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ORINS-37

RADIATION PROTECTION AT THE MEDICAL DIVISION

A summary of a few of the more important protection problems that are currently occurring at the Medical Division of the Oak Ridge Institute of Nuclear Studies

Edited by

Marshall Brucer and Elizabeth B. Anderson

TABLE OF CONTENTS

1. Protection problems . . . . . Marshall Brucer

2. Cobalt-60 leak . . . . . William D. Gibbs

3. Chronology and data . . . . . William D. Gibbs
William D. Jones

4. Manufacturers conference . . . . . J. H. Harmon

5. Alleged iodine-131 spill . . . . . .William D. Gibbs

6. Recommendations for wipe tests . . . . . .Marshall Brucer

7. Radiation warning signs in the Medical Division.Roger Cloutier

8. Preventive medicine for counting equipment. . . Douglas A. Ross

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PROTECTION PROBLEMS

Marshall Brucer, M.D.

In the Medical Division of the Oak Ridge Institute of Nuclear Studies we use large amounts of radioactive isotopes. As a prime contractor to a federal organization, we are exempt from laws concerning radiation protection; however, since we teach students the use of radioactive isotopes, the exact opposite to its infinite extreme is true. It is necessary in a teaching program to follow every and all radiation protection rules and regulations. This cannot be done. At one time we were about to establish the radiation-protection-dose-of-the-month club. But in setting up the dose-of-the-month club schedule we found that there were not enough months in the year. Therefore, this was changed to the radiation-protection-dose-of-the-week club in which we would set up a different set of rules and regulations promulgated by one or another organization for each week in the year and then follow a well defined and published set of rules and regulations for each week. However, we soon found that there were not a sufficient number of weeks in the year. Seventy-one national and international organizations have variable ideas on what radiation protection should be. Add to this the fifty highly individualized state governments in the United States that are rapidly developing uninterpretable regulations concerning unmeasurable quantities concerning an undefined risk and the problem becomes somewhat unmanageable.

There is a necessity for establishing levels of radiation. There is a difference between the Pacific Ocean and a glass of water, but there is also a real similarity between the two. However, many people die from

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drowning in the Pacific Ocean; few people die from drowning in a glass of water. But it might be possible to drown a man with a glass of water if one arranged the event properly. It is also possible to work in and around the Pacific Ocean without drowning. Exactly the same thing is true of radiation. There is such a thing as megacurie amounts of radioactive isotope. This is a disaster level of radiation, but not necessarily. It is possible to work around megacurie levels without being hurt. Millicurie levels of activity are simpler to handle, easier to work around, but if events are arranged properly you can hurt somebody with millicurie amounts.

Megacurie levels of radiation are usually (but not always) disaster levels. This level usually demands special instrumentation. The health physics problems are special problems not usually encountered in a medical situction. Kilocurie levels (a factor of a thousand less) are not disaster levels. This is a level that is commonly used in external therapy. It is not uncommon in the Medical Division that we have more kilocurie sources of radiation than we have patients. Although this level of radiation, uncontrolled, is dangerous in the extreme, with the controls that have been established in kilocurie machines, the use of this level in external therapy is routine. There is little or no question about its safety.

A curie level of radiation (a factor of a thousand less than the kilocurie level) has no medical use but it does have an industrial use and, in the field of medicine, has a very real radiobiological use. The instruments for measurement at this level are common; the health physics methods are routine and well known. We handle this material with care.

Millicurie levels of activity (a factor of a thousand less than the curie level) are levels for internal therapy. These are usually unsealed sources. The radiation measurement and protection instruments are well known, are commonly applied, the methods are routine; but since the level of

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danger is much less, the level of worry is much less. Usually very well trained persons handle these levels and there is seldom health physics trouble.

The microcurie level of activity (a factor of a thousand less than a millicurie level) is usually considered a diagnostic level. The instrument for measurement can be as insensitive as a Geiger-Muller tube; usually (in the United States in medical facilities) it is a scintillation crystal. There is usually no radiation monitoring problem necessary at this level since any one single source of activity at this level does not hurt people. However, at this point the criteria for radiation monitoring change. At microcurie levels of activity, although no one single source might be dangerous to people, a single source can be dangerous to instruments of measurement. Although no one single source can hurt an individual person, there can easily be the accumulation of many "accidents" from many sources with a build-up of activity that can be dangerous. At this level, in one sense, there is no need for radiation monitoring, but on the other hand, there is the greatest need for radiation monitoring.

The millimicrocurie level of activity (a factor of a thousand less than the microcurie level) is commonly called the tracer level of activity. By definition this is not a dangerous level because, if it were dangerous, it would cause some biological change. If it caused biological change, it would not be a true tracer. The definition of a tracer is that it does not cause a change in the system that is being studied. In this level the instruments for measurement must be a little bit more precise. At the present time this is usually a scintillation crystal. There are no radiation monitoring instruments and the physician is not worried about dangers to personnel, but he is very much worried about the contamination of his measuring instruments.

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The micromicrocurie level of activity (a factor of a thousand less than a millimicrocurie) is in the range of what is commonly called "low-level" activity. Nobody can yet measure micromicrocuries in such gross things as the human body. However, under special circumstances, it can be measured and the methods of measuring micromicrocuries in the human body approach, even if they do not measure this level. This low-level activity is in the range of natural background, in the range of the natural amount of radioactive potassium in the body, in the range of cosmic radiation. The instruments for measurement are very specially shielded, have very special electronics, and demand an educational competence that is certainly different from, and probably more stringent than that for the higher levels of activity. There are no health physics problems regarding personnel, but there are exceedingly great health physics problems regarding the instruments. There are no dangers (except electrical and mechanical and the fact that people can fall down stairs) connected with these machines, but this is the level at which health physics thinking has to start.

In 10 years of operation in the Medical Division no person has had sufficient experience with all of these levels, and this situation is probably true throughout the world. No person has had experience with all levels of radioactivity, but many persons have had some experience with different levels of activity. In the Medical Division we have had experience working at the millimicrocurie level through the kilocurie level. The radiation effects that occur with fairly large doses of radiation are described in other documents. But the "minor" accidents that occur are very seldom described. It is the purpose of this document to describe a number of these "minor" accidents and what is actually done about them. One accident is a cobalt leak. Another is an alleged iodine spill. Neither of these accidents hurt somebody but both could have hurt somebody. The

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interesting thing is that both incidents were handled in about the same way - with wipe tests and education. The interesting point is that there are no standard methods for doing wipe tests. It is so simple a technique that everybody should know how to do it, but nobody tells anybody else exactly how to do it.

One of the standard methods of immediate education is to establish warning signs. Again, there are no standard warning signs, primarily because many organizations have set up many methods of using many different kinds of warning signs.

Probably the most important single item that occurs in any organization doing radioactivity counting is the care of the counting equipment itself. Again, this is so simple and obvious that almost everybody knows, but nobody tells anybody else, exactly how to care for equipment.

Therefore, in this document we describe the methods that are used at the Medical Division, particularly in these three areas. To introduce it we describe one very serious radiation contamination incident and one very serious public relations (but not radiation) incident.

The document describes an example of the procedures followed in the first cobalt leak that was known to have occurred in a teletherapy source. The handling of the leak is described in great detail because 1) this was the first leak to be noticed officially, 2) there was a significant amount of activity leaked from the source, 3) it was an example of an unexpected incident being handled routinely, 4) it involved many persons and organizations in Oak Ridge, 5) it involved considerable time, effort, and expense, and 6) it is being used as a training example at tracer levels of what might be necessary at higher levels of activity.

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The Location of the Cobalt-60 Incident (Figs. 1 and 2)

The Medical Division has a laboratory area, a long hospital area containing patients, and two teletherapy rooms, each of which has two separate teletherapy devices in it. Two machines are in the room called the cesium room: a double-headed rotational cobalt-60 teletherapy machine and the first cesium-137 teletherapy machine containing 1500 curies of cesium. Each head of the double-headed machine contains approximately 800 curies.

In another room (called the cobalt room) is the original hectocurie cobalt-60 machine. It contains 730 curies of cobalt-60. The room also contains a 700-curie cobalt source in a special machine for total-body irradiation. The cesium room contains, in addition to the teletherapy machines, a treatment table for each of the teletherapy machines and a blower for air supply. Directly in line with the cesium room is a control room with two visible ports containing the control mechanisms for the two machines. The cobalt room contains, in addition to the teletherapy machines, a stand containing all of the cones, a treatment cot for total-body irradiation, and an air blower that directs air out onto the roof of the cobalt room. Hallways connect these two rooms with the patient area.

Institute Personnel Involved in the Incident

William D. Jones - Administrative Assistant

William D. Gibbs, M.S. - Health Physicist

Lynn A. West - Teletherapy Technician

D. A. Ross, M.D., Ph.D. - Medical Physicist

Walter E. Graves - Instrument Maker

Ruth C. Black, R.T. - Scanning Technician

F. Comas, M.D. - Radiotherapist

John M. Harris - Health Physics Technician

William L. Blankenship - Electrician

1136794

David B. Camp, Ph.D. - Chemist (Summer Research Participant)

J. Howard Harmon - Hospital Administrator

A. C. Morris, M.S. - Electronics Engineer

G. A. Andrews, M.D. - Chief of Clinical Services

Harry E. Kimble - Senior Instrument Maker

William T. Pope - Electronics Technician

Nelson Stephens - Senior Laboratory Technician

After the section containing the chronology and data on this very important leak of the oxide of cobalt-60, is a report of the manufacturers' conference held in December, 1958. The minutes of this conference are reproduced since they have an interest to many persons other than manufacturers of teletherapy equipment. The primary need for change in the design of the International Source Capsule was the method for sealing the cobalt-60 (or any sealed radioisotope source for that matter). No change was necessary in activity, size, geometry or availability. For information on the type of welding now used, write to E. E. Pierce of the Oak Ridge National Laboratory. This welding method is somewhat different from that ordinarily used in most cold welding procedures. There are special requirements for some radioactivity sources.

Another section of this document is devoted to a very short description of an alleged iodine-131 spill. This was a spill that never occurred. It was pure rumor; however, the monitoring problem, and especially the public relations problem, was just as serious as the problems connected with the actual cobalt leak.

Many other problems could be brought out, but they are not solved as yet and may not be solved for many years to come. One is the fact that with each group of students working on a specific training course there is a gradual build-up of background activity. Eventually, this is going to cause

instrumentation troubles. The distinction between real personnel monitoring and administrative monitoring for legal purposes is a serious one. It should, but will not, be described in detail. The whole problem of film badges, which are an administrative method of monitoring, how they should be worn, who should wear them, where they should be worn, when they should be worn, raises a host of questions that are not as answerable as they are arguable.

There is insufficient space in this document to describe all these problems. Therefore, we describe two events and describe in detail the methods that are used at the Medical Division for coping with this type of problem. Because of its ever-present importance to every person that touches a piece of counting equipment, we are also including an article on the very simplest kind of preventive maintenance. In a sense the entire document is leading up to the ubiquitous nature of Section 8.

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COBALT-60 LEAK

William D. Gibbs

(Editor's Note:

A significant radiation contamination was discovered on Monday, September 8, 1958. Mr. William D. Gibbs was the health physicist for the Medical Division at that time. The radioisotope was cobalt-60 dust from a leaking cobalt-60 teletherapy capsule in one of the heads of the double-headed teletherapy machine. In this narrative report Mr. Gibbs does not follow a strictly chronological order, but attempts to arrange the material by subject matter. The next section is a chronological report.)

Discovery of Contamination and Determination of Duration

On Monday morning, September 8, 1958, routine smear tests were started in the laboratory wing of the ORINS Medical Division. After a number of smears had been taken and counted, it was determined that a minor contamination was present in this wing. At about 11:30 a.m. the teletherapy technician, L.A.W. approached a scanning device being run by R.C.B. on which a patient was being scanned. As he neared the machine the scanner recorded counts that were obviously not from the patient. L.A.W. was then alternately removed from and brought toward the machine and it was thus determined that L.A.W. was the source of radiation and not the patient. Dr. D. A. Ross, Medical physicist, then checked L.A.W. with a simple hand scanner and found him to be contaminated. The earliest contamination was found on L.A.W.'s hands and a hasty analysis with a spectrometer led Dr. Ross to believe that the isotope was cobalt-60. L.A.W. was instructed to scrub his hands thoroughly and check them again. They were successfully decontaminated, but additional contamination was detected on his clothing and shoes. At this time the health physicist was notified and L.A.W. was decontaminated as described in another section. It was found that he had been working in the

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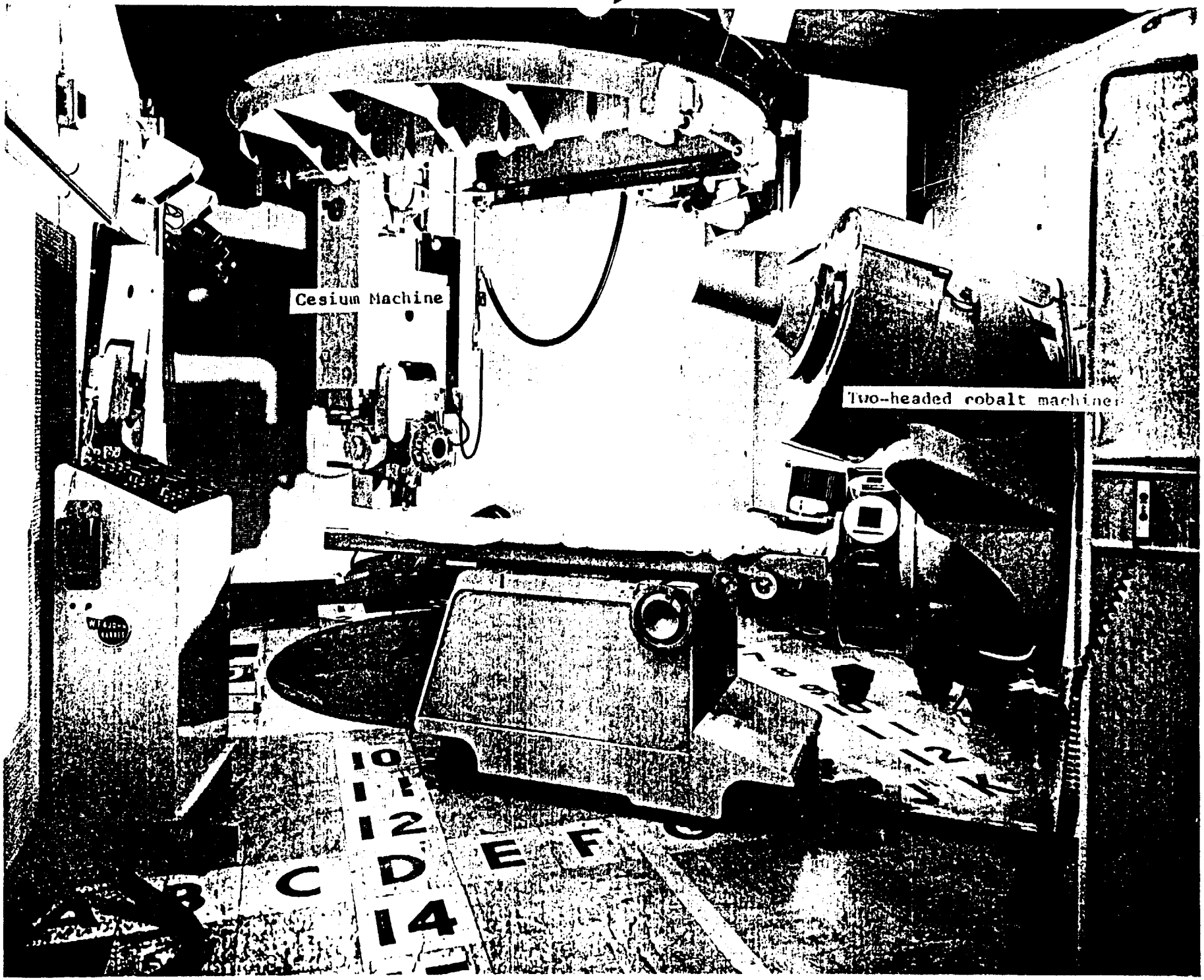

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cesium room doing a routine treatment of a number of patients. He had been using the double-headed cobalt-60 machine.

Smears were taken in the hallway adjacent to the teletherapy rooms, and these all showed a small amount of radioactive material. W.E.G., an instrument maker who had been working in the room, was then checked and he, too, was contaminated. This led us to believe that the source of trouble was in the cesium room. Access to this area was closed off. (See section entitled "Early Personnel Monitoring, Decontamination, and Protection.")

Subsequent checks of articles of clothing worn by technicians R.C.B. and L.A.W., and Dr. F. C. (radiotherapist) on Thursday, September 4, revealed barely detectable amounts of radioactive material. Therefore, we believe that this situation had not long existed. We believe that the cobalt-60 source in the No. 1 head of the double-headed teletherapy machine began to leak sometime between September 1 and September 4, and that the leak became increasingly serious from September 4 to September 8. If this source had been leaking to any great extent for a long period of time, articles of contaminated clothing and furniture would have been found in the homes of L.A.W., R.C.B., and Dr. F.C.

Identification of Radioisotope

Dr. Ross attempted to identify the radioisotope involved by running a gamma spectrum of several articles of W.E.G.'s contaminated clothing, and also by running a gamma spectrum on smears taken in the cesium room. These early attempts led him to believe that the isotope was cobalt-60, but a defect in his scintillation crystal made it impossible to say this definitely. Later after changing scintillation crystals, another gamma spectrum was run on both W.E.G.'s clothing and the smears and a spectrum similar to that of

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cobalt-60 was obtained. A known cobalt-60 source was analyzed and the spectrum of the known cobalt source was identical with those obtained from W.E.G.'s clothing and from the smears. Health physicists from the Oak Ridge National Laboratory (ORNL) also did a gamma spectrum on a number of smears taken in the cesium room, and they agreed that this was cobalt-60. In addition they did an absorption measurement to distinguish cobalt and cesium, and definitely established that the isotope we were faced with was cobalt-60.

Determination of Origin of Contamination

At about 6:15 p.m., September 8, John Harris (health physics technician) entered the sealed cesium and cobalt rooms and took smears at many locations. The counts on these smears indicated that the cesium room was much more highly contaminated than the cobalt room. We felt definitely that the trouble lay in the cesium room in one of the heads of the double-headed cobalt-60 machine. Smears taken in several collimators on both heads of the double-headed machine and on the outsides of both heads revealed that the No. 1 head was contaminated to an extent at least 10 times greater than the No. 2 head. The most severely contaminated area was inside the largest collimator on the No. 1 head. This smear was later assayed and contained about 15 microcuries of cobalt-60. Smears taken the following day by members of the Health Physics Division of ORNL supported this measurement.

Evidently the source capsule in the No. 1 head of the double-headed machine had somehow developed a leak and cobalt oxide dust was being liberated from this head.

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Extent of Building Contamination

Smears taken throughout the teletherapy area and E wing of the building revealed that the contamination level became much lower as the distance from the teletherapy rooms increased. Calibration showed that the average contamination level in the cesium room was slightly above 1 microcurie per square foot of surface area. The level of contamination in the cobalt room was estimated as between 0.1 and 1 microcurie per square foot. The level of contamination in the cesium control room and in the adjacent hallway was about the same as that of the cobalt room. The main hallway from the doors leading into the Oak Ridge Hospital to the area of the Frigidaire air-conditioning unit (see map) had a contamination level between 0.05 and 0.1 microcurie per square foot. The intake filters of the Frigidaire air-conditioning unit were surveyed and the activity present in these filters was about the same level as that present in the cobalt teletherapy room. The levels in the rest of the building were all determined to be much less than 0.05 microcurie per square foot.

Early Personnel Monitoring, Decontamination, and Protection

Immediately after the discovery of the contamination in the teletherapy area, all employees who had worked in this area were monitored. Four employees were known to have worked there during the morning of September 8. Of these four, L.A.W. and W.E.G. were carrying significant contamination on their clothing and bodies. These two employees immediately stripped and showered in the Medical Division. All their clothing was placed in waxed paper bags, sealed with tape, and stored for future disposition. The two employees were again monitored after a thorough scrubbing. A small amount of residual contamination was found on W.E.G.'s hands. L.A.W. was completely free of contamination except for the area around his nose. This was later

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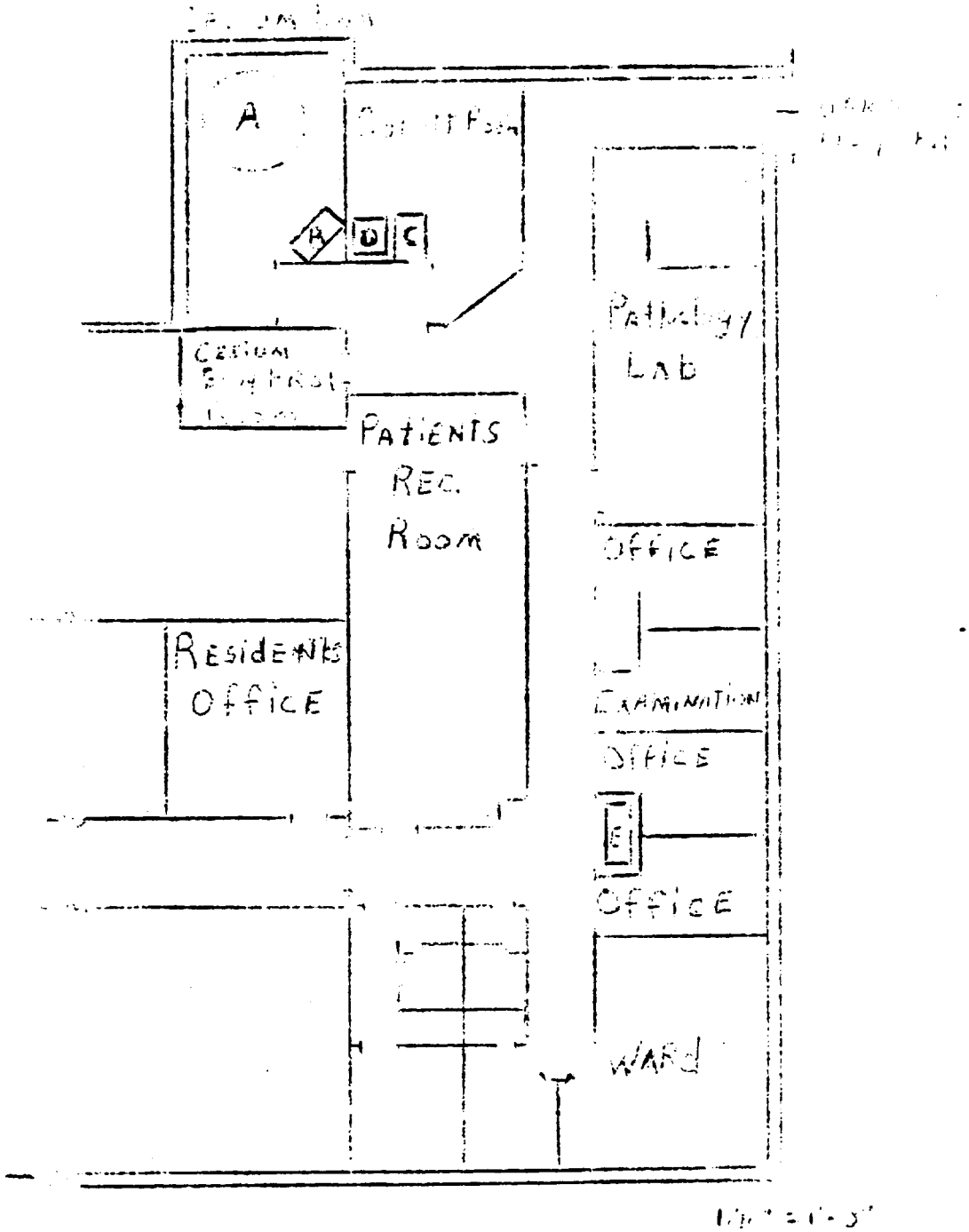

A- Cesium Teletherapy Machine
B- Westinghouse Cobalt Machine
C- Barnes Cobalt Machine
D- Temporary Total Body Irradiation
E- Frigidare Air Conditioner

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found to be due to an accumulation of cobalt-60 dust inside the nasal passages. The electrician, W.L.B., was called back to the Medical Division and monitored; significant contamination was found on his clothing and forearms. He was relieved of his clothing and placed in the shower for a thorough scrub down. After this no contamination could be found on his body. These men were given surgical scrub suits and laboratory coats to wear home. Their shoes were decontaminated by scrubbing with a stiff brush. Dr. D.B.C., a summer research participant from the University of the South, the fourth person who had been working in this room, was monitored, and no significant contamination could be found with the exception of a few low-level areas on his laboratory coat.

Warning signs were placed in the hallways and the shoes of all personnel of the Medical Division on duty were monitored. The shoes of several employees were found to be detectably contaminated and these employees were instructed to scrub the soles of their shoes with soap and water and a brush. After this they reported back to the health physicist for a check to see whether this procedure had been successful. Only two employees were unsuccessful in decontaminating their shoes; these shoes were placed in waxed paper bags and sealed for further action. These shoes were never successfully decontaminated. They were later buried at the ORNL waste disposal area.

At this time a number of filter paper smears were taken in the hallway leading through the teletherapy area. Assay of these smears revealed a significant contamination of the floor through this hallway. (See diagram for levels.) The floor in the hallway was mopped with warm soap and water, and wax remover was applied. After this, another series of filter paper smears were taken and counted. The level of contamination was reduced to about 10 per cent of that originally found. The hallway floors were again

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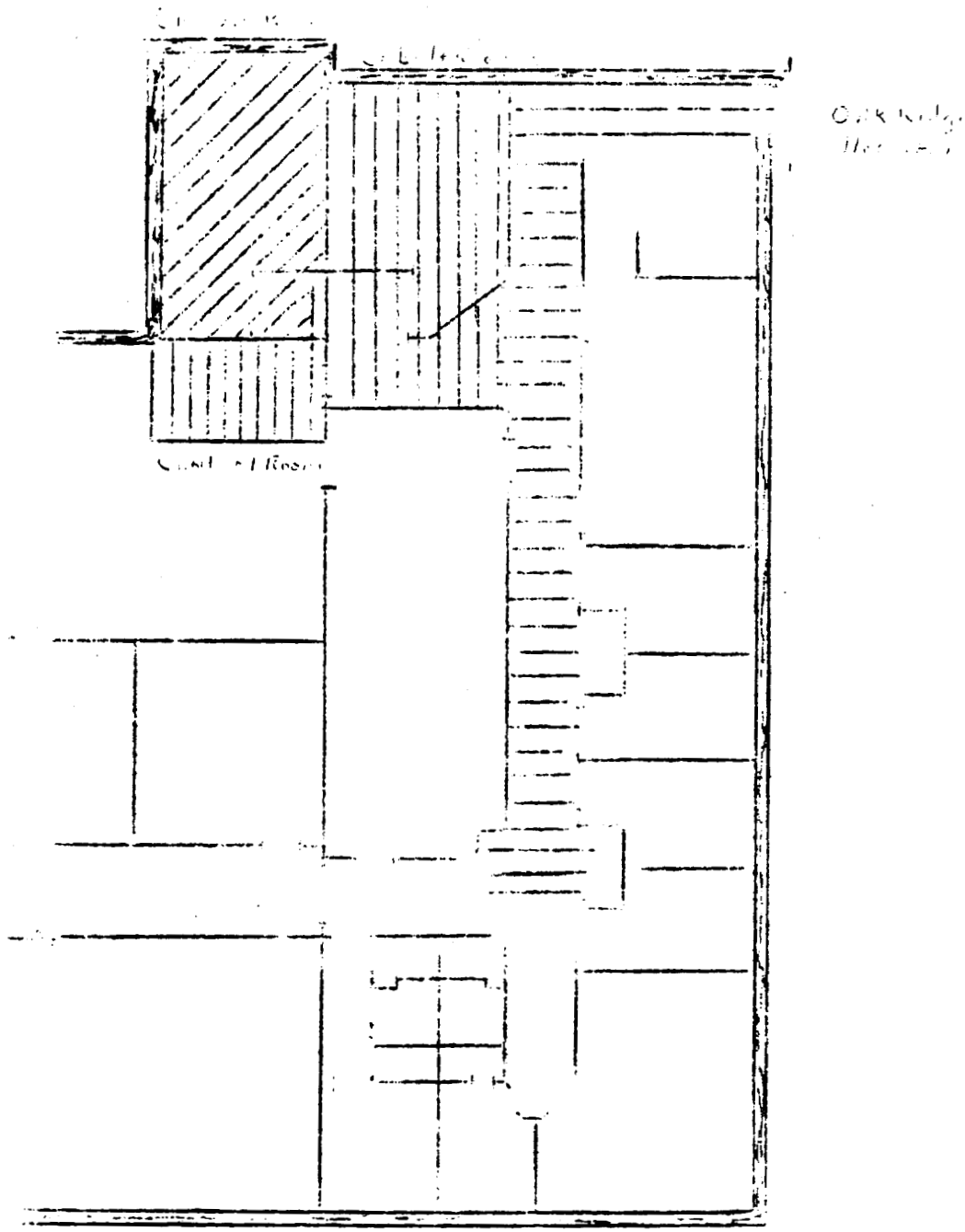

1 MICROCURIE AND GREATER / FT^2

ABOVE 0.1 MICROCURIE / FT^2

0.05 TO 0.1 MICROCURIE / FT^2

AREAS NOT MARKED - LESS THAN 0.05 MICROCURIE / FT^2

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mopped with warm soapy water, dried, and another set of filter paper smears was taken. At this time the contamination was only 2 or 3 times background. The hallway was then opened to employee traffic.

Monitoring and Decontamination in Areas Outside of the Medical Division*

Early in the afternoon of September 8, W.E.G. was supplied with radiation detection instruments and instructed to go to his home and monitor the areas he might have contaminated. About 30 minutes later W.E.G. reported that he had detected contamination present on his couch in the living room, on the rug in the living room, and on several articles of clothing worn by his wife and young son. W.E.G. was instructed to bundle up this clothing and bring it to the Medical Division immediately. Upon arriving at the Medical Division, he was furnished a vacuum cleaner and instructed to return to his home and attempt to decontaminate the sofa, rug, and any other contaminated areas in the house by use of this vacuum cleaner. At this time he was instructed that if the rug and sofa did not come clean under a thorough vacuum cleaning, that a commercial upholstery cleaner should be applied. These attempts were unsuccessful and W.E.G. took a cushion from the sofa out into his yard and saturated this with a stream of water from a garden hose.** This also proved to be unsuccessful. W.E.G. then loaded the couch and rug onto a trailer and took them to the ORINS warehouse.

Editor's Notes:

* It should be remembered that most of the personnel who are named here are well trained to use radiation detection instruments and are expected to be able to do their own health physics monitoring. This might not be the usual situation in an area outside of Oak Ridge, and in this case the procedures mentioned in this subsection might not be advisable.

** The dispersion of a small amount of activity is acceptable. If this were a large amount of activity dispersion would not be acceptable.

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During the morning of September 11, attempts were made to decontaminate W.E.G.'s rug and sofa. The rug was completely decontaminated with a vacuum cleaner. The attempts on the couch were not successful; the upholstery was buried in the ORNL waste disposal area.

Earlier W.E.G. had reported that his automobile, a 1948 Dodge, also contained a moderate degree of contamination. He reported that the steering wheel, floor mat, brake, and accelerator were contaminated as well as the front seat on the driver's side. W.E.G. was instructed to park and lock his car until further action could be taken. During the afternoon he returned to the Medical Division with another bag of laundry containing sheets, pillowcases, and various articles of clothing that were found to contain some radioactive material. These were placed in waxed bags and held for further disposition.

On the afternoon of September 9, the health physicist went to W.E.G.'s home and made a radiation survey. The only contaminated objects that could be located in the house at this time were one kitchen chair and the vacuum cleaner Mrs. W.E.G. had used on Saturday afternoon (September 6) in cleaning the house. W.E.G. was instructed to attempt decontamination of the kitchen chair and the vacuum cleaner was taken to ORINS Medical Division. On September 10 the vacuum cleaner was decontaminated, supplied with a new bag and back filter, smears were taken inside this cleaner, and revealed background or near background levels. On September 12 the cleaner was returned to its owner.

An estimate of the total amount of radioactive material present in W.E.G.'s house at any time, with the exception of his work clothes, was 10 microcuries.

W.E.G. was questioned about any visitors who might have been in his home during the weekend of September 6 or 7. He stated that his father-in-law, who lives in Knoxville, had visited on the afternoon of September 7

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(Sunday). Late in the afternoon of September 10 Gibbs went to Knoxville and surveyed the automobile of W.E.G.'s father-in-law for radioactivity. None could be detected. The clothing that his father-in-law had worn on his visit to W.E.G.'s home on Sunday was checked and no activity was detected on them. Since the clothing was in direct contact with articles in W.E.G.'s home and contained no contamination, and since his automobile was the first object that he touched upon leaving W.E.G.'s home and this also contained no contamination, no further survey was made in his home.

W. D. Jones, Administrative Assistant

Early in the afternoon of September 8 Dr. D.B.C. and /. took a laboratory monitor to Dr. D.B.C.'s apartment in Cambridge Hall. There was no increase in the monitor's sound or needle indication on anything in the room. His bed, floor, chairs, desk, and door were carefully surveyed. There was a questionable change in the sound of the monitor when the closet was surveyed; a pair of pants that Dr. D.B.C. had in a paper bag in the closet had some measurable counts. These were taken to the Medical Division and then sent to ORNL for decontamination.

Late in the afternoon of September 8, Mr. J. H. Harmon, Senior Administrative Officer, and Jones went to L.A.W.'s home in Wartburg to make a survey for possible contamination. They made a careful survey of everything in the bedroom. No detectable radiation was found except in the closet where L.A.W. had placed a pair of pants, a shirt, and a pair of shoes in a paper bag. The bag containing the clothing, which had been contaminated at the Medical Division, was removed and after a thorough examination of the closet, it was clear that no contamination was present. After a careful survey of the living room, its contents, the den and contents, hall rugs, and floor as well as the kitchen and bathroom, it was determined that no contamination was present in the house excpet on the clothing. L.A.W.'s family was not upset in any way, but they were relieved to know that the house had not been contaminated.

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On returning from Wartburg, Harmon and Jones went to R.C.B.'s home in Oak Ridge. They did a careful survey of the living room, study, bedrooms, kitchen, and automobile, but failed to detect any contamination.

During the afternoon of September 10, contaminated clothing and other items were sent to ORNL for decontamination. As these items were being packed for shipment to ORNL, they were identified by the owner and a list was made.

On the morning of September 11 W. D. Jones, and W. D. Gibbs visited Dr. F.C.'s apartment and made a radiation survey. No activity could be detected on the clothing that he had worn at work on September 4, and no detectable contamination was found at any location in his apartment.

Actions of Personnel Working in Contaminated Area

W.L.B. was in the cesium room for a total of 50 minutes on Monday morning, September 8, 1958, from 7:10 until 8:00. He was assisting W.E.G. in putting the protective covers on the double-headed cobalt-60 machine. These protective covers are located at the back and along the bottom of the machine. Both men had to crawl between the heads to get to the back of the machine. Both were working in very close quarters and had to sit on the floor and lean against the wall to do the necessary job.

Dr. D.B.C. was in the cesium and control rooms on Friday morning, September 5, for one hour between 8:00 and 9:00. He again worked in these rooms on Monday morning, September 8, from about 8:30 until 9:00. Dr. D.B.C.'s work required him to use one of the cobalt-60 heads to irradiate liquid samples, which were in test tubes. The test tube was in a holding device, which was placed over a selected collimator on the No. 1 head of the machine. After the tubes were placed in position, the machine was turned on and the samples were irradiated for about 3 to 5 minutes. Dr. D.B.C. usually

prepared 10 samples at a time for irradiation. Because he could irradiate only one test tube at a time, he made many trips between the cesium room and the control room.

L.A.W. assisted in the treatment of four patients on Thursday morning, September 4, between 9:00 and 11:00, with the double-headed cobalt-60 unit. On Friday, September 5, and Monday, September 8, L.A.W. assisted with four patients each morning between 9:00 and 11:00. On Thursday, Friday, and Monday, he spent a total of six hours in the cesium and control rooms. During this time he was using the double-headed moving-beam cobalt-60 teletherapy machine. (In this procedure he helps the patient onto the table, adjusts it, aligns the two heads, and selects the two collimators before he leaves the cesium room.) In the control room he selected the proper treatment factors and activated the machine. Average treatment time was 8 to 10 minutes. During this time he watched the patient through the observation port. When the machine cut off, he re-entered the cesium room and helped the patient off the table. *

W.E.G. was in the cesium room and control room for a period of 21 hours between Friday, September 5, at 1:00 p.m. and Monday morning, September 8, at 8:30. W.E.G. worked in the area on Friday afternoon between 1:00 and 6:30. On Saturday between 10:00 a.m. and 7:00 p.m., with time off for lunch, he spent 8 hours. On Sunday, September 7, he was in the cesium room between noon and 4:00 p.m., and 7:00 p.m. until 9:00 p.m. On Monday morning between 7:10 and 8:30 he was in this area. For W.E.G. to determine the exact location and type of trouble, it was necessary for him to completely check and adjust the entire computer circuit, both electrically and mechanically. To test and adjust the cobalt-60 machine, it was necessary that he remove the protective

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* Editor's Note: One of the most difficult features of attempting to track down radiation is to get a detailed summary of every person who was in the contaminated area and to follow his activities up to the time of the survey. Fortunately, in the Medical Division the patients are kept within the area and these could be surveyed expeditiously as a part of routine procedures.

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covers from the back and bottom of the machine. To remove these protective covers, he had to crawl between the heads. His dosimeter, direct reading type, registered 70 mr for the total time spent in the cesium and control rooms.

From 1:30 until 3:00 and 6:30 until 8:30 on the afternoon of September 7, A.C.M., electronics engineer, was in the cesium and control rooms. He spent most of the time in the control room testing the cobalt-60 unit for W.E.G. After the contamination was discovered on Monday, A.C.M. checked the clothing he wore on Sunday and found his front pockets were contaminated. He took a survey meter and surveyed his home but found no detectable radiation. No other clothing was contaminated.

Urine Collections

Twenty-four hour urine samples were started on W.E.G., LA.W., and W.L.B. at 4:30 p.m. on September 8, after an initial voided sample was collected separately. A similar 24-hour sample was started the following morning on Dr. D.B.C. Through arrangements made with Mr. Hart, Health Physics Division, ORNL, assays of the 24-hour urine specimens were performed. Detectable radioactivity was present, the highest level in W.E.G., lower levels in L.A.W., Dr. D.B.C., and W.L.B. No quantitation is reported since the whole-body counting gave much better results.

On the preliminary voided specimens, Dr. Ross found detectable radioactivity. This was in the neighborhood of twice background in the sample from W.E.G. A rough estimate made at that time was that there might be as much as 0.1 to 0.15 microcurie of cobalt-60 in the voided sample; therefore, the whole-body counting procedure was instituted.

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Whole-Body Counting

On September 9 or 10, Dr. Andrews called Dr. C. R. Sullivan of the medical staff of ORNL to inquire about the possibility of a whole-body assay with the highly sensitive methods they have available. Dr. Sullivan put us in touch with Mr. Burkhart, who is in charge of the whole-body counter. One appointment was made for studies on the four exposed persons, but this had to be canceled because of electronic difficulties at the plant; however, the studies were done on Friday, September 12.

Each person was asked to take a shower and dress in a clean gown. He was placed under the 4 x 9-inch scintillation crystal, which feeds into a 256-channel pulse-height analyzer. The crystal is in a room heavily shielded with iron and tungsten; it has very little directional quality, but was in general placed over the chest. A cobalt-60 standard was also counted. The following preliminary levels of activity were reported:

W.E.G.	0.18 microcurie
L.A.W.	0.098 microcurie
Dr. D.B.C.	0.007 microcurie
W.L.B.	0.003 microcurie

Consideration was given to using the linear scanner in an effort to determine the location of the radioactivity, but preliminary studies by Dr. Ross indicated that a tenth of a microcurie of cobalt-60, even in a concentrated source, would be barely detectable on the linear scanner.

The levels of radioactivity reported by the whole-body counter are low in relation to the maximum permissible level of 10 microcuries. On the other hand, this maximum permissible level is calculated on the basis of soluble cobalt compounds absorbed into the body. In this situation the liver has the largest concentration per gram, and the maximum permissible dose is based upon the liver as the one chief concentration. If a smaller amount of activity were present, as a small focal particle in the lung, the radiation

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at this location might be significant, even with less than 10 microcuries of activity.

Later measurements showed that the cobalt was being redistributed and excreted, with a biological half time of about 14 days.

Consultations

On the afternoon of September 8, after the extent and seriousness of the contamination had been partially determined, Dr. C. S. Shoup, Chief, Biology Branch, Research and Development Division, at AEC was notified. Within an hour Dr. Shoup came to the Medical Division and was furnished with all the information then available. Late in the morning of September 9 the Health Physics Division at the Oak Ridge National Laboratory was called. The problem was hastily explained and we requested that a health physicist come to the Medical Division to offer advice. Within two hours two health physicists, Mr. Kuna and Dr. Emerson, came to the Medical Division. The extent of the contamination was explained to them, and Dr. Emerson took several smears previously obtained from the cesium room to ORNL for spectral analysis and radioassay. Mr. Kuna was taken into the cesium room to look the situation over and make some measurements of his own. Mr. Kuna then suggested techniques for decontamination. At 3:00 p.m. Dr. Emerson reported that the samples he had taken to the Oak Ridge National Laboratory definitely contained cobalt-60 and that the amounts present ranged from 0.8 microcurie to 15 microcuries. They furnished us with an air sampler and some gas masks to use during the decontamination procedures. At about the same time Mr. E. E. Beauchamp and another person from the Isotope Sales Division of the ORNL came to the Medical Division to discuss the possibility of removing the No. 1 head of the double-headed machine for transfer to ORNL for the purpose of decontamination and determination of just what went wrong with the source capsule. This procedure was carried out.

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The capsule was removed from the No. 1 head of the double-headed machine and placed in water. The water was then slowly heated up and a stream of bubbles coming from inside the capsule indicated a definite leak. The capsule was then opened, decontaminated, and upon inspection it was found that the lead O rings had parted. There is a possibility that this could have been due to heating of the capsule by the intense activity of the source. It also could have been done by the mechanical action of sealing or opening the source.

Decontamination of Building and Equipment - Disposal of Wastes

The procedures used in decontamination of the building and equipment grew out of discussions with the health physicists from the Oak Ridge National Laboratory.

Decontamination of Cobalt Room: Upon entering the cobalt room a quantity of oil impregnated sawdust floor sweeping compound was spread over the floors and all objects inside the room. An air sampler was started to keep check of the air contamination. Vacuum cleaners were then moved into the room and a thorough vacuuming of the ceiling, walls, floor, and all objects in the room was begun. Because of a large accumulation of unnecessary junk in the cobalt room, the decontamination problem was greatly magnified. These many objects included chairs, beds (which are seldom, if ever, used), a large number of plywood boards, bed sheets, large jugs filled with water, many pencils, and numerous other small articles. All these articles were either decontaminated or sealed in plastic bags for disposal. After a thorough vacuum cleaning the floor, concrete wall, and all objects in the room were wiped with damp cheese cloth. Each square of cheese cloth was moistened with water, wiped over an area of about four square feet, and then placed in a disposal can. No piece of cloth was ever remoistened in the water. Upon completion of these actions a number of smears were taken in

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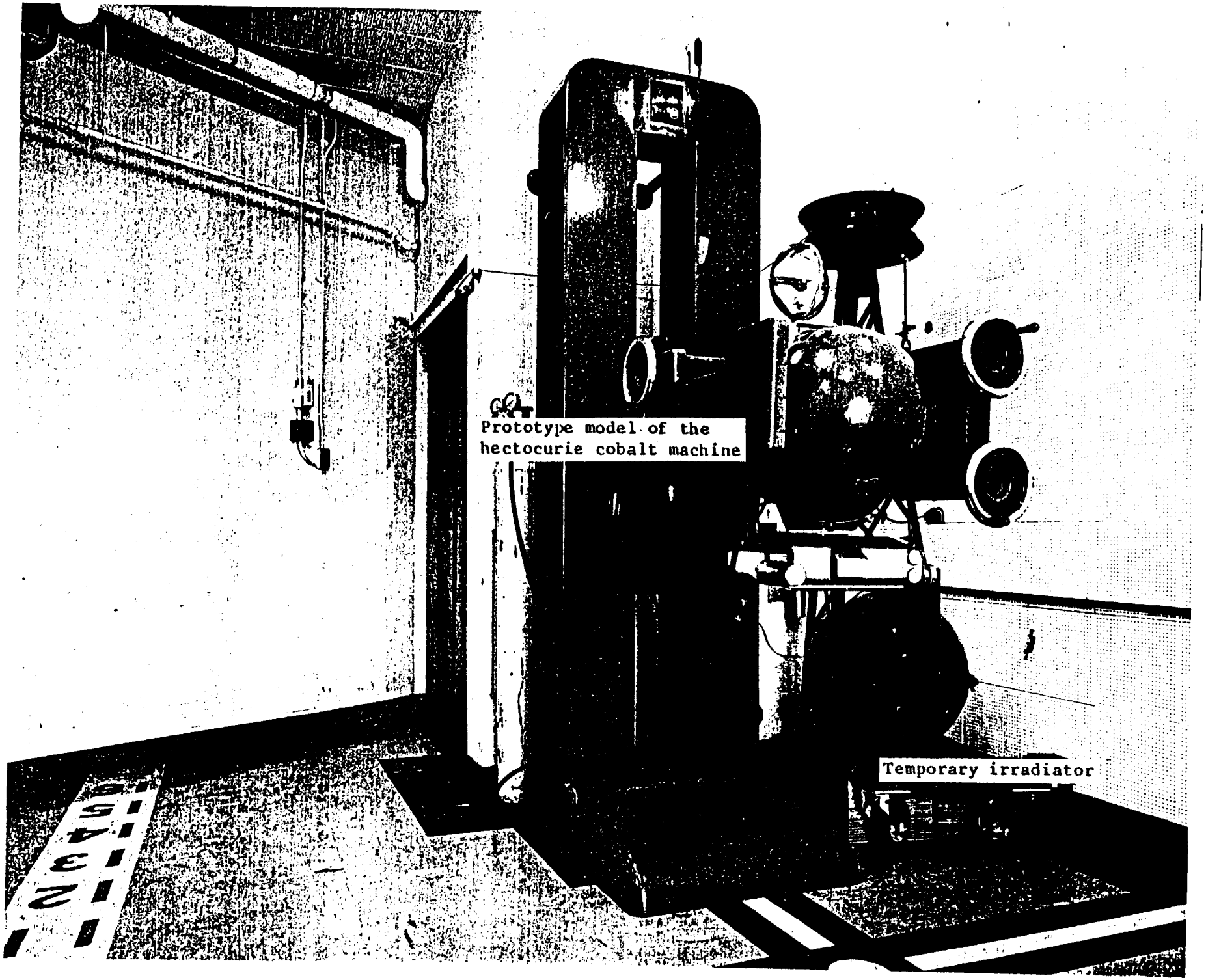
Prototype model of the
hectocurie cobalt machine
Temporary irradiator

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the cobalt room, and the activity present on these smears was background or near background level with the exception of a smear taken from the collimator of the hectocurie teletherapy machine and a smear taken from the base of the temporary total-body irradiator. The air-conditioners and blowers in this room had been deactivated before the decontamination procedures began.

Decontamination of the Cesium Room: Since the level of contamination present in the cesium room was about ten times that in the cobalt room, a great deal of care was taken upon entering the room to move slowly and avoid stirring up a cloud of cobalt dust. A quantity of oil impregnated sawdust floor sweeping compound was carefully scattered throughout the room and an air sampler was started. After the first air sample had determined that the air contamination in the cesium room was not dangerously high, a vacuum cleaner was moved in and the No. 1 head of the double-headed machine was carefully vacuumed. As this was done a survey meter was held near the exhaust port of the vacuum cleaner. The level of activity in the vicinity of this exhaust port increased rapidly. The vacuum cleaner was immediately turned off but the readings remained high. It was believed that the high reading was caused by dust particles being trapped in the filter placed in the exhaust port and that no significant amount of cobalt dust was escaping through this filter. This was confirmed by the data provided by the air sampler. Nevertheless, to insure that no dust would escape, the filter was then soaked with a light oil. After thorough vacuum cleaning of the No. 1 head, it was sealed under four layers of plastic material to prevent any further escape of cobalt-60. Next the machinery well beneath the bed of the cesium-137 machine was covered with a layer of plastic. (This well was decontaminated thoroughly only after the contaminated cobalt-60 head was removed from the room.) Upon completion of these actions the entire room - walls, ceiling, floor, and all objects present - was thoroughly vacuumed. After this the entire floor, concrete wall, and all objects in the room were

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carefully wiped with damp cheese cloths as previously described. A number of smears taken at various locations in the cesium room upon completion of these steps revealed that the levels of activity had been reduced to background or near background level in most areas. A 100 per cent clean-up of the cesium room was not attempted because it was felt that a further contamination would probably occur during removal of the No. 1 head. The levels had been reduced to a point well below the margin of safety for any persons working in this area. Decontamination of the cesium room was also greatly hindered because of an accumulation of unnecessary articles. As stated previously all these articles were either decontaminated or sealed in plastic bags for later decontamination or disposal.

Decontamination of Hallway: Many smears taken in the hallways (both on the floor and on the walls) indicated that the level of contamination on the walls was relatively low. In the light of this information, the decision was made to do a thorough clean-up of the floor and pay no particular attention to the low levels of contamination present on the walls until a final clean-up was done. The floor throughout the hallway (as far as the residents' office) was thoroughly mopped with soap and water, dried after a water rinse-down, and the wax was taken up. Smears taken after these steps showed that the levels of activity present were background or near background.

Decontamination of Air-Conditioner: The air-intake filters in the Frigidaire air-conditioning unit were significantly contaminated. These filters were sprayed with a thin oil and carefully removed from the unit and sealed in plastic bags. A careful check of the men performing this work was made and no contamination was detected on their clothing. No residual contamination was detected on the air-conditioner.

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Disposal of Wastes: All waste and all contaminated articles were sealed in either plastic bags or metal cans. This material was stored in the radiation storage vault in the laboratory wing of the Medical Division. All articles not successfully decontaminated and all wastes collected during decontamination procedures were subsequently buried in the Oak Ridge National Laboratory waste disposal area.

Estimates of Magnitude of Contamination

Radioassay of smears taken in the cesium room were performed at ORNL and also at ORINS Medical Division, and led to estimates of the total contamination in the Medical Division's facilities.

It is believed that the total amount of cobalt-60 that escaped from the No. 1 head of the double-headed teletherapy machine does not exceed 100 millicuries. A more realistic figure is in the neighborhood of 20 to 30 millicuries. This estimate was arrived at through the following procedure: A smear taken from a large (approximately 1 sq ft) area inside the large collimator of the No. 1 head of the double-headed machine was assayed. The cobalt-60 content was 15 microcuries. Taking this as an average contamination per square foot in the cesium room and multiplying by the total surface area of the walls, floor, and ceiling, and then multiplying by 2 (to take into account the surfaces of equipment and objects inside the room) leads to this figure of 100 millicuries. The smear from the large collimator was the most radioactive of the many smears taken in the room. Therefore, this estimate is undoubtedly very much above the true level.

Cost Estimates

An attempt to compute the cost of the contamination incident must depend on estimates that are somewhat arbitrary. The incurred costs up to the date of the report were carefully recorded, but future costs are based upon estimates.

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The main burden for decontaminating and monitoring the building and equipment was the responsibility of Medical Division personnel. The cost of this effort has been estimated at $925. The maintenance department was assigned responsibility for the removal of the No. 1 cobalt-60 head, shipping it to ORNL, reassembling the unit, andproviding miscellaneous services for the duration of the problem. A work order with a cost estimate of $700 was authorized.

The Oak Ridge National Laboratory has agreed to disassemble the cobalt-60 head, decontaminate, and inspect the source capsule, and make necessary replacement or repairs. The maximum cost was estimated at $1000 but a purchase requisition was made for $800.

The upholstering of W.E.G.'s couch and the cleaning of his rug was estimated at $175. The cost of discarded materials, supplies, and small items of equipment was valued at $300; about $100 worth of materials and supplies were consumed in the clean-up work. The total cost of the contamination incident has been estimated at $3000, in materials and work orders. This does not include the cost of time and consultations and the very significant amount of work that was done outside of actual purchase requisitions. It is estimated that if this were included the total cost of the contamination incident would run to approximately $6000.

Recommendations

1. It is highly recommended that no accumulation of unnecessary articles be allowed in any high-level radiation area. This will be a difficult recommendation to follow since the work that goes on in these high radiation areas naturally involves the accumulation of materials. A separate storage facility for this kind of room should be maintained.

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2. No articles made of unfinished wood should ever be allowed in any area where there is a possibility of a radioactive spill.
3. Where there is the possibility of a contamination or spill of significant amounts, there should be an "immediate" detection system. The doorway system recommended at Hanford is expensive and difficult to maintain. Although it appears to be the best of all possible systems, it is only available to fairly large installations. The hand and foot counter, which has been made for smaller installations, has proved to be inadequate. A simple laboratory survey meter is adequate for the purpose but poses impossible administrative problems.
4. In the process of collecting the many filter paper smears, it was noticed that a large amount of dirt, dust, and lint was present on the floors, walls, and on the tops of the bump boards in the hallways. High-level radiation areas should not contain crevices or unnecessary ridges.
5. Routine smear tests should be performed on a monthly basis.
6. The manufacturers of teletherapy equipment and the owners of teletherapy units should be notified of the details of this incident.

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CHRONOLOGY

William D. Jones and William D. Gibbs

September 8, 1958

0900 Routine smear tests were started.

1000 Routine smear tests indicated minor contamination.

1130 LAW approached scintiscanner. The scanner began to react and it was discovered that LAW was slightly contaminated. First, he washed his hands; he was relieved of his clothing and took a shower. After the shower, no detectable activity could be found except in the area of his nose. His clothes were placed in waxed bags and sealed. These were sent to the ORNL decontamination laundry. Dr. Ross suspected that the contamination was cobalt-60.

1145 WEG was checked and was highly contaminated. He, too, was given a shower and his clothes placed in waxed bags, sealed, and stored for later decontamination.

1200 Smears were taken in the hallway in the region of teletherapy rooms. Average activity per square foot was about 0.06 microcurie.

1220 WEG reported that his home was contaminated. Several articles of furniture were reported to be contaminated: 1) sofa, 2) rug, 3) other chairs in living room, 4) kitchen chair. WEG was asked to return to the Medical Division at which time advice and decontamination equipment would be supplied to him.

1230 WLB was monitored and found to be contaminated. He also was showered and his clothing stored for later decontamination.

1136821 1245 Mr. Harmon called Dr. Shoup and reported the contamination.

1300 The hallway in the area of the teletherapy rooms was mopped and the wax was removed.

1330 Employee shoe monitoring was started. Janitorial equipment was also monitored. Laboratory coats worn the previous week were also monitored. Several employees were found to have contaminated shoes. They were instructed to wash their shoes with soap and water, scrubbing with a brush, and report back for a further check. With the exception of two pairs of shoes, all were successfully decontaminated. These two pairs were sealed in a bag and stored for later decontamination. Laboratory coats worn during the first week of September were not contaminated to any detectable extent.

1345 Bill Jones and Dr. DBC went to Dr. DBC's room in the dormitory. They made a radiation survey and could discover no contaminated articles, with the exception of one pair of trousers that Dr. DBC had worn on September 5. WEG was supplied with an ORINS vacuum cleaner and several radiation detection instruments. He was advised to vacuum all contaminated articles in his home and then survey to determine the success of this procedure. He was advised that if these procedures were not successful a commercial upholstery cleaner should then be tried. At this time WEG brought several articles of contaminated clothing and linen from his home. These were sealed and stored to be sent to the ORNL decontamination laundry later.

1400 Smears were taken throughout the hallway in the patient wing of the building. All these smears were very low in activity, in the neighborhood of 3 to 5 times background. This calculated to an average activity per square foot of much less than 0.01 microcurie.

1420 Dr. Shoup came to the Medical Division.

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1445 Smears were again taken in the hallway near the teletherapy rooms. Contamination had been reduced considerably but a significant amount was still present.

1515 Smears were taken from the wall in the back hallway and on top of the bump board. Average contamination here was slightly less than 0.01 microcurie per square foot.

1615 Urine sample was collected from LAW.

1630 Urine samples were collected from WEG, Dr. DBC, and WLB.

1730 Mr. Harmon and Bill Jones went to the home of LAW in Wartburg. They made a radiation survey throughout the house and detected no contamination. Several articles of clothing that LAW had worn on September 5 were monitored and a pair of pants, a shirt, and a pair of shoes indicated possible contamination. Levels were so low as to be barely distinguishable above background.

1745 Mr. Harmon and Bill Jones went to the home of RCB and made a radiation survey throughout the house. No contamination was detected. A spectrum of WEG's clothing was run. Immediately after this, a spectrum of a known cobalt-60 source was run. These two appeared very similar although neither exhibited the spectrum of cobalt-60. (This was later found to be caused by a defect of the scintillation crystal in the spectrometer.)

1815 The cesium room and the cobalt room were entered and smears were taken at 12 locations in each room. The probable average contamination present in the cesium room at this time was greater than 1 microcurie per square foot. The average contamination present in the cobalt teletherapy room at this time was about 0.22 microcurie per square foot. Smears were also taken in the cesium control room. The average contamination present in this room was about 0.24 microcurie per square foot.

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1930 A spectrum was run on smears from the cesium room and appeared to be similar to the spectrum done at 1730. Also, at 1930 the couch and rug were removed from WEG's home to the ORINS warehouse.

1900 A europium spectrum was run. This was completely different from all the others.

1930-2100 Accumulated data were analyzed and plans were made for action on September 9, 1958.

September 9, 1958

0815 Wet filter paper was placed on the opening of the No. 1 head of the double-headed teletherapy machine. The machine was turned on for 5 minutes. No detectable contamination was present on the filter paper.

0945 Hallway in teletherapy area was mopped again with soap and water, and dried.

0950 A 0.1 and a 1.0 microcurie cobalt source were ordered from Abbott Laboratories for calibration purposes.

1000 Filters were changed in the air-conditioning systems in the patient wing. These filters had been found to be contaminated on September 8.

1020 Two teletherapy outpatients, who were treated on September 8, were monitored. No contamination was detected. Both patients stated that they had bathed since their treatment the previous day.

1100 The Health Physics Division at ORNL was called and we requested that a health physicist come to the Medical Division facilities for consultation.

1130 The two cobalt-60 sources ordered at 0950 were obtained from the Abbott Laboratories.

1230 Two health physicists from ORNL came to the Medical Division.

1245 Four smears that had been taken in the cesium room on September 8 were taken to ORNL for assay and isotope determination.

1300 Two radiation monitoring devices were calibrated with the sources obtained from the Abbott Laboratories.

1315 Two members of the Isotopes Division of ORNL came to the Medical Division and were consulted about possible removal of the cobalt-60 heads to ORNL for unloading, decontamination, and examination. They agreed that this could be handled.

1445 W. D. Jones and W. D. Gibbs went to WEG's home and made a radiation survey. The only contaminated articles were a kitchen chair and a vacuum cleaner. The chair gave a reading of about 1000 counts per minute on a survey meter, which was later calibrated. This calibration revealed that 25,000 counts per minute equaled 1 microcurie. The mop and broom in WEG's home were not contaminated although they had been used in cleaning the home during the weekend. It was estimated that with the exception of WEG's work clothes, the maximum amount of cobalt-60 present in his home at any time was less than 20 microcuries, and probably less than 10 microcuries. WEG at this time was involved in decontaminating his automobile, a 1948 Dodge. This automobile was contaminated on the steering wheel, front seat on the driver's side, floor board, clutch, brake, and accelerator pedal. Dr. Ross placed a new scintillation crystal on his spectrometer and ran another spectrum on WEG's clothing as well as on a known cobalt source. These spectra were similar.

1500 A report from the health physics people at ORNL verified that the contaminant was cobalt-60. The four smears that they had been supplied with ranged in activity from 0.8 microcurie to 15 microcuries. An air sampler and two gas masks were loaned to us by ORNL.

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1600 Estimates were made, based on information obtained from ORNL of total contamination in ORINS Medical Division facilities. The total amount of cobalt-60 liberated from the No. 1 head of the double-headed teletherapy machine was less than 100 millicuries. It was probably less than 20 millicuries.

September 10, 1958

0800-0900 Information concerning decontamination of the cobalt room and contents along with data obtained from smears, both before and after decontamination, was furnished to Mr. Harmon. This information was then relayed to Dr. Shoup.

0915 Decision was made not to attempt to begin decontamination procedures in the cesium room on this day.

0920 A scrub down was done in the passageway leading to the teletherapy rooms. Smears taken after this procedure revealed that the level of activity present had been reduced to near background levels.

1000 WEG brought several bags of contaminated articles, chiefly cleaning rags and a vacuum cleaner, to the Medical Division.

1030 This vacuum cleaner was decontaminated. Smears taken inside were background or near background level.

1045 Dr. Ross began to set up for cobalt-60 assay of urine specimens.

1320 WEG's couch and rug were examined. Significant contamination was present. Estimated total cobalt-60 content: 5 microcuries.

1415 Contaminated clothing and other items obtained from LAW, Dr. DBC, WLB, and WEG were placed in separate plastic bags. As these items were packed, they were identified by the owners and a list was made.

1515 Estimate of the total cobalt-60 contamination present in these articles was 250 microcuries.

1630-1830 WEG and W. D. Gibbs went to Knoxville to the home of WEG's father-in-law. A careful radiation survey was made of his automobile and the clothing worn during his visit to WEG's home on September 7. No evidence of any contamination was found.

1800-0030 Decontamination of cobalt room and contents was carried out. Smears taken after decontamination procedures showed that the residual contamination was less than two times normal background. The exceptions were the base of the temporary total-body irradiator and the throat of the hectocurie machine variable collimator. These two locations were about 10 times background. This area was O.K.'d for immediate use. Entrance to the cesium room was sealed with tape to prevent any further escape of cobalt-60 dust.

September 11, 1958

0830 A survey of the air-conditioning system filters in the patient wing was made. Observations revealed that the Frigidaire unit intake filters were about 10 times background.

0845 Smears were taken in the cobalt room and adjoining hallway.

0900 Arrangements were made to run four employees (WEG, LAW, Dr. DBC, and WLB) through the whole-body counter at ORNL at 1300 today.

0910 Jones and Gibbs went to Dr. FC's apartment and no contamination was detected on clothing worn on September 4, 1958. No contamination was detected at any location in this apartment.

0945 Mr. Hart of the ORNL Health Physics Division agreed to assay urine for cobalt-60. Autoradiograms of three smears taken in the cobalt room on September 8 were developed.

1030 Decontamination of WEG's rug and couch was begun. The rug was successfully decontaminated. No luck on the couch.

1136827 1245 The planned trip to ORNL by the four contaminated employees was

postponed. The whole-body counter was out of action - electronics trouble.

1330 Contaminated clothing belonging to WEG, LAW, Dr. DBC, and WLB was sent to the ORNL decontamination laundry. Urine samples from these four men were sent to Mr. Hart of the ORNL Health Physics Division.

1345 Efforts to clean WEG's couch were discontinued.

1445 Vehicle used to transport laundry and urine to ORNL was monitored. No contamination was detected.

September 12, 1958

0800 Air conditioners in the patient wing were monitored. Frigidaire unit contamination was at the same level as on September 11. No detectable activity was found on the other unit.

0830 Smears were taken in the cobalt room and adjoining hallway.

0840 LAW, Dr. DBC, WLB, and WEG left for ORNL to be checked by the whole-body counter.

1230 A new dust bag and filter were placed in WEG's vacuum cleaner. It was released for return to his home.

1245 Smears were taken from exhaust stacks on the roof in the teletherapy area.

1300 Smears were taken throughout the entire teletherapy and patient wing of the building.

1330 Gibbs, Andrews, and Ross went to ORNL to consult with Dr. Burkhart.

1500 WEG, WLB, LAW, and Dr. DBC returned to the Medical Division from ORNL.

1545 Gibbs, Andrews, and Ross returned from ORNL.

1600 The famous four were notified of the extent of their internal contamination.

September 14, 1958

1200 Materials needed for decontamination of the cesium room were assembled.

1300 The doors leading into the Oak Ridge Hospital were closed and sealed with tape. The door leading into the patients' recreation room and the doors leading into the cobalt teletherapy room were similarly sealed. Signs were posted at each end of the hallway to prevent people from using this area. Smears were taken in rooms E-31, E-33, and E-35.

1345 The cesium room was entered and sweeping compound was spread over the floor and all flat surfaces in the room. The air sampler was started.

1350 The cesium room was monitored with survey meter No. 4448. The general level of radiation in the cesium room, excluding the area near the double-headed teletherapy machine, was 10,000 counts per minute.

1400 The dust bag and back filter were changed in the Electrolux vacuum cleaner. A new bag and back filter were inserted. Mattresses present in the cesium room were placed in large plastic bags. These were sealed and moved into the adjacent hallway. At this point the background in the hallway increased, as indicated by popping of a laboratory monitor located in this area.

1405 The No. 1 head of the double-headed machine was vacuumed and sealed under four layers of plastic. As the head was vacuumed, the exhaust of the vacuum cleaner was monitored. Activity increased rapidly. The exhaust port filter was then soaked with oil.

1415 The first air sample was counted. Result: 374 counts per minute. This was about 0.01 microcurie trapped on the filter paper during a 30-minute period.

1435 General decontamination of the cesium room was done by using vacuum cleaners on walls, ceiling, floor, and all objects in the room.

1445 The second air sample was counted. The net result was 47 counts per minute.

1500 The area of the floor under the cesium teletherapy bed was sealed under a layer of plastic. The machinery well under the bed will be decontaminated at a later date.

1515 The third air sample was counted. Result: 19 counts per minute.

1545 The fourth air sample was counted. Result: 18 counts per minute. At this time smears were made in the hallway. Result: All smears were less than twice background. The hallway was then opened to traffic.

1615 The fifth air sample was counted. Result: background level.

1645 The sixth air sample was counted. Result: 29 counts per minute.

1730 All persons engaged in decontamination of this area changed clothing, washed, monitored themselves, and went to supper.

1830 Harris, Pope, Stephens, and Gibbs returned to the cesium room and continued decontamination procedures.

1855 The seventh air sample was counted. This was a 2 hour 5 minute collection. Result: 49 counts per minute. At this point all movable items were taken out of the cesium room and placed in the hallway. Those that showed detectable contamination were sealed in plastic bags.

2000 The eighth and last air sample was taken. Result: 58 counts per minute. Smears were collected at 24 locations in the cesium room. Significant contamination remained.

2100 The floor, concrete wall, and all objects in the cesium room were wiped with damp rags.

2200 Smears were again taken at a similar 24 locations in the cesium room. Contamination was reduced to extremely low levels (see attached data).

2240-2330 A general tidying up of the hallway area was performed. Then we all went home.

September 15, 1958

0830 Smears were taken in the cesium room and hallway.

0845 Counting was begun on a backlog of accumulated smears.

0930 WEG and Harry Kimble took measurements of the double-headed machine as an aid to removing the No. 1 head.

1000-1400 Smears were taken in the pathology laboratory, the adjoining hallway, rooms E-31, E-33, E-35, E-37, patients' recreation room, and nurses' station.

1500-1645 Harmon, Andrews, and Gibbs planned an outline of the report of this incident.

1900-2100 Gibbs dictated part of this report.

September 16, 1958

0815 Decontamination of the large vacuum cleaner borrowed from the Technical Services Department was begun.

0945 The warehouse was called and they were requested to move the large vacuum cleaner to the warehouse so that WEG's sofa could be worked on again. They said they could not move this vacuum cleaner until after lunch.

1015 Smears were taken in the cesium room and adjacent hallway. Counting of a backlog of smears was resumed. This ceased at 1130.

1045 The warehouse crew relented, and moved the large vacuum cleaner to the warehouse.

1200 Attempts to decontaminate WEG's sofa were resumed.

1300 Counting of the accumulated smears was again started.

1330 Mr. Kuna, ORNL Health Physicist, called and reported that an assay had been done on four urine samples sent to Dr. Hart at the Health Physics Division. WEG's and LAW's urine contained a higher amount of radioactivity than the urine of Dr. DBC and WLB.

1400 Gibbs went to warehouse to check WEG's sofa.

1500 Gibbs returned from warehouse. The sofa was still contaminated. Gibbs estimated a maximum of 3 microcuries of cobalt-60 remained in or on this sofa.

1515 Smears were taken in cobalt room.

DATA OBTAINED BY SMEAR TECHNIQUE

William D. Gibbs and Others

Each smear was taken from approximately one square foot. All were counted under the same geometry. For this geometry: 7600 counts/minute = 1 microcurie.

Date: September 8, 1958 Time: 1900

RESULTS OF SMEARS TAKEN INSIDE CESIUM ROOM

Location	Counts/Minute	Microcuries
Floor inside door	278	0.04
Top of head No. 1, double-headed machine*	Too hot	?
Top of head No. 2, double-headed machine*	7220	0.95
Top of body No. 2, double-headed machine	4683	0.62
Tile D-16	2584	0.34
Back of head, cesium machine	2642	0.35
Cesium control panel	827	0.11
Tile B-2	7068	0.93
Base of bed, double-headed machine	6453	0.85
Tile K-6	1600	0.21
Throat of large collimator, head No. 1, double-headed machine	Too hot	15.00+
Throat of small collimator, head No. 2, double-headed machine	608	0.08

*Heads positioned so that No. 2 is directly above No. 1

+Assay performed at ORNL

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Date: September 14, 1958 Time: 2200

RESULTS OF SMEARS TAKEN INSIDE CESIUM ROOM AFTER DECONTAMINATION

Location	Counts/Minute	Microcuries
Tile O-4	21	--
Tile O-10	55	--
Tile J-11	12	--
Tile O-12	5	--
Tile H-12	16	--
Tile I-14	15	--
Tile F-15	29	--
Tile B-15	18	--
Tile D-20	10	--
Tile H-20	7	--
Tile K-20	20	--
Double-headed machine bed	13	--
Base of double-headed machine bed	86	0.01
Cesium control panel	25	--
Pipes on wall above cesium control panel	21	--
Back of head, cesium machine	111	0.01
Top of cobalt head No. 2	174	0.02
Top of cobalt head No. 1	42	--
Wall behind cesium-137 machine	16	--
Wall beside double-headed machine	5	--
Wall above cesium control panel	10	--
Concrete wall between window ports	11	--
Wood portion of door	13	--

Date: September 8, 1958 Time: 1900

RESULTS OF SMEARS TAKEN INSIDE COBALT ROOM

Location	Counts/Minute	Microcuries
Floor inside door	2417	0.32
Head of hectocurie machine	985	0.13
Base of hectocurie machine	798	0.11
Tile H-7	1528	0.20
Throat of collimator, hectocurie machine	792	0.11
Top of temporary total-body irradiator	232	0.03
Door of temporary total-body irradiator	233	0.03
Base of temporary total-body irradiator	437	0.06
Collimator storage rack	910	0.12
Tile E-8	1094	0.14
Concrete wall near light switch	46	--
Top of interchangeable-source machine (now moved to another location)	152	0.02

Date: September 9, 1958 Time: 2400

RESULTS OF SMEARS TAKEN IN COBALT ROOM AFTER DECONTAMINATION

Location	Counts/Minute
Door	2
Tile G-16	2
Concrete wall near light switch	0
Mirror	2
Tile G	1
Tile E-8	2
Base of temporary total-body irradiator	30
Top of hectocurie machine	10
Head of hectocurie machine	16
Inside collimator, hectocurie machine	32
Tile A-9	1
Tile A-2	3
North wall	2
Tile J-4	2
Collimator storage rack	2
Top of interchangeable-source machine (now moved to another location)	11

1136836

Date: September 8, 1958

RESULTS OF SMEARS TAKEN IN CESIUM CONTROL ROOM

Location	Counts/Minute	Microcuries
Floor inside door	2513	0.08
Top of console	2377	0.07
Floor in front of console	5189	0.16
Top of computer	5805	0.18
Top of air conditioner	3408	0.11

Date: September 12, 1958

RESULTS OF SMEARS TAKEN ON ROOF IN TELETHERAPY AREA

Location	Counts/Minute
Inside exhaust stack, cobalt room	16
Base of exhaust stack, cobalt room	17
Inside exhaust stack, cesium room	3
Base of exhaust stack, cesium room	37
Inside north stack, cesium control room	0
Inside south stack, cesium control room	0
Air-conditioner intake, cesium room	249

1136838

MANUFACTURERS' CONFERENCE

Minutes of the Fifth X-Ray Industrial Conference

Oak Ridge Institute of Nuclear Studies Medical Division
Oak Ridge, Tennessee
December 1, 1958

Summarized by J. Howard Harmon

Present:

E. E. Beauchamp	Oak Ridge National Laboratory
Mortimer Beem	Curtis-Wright Corporation
M. G. Brown	Atomic Energy of Canada Limited
Marshall Brucer	ORINS Medical Division
Frank Comas	ORINS Medical Division
Eimo Galvanoni	W. F. and John Barnes Company
William Gibbs	ORINS Medical Division
J. H. Gillette	Oak Ridge National Laboratory
Allen M. Goldstein	Isotopes Specialities Company
C. R. Griffith	Westinghouse Electric Corporation
J. Howard Harmon	ORINS Medical Division
C. H. Hetherington	Atomic Energy of Canada Limited
James Hitch	United States Atomic Energy Commission
Sam R. Hollingsworth	National Lead Company
J. A. Lenhard	United States Atomic Energy Commission
E. Llewellyn	Curtis-Wright Corporation
W. E. Parker	Nuclear Systems, Division of the Budd Company
E. E. Pierce	Oak Ridge National Laboratory
A. L. Rupp	Oak Ridge National Laboratory
E. Dale Trout	General Electric Corporation
Yoichiro Umegaki	ORINS Medical Division
Ted Workinger	United States Atomic Energy Commission

The Fifth X-ray Industrial Conference was held in Oak Ridge for the purpose of evaluating four years' experience with the international teletherapy source capsule. Dr. Brucer informed the group of the recent ORINS' experience with a leaking capsule and the results of a survey of other sources. Since one or more leakages had occurred in the international source capsule, the primary objective of this meeting was to reach an agreement on recommendations to the United States Atomic Energy Commission, The Atomic Energy of Canada Limited, manufacturers of X-ray equipment, and other interested groups. A discussion on the production, availability, and encapsulation of cesium-137 sources was a secondary objective.

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Leakage of the International Source Capsule

Dr. Brucer emphasized that the ORINS contamination problem was not serious, but it could have been. This group should recognize that serious contamination could occur from such leakages and that some modifications in encapsulation techniques are probably necessary.

On September 8, 1958, a routine health physics survey, started in the laboratory section, indicated a background high enough to require investigation. About 11:00 a.m. atechnician (working in the teletherapy facilities) went to another area where a thyroid scan was being made. As he approached the scanner, the machine froze from the excessive counts. The scanner returned to a normal counting rate when the technician backed away. When this phenomenon was observed, it was reported to the health physicist who checked all personnel working in the area of the teletherapy equipment.

Wipe tests indicated that all equipment in the area was contaminated. The highest counts were found in the throat of the number one head of the Westinghouse cobalt-60 teletherapy unit. A spectrometric analysis of the wipes indicated that the contamination was cobalt-60. Health physics personnel of the Oak Ridge National Laboratory were consulted and plans were made to have that organization dismantle the teletherapy head and inspect the source capsule. The capsule was opened and a leaking seal was confirmed. The same source was repackaged and returned to ORINS.

After the ORINS source leakage had been fully established, Dr. Brucer called a selected group of radiologists owning teletherapy equipment and requested that they check their source to determine whether other leakages had occurred. Fifty owners were sent a piece of circular filter paper 3 cm in diameter and were requested to make a wipe test on the throat of their teletherapy unit. When the filter paper was returned the net counts ran from 0 to 42 counts above background. (This test was based on highly selected samples.) Dr. Brucer indicated that a count 6 times above background be considered significant and worthy of a spectrometric analysis.

A teletherapy unit owned by Dr. H. Stephen Weens, Emory University School of Medicine, had an unusual but significant count. This source has been used approximately five years. There had been a radium leakage in an adjoining building and Dr. Brucer expressed an opinion that the contamination was radium and not cobalt. Dr. Weens did a spectrometric analysis but this had not been completed at the time of this meeting. (Later tests confirmed that this probably was not radium but was cobalt-60. There is insufficient activity to confirm the impression without unusual tests.)

In addition, surveys were made on ten shipping containers used by the AECL, USAEC, Picker X-ray Corporation, and the Bar-Ray Corporation. The survey indicated that container contamination averaged about twice background, which under average conditions should be considered as clean.

Mr. C. R. Griffith, Westinghouse Electric Corporation, X-ray Division, described another problem, which had occurred on November 10, 1958. He was called to New York to do routine tests on a Westinghouse unit that had just been installed. While making the routine adjustment he followed their standard procedure of making wipe tests. Instead of using a filter paper he

1136840

used a wipe-stick and tested the inside of a cone throat in accordance with the recommendations of the National Bureau of Standards Handbook No. 54. The level of counts was such that he obtained an AECL shipping container and returned the source to AECL for inspection. During the unloading process he looked at the face of the capsule with a mirror and found that the face was heavily corroded with a greenish-gray material, but found no other visual defect. After the machine was unloaded he made a wipe test inside the beta shield and did a spectrometric analysis that indicated cobalt contamination. Other surveys on the teletherapy unit indicated that all contamination was contained within the unit. At the time of this meeting the source was on its way back to the Atomic Energy of Canada Limited for further testing.

Dr. Brucer asked Mr. Hetherington whether the contamination on this source capsule could have been obtained from an AECL shipping container. Mr. Hetherington said that he could not give a definite answer to this question because the capsule had not yet reached their company. He explained their procedure for preparing containers for shipment and stated that he was of the opinion that the problem did not result from a contaminated shipping container.

The available evidence indicated that one leak had definitely occurred and that possibly a second one may have occurred. These leakages were not to be considered as serious; however, since considerable experience has been accumulated in sealing capsules, and since new sealing techniques have been developed, this group should review these techniques.

In the discussion that followed, it was emphasized that it would be very difficult to determine the actual cause of a given leakage. Some participants expressed an opinion that the leakage resulted from a faulty seal. Members of the ORNL staff emphasized that each capsule is tested in such manner that faulty seals would be detected before shipment. They expressed an opinion that the seal had ruptured from an accumulation of heat inside the teletherapy head or shipping container. Participants questioned how this heat could accumulate from the absorption of the gamma rays and it was pointed out that the design and construction of equipment and shipping containers may be such that the heat cannot be well dissipated by the source capsule in contact with the metal parts of the machine or shipping container. At this point the participants were informed of the plans of Atomic Energy of Canada Limited and the United States Atomic Energy Commission for changing over to a welded-type source container. Reports from various encapsulating companies indicated that they are already adopting the welding principle as rapidly as techniques can be put into effect. Mr. E. E. Pierce, Oak Ridge National Laboratory, gave a detailed description of the techniques they are using for sealing source capsules.

The group turned its attention to what should be done with the sources that are already in use in teletherapy equipment. The suggestion was made that all these capsules be removed and inspected; however, this would be a difficult procedure for many owners of sources. Dr. Brucer pointed out that a section of the Handbook 54 has not been followed very closely and he recommended that greater emphasis be given to periodic wipe tests as recommended by the National Bureau of Standards. He felt that if this procedure were followed, this should be adequate control over any leakages that might occur in the future. It was also pointed out that on many of the machines an additional beta shield acts as a container for any cobalt that might be loose inside the machine. The group concurred with this suggestion.

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Availability of Cesium-137; Report by Mr. E. E. Beauchamp

Mr. Beauchamp started his discussion of the availability of cesium-137 by reviewing the current status of the availability of cobalt-60. At the previous meeting of the representatives of the X-ray industry there was some concern over whether enough cobalt-60 would be available to meet the industrial demands. He stated that the production of cobalt-60 has been such that the United States Atomic Energy Commission has stopped processing the isotope until the current inventory is appreciably reduced. The current inventory is being reduced at what is considered a satisfactory rate, and it is anticipated that before long the Commission will soon authorize further production of cobalt-60. One of the representatives of the X-ray industry wanted to know what the Oak Ridge National Laboratory and the Commission would consider a minimum inventory level. Mr. Beauchamp replied that this was a difficult question and no definite amount has been established at this time. He felt that he could assure continued availability of sources and that the minimum quantity that would eventually be established would be dependent upon the projected market. He reviewed the current catalogue cost of cobalt-60. Mr. Beauchamp explained that as of March 1958 the Oak Ridge National Laboratory was essentially out of the encapsulation business. They will do encapsulation only at the specific request of some governmental agency, which has obtained prior approval of the Commission. Mr. Beauchamp went on to emphasize that the Oak Ridge National Laboratory would no longer furnish cobalt-60 teletherapy sources as such.

In reviewing the cesium-137 production Mr. Beauchamp reported that ORNL had processed to-date about 13,000 curies of cesium and they have 10,000 more that should go to stock about one week after the date of this meeting. It was further anticipated that there would be a production of an additional 10,000 curies within this fiscal year (ending June 30, 1959).

The maximum specific activity of the cesium-137 is 30 curies per gram. This specific activity cannot be increased much higher without the use of a hot calutron. The developmental people of the Oak Ridge National Laboratory are looking at this problem and the laboratory has proposed to the Commission that a calutron be made available for the enrichment of the cesium-137. It is not anticipated that the calutron will be available within the near future. The cesium-134 content in the current production is about 8 per cent. The laboratory cannot predict with a certainty what will be the cesium-134 content of the next batch to be produced; however, they estimate that it will be somewhat lower than the 8 per cent. The percentage of the cesium-134 may be reduced by blending in some of the decayed materials that are now on hand. Mr. Beauchamp said that the Oak Ridge National Laboratory would like to have this group of industrial representatives indicate what level of cesium-134 they could accept for teletherapy sources. One participant reported on a source that had less than 1 per cent cesium-134. Mr. Beauchamp was acquainted with this source and pointed out that it had been made from fuel rods that were removed from a pile several years before the current processing and the cesium-134 had had an opportunity to decay to a very low level. It was stated that the quantity of cesium-134 present in fuel rods is dependent upon the length of time that the rod was in a reactor and the rate of power at which the reactor operated. A low-power reactor produces small quantities of cesium-134. Most reactors are operated at high level for various reasons and this means that most of the available fuel rods will be from reactors operating at a high-power level. Mr. Beauchamp emphasized that the Oak Ridge National Laboratory would not be able to take the current

1136842

production material and store it for several years to allow the decay of the cesium-134. He stated further that they would from time to time probably have small batches of materials from very old fuel rods but since the quantity would be limited he could only use this material to blend with the expected normal production of 8 per cent. If the industry could accept some level between 5 and 8 per cent, ORNL could blend the available material to assure this level. If the industry should insist on very low levels of the cesium-134 content, it would limit seriously the quantity of cesium-137 that would be available for teletherapy sources. At the 5 per cent level he thinks the Oak Ridge National Laboratory could blend out several thousand curies of cesium for teletherapy sources. Mr. Beauchamp stated that as he understood the problem, the high energy of the cesium-134 was not a serious problem for therapeutic uses but the problem arose as a shielding or health physics protection problem. It was pointed out the use of material having a large quantity of cesium-134 would require shielding of approximately the same size required for cobalt-60. Many of the early purchasers of the teletherapy units had assumed that as soon as cesium-137 was available they would use cesium sources in units designed for cobalt-60 sources. Dr. Brucer stated that in a machine designed to hold cobalt-60 there would be enough protection to permit using cesium sources having approximately 20 per cent cesium-134 content. However, for a machine designed specifically for using cesium-137, a difficult problem might be encountered. It was emphasized that this problem could be solved in another way. Either the manufacturers or the owners of cesium units could buy sources having a relatively high percentage of cesium-134 content, set the sources aside, and allow them to decay until the cesium-134, with its half life of 2.3 years, had decayed to an acceptable level. The question was raised from the floor as to how the cesium-134 would affect the beam characteristics of a cesium teletherapy unit. Dr. Brucer stated that the cobalt-60 sources are considered as a monochromatic beam; however, if one takes a careful spectrometric analysis of this or any other beam one finds that he does not actually have a monochromatic beam. It was his opinion that the cesium-134 content at the level they were discussing would not in any way be objectional to a radiotherapist. The participants agreed that a cesium-134 content ranging between 5 and 8 per cent would be acceptable.

Mr. Beauchamp announced that the Oak Ridge National Laboratory was still authorized to package cesium-137 sources for teletherapy units. He said that they would continue to do this until some private encapsulating firm expressed a willingness to take over this operation. If this occurs the Commission will then follow the same policy as in their withdrawing from the packaging of cobalt-60 sources.

Recommendations

It is emphasized that we know of no serious contamination accident that has occurred from cobalt-60 teletherapy sources. However, once for certain and probably twice an incident has occurred that could have been serious if not caught in time. Therefore, the participants concurred in the following recommendations:

1. The Standard Source Capsule should be changed to a double welded capsule design. This recommendation has already been adopted by the known manufacturers of teletherapy sources and is now in operation.

2. The NBS Handbook 54 should emphasize the necessity for periodic wipe tests. This recommendation is being sent to Mr. Carl Braestrup, the editor of NBS Handbook 54.

3. An additional shield should probably be recommended for each machine in order to forestall massive contamination should it occur. This is not a very strong recommendation. However, it is being sent to Mr. Carl Braestrup, the editor of Handbook 54, for the consideration of the Handbook 54 committee.

4. Cesium-137 sources should be sold with a cesium-134 contamination of less than 8 per cent on the date of sale. This recommendation has been transmitted to Mr. Beauchamp of ORNL. It appears to be a practical answer to the cesium-134, 137 mixture problem and has already been informally put into effect.

5. The United States Atomic Energy Commission should survey all teletherapy sources under their responsibility by a simple wipe test or some other similar easily accomplished means. No action as yet has been taken on this recommendation.

6. Although there is no definite recommendation, the participants of the Fifth X-ray Industrial Conference felt that some official cognizance should be taken of the impression that large teletherapy sources of the old design may begin to leak spontaneously after a period of time. These sources might be recalled after they have been fully used by the first customer and replaced with the new welded design before being shipped to a second user.

1136844

ALLEGED IODINE-131 SPILL

William D. Gibbs

The morning of February 25, 1958, a high background was noted in the experimental medicine laboratory. This was later found to be due to some autopsy specimens, which had been placed near the monitor in this laboratory.

However, before this fact was discovered, the technician that prepares and assays patient doses was called and asked to place a bottle containing 20 millicuries of iodine-131 behind lead shielding, because it was thought that this bottle, located inside the door of the storage vault in its original shielded shipping container, might be responsible for the high background.

Immediately someone began to twist this tale all out of shape. First, the health physicist was told that 2 millicuries of iodine-131 had been spilled on the floor of the vault and had not been cleaned up. Within 30 minutes the amount had increased to 20 millicuries, a sort of reverse decay of extremely short half life and the pregnant females (genus Homo) were in a state of panic and high indignation diverted against everyone who had ever uttered the word "radioisotope."

By noon the spill had moved outside the vault into the hallway, a definite spatial translocation, and everyone was wading through it with no attempt to clean it up. At 4:00 p.m. the health physicist was notified that the quantity of iodine-131 in the spill was now 200 millicuries, the rate of reverse decay having spontaneously slowed considerably. He was also told that all the pregnant employees were now doomed to giving birth to four-headed babies.

Early on the morning of February 26 a meeting of all office and laboratory personnel was called for 3:00 p.m. It was especially asked that all pregnant females attend. One such female decided to be otherwise busy.

1136845

At 2:30 p.m., February 26, one female employee was told of the "contamination" for the first time and she was left with the impression that AEC offices in Washington had been notified and were sending a group to investigate.

At the 3:00 p.m. meeting the true story was revealed to all. The tale of the growth of the rumor was also told. Certain areas of the building were placed off limits to pregnant employees and everyone except rumor spreaders went away happy.

1136846

COBALT-60 LEAKS IN OLD TELETHERAPY SOURCE CAPSULES

Marshall Brucer, M.D.*

Six source capsules (among about 300) have leaked minute amounts of cobalt-60. This is not dangerous but it is expensive to clean up. Also, if we get small leaks, we might get dangerous leaks. The danger has already been corrected in the encapsulations since January 1959. But about 300 possible sources will not be turned in for a few years. This explains how I think the leaks developed:

> The old source capsules (before 1959) were sealed with two lead 0 rings. The metallic cobalt begins to turn into dust in a few days, especially around its edges. Screwing down the cap in the capsule assembly breaks the continuity of some of the 0 rings. Within a few years a small amount of cobalt-60 dust may leak out into the room. Physicians and technicians who are often in the room breathe the dust. The amount patients breathe is probably minute, since they are in the room only a few times.

We have examples of from 0.5 to 2 microcuries body burden having been deposited in technicians with an initial half time of about 20 days. Handbook 69 gives a Maximum Permissible Body Burden of 10 microcuries. Therefore, these leaks are not dangerous, but they are expensive to clean up and a bigger leak could be a source of danger.

The newer sources are in double capsules. Each capsule is individually welded. The completed device is leak tested. No new capsule** has been known to leak but the expense and danger to instrument readings (not to people) is so severe that we suggest taking wipe tests even on the new source capsules. We suggest a simple wipe test as illustrated on the attached instruction sheet.

The way to prevent serious contamination is to do frequent wipe tests. Since the contamination develops slowly, one wipe test every six months is sufficient.

There are many better but more expensive ways of doing leak tests and if you have a capable person available, we recommend following his advice. For the many people who do not have facilities available, we offer this simplified method and, if necessary, we will even do the counting for you. The unfolded filter paper can be placed in an envelope and sent to M. Brucer, Medical Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee.

The leaking material is probably:

> Cobalt-60 oxide in small dust-like particles. It is breathed into the lungs, gets into the bloodstream, into the liver, is excreted via urine, and has an initial half time of about two or three weeks. It can contaminate clothing and especially shoes. At about the 1-microcurie level (typically, 1,000,000 - 2,000,000 counts per minute or 2,000 - 10,000 times background) we recommend throwing away the clothing and shoes since destruction is cheaper than attempts at cleaning. Whole-body counts are necessary only when the body burden is likely to exceed 10 microcuries. The whole-body counter is the only instrument capable of making adequate diagnostic tests of body burden.

*Chairman, The Medical Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, under contract with the United States Atomic Energy Commission.

**The first experimental new capsule with the new welding was a cesium source now six years old.

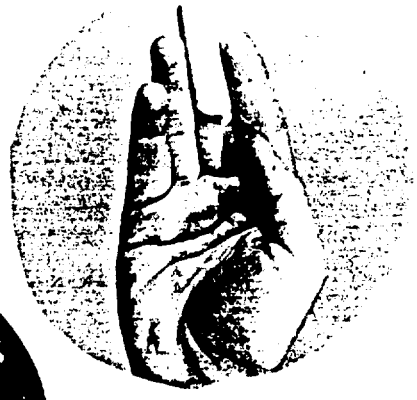
1136847

INSTRUCTIONS FOR MAKING A WIPE TEST

A few of the older cobalt-60 teletherapy capsules are developing minor leaks. Cleaning up these leaks is very expensive and periodic wipe tests may save you money.

---

1. Use a piece of filter paper (5.5 cm diameter) from any chemistry or pathology laboratory. (Write your name and date on the filter paper.)



2. Place filter paper between fingers as illustrated.

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3. With the machine turned off, make one wipe inside of the teletherapy cone between the source and the patient as close as possible to the source.

4. Fold filter paper 4 or 5 times (into a small ball).

5. Place the balled-up filter paper in the bottom of a test tube.

---

6. Count background in any well counter (at least 3000 counts).

7. Count folded filter paper sample in same counter (at least 3000 counts).

---

8. If paper count is <u>less</u> than 10 times background, repeat in six months.

9. If paper count is <u>more</u> than 10 times background (or if it builds up on repeated tests) send paper to M. Brucer, ORINS Medical Division, P. O. Box 117, Oak Ridge, Tennessee, to help decide what further tests should be done and if the leak is reportable.

1136848

RADIATION WARNING SIGNS

CAUTION RADIOACTIVE MATERIALS AREA	*Indicates the presence of 500 microcuries or more* ABIDE BY POSTED INSTRUCTIONS
CAUTION RADIATION AREA	*Radiation exposure rates exceed 5 milliroentgens per hour* ABIDE BY POSTED INSTRUCTIONS
CAUTION HIGH RADIATION AREA	*Radiation exposure rates exceed 100 milliroentgens per hour* ABIDE BY POSTED INSTRUCTIONS
CAUTION HIGH RADIATION AREA WHEN UNIT IS OPERATING	*Radiation exposure rates exceed 100 milliroentgens per hour when unit is operating* ABIDE BY POSTED INSTRUCTIONS
CAUTION RADIOACTIVE MATERIAL CONTAMINATION	*CONTAMINATION* ABIDE BY POSTED INSTRUCTIONS

1136849

RADIATION WARNING SIGNS

1. Purpose

Radiation warning signs are to be used to inform personnel of real or potential hazards from radioactive materials, and of the steps or procedures required to avoid these hazards. These signs must be used in accordance with the instructions of this directive. Each person using or responsible for radioactive materials or radiation that constitutes a real or potential hazard is responsible for posting signs. The radiation safety officer or the building health physics representative should be called on for posting instructions not covered specifically by this section. The building health physics representative will maintain a supply of signs for use by the divisions.

2. Types of Signs

Type I CAUTION - RADIOACTIVE MATERIALS AREA

Used to indicate the presence of 500 microcuries or more.

Posting Requirements: Each room or area in which radioactive material is used or stored in an amount greater than 500 microcuries shall be posted with the Type I sign. This does not prohibit the use of the sign for smaller quantities if posting would assist in reducing the possibility of hazard. The right hand side of the sign shall be used to record pertinent information which must be known by persons entering the area to insure or increase their radiation safety. Examples of the types of information that may be required are as follows:

1. Types and quantities of radioactive materials in the area
2. Location of the radioactive material in the area
3. Requirements for entry into the area
4. Person to call in an emergency
5. Requirements for personnel monitoring on leaving the area

1136850

Type II CAUTION - RADIATION AREA

Used to indicate that radiation exposure rates exceed 5 milliroentgens per hour.

Posting Requirements: Each room or area accessible to personnel in which radiation exists at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 milliroentgen or in five consecutive days a dose in excess of 100 milliroentgen shall be posted with the Type II sign. The right hand side of the sign shall be used to record pertinent information that must be known by persons entering the area to insure or to increase their radiation safety. Examples of the types of information that may be required are as follows:

1. See numbers 1 to 5 under Type I sign
2. Floor plan of the area showing the location and level of radiation
3. Personnel dosimetry requirements to enter the area

Type III CAUTION - HIGH RADIATION AREA

Used to indicate that radiation exposure rates exceed 100 milliroentgens per hour.

Posting Requirements: Each room or area accessible to personnel in which radiation exists at such a level that a major part of the body could receive in any one hour a dose in excess of 100 milliroentgen shall be posted with the Type III sign. The right hand side of the sign shall be used to record pertinent information that must be known by persons entering the area to insure or to increase their radiation safety. Examples of the types of information that may be required are as follows:

1. See numbers 1 to 5 under Type I sign
2. See numbers 2 and 3 under Type II sign

1136851

Type IV CAUTION - HIGH RADIATION AREA - WHEN UNIT IS OPERATING

Used to indicate that radiation exposure rates exceed 100 milliroentgens per hour when unit is operating.

Posting Requirements: Same as for CAUTION - HIGH RADIATION AREA except that the sign is to be used where high radiation levels exist only when the unit is operating. In addition to the sign, some form of alarm (light or bell) must indicate when the unit is operating.

Type V CAUTION - RADIOACTIVE MATERIAL CONTAMINATION

Used to indicate the presence of contamination.

Posting Requirements: To be used only under the direction of the radiation safety officer or the health physics representative. When contamination exists the health physics representative is to be called for specific posting instructions.

R. J. Cloutier
Radiation Safety Officer

November 1959

1136852

PREVENTIVE MEDICINE FOR YOUR COUNTING EQUIPMENT

D. A. Ross

Some of our training and other equipment has been taking a savage beating at the hands of newcomers who, although well-meaning, have not learned how to treat the instruments kindly. In the hope of improving this situation, we are giving this set of instructions to each visitor as he checks in. Please read and absorb this information before you use the counting equipment.

Humane treatment of scalers

Scalers are the electronic gadgets that count the pulses coming from a Geiger-Mueller tube or a scintillation detector. They usually have flashing lights here and there, and a register that clicks every time the lights tick off a selected number of counts --- 64, or 256, or 1000, etc. The health of a scaler will depend very much on how it is treated, and the following suggestions are offered in an attempt to lower the morbidity rate.

Turning a scaler on -

BEFORE you fire up a cold instrument:

(1) Turn the high voltage down --- that is, fully counterclockwise. If this is not done, the high voltage may overshoot before its regulating circuits take control, and excessive voltage can wreck the detector.

(2) Turn the power switch off. If this switch is on when you plug in the regulating transformer (3), a heavy surge of current may occur, and this can blow a fuse. Little damage, but a blasted nuisance.

Then,

(3) Plug in the regulating transformer --- if you need one.

(4) Turn the power switch on.

(5) After a minute or so, turn up the high voltage, slowly, to the proper operating level. If you're not sure what this should be, PLEASE FIND OUT, before you damage something. Tap the meter gently as you adjust the voltage; some meter movements are sticky.

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Turning a scaler off -

The next person to turn the instrument on may not be you, so he may be a moron. You can't help that, but you can at least leave the controls set so that if he carelessly slams on the power, without looking first, he won't hurt anything. Accordingly:

(1) Turn the high voltage down --- that is, fully counterclockwise.

(2) Turn the power switch off.

(3) Unplug the regulating transformer, since it will overheat when not loaded.

Question: Should you turn a counter off or leave the power turned on?

If it's going to be wanted again tomorrow, or sooner, don't turn it off, for the cooling and re-heating will do more harm than the extra day of ageing. The cost of the power consumed is small; repairs are expensive.

Exception: BATTERY-operated instruments must be turned off!

Standby operation

If you decide to leave an instrument turned on, there are some things you can do that will postpone old-age failures. Let us consider the scaler first and come to the detector later; sometimes their interests conflict.

The scaling circuits last longer if they are kept counting. If pulses are coming in, either from the detector or from the 60-cycle power line, the binary circuits keep switching back and forth from one side to the other, and the wear and tear is divided equally between the two halves of each tube. If you routinely leave the scaler reset to zero, on the other hand, the standby wear is all on one side, and failures will occur earlier. As far as the scaling circuits are concerned, then, it is better to leave them counting something.

The mechanical register, unfortunately, is something else; it will wear out if you keep it clicking. Some scalers have a switch that inactivates the register, and this permits the register to remain quiet while the scaling circuits count continuously --- an excellent standby arrangement. But if you can't shut off the register the scaler should count only slowly, for otherwise the register's loss may more than offset the scaler's gain. If the manufacturer hasn't provided you with a cut-out switch for the register, it is easy to put one in. In any case:

(1) If the register can be cut out, leave the scaler counting, either the background or the 60-cycle line. Have the whole of the scaling system in operation, not just the lower end of it.

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(2) If you can't shut off the register, the scaler must count slowly (perhaps background) or not at all. In the latter case, do not reset to zero --- just leave it showing your last count. Since each count is likely to be different, the ageing in the scaler will be better distributed if you do not reset.

Warmup times

Shortest:	Ordinary Geiger-Mueller counters (15 minutes or so);
Intermediate:	Halogen-quenched GM counters (about 1 hour);
Longest:	Scintillation counters (half a day, or overnight)

Reasons - The ordinary, alcohol-quenched GM systems do not require a long warmup time because the tube does not demand high-quality performance from the associated circuits. If you set the high voltage correctly, so as to operate the tube on its "plateau," a small drift in voltage will not alter the count rate significantly; consequently a rather ordinary grade of high-voltage stabilization is adequate. If the line voltage is reasonably constant, you might even get by without a regulating transformer. The halogen tubes are more fussy about the high voltage, so you let the scaler warm up for a longer time. The scintillation counters are still more fussy. In the Francis-Bell "medical spectrometer" the last thing to settle down is usually the zero on the rate-meter; check this before you start using the meter, particularly if your sources are so weak that the readings will be low. If the zero has drifted, you can reset it with the screwdriver adjustment.

Detecting devices

Classification:

(a) Ionization chambers - don't concern us here; turn off when not in use.

(b) "Pulse" counters (all of which involve scalers) -

(ba) Geiger-Mueller counters

(baa) alcohol-quenched GM's

(bab) halogen-quenched GM's

(bb) Scintillation counters

"Standby" policy:

Limited life; reduce voltage

Unlimited life; leave controls in operating position

Ordinary GM tubes (alcohol-quenched) -

In a GM tube the discharge caused by an ionizing particle must be quenched or the tube will "stay lit." When the quenching gas is alcohol, a little of it gets used up each time the tube fires; consequently the tube will count only so-many pulses and then expire. During standby, then, the tube should be inactivated.

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(1) Take the source away when you've counted it. Although the scaling circuits are shut off by the timer, the tube still counts any radiation that strikes it.

(2) Turn down the high voltage, for even after the source is removed the tube will still be counting background, thus shortening its life. When the voltage is low, the tube does not fire.

(3) Do not reset the scaler to zero; simply leave it showing your last count (see discussion under "Standby operation"). A better plan, if switching facilities are available, is to shut off the register and leave the scaler counting the 60-cycle line.

Halogen-quenched GM tubes -

These are much more rugged than the ordinary GM tubes, and they not only can, but should, be treated differently. They are almost student-proof: they can survive savage mistreatment with high voltage, they do not use up their quenching gas, and so they have a useful life that depends more on whether the manufacturer can keep their metal parts from corroding than on how many pulses they count. However, most of them suffer from the drawback that the plateau slopes more steeply than in an ordinary GM, so that the high voltage needs better stabilization and more careful adjustment (remember to tap the meter.) We therefore recommend a longer warmup time (1 hour), to let the circuits settle down adequately.

Since the halogen tubes do not wear out, they may be left counting background, with the voltage up at the operating level. This is good policy because the regulating circuits then stay at or near the working point, and drifting is minimized. Just remove the source when you finish counting it.

Standby operation -

(1) Take the sources away.

(2) Leave the high voltage at its normal, operating level.

(3) Cut out the register and leave the scaler counting, either the 60-cycle line or the background. If the register won't cut out, and background is more than a trickle, simply stop the scaler counting and don't reset.

Scintillation counters -

These devices always contain photomultiplier tubes, which are very fussy about their high voltage supply --- more so than either type of GM tube is. Consequently the regulating circuits should remain at the operating point in order to minimize drifting. You will almost always need an external regulating transformer, Sola or equivalent. Don't turn the machine off unless nobody is going to need it for two days, for warmup time is long --- say half a day, or overnight. Within reason, the crystal systems count pulses without wearing out.

Standby operation - same as for halogen-quenched GM tubes (see above).

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Regulating transformers

These are very helpful devices, but they are not fool-proof. They are so designed that if the line voltage (input) changes, the transformer's output voltage changes much less, and thus they supply "constant voltage" to the instruments that are powered from them. However, to make these transformers regulate properly they must be loaded up close to the rated capacity. The rated volt-amperes (v-a) are approximately equal to the watts for full load. Accordingly, you should operate a 105-watt medical spectrometer from a 120-v-a regulator, for if you use the 250-v-a size the transformer will be less than half-loaded and its performance will be poor. Changing the load will change the output voltage, so the load must contain no components that get turned on and off, unless their drain is negligible. If your laboratory is provided with a so-called "constant-voltage instrument line", obtained from a distant transformer, check to see (a) who else is riding on the line, (b) whether the total load is near the rated capacity of the transformer, and (c) whether your friends, or enemies,* who use the same line turn their equipment on and off or whether they leave it turned on. Generally it will be safer for you to have your own local transformer, for then you know what sort of load the regulator is driving.

If you turn off the load, unplug the transformer, so that it will not overheat.

If your detector contains a photomultiplier tube (as any crystal detector will), keep the detector at least 4 feet away from the regulating transformer. The magnetic field around the transformer disturbs the electron pathways in the phototube, changing the electron gain. For this and other reasons as well, the detector should provide adequate magnetic shielding (Mu-metal or equivalent) around the phototube.

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* One unforgettable day I found our regulated instrument line, 2000-v-a capacity, reeling under repeated blows from a 2500-watt, thermostatically controlled oven that some happy-go-lucky misanthrope had plugged into it!

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MINUTES OF THE FIFTH X-RAY INDUSTRIAL CONFERENCE

Oak Ridge Institute of Nuclear Studies Medical Division
Oak Ridge, Tennessee
December 1, 1958

Present:

E. E. Beauchamp	Oak Ridge National Laboratory
Mortimer Beem	Curtis-Wright Corporation
M. G. Brown	Atomic Energy of Canada Limited
Marshall Brucer	ORINS Medical Division
Frank Comas	ORINS Medical Division
Eimo Galvanoni	W. F. and John Barnes Company
William Gibbs	ORINS Medical Division
J. H. Gillette	Oak Ridge National Laboratory
Allen M. Goldstein	Isotopes Specialities Company
C. R. Griffith	Westinghouse Electric Corporation
J. Howard Harmon	ORINS Medical Division
C. H. Hetherington	Atomic Energy of Canada Limited
James Hitch	United States Atomic Energy Commission
Sam R. Hollingsworth	National Lead Company
J. A. Lenhard	United States Atomic Energy Commission
E. Llewellyn	Curtis-Wright Corporation
W. E. Parker	Nuclear Systems, Division of the Budd Company
E. E. Pierce	Oak Ridge National Laboratory
A. L. Rupp	Oak Ridge National Laboratory
E. Dale Trout	General Electric Corporation
Yoichiro Umegaki	ORINS Medical Division
Ted Workinger	United States Atomic Energy Commission

The Fifth X-ray Industrial Conference was held in Oak Ridge for the purpose of evaluating four years' experience with the international teletherapy source capsule. Dr. Brucer informed the group of the recent ORINS' experience with a leaking capsule and the results of a survey of other sources. Since one or more leakages had occurred in the international source capsule, the primary objective of this meeting was to reach an agreement on recommendations to the United States Atomic Energy Commission, the Atomic Energy of Canada Limited, manufacturers of X-ray equipment, and other interested groups. A discussion on the production, availability, and encapsulation of cesium-137 sources was a secondary objective.

Leakage of the International Source Capsule

Dr. Brucer emphasized that the ORINS contamination problem was not serious but it was one that could have been serious. This group should recognize that serious contamination could occur from such leakages and that some modifications in encapsulation techniques are probably necessary.

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On September 8, 1958, a routine health physics survey, started in the laboratory section, indicated a background high enough to require investigation. About 11:00 a.m. a technician (working in the teletherapy facilities) went to another area where a thyroid scan was being made. As he approached the scanner the machine froze from the excessive counts. The scanner returned to a normal counting rate when the technician backed away. When this phenomenon was observed, it was reported to the health physicist who checked all personnel working in the area of the teletherapy equipment.

Wipe tests indicated that all equipment in the area was contaminated. The highest counts were found in the throat of the number one head of the Westinghouse cobalt-60 teletherapy unit. A spectrometric analysis of the wipes indicated that the contamination was cobalt-60. Health physics personnel of the Oak Ridge National Laboratory were consulted and plans were made to have that organization dismantle the teletherapy head and inspect the source capsule. The capsule was opened and a leaking seal was confirmed. The same source was repackaged and returned to ORINS.*

After the ORINS source leakage had been fully established, Dr. Brucer called a selected group of radiologists owning teletherapy equipment and requested that they check their source to determine whether other leakages had occurred. Fifty owners were sent a piece of circular filter paper 3 cm in diameter and were requested to make a wipe test on the throat of their teletherapy unit. When the filter paper was returned the net counts ran from 0 to 42 counts above background. (This test was based on highly selected samples.) Dr. Brucer indicated that a count 6 times above background be considered significant and worthy of a spectrometric analysis.

A teletherapy unit owned by Dr. H. Stephen Weens, Emory University School of Medicine, had an unusual but significant count. This source has been used approximately five years. There had been a radium leakage in an adjoining building and Dr. Brucer expressed an opinion that the contamination was radium and not cobalt. Dr. Weens did a spectrometric analysis but this had not been completed at the time of this meeting. (Later tests confirmed that this probably was not radium but was cobalt-60. There is insufficient activity to confirm the impression without unusual tests.)

In addition, surveys were made on ten shipping containers used by the AECL, USAEC, Picker X-ray Corporation, and the Bar-Ray Corporation. The survey indicated that container contamination averaged about twice background, which under average conditions should be considered as clean.

Mr. C. R. Griffith, Westinghouse Electric Corporation, X-ray Division, described another problem, which had occurred on November 10, 1958. He was called to New York to do routine tests on a Westinghouse unit that had just been

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* A complete report of the accident may be obtained by writing to Mr. W. D. Gibbs, Health Physicist, ORINS Medical Division, Oak Ridge, Tennessee.

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installed. While making the routine adjustment he followed their standard procedure of making wipe tests. Instead of using a filter paper he used a wipe-stick and tested the inside of a cone throat in accordance with the recommendations of the National Bureau of Standards Handbook No. 54. The level of counts was such that he obtained an AECL shipping container and returned the source to AECL for inspection. During the unloading process he looked at the face of the capsule with a mirror and found that the face was heavily corroded with a greenish-gray material, but found no other visual defect. After the machine was unloaded he made a wipe test inside the beta shield and did a spectrometric analysis that indicated cobalt contamination. Other surveys on the teletherapy unit indicated that all contamination was contained within the unit. At the time of this meeting the source was on its way back to the Atomic Energy of Canada Limited for further testing.

Dr. Brucer asked Mr. Hetherington whether the contamination on this source capsule could have been obtained from an AECL shipping container. Mr. Hetherington said that he could not give a definite answer to this question because the capsule had not yet reached their company. He explained their procedure for preparing containers for shipment and stated that he was of the opinion that the problem did not result from a contaminated shipping container.

The available evidence indicated that one leak had definitely occurred and that possibly a second one may have occurred. These leakages were not to be considered as serious; however, since considerable experience has been accumulated in sealing capsules, and since new sealing techniques have been developed, this group should review these techniques.

In the discussion that followed, it was emphasized that it would be very difficult to determine the actual cause of a given leakage. Some participants expressed an opinion that the leakage resulted from a faulty seal. Members of the ORNL staff emphasized that each capsule is tested in such manner that faulty seals would be detected before shipment. They expressed an opinion that the seal had ruptured from an accumulation of heat inside the teletherapy head or shipping container. Participants questioned how this heat could accumulate from the absorption of the gamma rays and it was pointed out that the design and construction of equipment and shipping containers may be such that the heat cannot be well dissipated by the source capsule in contact with the metal parts of the machine or shipping container. At this point the participants were informed of the plans of Atomic Energy of Canada Limited and the United States Atomic Energy Commission for changing over to a welded-type source container. Reports from various encapsulating companies indicated that they are already adopting the welding principle as rapidly as techniques can be put into effect. Mr. E. E. Pierce, Oak Ridge National Laboratory, gave a detailed description of the techniques they are using for sealing source capsules. His report is attached as an appendix.*

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* Appendix is a transcript of comments made as each slide was projected.

The group turned its attention to what should be done with the sources that are already in use in teletherapy equipment. The suggestion was made that all these capsules be removed and inspected; however, this would be a difficult procedure for many owners of sources. Dr. Brucer pointed out that a section of the Handbook 54 has not been followed very closely and he recommended that greater emphasis be given to periodic wipe tests as recommended by the National Bureau of Standards. He felt that if this procedure were followed, this should be adequate control over any leakages that might occur in the future. It was also pointed out that on many of the machines an additional beta shield acts as a container for any cobalt that might be loose inside the machine. The group concurred with this suggestion.

Availability of Cesium-137: Report by Mr. E. E. Beauchamp

Mr. Beauchamp started his discussion of the availability of cesium-137 by reviewing the current status of the availability of cobalt-60. At the previous meeting of the representatives of the X-ray industry there was some concern over whether enough cobalt-60 would be available to meet the industrial demands. He stated that the production of cobalt-60 has been such that the United States Atomic Energy Commission has stopped processing the isotope until the current inventory is appreciably reduced. The current inventory is being reduced at what is considered a satisfactory rate, and it is anticipated that before long the Commission will soon authorize further production of cobalt-60. One of the representatives of the X-ray industry wanted to know what the Oak Ridge National Laboratory and the Commission would consider a minimum inventory level. Mr. Beauchamp replied that this was a difficult question and no definite amount has been established at this time. He felt that he could assure continued availability of sources and that the minimum quantity that would eventually be established would be dependent upon the projected market. He reviewed the current catalogue cost of cobalt-60. Mr. Beauchamp explained that as of March 1958 the Oak Ridge National Laboratory was essentially out of the encapsulation business. They will do encapsulation only at the specific request of some governmental agency, which has obtained prior approval of the Commission. Mr. Beauchamp went on to emphasize that the Oak Ridge National Laboratory would no longer furnish cobalt-60 teletherapy sources as such.

In reviewing the cesium-137 production Mr. Beauchamp reported that ORNL had processed to-date about 13,000 curies of cesium and they have 10,000 more that should go to stock about one week after the date of this meeting. It was further anticipated that there would be a production of an additional 10,000 curies within this fiscal year (ending June 30, 1959).

The maximum specific activity of the cesium-137 is 30 curies per gram. This specific activity cannot be increased much higher without the use of a hot calutron. The developmental people of the Oak Ridge National Laboratory are looking at this problem and the laboratory has proposed to the Commission that a calutron be made available for the enrichment of the cesium-137. It is not anticipated that the calutron will be available within the near future. The cesium-134 content in the current production is about 8 per cent. The laboratory

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cannot predict with a certainty what will be the cesium-134 content of the next batch to be produced; however, they estimate that it will be somewhat lower than the 8 per cent. The percentage of the cesium-134 may be reduced by blending in some of the decayed materials that are now on hand. Mr. Beauchamp said that the Oak Ridge National Laboratory would like to have this group of industrial representatives indicate what level of cesium-134 they could accept for teletherapy sources. One participant reported on a source that had less than 1 per cent cesium-134. Mr. Beauchamp was acquainted with this source and pointed out that it had been made from fuel rods that were removed from a pile several years before the current processing and the cesium-134 had had an opportunity to decay to a very low level. It was stated that the quantity of cesium-134 present in fuel rods is dependent upon the length of time that the rod was in a reactor and the rate of power at which the reactor operated. A low-power reactor produces small quantities of cesium-134. Most reactors are operated at high level for various reasons and this means that most of the available fuel rods will be from reactors operating at a high-power level. Mr. Beauchamp emphasized that the Oak Ridge National Laboratory would not be able to take the current production material and store it for several years to allow the decay of the cesium-134. He stated further that they would from time to time probably have small batches of materials from very old fuel rods but since the quantity would be limited he could only use this material to blend with the expected normal production of 8 per cent. If the industry could accept some level between 5 and 8 per cent, ORNL could blend the available material to assure this level. If the industry should insist on very low levels of the cesium-134 content, it would limit seriously the quantity of cesium-137 that would be available for teletherapy sources. At the 5 per cent level he thinks the Oak Ridge National Laboratory could blend out several thousand curies of cesium for teletherapy sources. Mr. Beauchamp stated that as he understood the problem, the high energy of the cesium-134 was not a serious problem for therapeutic uses but the problem arose as a shielding or health physics protection problem. It was pointed out the use of material having a large quantity of cesium-134 would require shielding of approximately the same size required for cobalt-60. Many of the early purchasers of the teletherapy units had assumed that as soon as cesium-137 was available they would use cesium sources in units designed for cobalt-60 sources. Dr. Brucer stated that in a machine designed to hold cobalt-60 there would be enough protection to permit using cesium sources having approximately 20 per cent cesium-134 content. However, for a machine designed specifically for using cesium-137, a difficult problem might be encountered. It was emphasized that this problem could be solved in another way. Either the manufacturers or the owners of cesium units could buy sources having a relatively high percentage of cesium-134 content, set the sources aside, and allow them to decay until the cesium-134, with its half life of 2.3 years, had decayed to an acceptable level. The question was raised from the floor as to how the cesium-134 would affect the beam characteristics of a cesium teletherapy unit. Dr. Brucer stated that the cobalt-60 sources are considered as a monochromatic beam; however, if one takes a careful spectrometric analysis of this or any other beam one finds that he does not actually have a monochromatic beam. It was his opinion that the cesium-134 content at the level they were discussing would not in any way be objectional to a radiotherapist. The participants agreed that a cesium-134 content ranging between 5 and 8 per cent would be acceptable.

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Mr. Beauchamp announced that the Oak Ridge National Laboratory was still authorized to package cesium-137 sources for teletherapy units. He said that they would continue to do this until some private encapsulating firm expressed a willingness to take over this operation. If this occurs the Commission will then follow the same policy as in their withdrawing from the packaging of cobalt-60 sources.

Recommendations

It is emphasized that we know of no serious contamination accident that has occurred from cobalt-60 teletherapy sources. However, once for certain and probably twice an incident has occurred that could have been serious if not caught in time. Therefore, the participants concurred in the following recommendations:

1. The Standard Source Capsule should be changed to a double welded capsule design. This recommendation has already been adopted by the known manufacturers of teletherapy sources and is now in operation.

2. The NBS Handbook 54 should emphasize the necessity for periodic wipe tests. This recommendation is being sent to Mr. Carl Braestrup, the editor of NBS Handbook 54.

3. An additional shield should probably be recommended for each machine in order to forestall massive contamination should it occur. This is not a very strong recommendation. However, it is being sent to Mr. Carl Braestrup, the editor of Handbook 54, for the consideration of the Handbook 54 committee.

4. Cesium-137 sources should be sold with a cesium-134 contamination of less than 8 per cent on the date of sale. This recommendation has been transmitted to Mr. Beauchamp of ORNL. It appears to be a practical answer to the cesium-134, 137 mixture problem and has already been informally put into effect.

5. The United States Atomic Energy Commission should survey all teletherapy sources under their responsibility by a simple wipe test or some other similar easily accomplished means. No action as yet has been taken on this recommendation.

6. Although there is no definite recommendation, the participants of the Fifth X-ray Industrial Conference felt that some official cognizance should be taken of the impression that large teletherapy sources of the old design may begin to leak spontaneously after a period of time. These sources might be recalled after they have been fully used by the first customer and replaced with the new welded design before being shipped to a second user.

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APPENDIX

Remote Welding of Stainless Steel Containers

E. E. Pierce
Oak Ridge National Laboratory

Radioactive materials, such as Cs^{137}, Co^{60} and Ir^{192} are routinely encapsulated by the Isotopes Division at Oak Ridge National Laboratory. A dependable seal must be made to prevent leakage of radioactive material from the capsule. Customer requests for radioactive sources containing large amounts of activity and for use in high-temperature regions or in corrosive liquid media necessitated the development of equipment for sealing sources by welding. Previously, sealing of the sources was accomplished by gaskets and soldering.

The Heliarc nonconsumable electrode process involving no deposition of filler metal is used for the following reasons:

1. The shielded cells available for source fabrication, and equipped with Model 8 Master Slave Manipulators, are used for several different operations resulting in frequent changes of equipment. Therefore, it is desirable that the remote portion of the device be portable, easily decontaminated, and simple to operate.

2. Because of the inert-gas atmosphere, the Heliarc welds are stronger, more ductile, and more corrosion resistant than welds made with ordinary arc-welding processes.

3. The use of a flux is avoided, and thereby the possibility of the flux penetrating the container and causing corrosion is eliminated.

4. Type 316 stainless steel, which was selected for the source containers because of its weld ability and its resistance to corrosion from chloride salts and the atmosphere, presents no unusual metallurgical problems to the Heliarc process.

The power supply unit consists of a standard power supply assembly, which is a Miller electric welding machine, model SR-200-A, a control unit model SR-32A and an amperage control.

The model SR-200-A is a portable D-C welder 220/440V with three welding ranges.

The model SR-32A control panel provides for automatic flow of argon to prevent oxidation and for a flow of water to cool the electrode during welding requiring high current. It has a high-frequency stabilizer for arc initiation.

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The current is regulated by either a model RFC-23 foot control or a model RMC-23 motorized control. The motorized control permits the current to be gradually decreased after the weld has been completed, to prevent the formation of craters and pinholes.

Figure 1 shows the welding machine, control panel and foot control. The motorized control is not shown.

The remotely operated portion of the welding assembly is placed inside the heavily shielded cells and operated with manipulators and electrical controls from the outside.

Three remote machines have been fabricated and tested. Two of the units have been used to seal hundreds of containers filled with radioactive compounds and metals.

The first unit fabricated was designed to accommodate a wide range of container sizes. Containers varying from 1/4" to 3" diameter and 1/2" to 11" long are welded.

The frame shown in Figure 2 is constructed of stainless steel angles welded to form two sections. One section supports the electrode assembly and the container holder is hinged to the other section, which serves as a base. This permits the welding of containers in a horizontal position or in a vertical position. Figure 3 shows the assembly adjusted for welding in a vertical position. The base section is 36 x 27 inches with lifting rings. The support section in a vertical position is 29 inches high; the assembly weighs approximately 100 pounds.

The electrode holder used is a Machine Heliweld Holder No. 2302-2190 manufactured by Air Reduction Company, Incorporated. It is mounted on a movable arm that may be rotated from a vertical position to a horizontal position for making side welds on containers. The 2 per cent thoriated electrode is 1/16" diameter and is sharpened to a point.

The electrode is positioned by means of 2 reversible Bodine motors mounted on rack and pinion drives. Extensions on the motor shafts permit positioning the electrode with the manipulators in the event of motor failure. Switches to control the motors are located outside the shielded cell.

The motorized container holder consists of a 5-inch chuck mounted on a Graham model 20 W 30 variable speed drive with a speed range of 0 to 40 rpm. The chuck is chrome plated to prevent corrosion.

This assembly worked well for the larger containers but was difficult to adjust for the small-size containers.

Figure 4 is a photograph of containers 3/4" diameter x 6" long welded with this equipment.

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When it was found that most of the requests were for the smaller sources the second assembly was fabricated to accommodate small containers (Fig. 5). It operates in a vertical position with the same type of container holder and rotating mechanism. Reversible Bodine motors are used with a small lathe bed and cross feed to position the electrode. The electrode is a Heliarc model HW-9 and can be positioned at various angles by means of a ball detent assembly attached to the electrode holder. Figure 6 is a photograph of stainless steel containers welded with the small assembly. Three complete source assemblies are shown; the ones with the plain top are inner containers and the ones with the handling post on top are outer containers. The container walls are 0.020 inch thick. Double encapsulation is used with most dry powdered compounds to give extra protection against leakage.

Figure 7 is an enlarged photograph, approximately 100 times actual size, of a cross section of a weld made on one of the small containers. The thickness of the container wall is 0.020 inches. The curved line near the top is a result of the current tapering feature of the welding machine controlled by the motorized switch. This reduces the formation of craters or pinholes that may occur when the current is quickly decreased. The container is 316 stainless steel, and the plug is made of type 410 stainless steel, which is magnetic. This enables the customer to use a small permanent magnet or electromagnet to handle the sources.

The sequence of operations for welding a container is as follows:

The model 8 manipulators are used to secure the container in the chuck and to adjust the speed of the rotator. The current to the rotator is controlled by a switch outside the cell.

The electrode is positioned by two Bodine motors that are controlled by switches located near the operating face of the cell. The motors operate at 6 rpm and are reversible. The positioning of the electrode prior to the welding operation is important and must be closely controlled. The container and electrode are observed through a monocular that has been modified for a short-range viewing.

The welding operation is controlled by two switches. One switch starts and stops the rotator. The other switch operates the motorized control which maintains the current during welding and decreases it at the end of the welding operation.

Experience has shown that the following conditions are important for successful welding:

1. The surfaces to be welded should be clean.

2. The material inside the containers should be dry.

3. There should be practically no clearance between the surfaces to be welded. A press fit is preferable.

4. Thoriated tungsten electrodes should be used.

5. Simulated welds should be made in order to establish welding speeds and current settings.

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The third remote unit has been tested for performance but has not been used to seal radioactive sources. The unit consists of two parts: a drive unit that is placed inside the shielded cells and a control unit that is operated outside the cells.

Figure 8. The drive unit consists of an electrode positioner controlled by reversible Bodine or Brown instrument motors similar to the ones on the other units that have been described. A chrome-plated chuck is used to hold the containers. The rotating mechanism is driven by a Selsyn receiver enclosed in stainless steel to make decontamination possible. The receiver is connected electrically to a Selsyn transmitter unit in the control assembly. This permits close speed control from outside the cell and the unit is also reversible. Figure 9. The control unit contains a Zero Max Gear Head Motor drive that permits close control of the speed of the Selsyn units. Switches to control the Bodine motors are mounted on the central unit.

The three units described are used for the most part for the routine sealing of standard containers; however, many special containers have been sealed by welding, some of them requiring linear welds. Tools, holders, and adapters are fabricated as needed in order to seal the special containers.

Most of the sealed containers are leak tested by first cooling them after welding, then immersing them in hot water and watching closely for bubbles. They are then cleaned, checked for contamination, and stored for a period of 30 days. They are again checked for contamination and leak tested by immersion before being packed for shipment.

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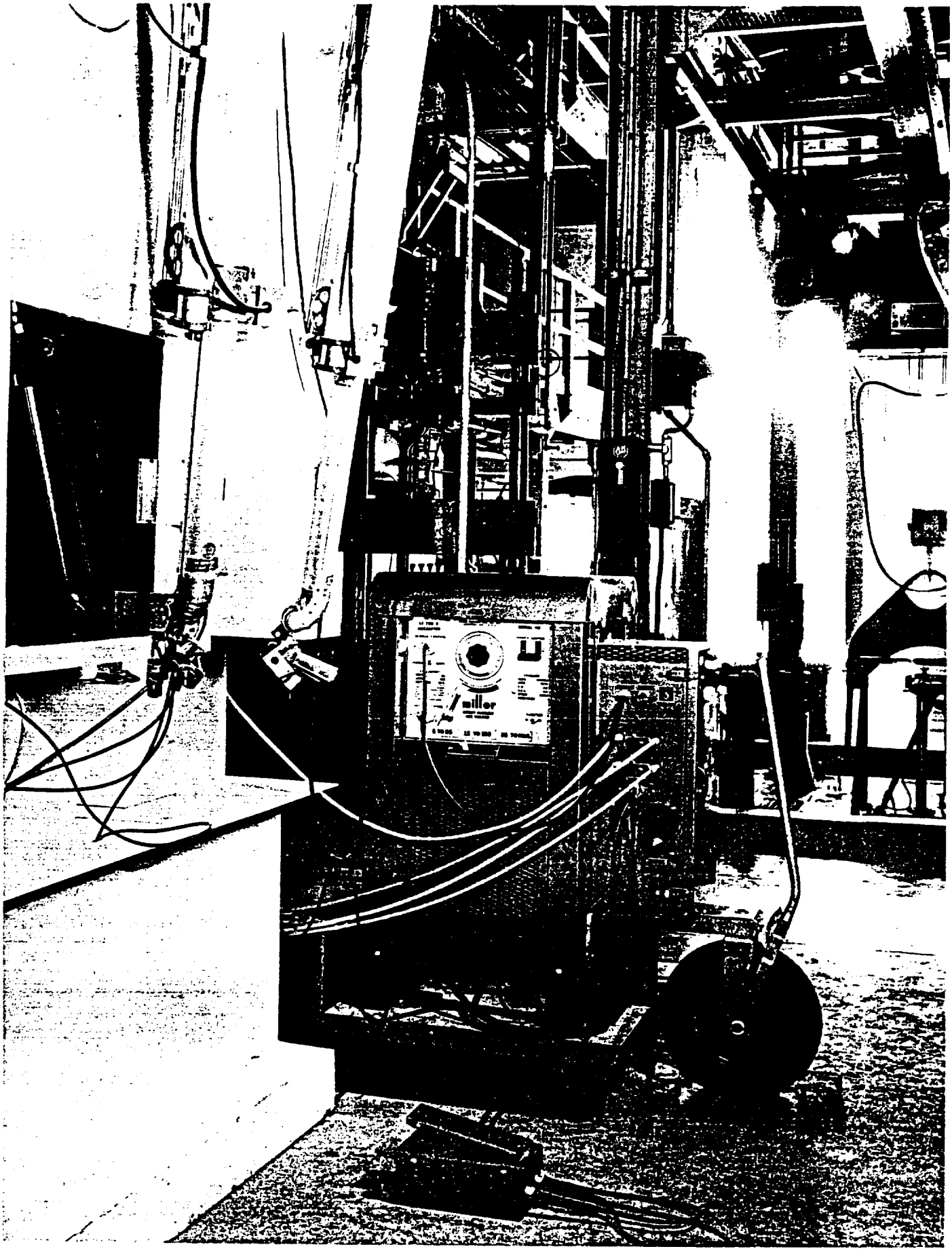

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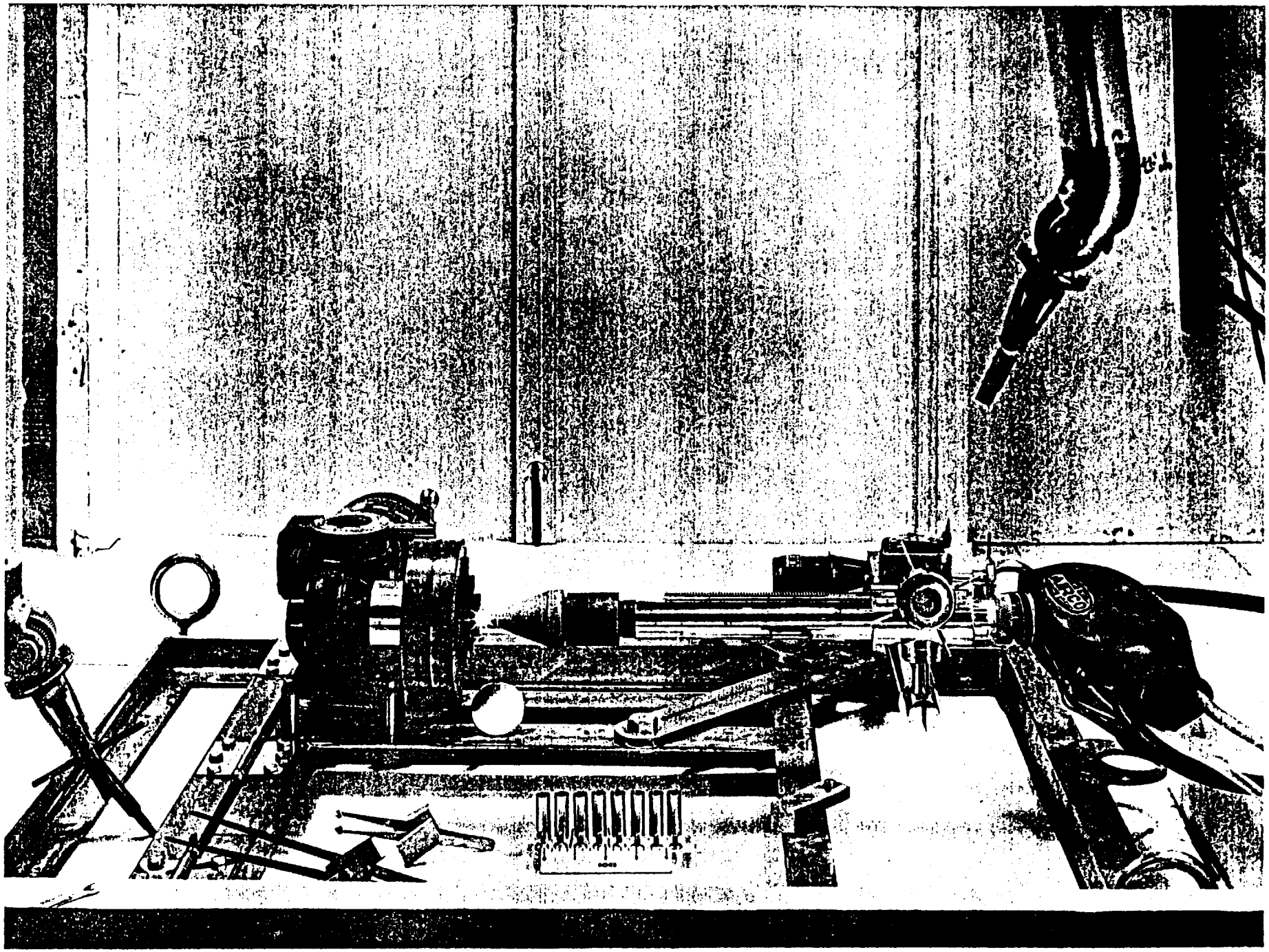

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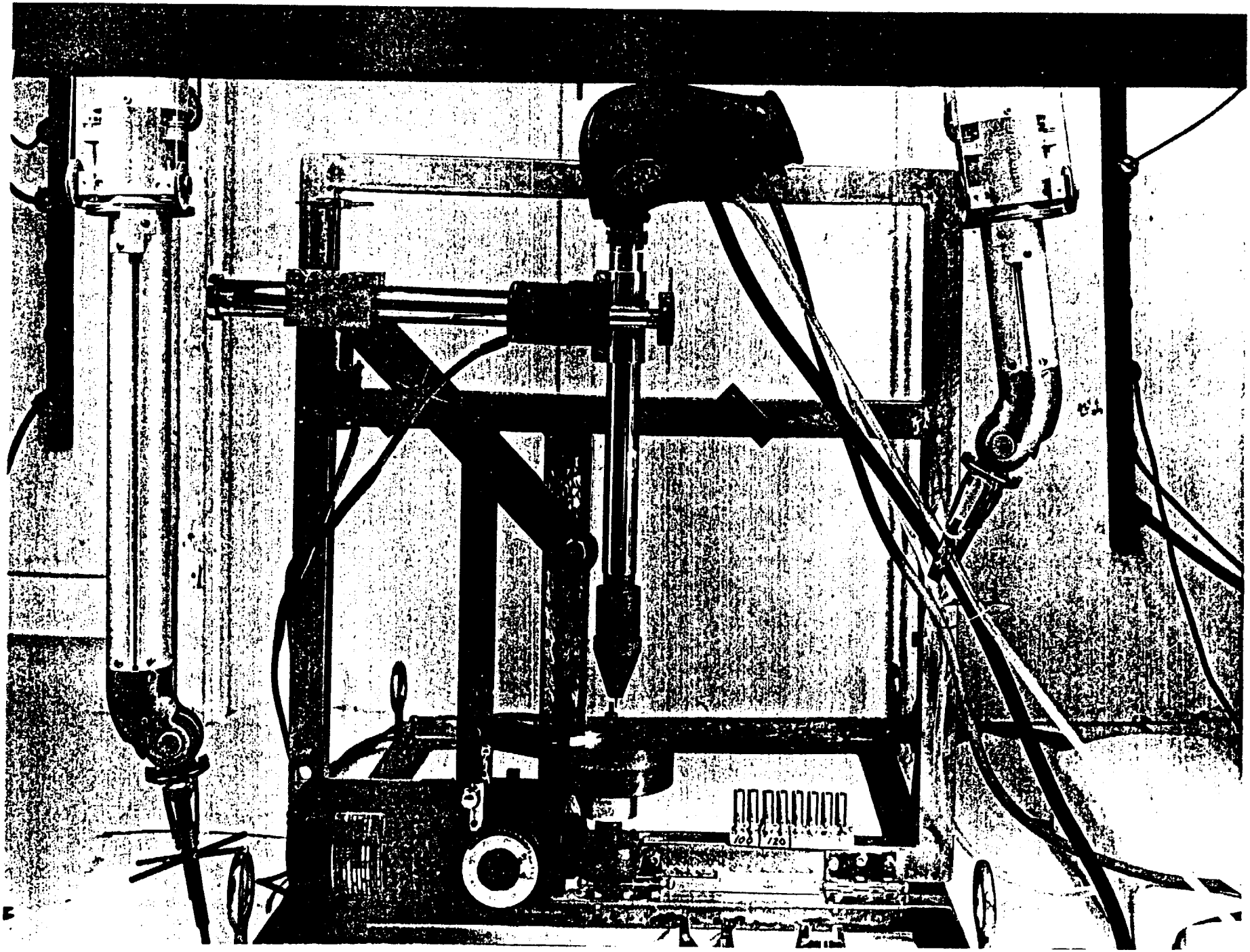

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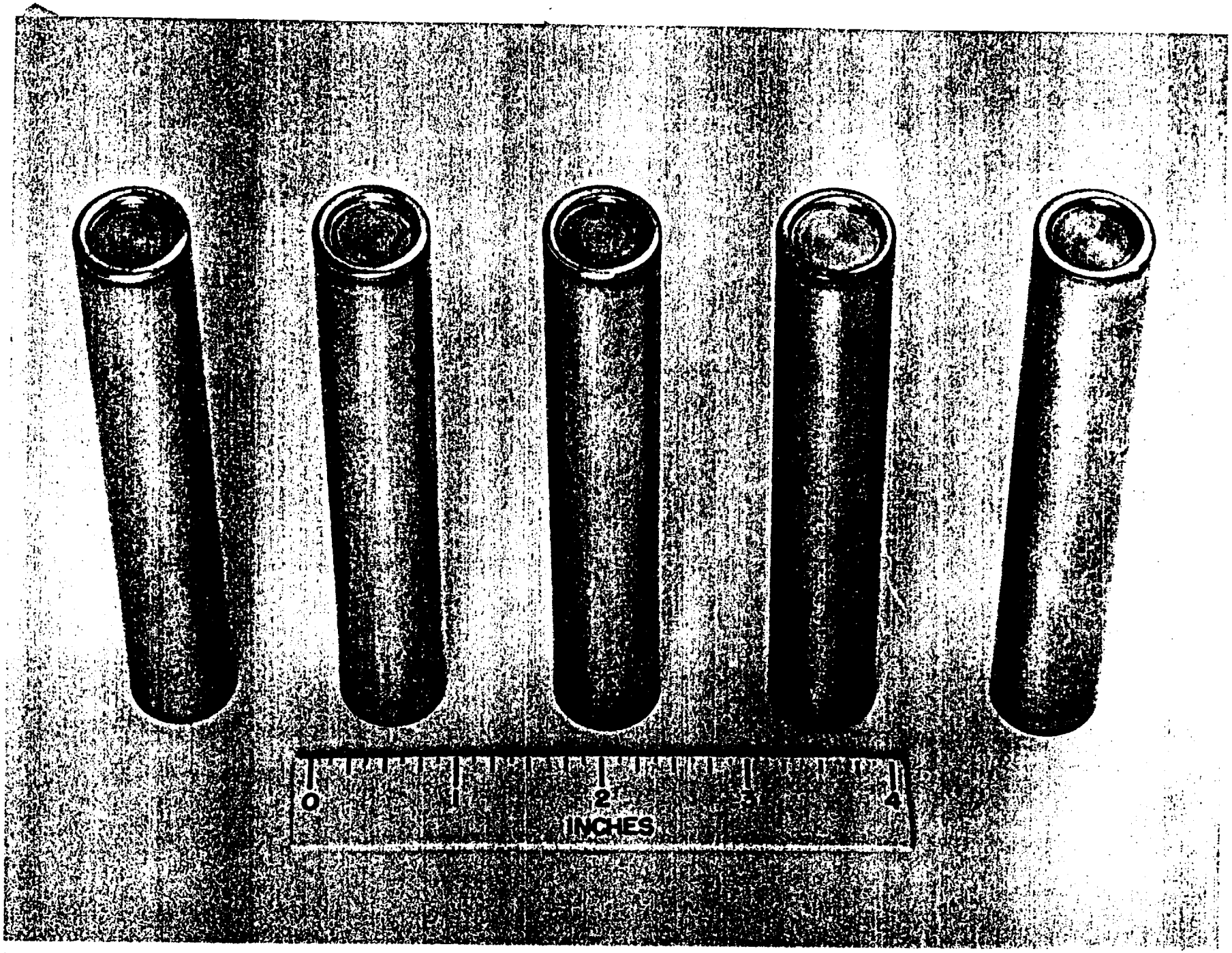

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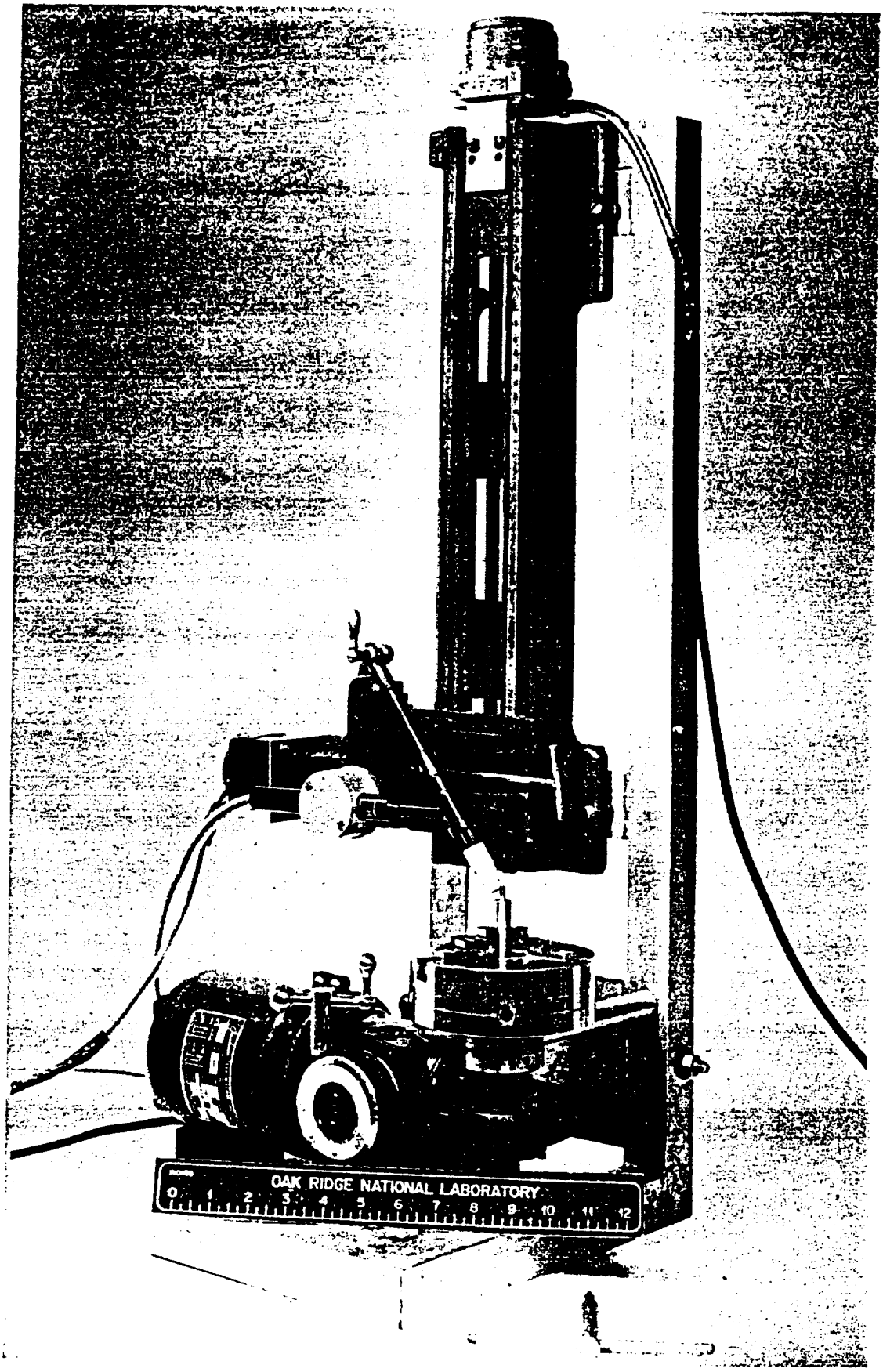

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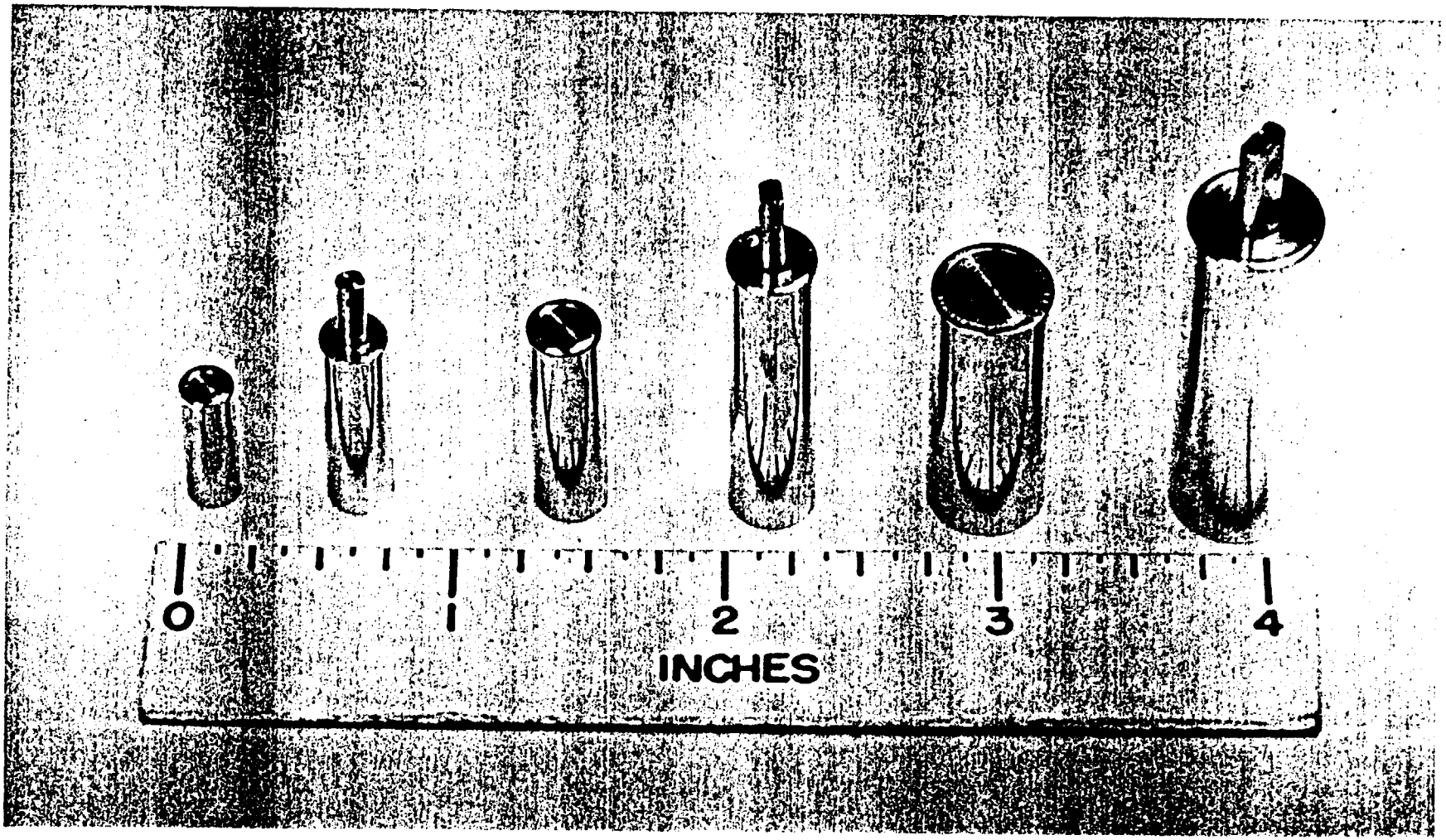

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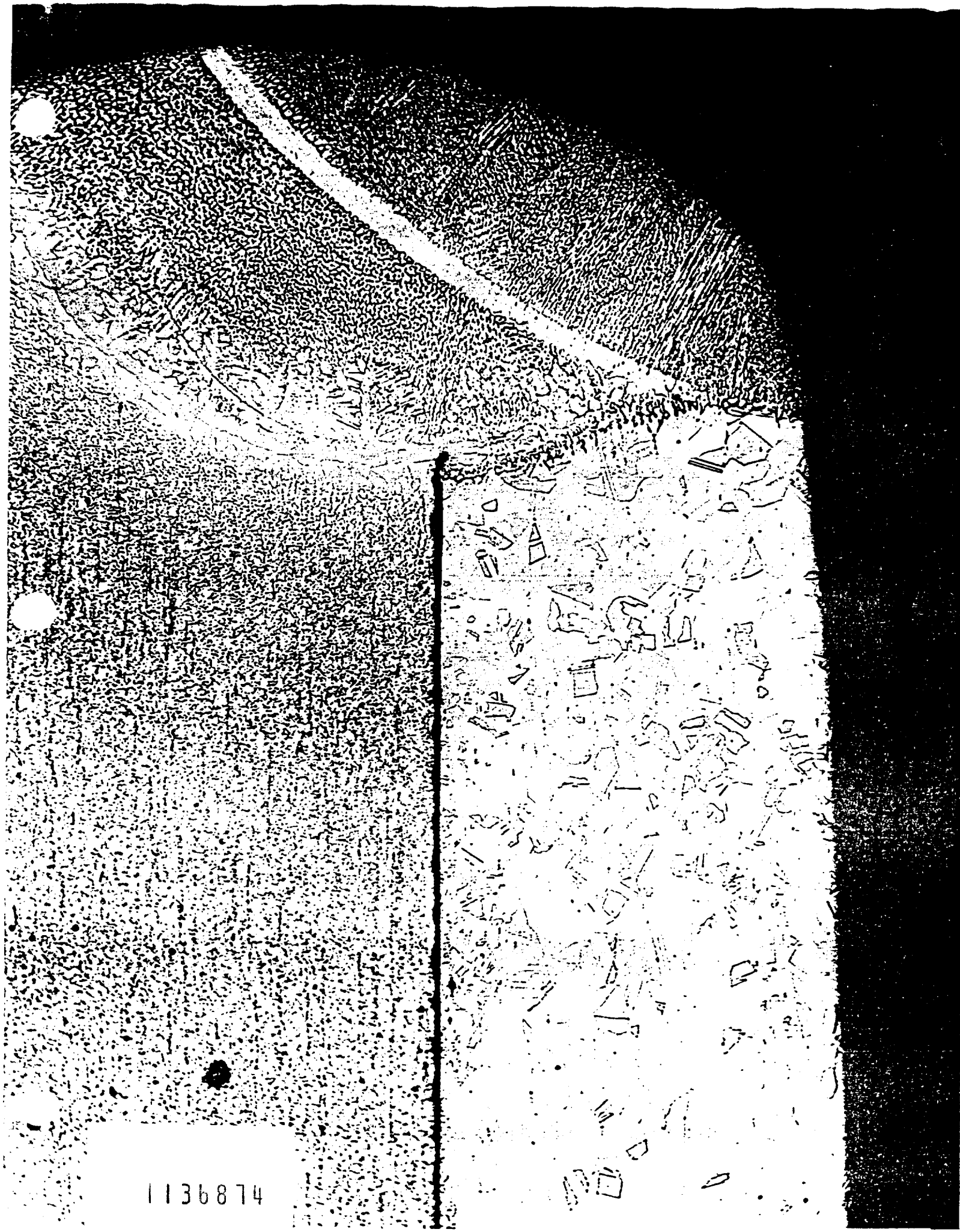
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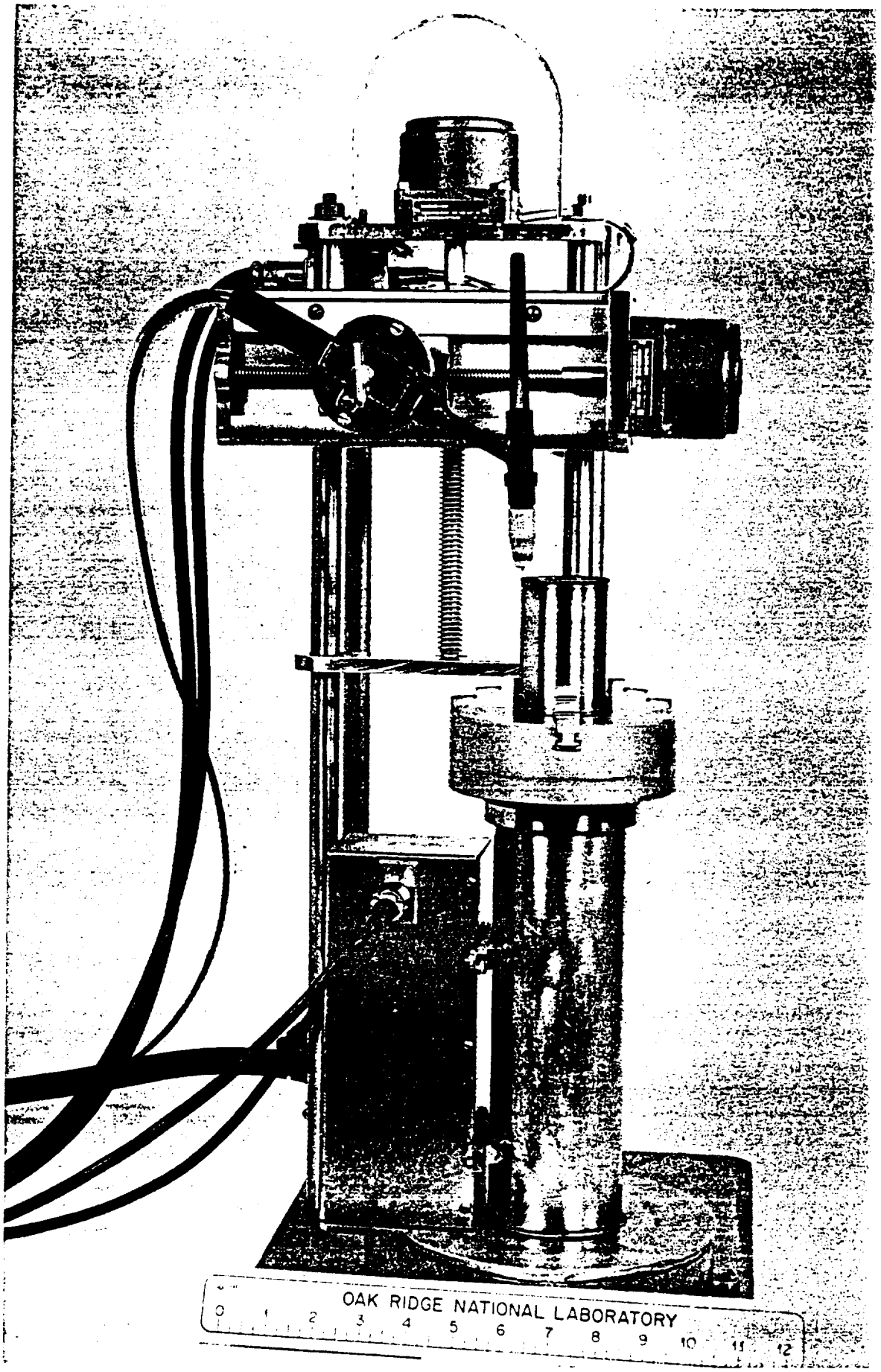

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LEAKS IN STANDARD SEALED TELETHERAPY SOURCES*

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Abstract—Teletherapy sources encapsulated in the United States and Canada from 1954 to 1959 were generally of the standard, single capsule, sealed type. One feature of the standard capsule was believed to be its tight seal and its ability to maintain this integrity. Late in 1958, a standard capsule source at the Oak Ridge Institute of Nuclear Studies (encapsulated 1½ years earlier with cobalt-60 metal pellets) developed a leak. This leak resulted in from 30 to 100 mc of activity being released before it was detected. Subsequent investigation of other sealed sources in the United States revealed that thirteen of 200 standard teletherapy capsules had developed leaks. A review of the possible causes of leakage, and of the standard capsule design, fabrication, sealing and initial and subsequent leak testing, has resulted in recommended changes to reduce the probability of future capsule failures. The incidence of failures already encountered, however, has made apparent the importance of routine leak testing of encapsulated sources.

INTRODUCTION

A SEALED source is generally defined as being any source that is encased in a capsule designed to prevent the leakage or escape of the radioactive material. The importance of preventing uncontrolled leakage of radioactive material was recognized in the early 1900's. Radium sources made at this time were frequently encapsulated. These capsules, however, sometimes failed, and widespread contamination often resulted with the attendant risk of persons ingesting or inhaling the radium or radon. The risk of source capsule failure is not a new problem.

When, in the late 1940's, radioisotopes became generally available, medical personnel recognized that the radiation from one of these isotopes, cobalt-60, could be used to advantage. Cobalt-60 offered a means of treating patients with photon energies in the supervoltage range. To produce photons of comparable cobalt-60 energy, two-million-volt peak X-ray units were required. These units are expensive to build and maintain.

It was recognized in the early design development of teletherapy units that they must be inherently safe and that a desirable feature would be the standardization of source capsules so that sources could be interchanged between units.[1] Thus a source that through decay was no longer adequate for one program could be transferred to another teletherapy unit that did not require so high a radiation output rate. The design of the first standard cobalt-60 teletherapy source was selected by the members of the X-ray industries, Atomic Energy of Canada, Ltd., and the United States Atomic Energy Commission in November 1953.[2]

DESCRIPTION OF THE FIRST STANDARD COBALT-60 TELETHERAPY CAPSULE

Most of the cobalt-60 sources produced for teletherapy units after January 1954 were of the standard cobalt-60 type. This was a single capsule, sealed by means of lead O-rings. The capsule (Fig. 1) consisted of a cap of tungsten alloy. Tungsten alloy was chosen because of its high density, its cost, and its ability to be machined. By placing the high density tungsten close to the source, where it could be used to best advantage as shielding, the overall weight of the teletherapy unit could be reduced. The

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end of the cap was open, thus permitting the γ-rays to pass through unattenuated in the direction of the useful beam. A cup of stainless steel fitted into the cap. A tungsten plug designed according to the shape of cobalt to be inserted was then fitted into the cup. Two lead rings were used to seal the unit. The first O-ring fitted at the shoulder of the plug, and the second fitted at the lid of the stainless steel can. The units normally held 1000 curies; hence, they were loaded remotely. To load the capsule the cobalt-60 was placed into the plug. The plug was then inserted into the stainless steel can, and the cap was placed over the can. With the lead O-rings in place, the units were screwed together with sufficient pressure to cause the lead O-rings to cold flow and form a leak-tight seal.

The units were then leak tested by the wipe method. This method consists of wiping the source capsule with filter paper and checking the wipe for contamination. Sources that showed negligible contamination were considered properly sealed. These sources were then held for about 30 days, when a subsequent leak test was made to ensure that the seal was maintained. If the source capsule passed both leak tests, it was shipped to the purchaser for installation in the teletherapy head.

DESCRIPTION OF REPORTED LEAKS

The design of the capsule and its testing before being used were believed in 1953 to be adequate for the prevention of leaks. In fact, routine leak testing after installation of the source was not required by the Atomic Energy Commission. The NCRP in the National Bureau of Standards Handbook 54, *Protection Against Radiations from Radium, Cobalt*-60, *and Cesium*-137, did, however, mention that smear testing of the source should be carried out.

A source, which was encapsulated in a standard capsule and had passed the 1957 standard wipe leak test, was placed in an Oak Ridge Institute of Nuclear Studies teletherapy unit. About a year and a half later, a leak developed and moderate contamination resulted. The capsule contained about 650 c of cobalt-60 in the form of cobalt metal pellets.

The manner in which the ORINS leak was detected is of interest, for some of the leaks noted at other installations were detected in a similar manner. A routine smear contamination check of the medical facilities had indicated that slight contamination existed. While a recheck of the areas was being carried out to determine the source of the contamination, a technician who had been working in the teletherapy rooms approached a NaI detector used to scan patients. The scaling unit attached to the detector began to indicate the presence of radioactive material. When the technician retreated and reapproached the detector, it was immediately apparent that he was contaminated. A spectrum of the contaminant indicated that it was cobalt-60. Monitoring of the teletherapy areas, where the technician worked, showed that contamination was more widespread in these rooms. Subsequent surveying showed that the contamination was from teletherapy head no. 1 of a two-headed teletherapy unit. The estimate made after an analysis of the many surveys and analysis of smears taken in the teletherapy area and in the cone of the teletherapy head indicated that from 30 to 100 mc of cobalt-60 had been released. Contamination of the medical facilities, although extensive, was not too difficult to decontaminate and only standard cleaning methods were required.[3]* The early detection of the leak and the control procedures used for the subsequent decontamination of the area were sufficient to prevent personnel exposures in excess of one-tenth of the permissible external and internal radiation exposures.[3] The teletherapy head containing the leaking capsule was sealed in polyethelene and the head was removed from its yoke. The head was sent to the Oak Ridge National Laboratory where, in a hot cell, the source was removed and examined. There was no external, visible sign of damage to the capsule. The source was removed from the capsule and the capsule and seal were examined. Some damage to the lead seal was noted.

Since one leak had occurred with the standard capsule, it was deemed advisable to conduct a pilot study and get in touch with some owners

* Reference (3) gives a detailed description of the leak and the problem of decontamination.

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of this type of source capsule and have them leak test their unit. At this time there were about 200 of the old O-ring standard capsules in use. Most of these sources were made by the Oak Ridge National Laboratory and the Canadian Chalk River Laboratories. Fifty owners of the old capsule type of sources were requested to leak test their units. The results were favorable in that there were no other apparent leaks. The leak testing technique used was similar to that recommended in NBS Handbook 54.[4] This method consists of smearing with a piece of filter paper either the capsule or parts of the unit that come into proximity with the capsule during some part of its movement.[3–5]

Since the request for leak testing was made, thirteen of the 200 standard capsules have developed leaks. Incidentally, although nonstandard capsules are not included in this report, it is known that three capsules of nonstandard design have developed leaks.

Decontamination costs for these leaks were always high. The costs, however, depended greatly on how soon the leak was detected after it started, the size of the leak, and the nature of the room in which the leak occurred.

CAUSE OF THE LEAKS

Although it is impossible to give the exact cause of the leaks, because complete studies were not carried out, causes can be postulated. One cause could be that the seals initially were not complete and that the test method used initially was inadequate. The method, as mentioned earlier, was the wipe test. This method is not a critical one because it does not actually measure the integrity of the seal.

For all leaks reported to date, there was a delay of more than one year between the encapsulation and the time that the leak was noted. This may be attributed to the fact that the source is a metal and many of them are coated with gold or nickel to prevent the surface from oxidizing. It is believed that cobalt oxide is the material that leaked from the capsules; if so, it would have been restricted in its formation and release. Therefore, a period of time would have to elapse before sufficient cobalt oxide was available for release.

Another possibility is that the seal was good at the time that the source capsule was checked, and that it failed only later. Seal failure could have been brought about by two causes. One, the failure could have resulted from the mechanical movement of the capsule or by the movement of the source itself inside the capsule. In general, the source is prevented from moving by means of shims. Repeated movement of the source could possibly have caused the failure of the mechanical seal, for lead acts like plastic and does not resume its original shape if deformed. The second possibility is that the heat generated by the source could have caused the seal to fail by causing expansion of the components, or could have melted the O-ring seal and caused it to flow. On cooling it would not return to its original shape. A kilocurie of cobalt-60 under certain conditions could reach a temperature high enough to cause this to occur. In most teletherapy units, however, there is a large heat sink in the form of the shielding and the shutter wheel to carry off the heat and prevent excessive temperatures from developing. In the loading, transfer, or storage of the source before loading, there is not always such a desirable heat transfer medium and high temperatures could be attained. The lead O-ring of the ORINS source that failed was damaged in one place. The damage was similar to that expected from melting. If failure was due to melting, it is not believed that the melting could have taken place in the teletherapy head because of the vast heat sink available to the source. In storage before loading, however, there were times when the source was in air with limited heat transfer. The O-ring failure may have occurred at this time. This, however, does not explain why the leak developed many months after the source was placed in the unit.

DESCRIPTION OF THE NEW STANDARD CAPSULE

Because the difficulty appeared to be at the O-ring seal, it was realized that the old standard capsule was not adequate, and that a new type seal was required. The size of the capsule was retained in order to permit the continued interchange of the units. The new capsule,

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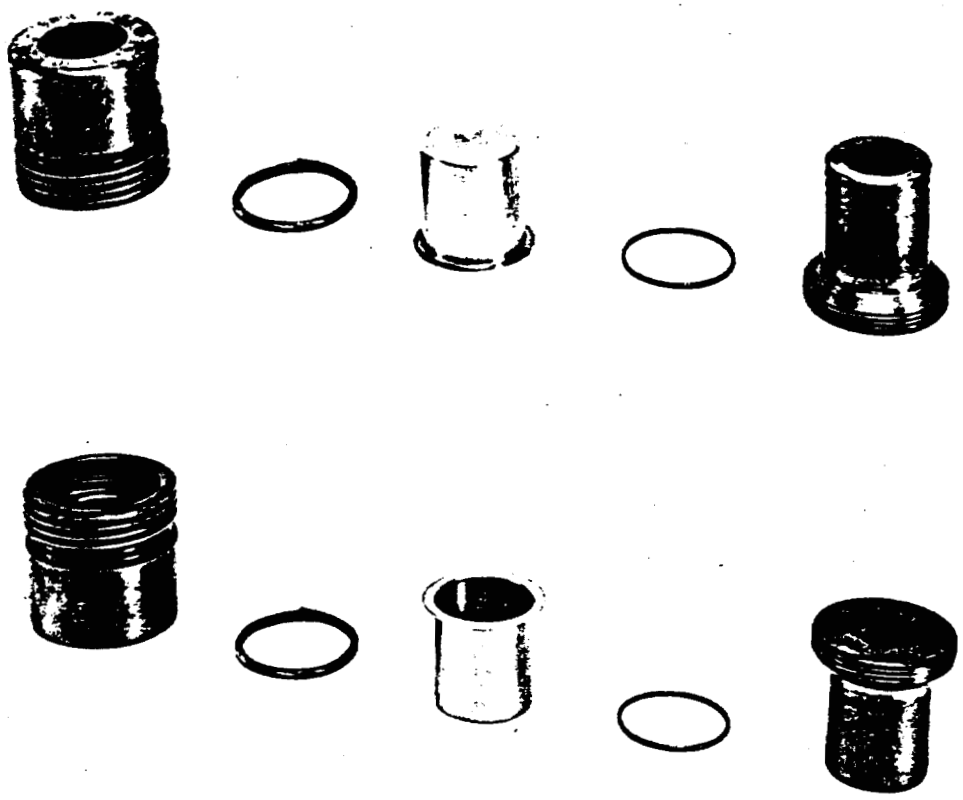

FIG. 1. Old standard teletherapy capsule.

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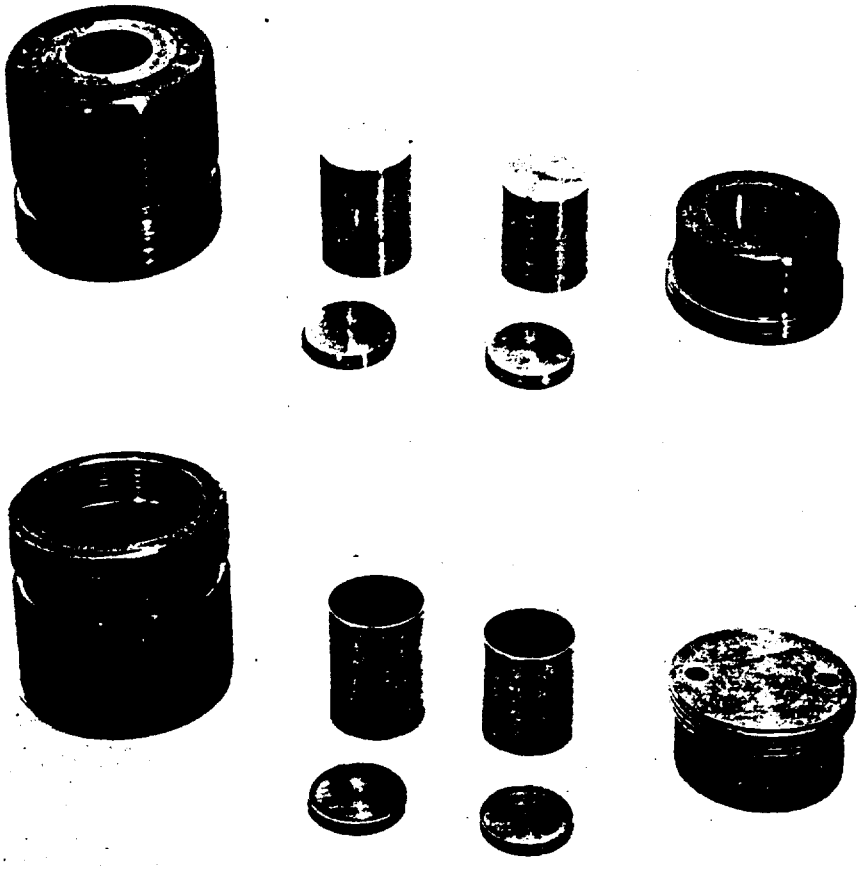

FIG. 2. New standard teletherapy capsule.

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recommended by the Fifth X-ray Industrial Conference in December 1958[3] is shown in Fig. 2. The capsule consists of a stainless steel can into which the cobalt is placed. The can is closed with a Heliarc-welded cap.[6] The sealed can is then placed in another stainless steel cup. A cap is placed on this cup and the unit is Heliarc welded closed. The source is now encapsulated in a double can, both of which are welded closed. As a check on the integrity of the seal, the capsule is leak tested by the heated water or helium leak test method before being installed in a teletherapy unit. The leak test methods now used actually measure the integrity of the seal. A wipe test, however, is still performed to determine the degree of contamination of the outside container.

The capsule after passing the leak and wipe test is placed in a capsule holder that has the same outside physical dimensions as the old standard capsule. Most of the units now being made are of this type. To date no failures of the new capsule have been reported.

SUMMARY

It is now known that thirteen cobalt-60 teletherapy capsules, encapsulated in the standard O-ring type teletherapy capsule have developed leaks. About 200 of these capsules are still in service. It is impossible to state the cause of the capsule failures that have already occurred, or to state that all the capsules that are going to fail have already done so. Certain general things can be said. Capsules that have leaked were in service for more than a year before leaks occurred. Also the cobalt dust that leaked usually resulted in rather widespread contamination before detection.

Until recently, AEC regulations did not require the routine checking of cobalt teletherapy capsules for leakage; however, the AEC now requires leak testing every 6 months. The new teletherapy capsule has been designed to reduce the possibility of leakage; however, it must be remembered that during the initial design work of the old capsule it was believed that the initial capsule "wouldn't leak in a million years." The problem of ensuring the integrity of capsules should be re-examined at each site, and especially at sites using the old type of capsule. Although this paper has dealt only with teletherapy sources, a comparable number of leaks has been noted for other uses of sealed sources. Periodic leak testing should be carried out regardless of the type of capsule or its use, if the problems of contamination and the attendant high cost of decontamination are to be avoided.

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