dose can be accurately measured with a timer.

An entirely different form of leakage current occurs in coaxial systems (cable) in high intensity fields of cobalt 60 due to excess electrons going into plastic from braid of cable.

Another shortcoming of available instruments is seen when one wishes to measure depth dose in a water phantom. The chambers are open to atmospheric

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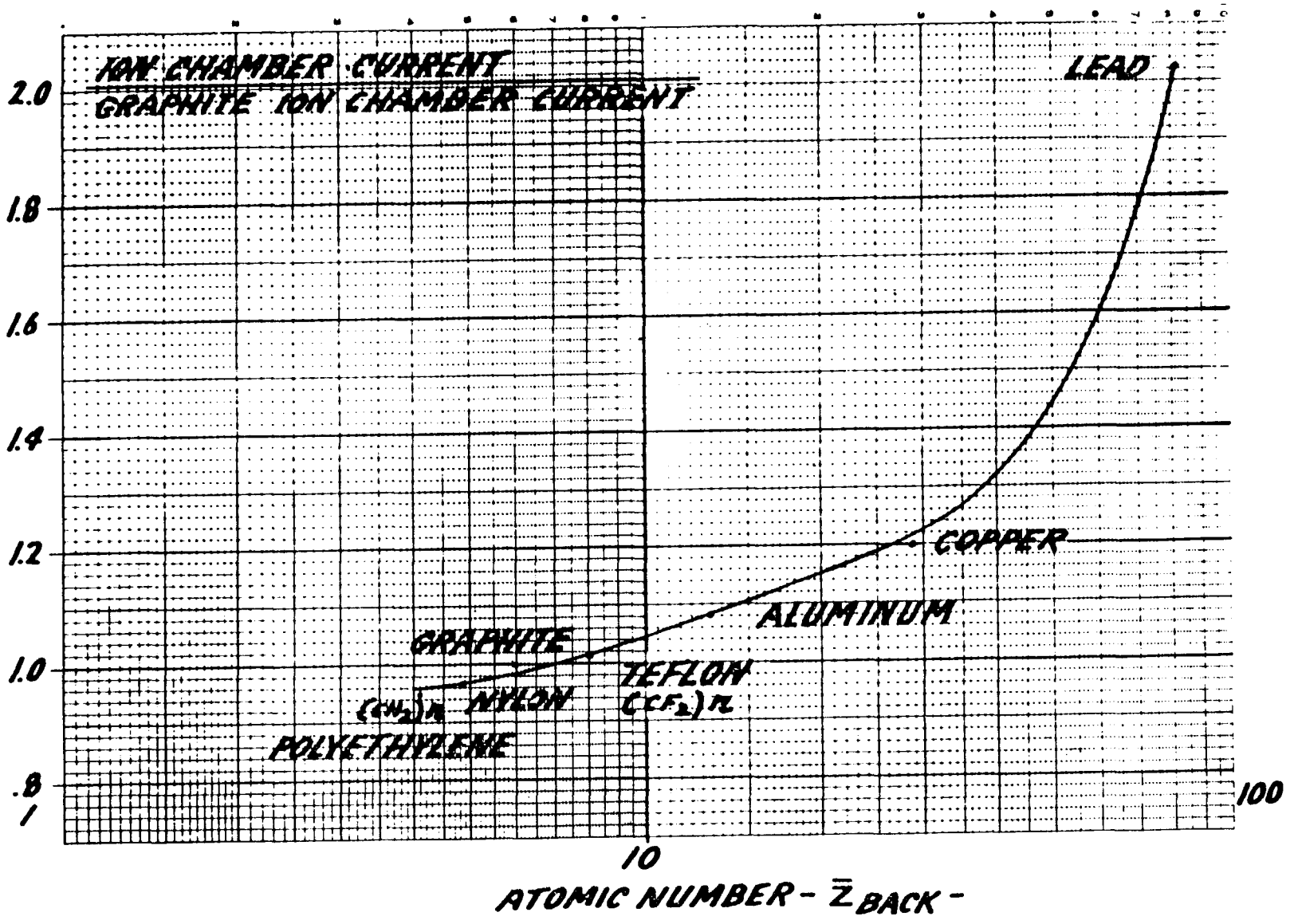

COBALT 60 GAMMA RAY RESPONSE OF ION CHAMBERS VS ATOMIC NUMBER. FOR COMPOSITE MATERIALS THE EFFECTIVE ATOMIC NUMBER ($\bar{Z}$ BACK) FOR ELECTRON BACKSCATTERING IS USED.

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Mr. Stober: The Keleket Company will also have a pushrod with a tongue on it for use if the capsule becomes stuck in the source wheel. This pushrod could be used to guide the capsule back into the shipping container. One wonders if it isn't too early in the development of teletherapy equipment to standardize the shipping cases.

Mr. Stickney: Should the source capsule come back to the Commission for a wipe test?

Dr. Aebersold: This is an ideal time for a wipe test; however, neither the Commission nor its contractors should have this responsibility. The responsibility for a wipe test must be the responsibility of the persons transferring the source.

Mr. Stickney: The statement is well taken that we should not prematurely do anything that would freeze the design of teletherapy shipping containers. The problem of transferring second-hand sources from one to another will not come up for several more years, and there is lots of time to talk about the standardization of shipping containers.

Chairman Mason: All representatives of the X-ray manufacturers appear in agreement on this point, so all action on standardization of shipping containers will be delayed until a future date.

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REQUIREMENTS FOR INSTRUMENTS TO BE USED WITH TELETHERAPY INSTALLATIONS

Mr. W. W. Managan
Victoreen Instrument Co.
Cleveland, Ohio

1. Survey Instruments

While the manufacturer's are familiar with the requirements regarding radiation levels in and around teletherapy installations, it will be useful for the discussion presented here to list the surveys required, the rad intensities, and the radiation spectra to be expected. This will provide a basis for discussing the performance of survey instruments. The surveys which we will list will be based partly on the tentative draft of "Protection against Radiations from Radium, Cobalt 60, and Cesium 137 (Encapsulated Sources)" as published in "Planning Guide for Radiologic Installations", by Scott, and partly on private communications. As such, they are subject to change, but it is believed the instrument requirements will not change substantially.

Quoting section 7.3 on "Teletherapy", "No teletherapy installation should be use routinely until its safety has been established by a protection survey. This survey should be made with the beam in the "off" position to determine that it complies with the requirements of a protective source housing (see section 5.23). Operation procedures based on such a survey should be established for all personnel concerned.

"A survey should also be made of all regions adjacent to the radiation room the aperture open and a patient or phantom in place. Such measurements should be for typical useful-beam directions to determine the dose to personnel under actual conditions of operation. The report should include restrictions of operation or occupancy if indicated by the measurements."

"The housing and collimating devices shall be so constructed that at one meter in any direction from the source in the "off" position, the maximum and average dose rates do not exceed 10 mr per hr and 2 mr per hr respectively. I think we see that in order to reduce the integral dose to the patient, the leakage radiation in the "on" position should not exceed 1 per cent of the useful beam, both measured at one meter from the source. A reduction of the leakage radiation to 0.1 per cent or lower will result in a more economical secondary protective barrier."

There are three separate surveys required:

Region	Radiation Intensities
1. Adjacent regions (i.e., outside treatment room) with aperture open and a phantom in the beam.	Below Tolerance
2. Around source housing with aperture closed.	From less than 2 up to 10 mr/hr
3. Around source housing with aperture open.	Less than 1 per cent of useful beam or 0.6 to 30 r/hr

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RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL UNITS

Revised at the Seventh International Congress of Radiology, Copenhagen, July 1953

I. Definitions and units

1. *Intensity of radiation* is the energy flowing per unit time through unit area perpendicular to the beam. It is expressed in ergs per square centimetre per second or watts per square centimetre.

2. *Quantity of radiation* is the time integral of intensity. It is the total energy which has passed through unit area perpendicular to the beam and is expressed in ergs per square centimetre or watt-seconds per square centimetre.

3. *Absorbed dose* of any ionizing radiation is the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It shall be expressed in *rads*.

4. The rad *is the unit of absorbed dose and is* 100 *ergs per gramme.*

5. Inasmuch as calorimetric methods of determining absorbed dose are not usually practicable, ionization methods are generally employed. The quantity which must be measured is the ionization produced in a gas by the same flow of corpuscular radiation as exists in the material under consideration. The energy E_m, imparted to unit mass of the material is then essentially related to the ionization per unit mass of gas J_m, by the equation:—

$$E_m = W s_m J_m$$

where W is the average energy expended by the ionizing particles per ion pair formed in the gas, and s_m is the ratio of the mass stopping power of the material to that of the gas.

6. Since the calculation of the absorbed dose from measurements of ionization requires a knowledge of the parameters W and s_m as well as variables characterising the radiation and the irradiated material, it is recommended that tables of the best available data be prepared and held under continual review.*

7. The röntgen (r) remains the unit of X- and γ-ray dose and its definition remains unchanged as below:—

The röntgen *shall be the quantity of X- or γ-radiation such that the associated corpuscular emission per* 0·001293 *gramme of air produces, in air, ions carrying* 1 *electrostatic unit of quantity of electricity of either sign.*

8. It becomes increasingly difficult to measure the dose in röntgens as the quantum energy of the X- or γ-radiation approaches very high values. The unit may, however, be used for practical purposes for quantum energies up to 3 MeV.

9. *Integral absorbed dose* is the integration of the energy absorbed throughout a given region of interest. The unit is the *gramme-rad*. 1 gramme-rad = 100 ergs.

10. Amount of radioactive material shall be expressed in curies (c). The accepted definition of the curie is:—

The curie *is a unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is* $3{\cdot}700 \times 10^{10}$.

With this definition the curie is independent of the disintegration rate of radium.

11. It is suggested that the γ-ray emission be expressed in terms of röntgens per millicurie-hour (r/mc.h) at 1 cm from a point source. This quantity is different for every isotope. (Preliminary data have been compiled relating to a number of radioactive isotopes and will be supplemented from time to time.)*

12. The I.C.R.U. requests the national standardising laboratories to set up, interchange and compare standards of X rays, γ rays and radioactive isotopes, maintain close contact with each other, and generally by every means within their power further the improvement of methods of standardisation.

* Preliminary reports on this subject were presented to the Commission and it is hoped will be published in the near future.

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Consider first the survey of regions adjacent with the aperture open and the phantom in place. The survey should establish that the intensity of the radiation transmitted through the wall is less than some maximum permissible value - usually 6.25 mr/hr for a 48 hour week. To do this, the survey instrument should have one of its sensitivity ranges near 10 milliroentgens per hour (mr/hr) full scale. Many of these surveys will be conducted with Geiger tube or scintillation type instrument where the levels are low, and with conservative design it is hoped the radiation levels will be low outside the treatment room. Most of the commercially available G-M or scintillation counter survey instruments have full scale ranges of 0.2, 2.0, and 20 mr/hr for radium gamma rays. Those ranges are convenient for surveying with portable instruments. However, it is stated that ionization chambers are required if a prior scanning with a suitably calibrated Geiger Mueller or scintillation type of instrument indicates occupied regions to have a radiation level of over one-fifth of permissible dose rate. Thus for radiation intensities above about 1 mr/hr, an ionization chamber instrument is required, principally because the ionization chamber is capable of measuring absorbed dose in roentgens (r) or dose rate in mr/hr much more accurately than other types of instruments. Possessing the capability does not mean that all ionization chamber instruments measure accurately.

For example, many ion chamber instruments boast of energy independence from 1 or 2 Mev down to 80 kev. The inadequacy of this lower limit is shown by the spectrum transmitted through water as measured by Weiss and Bernstein at Brookhaven National Laboratory. Moving away from a cobalt 60 source in a water tank, they found the spectrum shown in Fig. 1 did not change its shape or peak energy of 55 kev for distances of 30 to 160 cm. The proportion of soft X rays to primary radiation increases with distance from source. This buildup of soft X rays continues until their energy is degraded to that energy below which photoelectric absorption sets in. In a homogeneous medium, this causes a natural equilibrium spectrum. Once this equilibrium is reached the spectral distribution remains quite constant for increasing distances from the source. This degraded spectrum in the case of water has a maximum in the range of 50 to 60 kilovolts.

For concrete shielding around the teletherapy installations, the calcium present in the concrete would move the peak energy of the spectrum to a higher value, perhaps even to 80 kev. However, if one converts this transmitted radiation flux from photons per square centimeter per second to absorbed dose in milliroentgens per hour, it is apparent that the region below 80 kev and especially below 50 kev cannot be neglected.

The response of ionization chambers need not be uniform in this region, but it is preferable that it be uniform - or high, that is, fail safe. It is important that the low energy cutoff be well below 50 kev. The response of Geiger tubes and sodium iodide scintillation type instruments varies rapidly in this energy range. Here again it is important that the low energy cutoff be well below 50 kev.

Passing to the survey around the protective source housing, with the beam in the "off" position, the radiation intensities of interest seem to be in the range of 1 to 10 mr/hr and higher. The spectral distribution of the radiation transmitted through the lead or other heavy metal of the protective source housing is presumably similar to the one discussed above with a peak at a higher energy.

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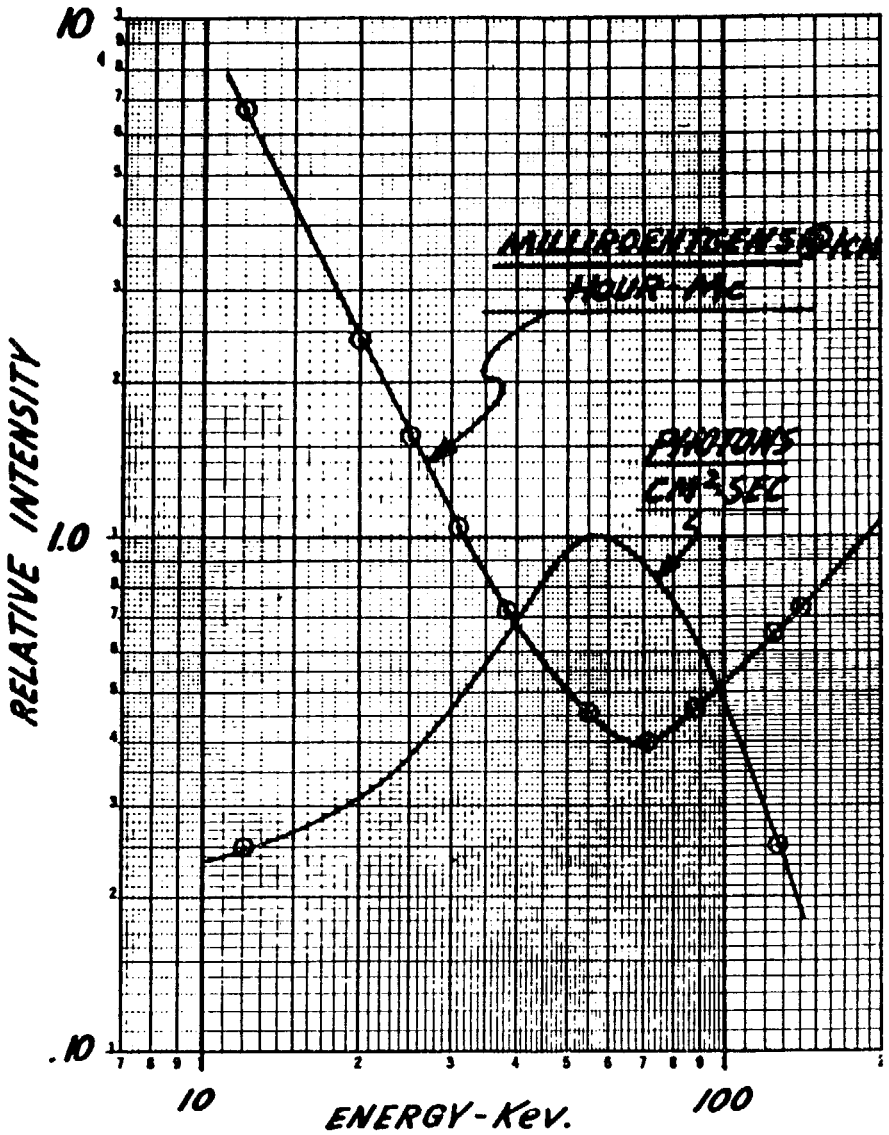
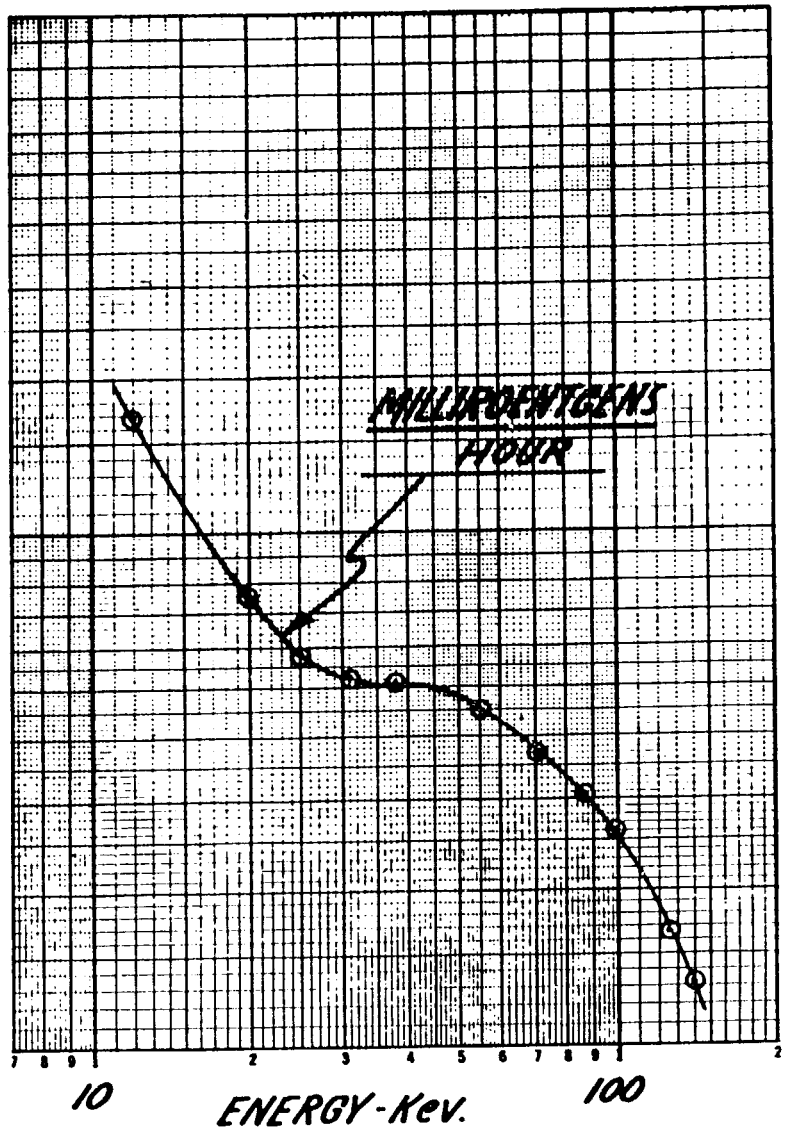


SPECTRAL DISTRIBUTION OF COBALT 60 GAMMA RAYS TRANSMITTED THROUGH 30 TO 160 CENTIMETERS OF WATER.



ABSORBED DOSE (mr/hr) FROM COBALT 60 GAMMA RAYS TRANSMITTED THROUGH 30 TO 160 CENTIMETERS OF WATER.

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Hence most of the available ion chamber survey meters are suitable. For this survey, it may be desirable to have a detector of small size for localization of peak radiation intensities around the housing. It may also be desirable to wrap the protective source housing in film as a means of recording the survey.

The third survey may differ from the second in two ways. The source is moved in the housing from "off" to "on" position and there will be some scattered radiation from the beam, phantom, table, etc. For this survey the use of an instrument with a long meter cable or probe will permit the readings to be taken with no exposure to personnel. Radiation intensities of 0.1 per cent to 1.0 per cent of the useful beam at one meter from the source would be .01 to 3 r/hr and 0.6 to 30 r/hr respectively.

To sum up the requirements on survey instruments for teletherapy installations, they should first be reliable, and accurate as a second consideration. The accuracy is dependent on enough factors, including reliability or proper performance, to warrant the use of a generous factor of safety. With this in mind ± 10 per cent accuracy should be adequate. The low energy cut off of the instrument, that is, the energy dependence, is important and should extend well below 50 kev. The energy dependence need not be uniform if it is fail safe. Future survey instruments should incorporate this design feature in so far as it does not impair the reliability of the instrument by requiring the detector walls to be thin and fragile. Size, portability, and price are also important considerations. Full scale sensitivities of 2.5 mr/hr, 10 mr/hr and up to 50 r/hr are desirable.

II. Therapy Dose Measuring Instruments.

A. Minimum requirements.

In order to use the equipment, the radiologist must have some means of checking by measurements the radiation intensity (roentgens per minute) and dose (roentgens). A minimum requirement would indicate selection of the least expensive instrument which will do the job satisfactorily. Traditionally this measurement has been performed with a Model 70 Condenser r-Meter (see Fig. 2) and appropriate ion chambers. Special ion chambers having walls thick enough to insure electronic equilibrium for cobalt 60 and radium gamma rays are now available for use with Model 70 Condenser r-Meter. This instrument is satisfactory, although there are some limitations when used for total dose in roentgen from teletherapy units, and these difficulties will be discussed below. Because of its simplicity, it is the least expensive of the high quality radiation measuring instrument, and one of the most reliable.

B. Energy Dependence Requirements.

With radium, cobalt 60 or cesium 137 it is important that the ion chamber meet two conditions:

1. It must have walls thick enough to stop any electrons originating outside the chamber, and

2. Its response must be independent of energy to as low an energy as is practical (50 kilovolts); i.e., it must be air equivalent.

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Chemical processing of cyclotron targets is handled by the Production Division of Oak Ridge National Laboratory. For Co 57 production, nickel containing the radioactive cobalt is stripped from the target base with hydrochloric acid. Cobalt is separated from the nickel by a column cation exchange process. Nickel passes through the column readily, leaving the cobalt on the resin; complete separation is achieved.

At present there is no standard source design for cyclotron-produced radioisotopes. Designs are currently in progress for Co 57 sources for dental X-ray experiments and for industrial radiography application. In general, cyclotron produced sources are custom designed.

Cyclotron achievements have been truly remarkable since E. O. Lawrence and M. S. Livingston, in 1932, predicted a future 25-Mev proton cyclotron with a current of 10^{-4} milliamperes. Such a machine, which was a remarkable prediction for that time, could never have produced multicurie quantities of Co 57 because, after production of millicuries in continuous year-long operation, equilibrium would have been reached and decay would have equaled production. Today the ORNL 86-inch cyclotron, with more than 10,000 times the predicted proton current, is able to present two sources -- curie quantities of Co 57 and Co 56 -- as teleradiation candidates for soft-gamma and hard-gamma application.

Not only Co 57 and Co 56 sources, but also entirely new sources, of pure characteristic X rays of from 5 to 70 kev for teleradiation and radiography may be produced in the future with increased rates by the 86-inch cyclotron. If any of these radioactive sources prove to be useful to mankind, they will be peacetime benefits of World War II research and development which made significant contributions to the design of the ORNL 86-inch cyclotron through the electromagnetic process for the enrichment of uranium.

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THE DEVELOPMENT OF THE ATOMIC ENERGY INDUSTRY

Mr. Jerry Luntz
Nucleonics

In requesting that this closing talk be made, Dr. Brucer asked me to act as a cork in the bottle and to not say anything that was controversial. Obviously I cannot do this, and since I will assume that each of you are not 100 per cent with me, I will, for example, make the prediction that the AEC Isotopes Division does not have a half life of another five or ten years. I am sure that no one is going to agree.

I want to give, very briefly, my concept of the atomic energy industry. The first category in the industry consists of getting the raw materials out of the ground, to a rather expensive refining location, and the processing of fissionable materials ready for use. The second category is that of reactor technology, and I wish to emphasize reactors for full time research or production. The third category is radioactive materials such as isotopes, and I am not going to much more than touch on radioactive isotopes since all the people in this room are quite familiar with this field. Rather I am going to spend most of my time discussing the reactor industry since in fact this will affect each of you in a very substantial way.

There are three or four kinds of reactors. The atomic energy industry is concerned first with the central station power plants which might range in size from 50,000 to 60,000 electrical kilowatts, and the costs of these plants can run anywhere from the very lowest guesses of 30 million dollars to hundreds of millions of dollars. The second group would be the packaged reactors that would produce about a thousand to a hundred thousand kilowatts, and would be proportionate to the military reactors but would be built by industry. There are also reactors, the size of which are not quite clear, but would produce from 10 to 20 thousand electrical kilowatts. A fourth group consists of small research reactors, for university and industrial research, they operate from 10 to a thousand kilowatts.

There has been in the past two or three months considerable publicity on the AEC five year reactor program. This is a program for the development of power reactors that will cost somewhere between 200 and 250 million dollars. It includes many diverse kinds of reactors such as the Westinghouse reactor for the Navy, the homogenous reactor being worked on here, the Argonne experimental sodium reactor, and the second version of the Argonne water boiler. The homogenous reactor will be a second version of the one that is in the process of being dismantled here at Oak Ridge. Very briefly that is the government side. And now for the industry side.

Industry is now expending about 45 million dollars a year on research and development activities in the power reactor field. On the other hand the Atomic Energy Act forbids any dollar return on this investment. It is therefore significant that Dow-Detroit, a twenty-six industry group, announced a couple of weeks ago that in 1954 they would spend 2.6 million dollars on program of fabricating and testing components for central station power reactors.

As an example of industries interest, a fabulous offer was made by Duquesne Power and Light Company to operate a pressurized water reactor. Thus far, no one

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has been able to really figure out why Duquesne is willing to contribute five million dollars toward the cost of the reactor, and pay for the steam that is produced at a rate that is probably 50 to 100 per cent the cost of an equal plant. Duquesne is sitting over a coal field, one of the cheapest sites in this country. The feeling I get is that Duquesne apparently have the idea that by using a modified version of present reactors they can come close to being competitive. If Duquesne were not going to build this new plant, they would probably have to build a conventional plant to take care of their increased requirements. If one figures that the five million dollars for the reactor, plus the cost of the conventional generator and other equipment would be about the size of the conventional capital investment, one would estimate that it would cost Duquesne about a million dollars a year more than they would have to pay for the conventional steam system. Regardless of what you think about the expenditure of this money, it is a substantial contribution by industry.

It is interesting to note that industry is working on the packaged reactor problem. In February of this year, the AEC and the Army sent out letters to supposedly interested companies asking whether they were interested in bidding on the first packaged reactor. The invitations were solicited on the basis that the awarded contracts would be on fixed price basis. The Commission had 18 responses to the original inquiries, seven of which they considered to be qualified responses, or at least companies that were willing to build the first reactor on a risk basis. A couple of companies were willing to do this because they want to get a foothold in the atomic reactor field. The interest in these research reactors was borne out in February when a two-day conference on research reactors was held here in Oak Ridge. There were four or five industrial companies that displayed a great competitive attitude in trying to sell their ideas to interested universities.

The Commission has come up with some guesstimates of what the growth of the nuclear power industry might be. Assuming that nuclear power could cost somewhere around 7 to 8 mills per kilowatt in the year 1960, we could then assume that 10 per cent of the electric generator capacity would be nuclear; and if in the year 2000, the cost in nuclear power could be dropped to somewhere around 5 mills, 50 per cent of the new electric generator capacity would be nuclear. I think that these guesstimations go on an assumption that this capacity is going to be built in a 25-year period from 1960 to 1985. The capital investment by industry will be over 11 billion dollars, the makings of a very substantial industry. Some people argue the validity of these figures; but there may be some validity to them.

We should use some time to talk about the Atomic Energy Act, and pending atomic energy legislation, because what happens to the legislation would determine whether or not the referenced growth will come about. The Atomic Energy Act of 1946, as it is presently constituted, forbids anyone except the government from owning a nuclear reactor that is capable of producing quantities of fissionable material sufficient to manufacture atomic weapons. It gives the Commission very considerable control over classified information, and forces the Commission essentially to keep reactor technology, by and large, in a highly classified stage. The trend is not to get AEC out of the field, nor to get the government out of the business, but to change the Atomic Energy Act and permit industry, with their own money, know how, and mechanical ideas, to go ahead and build plants.

About a month or so ago the Chairman and Vice-Chairman of the Joint Committee on Atomic Energy, introduced a bill calling for a major overhall of the Atomic

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Energy Act. It's a bill that has gone a lot further than most people anticipated that it would go. The reason for this is that the Committee couldn't come to an agreement on certain points. They included some extreme views so as to have something on the table to offer for consideration in public hearings. I want to enumerate some of the provisions that are contained in the proposed bill. There is already evidence that some compromises are going to be made and some things are going to be completely knocked out of the bill. First, the bill would permit industry to have research done in a government owned laboratory at a price determined by AEC. The bill would permit you to own reactors and other facilities which produce and utilize fissionable material. You would be permitted to own reactors and other facilities to produce "special" materials if you were first licensed by the AEC. It would permit you to lease, but not to buy "special" materials from the government for the use of fuel in your privately owned reactor. It would permit you, subject to AEC license and regulations, to use your own reactor to produce electric power, to irradiate isotopes, to produce fission products, and to produce these "special" materials. It would not permit you to own the special materials produced but it would require the government to afford you "just compensation" for these materials. It would not prohibit you from selling the electric power you produce to others who apparently would not need any kind of license to buy. It would permit you to sell the irradiated materials and fission products to anyone licensed by AEC to buy them.

The regulations become a very confusing thing. You can't own fuel; and if you are not permitted to own fission products, the question is at some period of operation of the reactor you must pull your slugs to send them back to the Commission for reprocessing. Now what is not clear is what happens to the fission products. Do you pay a government price for processing the fission products, or just what happens? The whole thing has been left in a very nebulous state. Some of the proposed systems, for example, tend to doubt the Dow-Detroit system which is predicated on the basis that they would have their own reprocessing cycle; and I don't know whether or not the Commission is going to pay Dow-Detroit for doing their reprocessing. I think it is one of the major questions still up in the air. You can produce fission products, but how do you get the fission products out of your reactor? I do not know.

There are indications that the implications of the nuclear power have been studied sufficiently that we now know that the industry is not going to bring about any major changes in our economy. The effects upon our economy, which Congress was first concerned with back in 1946, are not now considered serious.

(Mr. Luntz continued with a detailed report of the Cole-Hickenlooper bill. A revised version is reported in Nucleonics, June 1954, and will not be repeated here.)

DISCUSSION

Dr. Aebersold: In regard to Luntz' paper, I think he has done a fine job following these developments at Washington. I am glad there is someone like him running Nucleonics to keep us informed of what is going on. I would like to make one comment regarding the reactor business. There is a lot of industrial and medical interest in reactors because it is possible to get radiation quite cheaply, both gamma rays and neutrons. A contract is being negotiated for a medical reactor

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which will give out a gamma ray beam comparable to the high energy gamma rays from cobalt. The beam will not be collimated as from teletherapy units, but it will be very penetrating and the intensity will be greater than that from a teletherapy machine. We can't build a reactor just for a gamma ray beam, because the cost is about 250 thousand dollars. The reactor could produce an appreciable amount of short half-life radioisotopes for use in a region such as Los Angeles.

Dr. Lough: I am interested in the suggestion of changing the licensing program. The more I work with the physicians who are authorized by the AEC to use radioisotopes, the more I am impressed with the inadequacy in handling techniques. If the program of licensing produces 25 reactor operators, I wonder how much dissipation of control will be implied and voted.

Mr. Luntz: The first thing is that the control is going to be very extreme at the outset. I think that is for nothing but political reasons. The same extent of controls you now have is going to be maintained, and even extended a little further. Reactor fuel will be maintained by the government for this reason.

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THULIUM IRRADIATOR

Dr. James W. J. Carpenter
Argonne Cancer Research Hospital
Representing American College of Radiology

I wish to take a few minutes to demonstrate the thulium irradiator, which we have been playing with at Argonne. The first public announcement was premature and created a tempest in a teapot. People in the X-ray manufacturing business need not get very excited about thulium at the present time, or for a long time to come. This unit I am demonstrating has had a thulium source with a diameter of 5 millimeters on its face by 15 millimeters long. This source produced 7 roentgens per hour at one inch. We are not getting much radiation from the source even when it is fresh out of the pile. The radiation is primarily 85 kev and 52 kev. This unit has no collimation or diaphragm, and it allows a lot of scatter radiation. We are now making a diaphragm for use with the unit.

Our first source was thulium oxide, and we are getting another source which will be thulium metal and will be three times the specific activity of the first source. The increased specific activity will shorten the exposure time so we will probably be able to make a hand film in one second. It will be impossible to use thulium for trunk and chest work.

A small unit was demonstrated this week in Washington. This design moves the source in the position by a camera release, and I have heard that Argonne is proposing to make about 25 units of this design to send out as prototype units. I have heard that one unit has already jammed in the "off" position. One bad feature is the absence of an indicator to show when the source is in the "on" or "off" position. The cable release could break and not serve as a positive indicator. An article in which everybody might be interested has appeared in the current issue of Nucleonics.

Chairman Mason: These units have been considered for civilian defense, but the half life of 129 days makes this an impractical consideration.

Mr. Beauchamp: How much does it cost to make the thulium metal?

Dr. Carpenter: The price of thulium has been quoted at $500 per gram.

Chairman Mason: I heard recently that Dr. Spedding could produce thulium at $50.00 per gram if the quantities were relatively large. He is not interested in producing it on a production basis but will make his techniques available to anybody else who wants to do the manufacturing. The source uses about 200 mg basic metal and the radiation cost has not been determined.

Dr. Aebersold: My office is interested only in the radiological safety aspects of the device. The allocation criterion will be similar to that for Co 60 sources. The person who wants to use the thulium source for medical use would have to be a physician qualified in whatever application he wants to do. If the thulium radiator has some industrial use the operator should have experience with a radiation source and be able to ascertain the radiological safety aspects of the unit.

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In regard to the first condition, it can be shown that wide variations in response of a thin wall ion chamber may occur with no change in the incident gamma ray intensity, e.g., lead shielding near the ion chamber may cause response to nearly double. Absence of an equilibrium thickness of low atomic number material may cause a signal to be cut in half. In Fig. 2 the response of a polyethylene ion chamber versus wall thickness is shown and along with it, the response of the same chamber with a thin layer of lead wrapped around it. The necessity of having the equilibrium wall thickness is apparent. If a series of materials of different atomic number is tested in this manner (see Fig. 3) it is found that the response increases slowly with increasing atomic number up to copper ($Z = 29$) and more rapidly for higher atomic numbers. This is due to the differences in the stopping power of the different wall materials relative to the air in the ion chamber. By this we mean the range of the electrons in the chamber wall material increases with increasing atomic number. The net result is that the number of electrons passing through the gas increases and hence, the ion current.

A study of the response of different materials to cobalt 60 gamma rays indicates that none of the present commercial thimble chamber materials is air equivalent. It further indicates that one may wish to consider the possibility of having chambers which are not air equivalent but fat, muscle, or bone equivalent. This is not believed necessary or practical for general use. It would appear that a composite chamber could be made which would be air equivalent and this is believed to be the proper choice of material. Chambers for use on cobalt 60, radium and cesium 137 have walls of 440 mg/cm. Their energy dependency is surprisingly good down to 25 kev, despite the added wall thickness. This is important for use in phantoms.

On accuracy, it should be observed that there exists at present a difference between "r" on X rays and Co 60 of the order of 6 per cent. National Bureau of Standards calibration on secondary standards for Co 60 is $\pm$ 3 per cent.

C. Available Instruments.

For measurements beyond the minimum requirements there are several instruments available for measuring dose and dose rate. There are two commercial companies in the United States, one in England, and several on the continent offering integrating condenser meters for measurement of total dose. These are of the portable or battery-operated variety. In addition there are several AC operated integrating condenser dose meters offered. None of these is considered completely satisfactory with million volt radiations for reasons discussed below. There are available dose rate meters covering a wide range of intensities and radiation energies. Finally, there is an instrument which offers both the instantaneous dose rate in roentgens per minute and the total dose in roentgens.

It is believed that the dose rate meter is the most suitable for use with teletherapy installations. There are several reasons for this belief. First, the radiation intensity from teletherapy is quite uniform over periods of time covering a treatment. Second, use of a ratemeter greatly speeds taking isodose and depth dose data. Third, the ion chamber, and hence the energy dependence, is the same as with the condenser type instrument. The dose rate meters do not suffer from the major shortcoming of the condenser type integrating dose meters.

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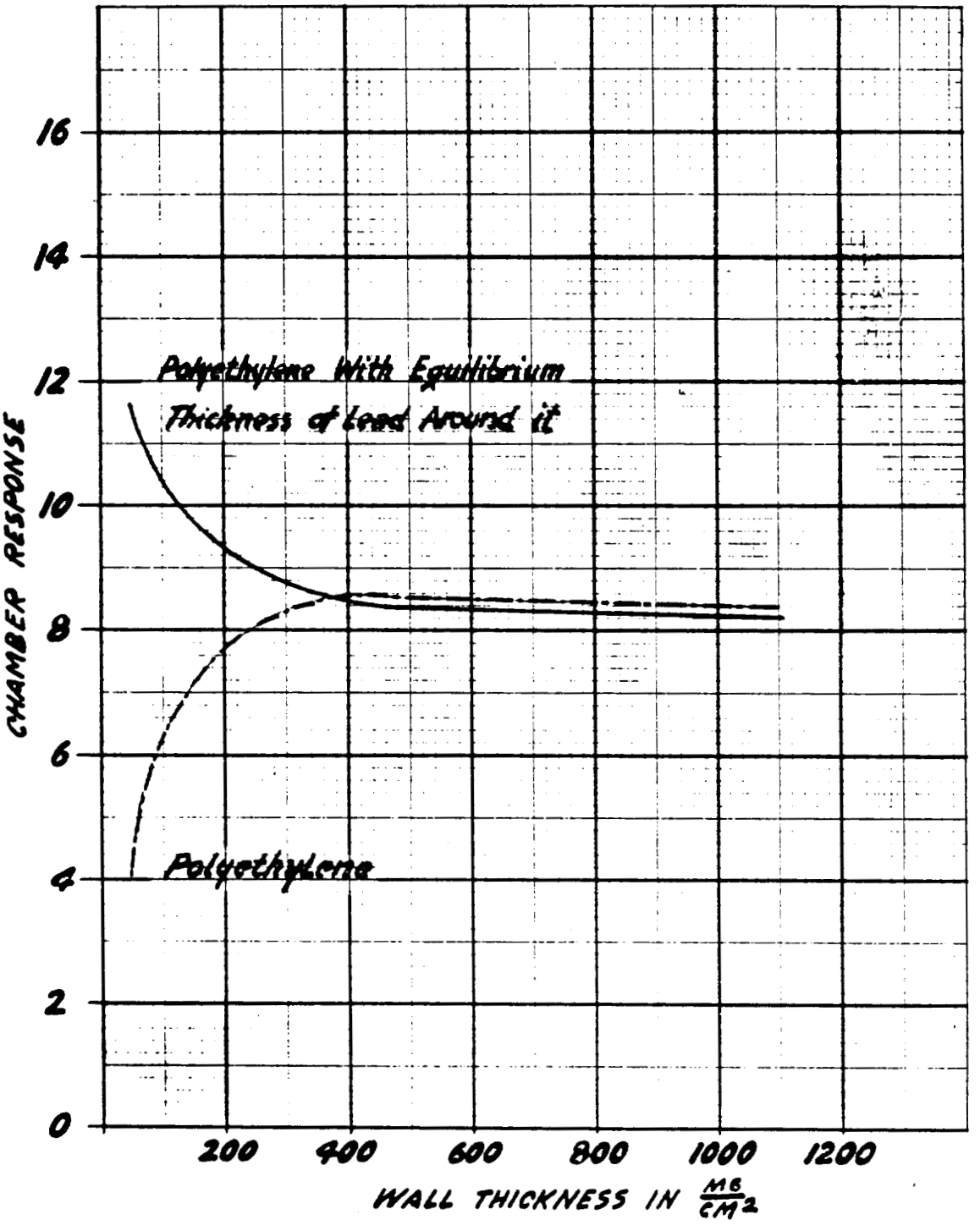

COBALT 60 GAMMA RAY ION CHAMBER RESPONSE VS CHAMBER WALL THICKNESS, WITH AND WITHOUT ADDED LEAD AROUND THE CHAMBER.

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some physicist with whom he is not acquainted make the calibration. If there should be a disparity, the radiologist should know about it.

I think that the radiologists should be provided with some data on instrumentation. Perhaps this is equivical; however, the radiologist should know whether the measurements made with the standard Victoreen chamber are going to be acceptable, or whether the specific chamber should be used with a greater wall thickness, with added filtration, or with whatever might be essential for an adequate calibration.

The isodose curves of the beam become the most important consideration, other than the rhm factor, when one is attempting to start a clinical therapy program. Certainly, it is going to take the radiologist a long time to procure all the isodose patterns, with all possible field sizes at various distances; but if the curves are available, and Mr. Stickney has stated that he is going to have his first one or two customers provide this material, such curves should form a base line for operations of any unit of this type. I think that such curves are just as acceptable as turning through standard text books as a great many radiologists do for isodose curves for standard X-ray equipment. I wish to emphasize that this information should be provided.

Data on secondard electron emission should certainly be provided to the user for this is something that a great many radiologists will overlook. The customer must know anything that relates significantly to the penumbra for the particular design of the unit he has obtained. I do not think this would be a breach of ethics on the part of the industry.

Along with all other useful general information, such as the Handbook and other data, that Mr. Stickney refers to, which is going to be provided by the sales organization, there should be included the half-value layer, the decay curves, and any information relative to recalibration. These represent niceties that the radiologist would appreciate having convenient for use with his particular unit.

Relative to the rotational problem, I have mixed emotions. It seems that any radiologist embarking upon a program in rotational therapy with any type of radiotherapeutic device, should anticipate the very profound problems of isodose determination. Obviously it would be impossible to expect the manufacturer to supply even sample curves in all of the innumerable possibilities that exist. However, I do feel that it would be well to supply at least sample isodose curves, or patterns, so that a neophyte would not be taken unaware and would not look upon rotational therapy in the same manner as he would stationary beam therapy. We must realize the potential dangers of hot spots; and certainly a great deal of damage can be done if we are not aware of these factors. The industry presumes a vast amount of intelligence on the part of the radiologist, and this is very flattering, but the X-ray industry knows, as well as I do, that radiologists all have their limitations.

The data relative to housing, and I am talking about external housing and not the primary housing of the source, is generally available in various bulletins. Mr. Stickney has indicated that sales people will provide this conventional bit of information. I think it would be advisable to submit in the sample layout some of the information that is definitely known about the half-value layer determinations at various points in the room with the particular unit that is being purchased. It would aid considerably in the designing of adequate protection for any given unit. Most certainly, the radiologist, in the final analysis, must assume all the responsibilities where these high energies are employed in clinical therapy, just

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as he does in the use of all other modalities. That obligation is a serious one. It should be taken seriously but I am afraid it is often considered lightly. I think that Dr. Donaldson emphasized the point this morning when he indicated the number of men who do therapy under protest. The hospital Board of Directors are going to insist that their institution have one of these fine units. The radiologist uses it without any feeling, without any desire for it, and therefore, they are likely to make compromises. Therefore, we must all combine to share and give freely of whatever knowledge we have obtained to the end that the value of teletherapy can be adequately exploited for the patient's benefit. I would like to challenge the X-ray industry to move cautiously. This is not a household appliance, it is a dangerous implement and it should not be peddled. The company at home, and the factory may not be attempting to peddle the units but the sales people are; they are looking for customers who will take one of these units. I believe that the potential user should be cautioned and should be adequately advised. This is not the type of unit that a hospital or radiologist can purchase and employ a technician to operate from a prescription. This is a unit that is going to have to be controlled adequately under competent supervision. I hope that we can all work together in that direction.

DISCUSSION

Dr. Brucer: There are two things I want to talk about. One of the things that hasn't been mentioned is the records that are kept on the source capsule of both the Canadian and U.S. produced sources. These sources are all going to come in identical capsules. After the capsule has been closed no one can find out what is in it, and if these capsules are going to have a resale value from machine to machine, some organization must keep a record of each source capsule.

Mr. Sticknev: This information has to be supplied by the man who sells the source.

Mr. Green: Shouldn't the supplier of the cobalt keep that record? Nobody else could keep a record of all of it.

Dr. Brucer: Maybe that question goes back to the supplier of the cobalt. Is ORNL keeping records of what the sources would be?

Mr. Gillette: We are keeping records. We have duplicate copies of every shipping document and, of course, of the purchase order and the authorization; however, the period of time this information is maintained on file will be up to ORNL and AEC. They would not necessarily keep the records readily available after five years. The chances are, they'll probably be around for five years but not after that.

Mr. Beauchamp: This sounds like a pretty good thing to talk about. Would industry and radiologists like some kind of number put on the container and do you want to suggest how it could be put on?

Mr. Green: Can you put the number on before it's loaded?

Dr. Aebersold: A number can be itched on the source capsule.

Mr. Beauchamp: Where would you want the number? Could we use a vibro tool to put it on?

Dr. Brucer: The number would have to be in a position on the face of lip of the

capsule.

Mr. Green: It should be engraved very deeply with a vibro tool.

Mr. Stickney: There should be some code letter indicating whether it was loaded at Oak Ridge or in Canada.

Mr. Hetherington: The Canadian-loaded capsule will have a serial number and the suffix CR.

Mr. Green: I wish to emphasize that adequate records should be kept until the source is utterly destroyed.

Mr. Gillette: I agree that this is very important but the person who buys the cobalt should be the one who would keep the records.

Dr. Aebersold: Each source will change hands several times and the records may be lost.

Mr. Moffett: A source may only change hands with an AEC authorization, and I suggest that the AEC keep the records.

Mr. Gillette: The customer should not proceed on the assumption that the records will always be available from Carbide and Carbon.

Mr. Hetherington: The sources that have been sold by Atomic Energy of Canada, have been certified by the National Research Council. One certificate goes to the customer, and one is retained by the Atomic Energy of Canada Limited. Each capsule serial number is stamped on the end of each drawer, and unless somebody takes the source out of its drawer, it could be identified at all times. We agree that the safest manner would be to have the serial number stamped right onto the capsule.

Dr. Brucer: On the present arrangement, can you identify any sources that have been sent out?

Mr. Hetherington: From the outside of the capsule, I don't think so.

Mr. Gillette: Oak Ridge sources sold prior to this date cannot be identified by ORNL. The Oak Ridge National Laboratories can put a serial number on the capsule with the date and the curiage, and the type of cobalt.

Mr. Stober: Could the source be accompanied with a name plate on the shipping container? Such a plate could be taken off and fastened on to the machine. If the source should be reshipped, the name plate could be taken off the unit, put on the shipping container to the new customer.

Chairman Mason: This is something that should be decided upon. It would be better if both the Canadians and Americans used the same system. I suggest that the Canadian and the U.S. isotopes division decide on a system they will follow and report to the next meeting. (This suggestion was unanimously approved.)

Dr. Brucer: I wish to call attention to the problem of isodose curves, which should be available before therapy is commenced. To make a set of isodose curves

involves a considerable amount of equipment and personnel time. This work can become very expensive and I know that every radiologist who gets a therapy machine is not going to run a set of curves. I think that the manufacturers should make up the set of isodose curves because it is an impossible thing to ask of each therapist.

Mr. Stickney: I did not make myself clear on that point. I am perfectly willing to make every effort to supply any kind of radiation data which has been published by an independent authority.

Dr. Aebersold: Suppose you have a cloverleaf source and you change to a plain right cylinder source of the same strength, how much difference would there be in the isodose curves?

Dr. Brucer: We have isodose curves on two different sources, each having a different intensity. One is on the square source and one is on a cloverleaf source. There are the following differences:

1. The corners of the end of a percentage line are more sharply defined in the cloverleaf.
2. The bulge in the cross field axis is less prominent in the cloverleaf and even less in Braestrup's pellet type Canadian source.
3. We think we may be able to detect a very slight cross field variation in the cloverleaf.

All of these variations are insignificant in therapy. More important variations occur due to cone design and of course the source face diameter will make a difference at short SSD. I believe it would be more feasible to use one set of isodose curves on all cobalt 60 machines than it would be to use 250 kvp tables published in a book.

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THE REQUIREMENTS OF A SHIPPING CONTAINER

Mr. Gene Stober
Technical Division
Keleket X-ray Corporation

The problem of a shipping container is one that the NBS meetings have not covered. Dr. Brucer probably thinks that this is a good way to get the subject opened for discussion and to determine whether all shipping containers should be of a standard design.

I wish to emphasize that I do not think our design is likely to be the standard; however, it is a starting point. The one container we have built will be sent to the Oak Ridge National Laboratory on May 24 to receive its first cobalt capsule.

The first job of loading will require the transfer of a 600 rhm source from the shipping container to a hectocurie head. We will ultimately have two standard sizes of shipping containers because we don't want to penalize a customer on express or freight charges for a shipping container big enough to handle 1800 rhm when he is receiving only a 600 rhm source.

In designing a shipping container we soon learned that we must serve several masters. First of all it has been determined that the standard capsules will be employed and in the hectocurie range the shipping container must shield 600 rhm of cobalt 60. The significant thing is that the shipping container should attenuate the radiation to a level of less than 10 mr per hour at 1 meter. There is a second stipulation that the shipping container shall not have more than 200 mr per hour at the surface.

The second master is the requirements that must be met in order to obtain two shipping permits. One is an ICC permit No. 7870. The other is a Bureau of Explosives permit called MEICC 7099, which may be obtained by writing to Mr. Harry Kimball, Bureau of Explosives, 30 Easy Street, New York 7, New York. Mr. Kimball called our attention to their problems. The Bureau of Explosives has specified certain thicknesses of steel walls for the container, as a protection if the shipping container should be caught in a fire and all the lead should melt. The steel walls must be smooth so that the Oak Ridge National Laboratory can decontaminate the exterior surfaces. After the Bureau of Explosives has approved the design they give an approval number, which must be stamped on the outside of the container along with the identification of radioactive isotopes being transported.

There is a third master. The Keleket Company was instructed to get in touch with the carrier and obtain data on the floor loading of express or freight railway cars. The biggest trouble came when we found that we had to distribute the weight of the shipping container over an area much greater than the area of the container itself. The weight had to be distributed over a width of 24 inches and a length of 36 inches. The use of 4" x 4" hardwood skids became the most awkward design feature of the container.

There is another factor that has to be considered. The Oak Ridge National Laboratory must use a handling device, and this we provided by two eye hooks so that you can pick up the container by a chain hoist.

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In designing a shipping container we set a target of 1000 pounds. The Keleket Company considers this a prototype unit and I hope that it is a little over-designed. The shipping container will be monitored while it is in use and a second shipping container will be designed from the data obtained from experience with the prototype.

The techniques of loading becomes the fourth master that we must serve. It is inconceivable that anybody is going to pick up 1200 curies or 600 curies of radiation and walk across the room and put it into a teletherapy unit. The Canadians have a design whereby they simply push a piece of the shipping container right into the teletherapy unit. The teletherapy unit designed by Keleket does not lend itself to the Canadian method of loading, however, we did take an idea from the Canadians and are going to "marry" the shipping container to the teletherapy unit during the loading procedure. After the teletherapy unit and the shipping container are joined, the capsule may then be pushed from the shipping container to the teletherapy unit without ever coming into the open. Again, borrowing from the Canadians, we started the container design with a drawer arrangement. The drawer contains two sockets each with a shoulder. The drawer slips back and forth to permit loading and unloading a source though a chute which is off center of the pig. This chute is the diameter of the source container (see diagram).

In earlier meetings the Keleket Company stated that they were going to load and unload the source capsule by gravity, and with modifications we stick to that fundamental principal. One of our units is most conveniently loaded when the head is about 5 or 5½ feet above the ground, with the part perpendicular to the ground, so we have decided to load all units from this position. The physicist will have a light welded aluminum "A" frame and a pair of chain hoists as a part of his equipment. With the "A" frame he will pick up the shipping container, its adapter unit, and insert the chute directly into the source wheel.

In the last industrial meeting, I explained that the Barnes-Keleket design proposed a socket in the source wheel with a lead housing around the entire source wheel. In our first design we were going to push the source into the socket, and with a constriction in the portal the capsule would ride as a free floating bearing. I still think this is a good method but there were a lot of objections. We now have a design that gives a positive method of locking a capsule in the source wheel. The new design consists of a narrow ring around the nose of the source wheel. The ring extends over the capsule socket, with a scalloped cutout for inserting the source capsule. The retaining ring is held tight by a positioning screw which can be adjusted through a screwdriver portal. A restrictive portal is then screwed in from the portal opening providing a second safety feature.

In preparing the Keleket-Barnes machine for the initial loading, we will first take out the restrictive throat, leaving the diameter of the portal slightly larger than the capsule itself. The scalloped retaining ring will then be rotated to the open position so that when the source wheel is turned to the "on" position, the capsule can be pushed right into the source socket. The shipping container is next positioned below the machine and is brought into position by the use of the "A" frame and the chain hoists. The shipping container is "married" to the machine by removing the plug of the loading orifice in the shipping container and inserting in its place a nose piece, constructed to fit the orifice of the teletherapy head. The nose piece connects into the source wheel and locks the head and the shipping container together. When this nose piece is in place, we will have a chute exactly

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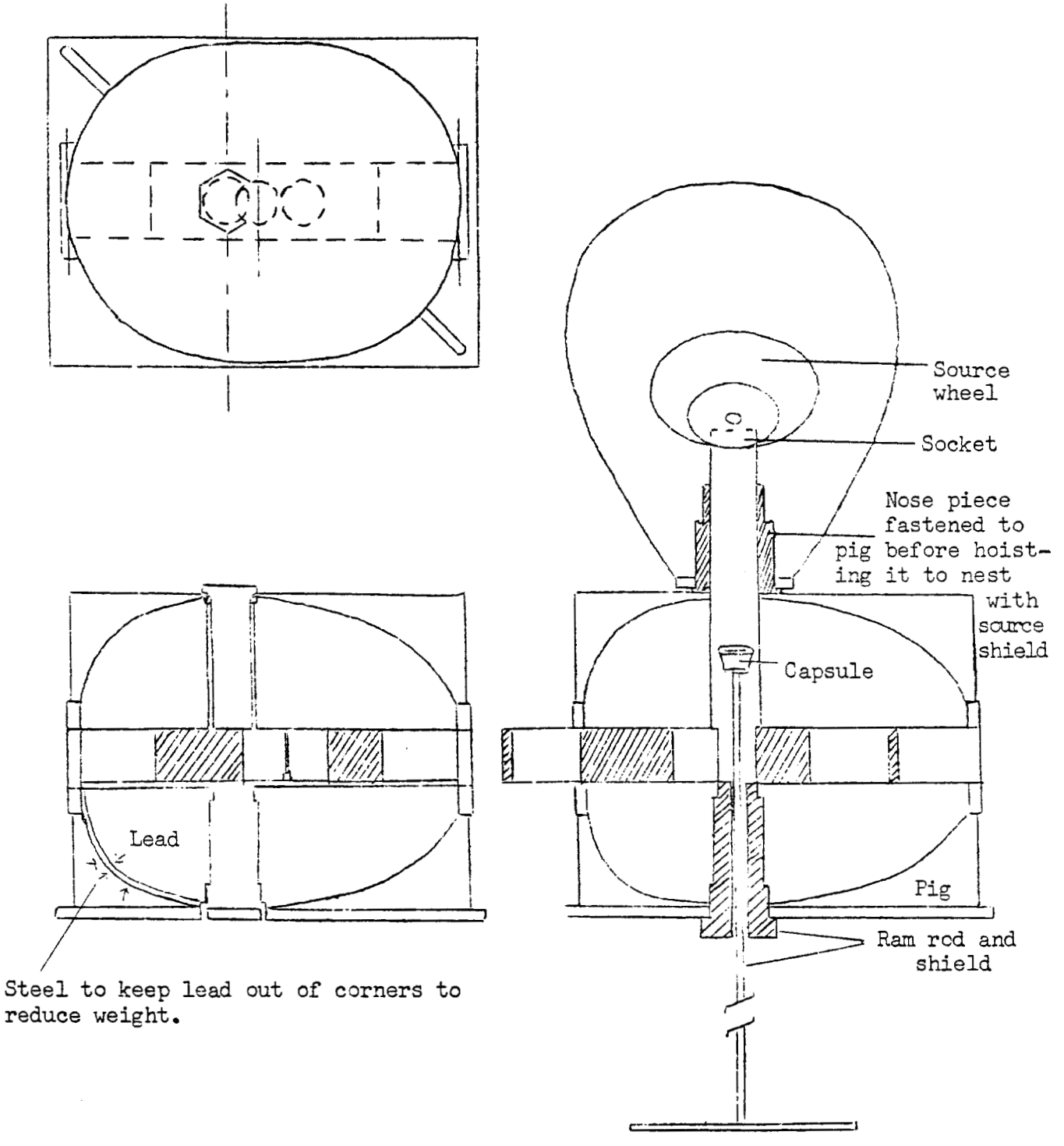
SKETCH SHOWING CAPSULE BEING
PUSHED UP LOADING CHUTE



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the diameter of the socket in the source wheel.

The next step is to withdraw the bottom plug in the shipping container leaving a tube that extends all the way through the shipping container, and into the teletherapy source socket. This tube will accommodate a pushrod, constructed of steel, for a 600 rhm source, and possibly equipped with a tungsten alloy head for an 1800 rhm source. The lower end of the pushrod extends down long enough so that a T-type handle will extend out of the direct beam of any radiation leakage. The assistant next turns the handwheel over 180 degrees bringing the source socket over the top of the prepared chute; the first empty opening in the drawer of the shipping container is moved to the left, and the socket is lined up with the loading chute. We then make a practice run to be sure that everything is lined up. When preliminary preparations and testing are completed, the drawer of the shipping container is moved to align the source with the loading chute. The pushrod then raises the source up into the socket and the assistant releases the tension on the handwheel allowing the source wheel to make the 180 degree return to the "off" position. On the return the capsule is wiped off the top of the pushrod and rides as a free floating bearing until the restricting throat and the retainer ring are placed in the closed position. In making a replacement of the source we would follow the same general procedures. Practice loadings have been completely satisfactory.

DISCUSSION

Dr. Lough: Is there enough shielding in the shipping container to adequately shield a partially exhausted source and a replacement source?

Mr. Stober: Our engineers have designed the container in the shape of an oval to provide shielding for both sources. I believe there is adequate shielding for the two sources for a brief period of time.

Dr. Brucer: The next problem that comes up is the standardization of shipping containers. Some radiologists are asking, "When you buy a teletherapy machine, do you have to stick with that company for replacement sources?" I maintain that the shipping container should be made so that it could be fitted to anybody's machine. Also, the pushrod of the shipping container should be so fixed that it would fit the standard source capsule and would do the loading in different kinds of machines. To adapt the Keleket shipping container to a Picker machine it is only necessary to have a special pushrod that can screw the capsule into the source wheel. It should not be too much of a job for the manufacturers to settle on one kind of container that is adaptable to all designs of teletherapy machines.

Dr. Lofstrom: It would be advantageous from the point of view of various service people. It would facilitate the sale of a second-hand capsule from a Picker unit for installation in a Keleket unit.

Dr. Brucer: It looks as if there will be a necessity for some kind of an interchange mechanism between machines.

Mr. Stickney: In an unloading operation it would be rather difficult to slide the capsule from the source wheel to the top of the pushrod.

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MEETING OF SUBCOMMITTEE NO. 2, SMALL SOURCE DESIGN

June 12, 1954

Members Present: Dr. Henry Jaffe - University of Southern California
Dr. James F. Kelly, Jr. - Crieghton University
Mr. John H. Tolan - Emory University
(Representing Dr. H. Stephen Weens)
Dr. Marshall Brucer - ORINS Medical Division
Mr. J. Howard Harmon - ORINS Medical Division

Members Absent: Dr. John A. Isherwood - Baylor University Graduate School
Dr. Harold W. Lewis - Duke University

CURRENT STATUS OF HECTOCURIE MACHINES:

The Subcommittee reviewed the current status of the hectocurie teletherapy units and was informed that the design recommended by the Teletherapy Evaluation Board is now on a production basis. The Subcommittee was also informed that the Picker X-ray Corporation has a design under construction, and that the Westinghouse Company is considering the design problems of the hectocurie unit.

Dr. Brucer stated that he had been informed that the United States Atomic Energy Commission had approved research grants for four TEB member universities.

The Subcommittee reviewed briefly the current availability of high and low specific activity cobalt 60 for teletherapy sources. This material is now being published as a quarterly report.

The current quoted sales prices of hectocurie units were compared to the construction cost of units being built by individuals.

RELATIONSHIPS OF FACTORS INVOLVED IN THE DESIGN OF LOW CURIAGE UNITS:

The Subcommittee discussed the increasing interest in very low curiage units in 5 to 300 curie range. A preliminary chart was shown to give the relationships of factors involved in the construction of low curiage units. This chart is not ready for publication but will be presented at a joint meeting to be held in Rockford, Illinois on July 22.

DESIGN CRITERIA FOR LOW CURIAGE UNITS:

The Chairman reviewed the possibility of using multiple sources in opposing positions. Two opposing units may be supported in opposite positions on a "C" frame, or multiple units may be suspended on ring supports. The "C" and ring supports may, or may not, be designed for rotational therapy.

The Subcommittee reviewed the standard capsule, which was designed for sources in the hectocurie range. It was agreed that another capsule should be designed for sources in the curie and multicurie ranges. The necessity for a modified design for very low curiage units was emphasized when the standard source capsule was scaled onto the diameter of the shielding required for very low curiage units.

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The Subcommittee agreed that the design criteria for curie and multi-curie units should follow, in general, the criteria established for the hecto-curie unit, with the addition of a light localizer. A selection was made of the ranges to be emphasized to manufacturers.

COST OF COBALT 60 FOR TELETHERAPY SOURCES:

Dr. Brucer discussed the cost of cobalt 60 for hectocurie and kilocurie teletherapy units, and briefly reviewed the cost analysis which was included in the minutes of the meeting of the Third Industrial Conference on Teletherapy. The minutes of this meeting have been previously sent to all TEB members.

RECOMMENDATIONS FOR FUTURE PROGRAM OF SUBCOMMITTEE NO. 2:

On a motion by Dr. Jaffe, seconded by Dr. Kelly, the Subcommittee recommended the building of three pilot models in the range of 10, 40, and 150 curies; the initial effort to be an engineering study to determine that the machines will not exceed an estimated price in the range of practicability. It was agreed that other isotope sources should be included in the study. Since cesium 137 is still a few years off, europium 152-154 will be emphasized.

J. Howard Harmon

J. Howard Harmon
Executive Secretary

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MINUTES OF THE JULY 22nd MEETING OF THE EXECUTIVE COMMITTEE AND INTERESTED SUBCOMMITTEES OF THE TELETHERAPY EVALUATION BOARD

TEB Members Present:

Executive Committee

Marshall Brucer, M. D., ORINS Medical Division
Vincent Collins, M. D., Baylor University Graduate School
Herbert D. Kerman, M. D., University of Louisville
James E. Lofstrom, M. D., Wayne University
Carl E. Nurnberger, Ph. D., University of Tennessee
Henry Jaffe, M. D., University of Southern California

Subcommittee No. 5

Vincent Collins, M. D., Baylor University Graduate School
Isadore Meschan, M. D., University of Arkansas
George Cooper, M. D., University of Virginia

Subcommittee No. 2

Henry Jaffe, M. D., University of Southern California
John A. Isherwood, M. D., Baylor University Graduate School
James F. Kelly, Jr., M. D., Creighton University
H. Stephen Weens, M. D., Emory University

Subcommittee No. 1

Herbert D. Kerman, M. D., University of Louisville
David S. Carroll, M. D., University of Tennessee
Carl E. Nurnberger, Ph. D., University of Tennessee
John Tolan, Emory University School of Medicine

Subcommittee No. 3

R. Kenneth Loeffler, M. D., Jefferson Davis Hospital

ORINS Staff Members Present:

Gould A. Andrews, M. D.
William G. Pollard, Ph. D.
J. Howard Harmon

Visitors Present:

J. R. Mason, United States Atomic Energy Commission
George T. Harrell, M. D., Chairman, Medical Advisory Panel
E. E. Beauchamp, Oak Ridge National Laboratory

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A joint meeting of the committees interested in the problem of the moving field teletherapy machine, and certain construction problems of the small fixed fields machines, met at the Faust Hotel in Rockford, Illinois July 22, 1954. Dr. Brucer discussed the design and construction details of the large rotational teletherapy unit, and the desired operation of the automatic control features of the unit.

Mr. L. J. Bulliet of the W. F. and John Barnes Company described the analogue computer designed for the automatic operation of the unit. The attached brochure gives representatives detailed information as presented by Dr. Brucer and Mr. Bulliet.

In the afternoon the Barnes Company demonstrated the cesium kilocurie teletherapy unit and models of the hectocurie cobalt 60 therapy unit. There was also a tour of the Barnes plant which preceded the showing of the teletherapy unit.

J. Howard Harmon

J. Howard Harmon
Executive Secretary

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MINUTES OF THE SEPTEMBER 20, 1954 MEETING OF THE HOUSING DESIGN SUBCOMMITTEE

A meeting of Subcommittee No. 4 was held at the Shoreham Hotel in Washington, D. C. on Monday afternoon, September 20, 1954. The following members were present:

Dr. James E. Lofstrom
Dr. Robert Reeves
Dr. Sidney Rubenfeld
Dr. Alfred Berne
Dr. G. Ferlazzo

Dr. Brucer presented the protection studies on marble by reviewing the data published by the Marble Institute of America. Copies of the published report have already been mailed to members of the Teletherapy Evaluation Board.

Item 2 on the agenda was to have been a presentation of protection studies on lead; however the subcommittee was informed that these studies had not been completed and that the final data will be published later.

Various members of the teletherapy board reported on the design and cost of housing for hectocurie units. These data are now being collected and will be published at a later date.

J. Howard Harmon

J. Howard Harmon
Executive Secretary

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MINUTES OF THE NOVEMBER 6, 1954
TELETHERAPY EVALUATION BOARD CLINICAL PROGRAM SUBCOMMITTEE MEETING

Subcommittee Members Present:

Dr. Vincent Collins - Baylor University Graduate School - Chairman
Dr. Marshall Brucer - ORINS Medical Division
Dr. George Cooper - University of Virginia
Dr. Galen M. Tice - University of Kansas
Dr. Herbert D. Kerman - University of Louisville
Dr. James E. Lofstrom - Wayne University
Dr. H. Stephen Weens - Emory University
Dr. David Carroll - University of Tennessee
Dr. I. Meschan - University of Arkansas

Dr. Harold Tivey - Baylor University Graduate School - Consultant

Case Histories of Patients Treated with TEB Cobalt 60 Units:

The subcommittee meeting was held in Oak Ridge under the chairmanship of Dr. Vincent Collins who requested Dr. Lofstrom and Dr. Carroll to open the meeting by reporting case histories of patients treated with Co 60 units installed at their respective medical schools. The initial evaluation of the results is encouraging.

Evaluation Program:

The qualifications of this committee to undertake a clinical evaluation program has been questioned, and Dr. Collins stated that this committee should carefully define its treatment and evaluation procedures so that measurable benefits to patients, radiologists, and departments of radiology will be clearly indicated.

Charts of Treatment Patterns Obtainable from the TEB Cobalt 60 Unit Design:

From isodose curves of the TEB Co 60 unit design distributed by ORINS, Dr. Collins constructed charts to demonstrate the different tumor doses obtainable by using various port arrangements and crossfire techniques. These charts also demonstrated the advantages of treating at different distances.

Dr. Brucer discussed a chart comparing the isodose curves of Co 60 with those of 250 kv X-ray units and showed the effect of cone to skin distance.

The committee was informed that TEB members with cobalt units had received copies of the isodose curves from various treatment cones at 35 and 50 cm SSD. Dr. Brucer reported that tables under preparation would give data that would permit each radiologist to draw his own isodose curves for any port size, shape, and treatment distance. These tables would contain data on central axis dose, visual penumbra, transmitted penumbra, and distance from source.

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Approved Treatment Pattern:

The committee chairman called attention to the fact that if the results from all participating institutions are to be compared, there must be an agreement on the treatment pattern for that percentage of patients receiving care under the TEB program. In the discussion of this recommendation the following thoughts were offered:

1. Deliver the treatment within a prescribed time.

2. Prescribe the maximum dose and permit the radiologist to determine the treatment time.

3. Permit the radiologist to determine the number of ports to be used for delivering maximum dose with minimum skin reaction.

4. Remember that any schedule of radiation therapy may be upset by sickness and other side effects.

5. Consider that any percentage of procedures not completed within an approved plan would be measurable and of significance for comparison with 250 kv X ray.

6. Realize that as an evaluation board the primary emphasis should be to record figures, factors, and results in such a manner that evaluation is possible.

Dr. Lofstrom summarized the discussion by emphasizing that the board must standardize on some criteria and realize that some patients will fall outside the accepted standards and will have to be excluded from the percentage that will be evaluated by the TEB. This does not mean that these cases should not be evaluated by other standards.

The subcommittee approved the following treatment plans for patients to be treated under the TEB program:

Tumor Site	Treatment Time		Central Tumor Dose (r)*
1. Brain	4 wks.		5,000 (2, 3, or 4 portals)
2. Esophagus	5 wks.		6,000
3. Nasopharynx	4 wks.	**	50 cm^2, 6,000 depth dose
4. Posterior 1/3 tongue	4 wks.	**	80 cm^2, 5,500 depth dose
5. Tonsil	4 wks.	**	120 cm^2, 5,000 depth dose
6. Intrinsic Larynx	4 wks.	**	150 cm^2, 4,500 depth dose
7. Hypopharynx	4 wks.	**	
8. Bone Metastases	1 day		1,000
9. Lung	5 wks.		5,000

* Tissue dose in center of tumor bearing area based on ORINS unit calibration and depth dose data.

** For tumors represented by types 3 through 7, the radiologist should observe a standard time, but the number of roentgens must be varied with the volume of tissue in the tumor area. Therefore, the radiologist must decide the number of roentgens that would represent the maximum tolerable dose.

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The committee discussed but did not formalize a treatment plan for cancer of the bladder. Collected data on treatment procedures are to be brought to the next meeting at which time a plan will be prepared.

Data Forms:

The committee reviewed the data sheets designed for carcinoma of the lung. Trial runs with these designs indicated the need for some changes and the revised forms are attached. Forms for brain tumor were approved and copies are attached. In reviewing the forms for carcinoma of the lung and of brain tumor, it was evident that the "Summary of Therapy" and "Terminal Evaluation" forms would serve for both diseases and probably would serve for all other diseases to be studied by the board.

The subcommittee requested that enough forms for six months clinical cases be sent to each participating institution. (Dr. Collins, subcommittee chairman, will write the letter of transmittal.) Those institutions having a Co 60 unit were requested to start using the forms for those cases treated under the TEB evaluation program. All institutions are requested to start using the forms for reporting cases treated with 250 kv X ray in accordance with the plan approved for the Co 60 unit. The committee requested reports of unselected cases treated by the usual 250 kv X-ray procedures; on such reports the radiologist should indicate the pattern of radiation.

Selection of Cases:

The committee discussed various methods of making random selections of comparable patients to receive treatment with 250 kv and Co 60 unit under the TEB program. The importance of and criteria for a controlled study were elaborated. Various practical obstacles were noted by participants. Detailed plans will be formulated later.

Reporting:

The committee recommended that institutions start sending reports to ORINS at their earliest convenience. The "Initial Appraisal" and "Summary of Therapy" sheets should be completed immediately after the first treatment is given. A report on each follow-up and the terminal evaluation should be completed after death.

The committee recommended an annual report from each institution giving the number of bronchogenic carcinomas seen at the institution among "out" and "bed" patients. The report should indicate the number of patients treated with X ray, Co 60, by surgery, and the number not treated. The purpose is to test for uniformity of patient material among participants. To facilitate this reporting the board will send out an annual questionaire.

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BRAIN TUMOR
TEB STUDY

ORINS Accession No.

INITIAL APPRAISAL
On 1st day of Treatment

IDENTIFICATION

NAME _____ AGE _____ SEX _____ DATE _____

ADDRESS _____ WEIGHT _____ RACE _____

HOSPITAL NO. _____ INSTITUTION _____

OCCUPATION _____ DIAGNOSIS _____

HISTORY

Family History of Cancer _____

RELATED SYMPTOMS (Circle Earliest)	Date of Onset	DURATION IN WEEKS	
		To Dx	To Rx
1. Headache			
2. Vision			
3. Motor Changes			
4. Sensory Changes			
5. Equilibrium			
6. Other			
7. X ray: Plain Film			
Air Study			
Angiograph			
8. EEG			

PRESENT ILLNESS _____

OPERATIVE PROCEDURE: Date _____ Craniotomy _____ Complete Removal _____

Incomplete Removal _____ Biopsy Only _____ Decompression _____

Ventriculogram _____ Surgery Contraindicated _____ Surgery Refused _____

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INITIAL APPRAISAL

DESCRIPTION OF DISEASE

OPERATIVE FINDINGS _____

ADDITIONAL SIGNIFICANT DISEASE: CV____ Skeletal____ Nervous System____

Urinary____ Reproductive____ Metabolic____

Explain _____

MICROSCOPIC PATHOLOGY

DIAGNOSED BY:

Institution

ORINS

Consultant

Physician's Signature

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BRAIN TUMOR
TEB STUDY

FOLLOW-UP
(one sheet for each visit)

ORINS Accession No.

IDENTIFICATION

PATIENT _____ HOSPITAL NO. _____

INFORMANT (Patient or Other) _____

PROGRESS REPORT

Date of this follow-up _____

Date of previous follow-up _____ Interval _____ Weeks

Date of 1st appraisal _____ Interval _____ Weeks

Activity since previous follow-up	No. Weeks
Normal activity	
Reduced activity	
Confined to home or nursing home	
Confined to bed	
Confined to hospital	

Persisting Symptoms:

Headache: Worse ____ Better ____ No Change ____

Vision: Worse ____ Better ____ No Change ____

Motor Changes: Worse ____ Better ____ No Change ____

Sensory Changes: Worse ____ Better ____ No Change ____

Equilibrium: Worse ____ Better ____ No Change ____

Other _____

Narcotics: Type _____ Approximate Requirements _____

PERSISTENCE OR RECURRENCE OF DISEASE

Notes _____

RADIATION SIDE EFFECTS

SKIN CHANGES

Epilation ____
(De) Pigmentation ____
Atrophy ____
Radiation Necrosis ____

Telangiectasia ____
Sub-dermal Fibrosis ____
Moist Desquamation ____

Skin Changes _____

Bone Changes _____

Occular Changes _____

Other _____

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FOLLOW-UP

LABORATORY DATA

White Blood Count _____ Hemoglobin _____

Other Laboratory Procedures _____

ADDITIONAL TREATMENT

Radiation _____ Chemotherapy _____ Surgery _____ Other _____

ADDITIONAL PROGRESS NOTES _____

EVALUATION

CLINICAL EVALUATION OF TREATMENT _____

Physician's Signature

1136623

CARCINOMA OF THE LUNG
TEB STUDY

INITIAL APPRAISAL
On 1st day of Treatment

ORINS Accession No.

IDENTIFICATION

NAME _____ AGE _____ DATE _____
ADDRESS _____ WEIGHT _____ RACE _____
HOSPITAL NO. _____ INSTITUTION _____
OCCUPATION _____
DIAGNOSIS _____ DATE _____

HISTORY

Family History _____

RELATED SYMPTOMS (Circle earliest)	Date of Onset	DURATION IN WEEKS to Dx	To Rx
1. Cough			
2. Weight loss			
3. Hemoptysis			
4. Pain			
5. Other			
6. X ray: 1st suggestive finding			
Prev. neg. X ray			

PRESENT ILLNESS _____

Additional significant disease: CV ___ GI ___ Nervous System ___ Urinary ___
Reproductive ___ Metabolic ___

Previous Diseases: TB ___ Recurrent Pneumonia ___ Bronchiectasis ___
Other _____

Previous Treatment: Surgery ___ Radiation ___ Chemotherapy ___

Operation: Date _____ Exp. Thoracotomy _____ Resection complete _____
Resection incomplete _____ Surgery contraindicated _____ Surgery refused _____

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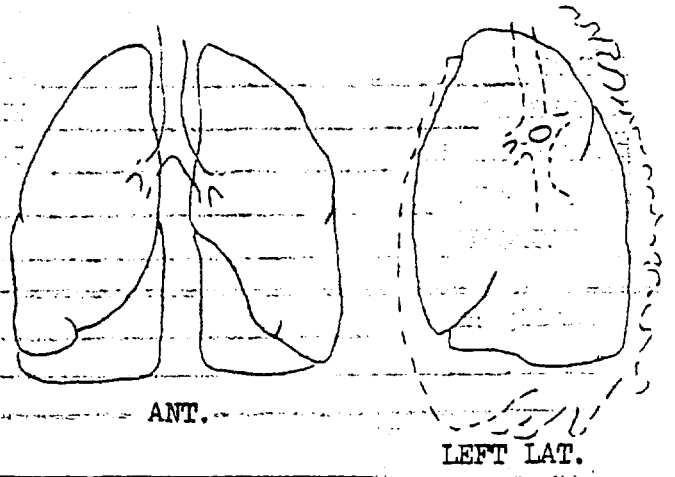
INITIAL APPRAISAL

DESCRIPTION OF ILLESS

Physical Findings _____

X-ray Findings
- Chest
  - Hilar _____
  - Peripheral _____
  - Cavitary _____
  - Pancoast _____
  - Multiple nodules _____
  - Pleural effusion _____
- Other _____



Operative findings: _____

PATHOLOGY

Material obtained by bronchoscopy _____ Thoracotomy and biopsy _____
Resected specimen _____ Cytologic studies on pleural effusion _____
Autopsy _____
Histologic diagnosis _____
- Dx by Institution _____
- Dx by ORINS _____
- Dx by Consultant _____

PULMONARY EXPOSURES

OCCUPATIONAL EXPOSURES

	Yes	No	Explanation of Positive Occupational Exposure
Benzol, oils, tars, etc.			
Radiation			
Mining			

SMOKING HISTORY

	Yes	No	Age Began	No. of Years	How Much
Pipe					
Cigars					
Cigarettes					
Cigarette Cough					
Chronic Mucositis					

Patient referred by: Private Physician _____ Clinic _____
Patient referred because of availability of cobalt 60 unit _____

Physician's Signature

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CARCINOMA OF THE LUNG
TEB STUDY
FOLLOW-UP
(one sheet for each visit)

ORINS Accession No.

IDENTIFICATION

PATIENT _____ HOSPITAL NO. _____

INFORMANT (Patient or other) _____

PROGRESS REPORT

Date of this follow-up _____

Date of previous follow-up _____ Interval _____ Weeks

Date of 1st appraisal _____ Interval _____ Weeks

Activity since previous follow-up	No. Weeks
Normal Activity	
Reduced Activity	
Confined to home or nursing home	
Confined to bed	
Confined to hospital	

Persisting Symptoms:

Cough____ Hemoptysis____ Pain____

Weight: Loss____ Gain____ No Change____ Actual Weight _____

Appetite: Loss____ Gain____ No Change____

Strength: Loss____ Gain____ No Change____

Other _____

Narcotics: Type _____ Approximate Requirements _____

EXTENSION OF DISEASE

	Extension of tumor	Other Significant Disease (Write name of disease)
Pulmonary		
Gastrointestinal		
Skeleton		
Nervous System		
Cardiovascular		
Urinary		
Reproductive		
Metabolic		

Notes (How was extension determined) _____

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FOLLOW-UP

RADIATION SIDE EFFECTS

SKIN CHANGES

(De) Pigmentation ____ Telangiectasia ____
Atrophy ____ Sub-dermal Fibrosis ____
Radiation Necrosis ____ Moist Desquamation ____

Lung Changes ____
Bone Changes ____
Gastrointestinal Changes ____
Other ____

LABORATORY DATA

White Blood Count ____ Hemoglobin ____
Other Laboratory Procedures ____

ADDITIONAL TREATMENT

Radiation ____ Chemotherapy ____ Surgery ____ Other ____
ADDITIONAL PROGRESS NOTES ____

EVALUATION

CLINICAL EVALUATION OF TREATMENT ____

Physician's signature ____

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SUMMARY OF THERAPY
TEB STUDY
(complete during treatment)

ORINS Accession No.

PATIENT _____ HOSPITAL NO. _____
INSTITUTION _____
DIAGNOSIS _____
Factors: Co 60: rhm _____
X ray: kvp _____ hvl _____ filter _____ ma _____

DIAGRAM OF TREATMENT PLAN

AP diameter of part _____ cm Lat. diameter of part _____ cm (At treatment level)

Field Size	Inclusive days of treatment	No. of treatments	Max. dose on skin	Tumor Dose		
				Center	Maximum	Minimum
1.						
2.						
3.						
4.						
5.						
6.						
Total elapsed days		Total tumor dose Integral dose estimate				

Intent at beginning of treatment: Cure _____ Palliation _____
Initial proposal: Central tumor dose _____ Time _____

Treatment completed as planned? Yes _____ No _____
If no, comment _____

Adjuvant therapy: Chemotherapy _____, hormone _____, antibiotic _____, blood _____

Physician's Signature

1136628

SUMMARY OF THERAPY

Fields						
1.						
2.						
3.						
4.						
5.						
6.						
Radiation Sickness*						
Skin Reaction*: Dry						
Wet						
Epilation						
Mucositis*						
Hospital Days*						
Usual Occupation*						

* Check if positive, leave blank if negative, and comment if desired _____

_____

_____

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TERMINAL EVALUATION
TEB STUDY

ORINS Accession No.

Patient died_____ Lost to follow-up_____

IDENTIFICATION

PATIENT_____ HOSPITAL NO._____

INFORMANT_____ DATE_____

INSTITUTION_____

DIAGNOSIS_____

PROGRESS

Date of 1st appraisal_____. Date of Death or Final F.U._____.
Total days under treatment since first day of radiation treatment_____.
(Treatment day = day of treatment, day of follow-up visit, or day in hospital.)
Days in hospital since first day of radiation treatment_____.

	No. wks. from first day of Rx
Normal activity	
Reduced activity	
Confined to home or nursing home	
Confined to bed	
Confined to hospital	

Duration	No. Weeks
Onset to death	
Diagnosis to death	
1st radiotherapy to death	

Date of death_____

THERAPISTS' EVALUATION OF TREATMENT_____

INSTRUCTIONS TO PATHOLOGIST

A series of 8 tissue blocks should be sent in to ORINS

1. Full thickness skin block from skin in center of treated area.
2. Full thickness skin block from skin well outside of treated area.
3. Tissue blocks from bone (including marrow) in center of treated area.
4. Tissue blocks from bone (including marrow) well outside of treated area.
5. Tissue block from tumor in center of treated area.
6. Tissue block from tumor outside of treated area if possible (or slide of previous biopsy).
7. Tissue block from intervening normal tissue in center of treated area.
8. Tissue block from intervening normal tissue well outside of treated area.

Make diagram to indicate the area from which blocks were removed. A copy of the Autopsy Protocol should be attached to this report.

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CLASSIFIED BY THERAPIST

CLASSIFIED BY PATHOLOGIST

CLASSIFICATION OF RADIATION EFFECT AT DEATH
(Compared with status at time of start of therapy)

Therapy was started at primary site to irradiate only site of cancer known at that time. (i.e. the disease was apparently localized and potentially curable.)

TERMINAL CLASSIFICATION IS:

1. No persistent disease at primary site. No distant metastases.

_____ a. No complications at primary site due to radiation. _____
_____ b. Complications at primary site did not appreciably affect morbidity. _____
_____ c. Complications at primary site did appreciably affect morbidity. _____
_____ d. Complications at primary site did contribute to cause of death. _____

2. No persistent disease at primary site. Distant metastases present.

_____ a. No complications at primary site due to radiation. _____
_____ b. Complications at primary site did not appreciably affect morbidity. _____
_____ c. Complications at primary site did appreciably affect morbidity. _____
_____ d. Complications at primary site did contribute to cause of death. _____

3. With persistent disease at primary site. No distant metastases.

_____ a. No complications at primary site due to radiation. _____
_____ b. Complications at primary site did not appreciably affect morbidity. _____
_____ c. Complications at primary site did appreciably affect morbidity. _____
_____ d. Complications at primary site did contribute to cause of death. _____

4. With persistent disease at primary site. Distant metastases present.

_____ a. No complications at primary site due to radiation. _____
_____ b. Complications at primary site did not appreciably affect morbidity. _____
_____ c. Complications at primary site did appreciably affect morbidity. _____
_____ d. Complications at primary site did contribute to cause of death. _____

Therapy was started at secondary site, or at primary site with other areas of cancer known to exist. (i.e. disease was not believed curable.)

TERMINAL CLASSIFICATION IS:

1. No persistent disease at site of therapy.

_____ a. No complications at primary site due to radiation. _____
_____ b. Complications at primary site did not appreciably affect morbidity. _____
_____ c. Complications at primary site did appreciably affect morbidity. _____
_____ d. Complications at primary site did contribute to cause of death. _____

2. With persistent disease at site of therapy.

_____ a. No complications at primary site due to radiation. _____
_____ b. Complications at primary site did not appreciably affect morbidity. _____
_____ c. Complications at primary site did appreciably affect morbidity. _____
_____ d. Complications at primary site did contribute to cause of death. _____

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