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REPORT NO. CH-708

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Human Subjects Project

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Metallurgical Project

A. H. Compton, Project Director

* * *

Metallurgical Laboratory

S. K. Allison, Director

* * *

HEALTH, RADIATION, AND PROTECTION

R. S. Stone, M.D., Division Director

* * *

REPORT FOR MONTH ENDING JUNE 7, 1943

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GENERAL SUMMARY

Dr. Robert S. Stone
Division Chief

Clinical, Medicine and Medical Research

The main interest of the medical section continues to be the health of individuals, with particular reference to the radiation hazards. No troubles have turned up on this score. During the month, a survey of the safety features of the metallurgical laboratories was made, on request, by Mr. R. B. Smith. This showed a high accident-injury frequency rate as compared with the chemical industry. The report points out the many factors contributing to the high rate, but indicates principally that this is due to the lack of interest, both in the leaders and in the men. It has been said that most accidents are due to recklessness, foolishness, and ignorance, none of which should be permitted on the project. Mr. Smith's report should be read in toto by every division director and every section chief.

Biological Research

The biological research has continued on a limited scale because Site B has not yet been available. Dr. Zirkle's discussion of previously obtained x-n ratios and those which he is finding is interesting. He shows that the γ ray energy in the mixed beams from cyclotrons without proper lead filter contributes so definitely to the effect that it completely upsets the x-n ratios made prior to the time when lead filtration was used. Dr. Mahon has started her work with the pathological material in order to find criteria of early cell injury. Total body radiation with β rays has started on mice, but it is too soon to give any results.

Health Physics

The physics section has been engaged in two major calculations during the month, one on radioactivity in the river at Hanford which showed that there was nothing to be alarmed about, and the other on the military uses of fission products. These reports are not for general circulation. A recording integron for use at Site M and probably for more extensive use at Hanford has been operating and seems to be fairly satisfactory. The film radiation meter is still being worked upon and while it looks as if it may be possible to construct a meter that will be satisfactory for radiations from 70 kv up of kinds of radi[illegible] it will not be satisfactory for β rays or neutron exposures. Investigation into various types of measuring instruments is still continuing and being extended.

It has finally been decided that probably the most accurate method of measuring the β ray emission from the surface of the metal is by the accumulation chamber method. Drs. Taylor and Kanzmann in [illegible]ement that β ray emission from the metal amounts to .22 r/hour or radiations of sufficient energy to penetrate into the [illegible] layers of the skin. At a meeting of Drs. Warren, Bollen, Friedell, and Stone, it was decided

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that a tolerance figure of [illegible] r/24 hours for the hands when exposed to [illegible] rays should be established and maintained for the next six months or until further information is available. It is felt that this dose is absolutely safe for a period of six months' exposure and it may be safe for much longer periods. Thus, with Mr. Parker's reading and this tolerance dose it will be possible for an individual to have his hands in contact with the metal for over two hours per day. It is doubtful whether many workmen exceed this limit.

Mr. Church outlines the meteorological studies being arranged for Site W. They have obtained four meteorologists who are going to make studies on the grounds.

U.C. Radiation Laboratory

Dr. Hamilton reports that 16 days after the intra-pulmonary injection of unseparated f products, from 1/5 to 1/3 remained in the lungs and almost all of the absorbed material was in the skeleton. Sixteen days after oral administration of the same material, 3% to 5% of the activity was absorbed and 70% of the absorbed portion was in the skeleton.

Injected ruthenium concentrated in the kidneys at the four day interval and excretion was by way of the kidneys. When introduced into the lungs directly, it tended to stop there. When given by mouth, there was no appreciable absorption from the gastro-intestinal tract.

A preliminary experiment using short-life products for inhalation 20 seconds after bombardment showed these to be distributed throughout all the tissues after one hour of exposure. Radio-autographic studies have been started with re[illegible] f mixtures, cerium and ruthenium.

N.C.I.

Dr. Henshaw calls attention to the fact that acute doses of 200 r (x-rays) when given to the whole body of guinea pigs is lethal, whereas Drs. Lorenz and Heston have given doses up to 800 r (γ-rays) protracted over several months and at low intensities with no lethal effect. "This observation alone furnishes strong evidence that the rate of administration is an important factor in determining the degree of effect."

The experiments on continuous exposures for 8 hours daily with doses up to 3 r/day at rates up to 1 r/hour have not shown effects as yet, even though some mice have already received 600 r. Single acute exposures of 12.5 r at a rate of 0.[illegible] r/hour superimposed on the above have shown no effect. Single acute exposures of 30 r at the rate of 11 r/hour do show some effect but the animals recover by the fourth week. Guinea pigs are a little more sensitive to these doses than mice.

Mice who have received continuous exposures for [illegible] hours/day at the rate of 1 r/day up to total doses of 600 r have been bred and have average size litters. (breeding 18 days after finishing exposure). Previously mice of another strain (C3H) had become sterile after total doses of 100 r at the rate of 1 r/day. Age or strain factors may account for this.

[illegible] (blood count) the total dose is much [illegible]

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J. A. Hospital

The total body radiation of eight incurable patients at the U.C. Hospital is briefly reported to date. So far as one can generalize from so few cases, this shows that individual doses of 10 r given in around 10 min. at daily intervals have very little effect up to total doses of 300 r. Doses of the order of 20 r up to 200 r have little subjective effect, but occasionally cause some disturbance to the patients. Doses in the neighborhood of 30 r occasionally cause temporary weakness and very occasionally, nausea. If doses of equal quantities of 200 and 100 kv x-rays are given, the higher kilovoltage radiations are likely to cause more marked changes. The blood counts of nearly all of the patients are somewhat disturbed by the doses given but it is too soon to tell the final result.

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A. CLINICAL [illegible] AND [illegible] RESEARCH

[illegible]

1. Laboratory and Clinical Control

There have been no abnormalities of blood count directly attributable to radiation which have appeared during the month. Blood counts on personnel at Argonne have been placed on a more frequent basis.

2. Plant Surveys

Drs. Nickson and Norwood have revisited two plants concerned with casting and machining of the metal cylinders. The Health Division report of the previous month (CH-630) contained a survey of the original findings and recommendations. Conditions were essentially the same as previously reported, with the exception of the introduction of fume masks in one plant. No significant findings were encountered.

Plants supplying metal are now being surveyed from the health standpoint by the Army. Our own group functions in a consultant capacity for certain plants holding contracts with du Pont, and is ready to serve in the same capacity for the Army upon request.

3. Toxicology.

Dr. Tannenbaum is proceeding with the autopsy analysis for T distribution in the body of animals which have been fed varying daily amounts of oxide or nitrate over a period of seven months. A detailed study of x-material deposition in the mice is proceeding by injection of large amounts (lethal) of the nitrate.

4. New Personnel

Dr. Margaret Nickson has joined the Section of Clinical Medicine. Her duties for the present are those of assisting in examinations and in reviewing pertinent literature. During the past month she has been preparing an analysis of the normal leukocyte values, which has formed the basis for considerable discussion referable to borderline abnormal values encountered among personnel. This will be issued shortly in a separate report.

5. Accident Prevention

The following is the report of Mr. R. B. Smith who was requested to survey the Metallurgical Laboratory and recommend measures to improve the safety of working conditions. In regard to recommendation No. 19, the University of Chicago who is the employer has arranged for the care, at the University Clinics, of accidental injuries occurring anywhere in the University including the Metallurgical Project. We have attempted to expedite this care, but further steps do need to be taken to improve facilities. In this respect we are trying to arrange more efficient measures with the University so that injuries can more promptly be cared for.

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5. [illegible] - R. [illegible] Smith

The Chicago X-10 Project was reviewed May 17th through May 24th to determine methods by which the injury frequency rate on this Project could be reduced. Conclusions of this study are listed below.

Injuries on the X-10 Project from October 1st, 1942 to April 30th 1943 were reviewed with Dr. Cantril. Since complete detailed records of injuries and employment during this period were not available, classification of injuries were largely based on accident details as judged by Dr. Cantril. This data shows an average X-10 Project accident-injury frequency rate per million man exposure hours of 44.6, compared to 7.5 for the chemical industry as a whole (1939). This high accident rate is attributed to the following factors which are based on accident analysis and inspection of Project buildings.

1. 34.5% Lack of Administrative interest in preventing injuries.

2. 33.8% Lack of employee safety morale.

3. 14.15% Improper method of doing job.

4. 10.45% Poor housekeeping.

5. 4.38% Improper equipment design.

6. 2.7% Failure to provide safety devices.

The above shows that human failures were the direct cause of most X-10 injuries, which failures were largely attributable directly to Administration.

Administration laxity in safety work was partially indicated by -

1. A comparatively poor standard of housekeeping allowed to exist in many buildings.

2. Failure to correct many mechanical conditions even after recurring injuries from the same cause had taken place.

3. Failure to investigate accidents and determine methods for preventing recurrence of similar accidents.

4. Incomplete records kept of injuries occurring on the Project.

5. Lack of any organized safety program.

To date, accidents have been largely accepted on the Project as "inevitable" and accident prevention work looked upon as desirable although many appear to seriously feel that such work would slow down the Project. With [illegible] exceptions both of the above assumptions are false.

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(1) Accidents are not inevitable, there are underlying preventable causes, elimination of which can prevent injuries.

(2) Safety work if properly carried out results in increased job efficiency and can speed up the project as a whole.

These basic facts must be recognized, believed and accepted by top supervision before any contemplated safety program for the X-10 Project can be effectual.

Although placing of a full time safety engineer on this Project is desirable to investigate and coordinate safety activities, it is far more important for the immediate future that steps be promptly taken by Administration to stimulate the thinking of the entire organization that it is a part of every man's job to see that work under his jurisdiction is done safely.

This statement is meant to be broadly interpreted since in general no man knows the details of an individual job and its attendant hazards better than the individual himself. Where specialized work is continually changing from day to day this point is of particular importance since rigid general methods for accident elimination would be difficult or impossible to formulate to any marked detail. Towards this end it is suggested that the injuries of each Section to date be reviewed by the Section leader and a report made to Administration indicating what steps have been taken to prevent recurrence of these injuries. This method of carrying out safety is simple in that past experience to a major degree is used as a guide in formulating an accident prevention policy and originates, on a whole, from the individual. A periodic injury summary report sent to Administration by Section leaders not only serves as a guide to Administration in determining additional steps required for promoting safety but in addition allows analysis of progress made up to that time.

Formation of individual Section Committees to inspect and constructively criticize from a safety standpoint other sections on the project would serve to stimulate unification of safety methods. By allowing the passing on of safety methods from one section to the other, as well as educating members of the Inspection Committee by visual observation of safe conditions in other areas. Most important, individual thinking along safety lines is stimulated. Such inspections should be made monthly and a written record of findings sent to the area concerned, with a copy to Administration. Committees should stress elimination of unsafe conditions, unsafe practices, and improvement of housekeeping. Interpretation of individual controversial points should be referred to Administration for decision (or to the Safety Engineer).

The above two simple points are believed the most important contributions that could be made toward immediate improvement of the injury record of this Project.

The entire safety program recommended for immediate adoption is summarized below and detailed in a seperate section of this report.

1) Administration must be made to recognize the need for all employees (including Administration) to take an active part in a laboratory-wide accident prevention program.

2) A full time safety engineer should be employed to coordinate, analyze, inspect and promote safety activities.

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2) Detailed records of all accidents should be kept and frequently analyzed.

3) Each accident should be investigated and methods developed to prevent recurrence.

5) Section leaders should meet at least once each month with the Assistant Director and Safety Engineer to review the safety program as a whole and formulate basic policies.

6) Safety rules applicable to the whole Project should be formulated by the above Committee, issued by Administration and enforced.

7) Each Section leader should meet at least once each month with employees under his jurisdiction for discussion of safety subjects and reviewing of suggestions.

8) Section heads should make frequent (tri-weekly) high spot inspections of their area and verbally pass on suggestions as found necessary to insure maintenance of good housekeeping and enforcement of safety rules.

9) Safety rules for each section should be formulated and enforced.

10) Committees appointed by each Section head should carry out monthly inspections of another section and a written report to be issued to all concerned. All suggestions thus made to which the section concerned does not agree should be submitted to the safety Engineer for arbitration.

11) Reduce congestion within buildings.

The above program should serve as a nucleus for future modification as found necessary. It is believed that this program will result in reduction of the accident frequency rate within a period of 6 months or less from the present 44.6 to about 5.0 injuries per 1,000,000 exposure hours.

General Recommendations

Rec. 1. Injury Reporting, Investigation and Classification.

It is impossible to make a complete analysis of injuries that have occurred on this Project to date since all injuries have not been reported and the records of injuries available are incomplete. It is strongly recommended that all injuries regardless of severity be reported on an injury form of a type similar to Form G-113, attached to the back of the memorandum to Dr. Stone covering "Suggested Safety Program for Use at Site X". Emphasis, in filling out these forms, should be placed on the method to be used to prevent recurrence of injuries of a similar type.

The recommended methods for investigating and classification of injuries are listed in Appendix "C" of the above mentioned memorandum. For summarization of injuries to be submitted to Administration monthly

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Form #2 issued by the National Safety Council, 20 N. Wacker Drive, Chicago, is recommended. If a Safety Engineer is ultimately employed on this job, individual injury records should also be kept for each man and for this purpose Form #3, available from the National Safet, Council, is suggested.

Rec.2. Central Safety Committee

An Administrative Committee, headed by the Assistant Director and including all Division Directors immediately under his supervision should meet at least once each month, with special meetings as found necessary for the purpose of formulating basic safety policies and to originate, guide and coordinate Laboratory safety activities in general. Sub-committees of this Administrative Committee will undoubtedly be formed at different times for investigation of specific problems and to aid in formulation of Administrative policies. Proper functioning of this group is of utmost importance in the recommended program.

Rec. 3. Divisional Committees

Each Division Director should be made Chairman of a Committee composed of the Section Chiefs under his jurisdiction. Function of this Committee corresponds to that of Departmental Committees described in detail under Appendix "A" of the memorandum to Dr. Stone covering suggested Site X Safety Program.

Rec.4. Sectional Committees

Each Section Chief should meet weekly with all employees under his jurisdiction for a discussion of safety items passed down by higher Committees, as well as discussing and acting upon suggestions from Committee members. Detailed functions of this Committee are covered in Appendix "A" of the memorandum to Dr. Stone.

Rec.5. Safety Engineer

It is recommended that a full time Safety Engineer be employed whose duties should consist of following the safety program as a whole, carrying out periodic inspections of all buildings and equipment, reviewing progress made by various committees, analyzing injuries and determining the steps to be taken for reduction in number of same, and performing numerous miscellaneous other functions for the purpose of stimulating the Safety Program.

Rec.6. Inspection Committee

Each of the Committees mentioned above should appoint a sub-committee to make periodic inspections of all sections of the Project with which they are directly associated. The "Inspection" Committee should consist of approximately 3 people appointed by the Committee Chairman, with members rotated at frequent intervals. It is suggested that each Sectional "Inspection" Committee [illegible] not inspections in other sections, that [illegible] those selected and that those reports be

immediately acted upon with controversial items being referred to the Safety Engineer for study and arbitration. In addition all employees are expected to carry out continuous inspections within their own sections and to pass on suggestions verbally as the need arises. The emphasis in these inspections should be placed on elimination of unsafe practices and unsafe conditions as well as the improvement of housekeeping in general.

Rec.7. Safety Rules

Safety rules applicable to the Project as a whole should be formulated and issued by the Administrative Committee to all concerned. The following typical rules are given to illustrate the point.

(a) All injuries must be reported to immediate supervision, and standard injury forms filled in as soon as possible after the injury occurs.

(b) Equipment, buildings and surrounding grounds must be kept clean at all times.

(c) You are not required to carry out any operations that cannot be done safely. Help us to help you in this direction by reporting unsafe conditions to immediate supervision.

(d) Do not use unsafe tools or equipment.

(e) Learn the location, purpose, limits and method of use of all safety equipment such as gas masks, safety showers, fire extinguishers, etc., provided for your protection.

(f) All moving belts and equipment within 6 feet of the floor level should be guarded.

(g) All portable straight-ladders must be equipped with safety feet and the ladder tied at the top or held by a second employee at the ladder base while it is being used.

(h) Only authorized persons are allowed to carry out work on electrically or mechanically operated equipment. Before carrying out repairs or alterations, control switches should be locked in "Off" posisition and suitable warning tags posted. Authorization to remove warning tags and equipment safety locks is limited to the employee applying the tag or lock. Equipment on which warning tags have been placed must not be operated.

(i) Horseplay is forbidden.

(j) Aisle ways as well as the path to all emergency safety and fire protection equipment must be kept free from obstruction.

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(k) Place all oily rags, scrap and waste material in the proper receptacle.

(l) Protruding nails are to be removed or bent over as soon as possible.

(m) No machines are to be operated without proper authorization.

(n) Warning tags should be used whenever it is desirable to prevent operation of machines, switches or other equipment.

Rules formulated by the Administrative Committee should be issued to all Section Chiefs and enforced by all concerned. In addition, specific rules should be set up by each section as found necessary to cover hazards peculiar to that section. A copy of these rules should be given to each employee and the purpose and intent of the rules explained at periodic safety meetings.

Rec. 8. Housekeeping and Congestion

Observation showed that housekeeping on the Project as a whole was poor and considerable congestion was noted. Although the congestion can be reduced by placing emphasis on good housekeeping, it is believed that future expansion of facilities must be carried out, especially in the New Chemistry Building. The needs in this direction should be determined by Section Chiefs and a list of required facilities sent to Administration. It is believed that emphasis on housekeeping and eliminating congestion alone will materially aid in reducing injuries.

Rec. 9. Guarding of Equipment

Although most injuries on this Project have occurred as a result of human failures, all people encounter moments of thoughtlessness, carelessness and distraction and at such times injuries can and have occurred from exposure to moving power driven equipment. It is recommended that in general all moving belts, shafts, pulleys, saw blades, etc., within 6 feet of the floor level be guarded to protect personnel. Especial mention might be made of power driven circular saws since several injuries have occurred on this equipment due to failure to utilize the guard that has been provided, as well as inadequacy of the guard itself. A standard Floor guard should be installed on all power driven circular saws and a Flohr or Surty guard on the band saw.

Rec. 10 Working on Energized Electrical Circuits

At least one injury has occurred as a result of work carried out on energized electrical circuits. As far as could be determined during this inspection there is no need for employees to work on energized power or lighting circuits. It is recommended that an Administrative Rulin be made prohibiting employees from working on electrical power or lighting circuits while energized.

Rec. 11 Grounding Non-current Carrying Parts of Electrical Equipment

In the event of insulation failure within electrically operated equipment, the exposed metallic parts may become energized, which in turn

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may result in severe injuries to employees contacting such surfaces. To eliminate this hazard the non-current carrying parts of electrical equipment, operated at 110 volts or higher, should be connected to a suitable ground such as a water main. One means of readily accomplishing this is through grounding of the metallic conduit connected to the equipment (where such is provided).

Rec.12 Safety Shoes and Goggles

Although safety shoes and goggles do not eliminate the cause of injuries they can be of considerable aid in preventing or reducing the severity of injury. It is understood that equipment of this type has been ordered and the program for its use should be instituted as soon as possible.

Rec.13 Blocked Fire Extinguishers.

The number of fire extinguishers provided within buildings appears to be ample although this equipment was found inaccessibly located in many cases. As a general rule extinguishers should be located near building or room exits and hung up on the wall at a conspicuous location. The path to such equipment should be kept free from obstruction and the frequently noticed practice of hanging clothing and other articles over fire extinguishers should be forbidden.

Rec.14 Grinding Wheels.

Numerous instances were found where clearance between grinding wheels and the tool rests were inadequate. This clearance should be kept at approximately 1/4" or less, since at large clearances the leverage provided can and has resulted in serious injuries.

Rec.15 Guards for Grinding Wheels.

The paper on the sides of all grinding wheels should be removed and Park's Safety Washers and Flanges covering at least 50% of the wheel diameter installed. These washers have been shown to be capable of holding a grinding wheel together even when it was operated while split completely through, and as a result they offer considerable protection against injuries from grinding wheel breakage.

Rec. 16 Tripping Hazards

A number of injuries on the Project have occurred as a result of loose or permanent protrusions on the floor. Despite the occurrence of several severe injuries from this cause, numerous instances were noted during the Laboratory inspection where this condition still existed. A Laboratory wide program should be carried out to discover and eliminate such hazards as far as possible.

Rec. 17. Handling and Stacking Hazards.

A comparatively large number of injuries have occurred as a result of improper methods used in handling and stacking, especially in the sections dealing with Pile operations. It is noteworthy that many

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employees are apparently able to carry out similar operations without injury, indicating that the methods used by injured employees require study by supervision. Such a study should be made where injuries of this type have taken place, suitable handling methods developed, and employees instructed accordingly so that this large category of injuries can be reduced.

Those injuries that occurred from improper stacking may be attributed to carelessness although when they continue supervision must also be held responsible. It is believed that further emphasis on orderly stacking of materials is desirable.

Rec.18 Compressed Gas cylinders.

All compressed gas cylinders should be securely supported. Despite a drive in this direction in the past several weeks, over 50% of the cylinders encountered during the inspection were not secured. Injuries have occurred on the Project from this cause and may be expected in the future unless further action is taken on this point by Supervision.

Rec.19 Medical Service

The extent of a minor injury and its treatment are to a large extent left up to individual employees to determine, and treatment is often effected through use of the First Aid kits placed throughout the Laboratory. Should secondary complications occur, the Laboratory could be held responsible without necessarily having had any previous knowledge of the fact that an injury had occurred. For the purpose of allowing a more accurate analysis of injuries and to insure that the proper medical aid is provided, it is strongly recommended that all First Aid equipment in the areas be removed and that injured employees report for medical service to the Health Section. This may require that additional facilities be provided and that one or more doctors within the group be appointed to take care of such injuries and determine course of further treatment if required. It is believed that this will safe guard the Project from possible minor injuries that might develop into more complicated cases and would materially aid in uncovering all hazardous operating conditions.

Accidents requiring more elaborate treatment than can be offered by the Health Group should, at the discretion of the Health Division doctor, be referred to Billings Hospital. Excluding extreme exceptions, no case should be sent to the Hospital without approval from the Health Division.

7. Work for the Coming Month

1) Continuance of surveillance of hazards and health.

2) Total body radiation in man is continuing along the same basis as outlined in the April report.

3) Dr. Tannenbaum will continue with his studies on the toxicology of x-metal, oxide, nitrate, chloride and fluoride.

4) An analysis of blood counts obtained to date will be made to determine any significant variations among radiation workers.

5) Dr. Fuqua is preparing a survey of the known toxicity of beryllium which is of interest to the Technical Division.

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C. BIOLOGICAL RESEARCH
K. S. Cole, Section Chief

8. Inhalation of Short-lived F.P. - W.E.Cohn, J.G.Hamilton, E.R.Tompkins.

Dr. Cohn observed and assisted with the inhalation experiment described in Hamilton's section of the current report since it is a model for the studies on gaseous fission products to be carried out at X. An estimated activity of the order of 10^{-7} C/cm^3 was attained in the gas to which the animals were exposed. In the one animal sacrificed after a one hour exposure there was an activity corresponding roughly to 2% of the total activity inhaled. This agrees well with the absorption of Xenon as calculated from previous experiments with radioactive Xenon, reported by Hamilton. The decay of activity in the gas showed the log-log relationship to be expected of such a mixture. The activity of the animal tissues was too low for accurate measurement after two days, but the animals exposed for four hours should contain a readily measurable amount after such an interval.

The results of this experiment, while not yet complete, indicate that the activity which will be obtainable at X (Ca 10^{-5} C/cm^3) will enable a complete determination of the metabolism of inhaled recoil fission products to be made.

Dr. Tompkins has carried out a similar preliminary experiment on radioactive gas produced in the Chicago cyclotron by neutrons on metal. Sugarman's apparatus (CC-680) was used to collect and measure the activity of the air to which the animals were exposed and showed that an activity of about 10^{-9} C/cm^3 was attained at about 2 seconds from the source. The lungs of an animal exposed three and one-half hours to this concentration contained a barely measurable amount of activity three hours later. This is not surprising considering the activity of the air used, but the fact that activity was deposited in the animal is significant.

9. Cd Tracer Experiment. - R.W.Gerard, E.R.Tompkins

A preliminary experiment has been made on the metabolism of Cd^{115} as a guide to experiments on dust inhalation which are now planned. A specific activity of 0.1 in mC/mgm. was used with the results given below.

Dog	Type of injection	Cd injected (mg/kg)	Time between injec. & sacrif.	Concentration Factor				
				Liver	Kidney	Spleen	Muscle	Lung
1	intraven.	1	6 hours	16	3.5	1.5	0.25	0.6
2	intraven.	1	30 hours	20	3.5	1.5	0.25	0.6
3	intraper.	1	30 hours	20	3.5	1.5	0.25	0.6
4	intraven.	3	30 hours	20	25	1.8	0.4	0.8

10. Fast Neutron and γ-ray Experiments - R.H.Sirkle

A. Protozoan Work. A nearly complete survival curve for eggs exposed to the spectrum emission filtered through four inches of Pb has been made. In general this curve now resembles, but is not at present identical in shape with, the one

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obtained with unfiltered cyclotron emission. The 50% survival dose leads to an x/n dosage ratio of 5.9, whereas that given by the unfiltered emission is 4.0. The three curves (x-ray, filtered cyclotron emission (n) and unfiltered emission (n plus gamma)) are presented on a chart attached hereto. The difference in shape of the x-ray and neutron curves may have some theoretical interest, but discussion of this will be deferred until the curve for filtered emission is verified.

The difference in the 50% survival doses obtained with filtered and unfiltered emission emphasizes the role played by gamma rays in an unfiltered cyclotron emission monitored with a Victoreen chamber. The presence of the gamma rays has been realized from the very beginning of biological work with cyclotrons, but the magnitude of their effect on the observed x/ n ratio has not been fully appreciated in many instances.

b) Effect of n plus gamma radiation. From the following brief analysis, it can be seen that a relatively small gamma-ray component in the cyclotron emission can modify the x/n ratio to a marked degree:

Assuming complete additivity of the effects of neutrons and gamma rays, let

f = the fraction of the total energy absorbed by the eggs from the fast neutron component of the beam,

$1-f$ = fraction of total energy which is absorbed from the gamma ray component,

R_g = the Victoreen reading produced per 84 ergs of gamma ray energy absorbed per cc of eggs,

R_n = ditto per unit of neutron energy absorbed,

E_g = the true effectiveness of gamma rays with respect to x-rays,

E_n = the true effectiveness of fast neutrons with respect to x-rays.

The true effectiveness of any radiation or mixture of radiations with respect to x-rays is taken as the 50% survival dose of x-rays (expressed in r) divided by the 50% survival dose of the other radiation or mixture of radiations, expressed in units of 84 ergs absorbed per cc of eggs. Because the relation between neutron energy absorbed in tissue and Victoreen scale deflections produced has not yet been satisfactorily determined, it is as yet impossible to assign a numerical value to the true effectiveness of neutrons or of any mixture containing them. Experimentally we determine the apparent effectiveness of the neutrons or of a mixture containing them. This quantity is numerically equal to the so-called x/n dosage ratios mentioned above. For any mixture of neutrons and gamma rays, the apparent effectiveness is expressed by:

$$E_a = \frac{E_n f + E_g(1 - f)}{R_n f + R_g(1 - f)} \qquad (1)$$

When the gamma rays are filtered out with lead, f becomes unity and the apparent effectiveness obtained experimentally is 5.9. The expression (1) above then reduces to

$$E_n/R_n = 5.9 \qquad (2)$$

For the mixture of neutron and gamma rays emitted by the Chicago cyclotron it has been found experimentally that

$$\frac{E_n f + E_g(1 - f)}{R_n f + R_g(1 - f)} = 4.0 \qquad (3)$$

According to earlier data of Henshaw and Francis we can deduce that E_g may be set equal to 0.67 for the Drosophila egg. For R_g we may write 0.95 (Parker). Substitution of these numbers into equation (3) leaves us with two simultaneous equations (2) and (3) in three unknowns: E_n, R_n and f. If the value of one of these can be determined, the equations can be solved for the others. Although it was pointed out above that R_n has not been measured satisfactorily, Aebersold estimates that it lies between 0.4 and 0.5 and Gray in a recent letter to Dr. Stone apparently regards the former figure as approximately correct. Making this substitution, we get

$$E_n = 2.4$$

and

$$f = 0.80$$

This would mean that 20 percent of the energy absorbed by the eggs is gamma ray energy, when our mixed beam is used. This figure seems to be reasonable in view of the measured values of the gamma ray quanta and their estimated frequencies of emission taken with the usually quoted values of the extent of the neutron energy spectrum. We therefore see that, because of the poor response of the Victoreen meter to the neutron rays, even a rather small gamma ray dilution of the neutron beam can produce an appreciable effect on the apparent effectiveness of the latter (in our case a decrease from 5.9 to 4.0).

This realization that the gamma component is not negligible, makes it impossible to compare the values of apparent effectiveness obtained for various organisms with different cyclotron beams which are unfiltered, although comparative effectiveness ratios obtained with the same beam still retain some value. For example, we cannot compare our present Drosophila data with the early results obtained at Berkeley and Ann Arbor, because the value of f may be different. It is interesting to compute by means of equations (2) and (3) the value of f which must be assumed for the Berkeley beam of 1936 in order to bring the apparent effectiveness of 2.1 into line with our present results on the eggs. This value of f turns out to be 0.48; that is, not more than half of the absorbed energy was contributed by the neutron portion of the beam. This value seems excessively low, so that at least a part of the discrepancy is probably to be ascribed to the use of different strains of flies in the two sets of experiments.

A further result of the recognition of the importance of the gamma rays is that we can no longer attempt a comparison of our x/n dosage ratios for lethal action on rabbits with those obtained by J. H. Lawrence with mice. Lawrence's apparent effectiveness ratio, obtained by plotting survival curves from the tables in his paper with Tennant, was 3.5. If we assume 20% gamma rays in the beam, the apparent effectiveness increases to 5; if we assume 30% gamma rays, it becomes 6. Since neither assumption is entirely unreasonable, it is evidently futile to attempt any comparison with results obtained with another neutron beam.

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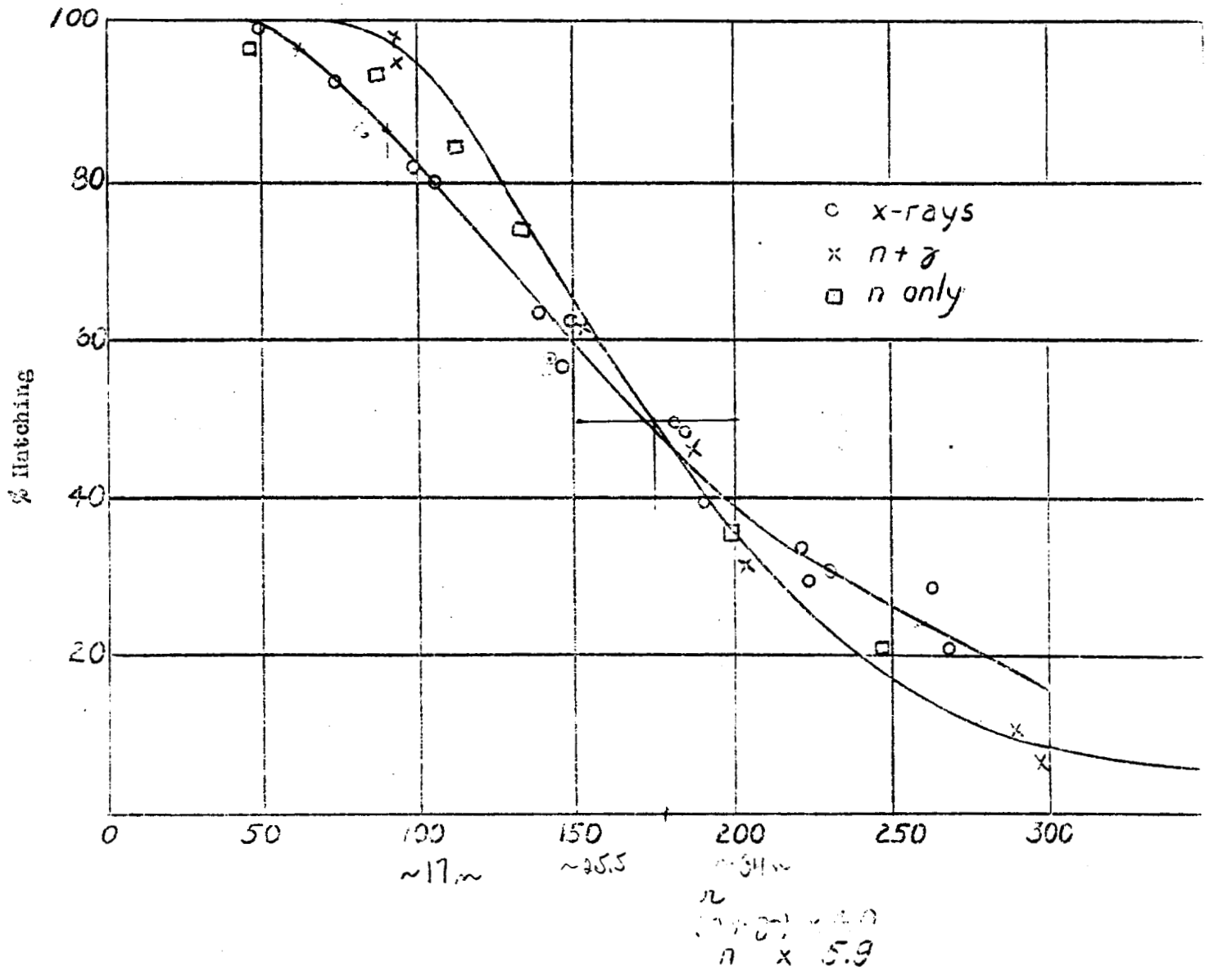
Comparative Action of X-Rays, Fast Neutrons and

Unfiltered Cyclotron Emission on Drosophila Eggs.



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11. Comparative Lethal and Hematologic Effects of Fast Neutrons and X-Rays - R.E.Zirkle, L.O.Jacobson, E.C.Mahon.

This work, held up temporarily some weeks ago because of inability of the breeder to supply rabbits of sufficient size, was resumed May 28. The work is still proceeding at a subnormal rate because of shortage of animals, but it is expected that normal progress will be resumed in about one week.

Dr. Mahon has supervised the preparation of some slides of the various tissues obtained at autopsy or sacrifice of animals irradiated earlier in the year. Examination of the slides indicates the possibility of arriving at certain criteria of injury which will permit quantitative comparison of the x-ray and neutron effects.

12. Effects of External Beta Irradiation - R.E.Zirkle.

A preliminary experiment on the effect of external beta-irradiation on mice has been started. Bombarded nitrate is being used as the source. Special mouse cages have been designed and built with the following special requirements in mind: Uniformity of beta intensity throughout the cage; confinement of the finely divided nitrate crystals behind a limiting membrane of minimal stopping power; minimal stopping of the betas by the mesh of the cage and by the facilities for watering, feeding and sanitation.

13. Effects of X- and Gamma-Rays and of Dissolved F-Products on Laboratory Fish - R.E.Zirkle, E.R.Tompkins, J.R.Raper.

A preliminary experiment has been designed to investigate the effect of isolated F.P. on goldfish. Active residues have been obtained from the Technical Division. Goldfish, containers, and other essential materials have been ordered. Experiments will start as soon as fish arrive. Radio-cerium will be used first and a parallel control will be run with ordinary cerium to establish the limits of chemical toxicity due to cerium added as a carrier in the isolation of F.P. Experiments with mixtures of F.P. are expected to follow shortly.

14. Inhalation Experiments - R.Abrams

a) Argon. The A^{41} experiments reported last month were extended somewhat this month. Two animals each received approximately 300 mC in five successive doses. The exposures to A^{41} had no effect either on the blood picture or on tissue pathology. A third pig showed no effect on metabolism (O_2 consumption, CO_2 production, and respiration rate). Since the amounts of Argon available are definitely too low to produce pathological changes, these experiments have been discontinued.

b) Xenon. No Xe has been available during the past month for animal experiments. Some Xe^{133}, extracted from bombarded nitrate was used to test silica gel as a means for recovering and concentrating Xe. Tentative results seem to indicate that fresh silica gel at -80° is very effective (~100% recovery), but with each subsequent use the gel becomes a much poorer absorber (with a lower reactivation at 350-400° C).

c) Nitrate Dust. Some preliminary work has been carried out to test methods of maintaining an atmosphere laden with dust. These preliminary tests were made with nitrate. Two different types of atomizer were used with the nitrate in solution, and in addition an experiment was carried out in which finely ground nitrate was blown into a bottle housing a guinea pig. Both pigs used in these experiments showed some effects but more work needs to be done before these can be interpreted. These experiments are being continued this month.

15. Analysis of Erythema Experiments - G.A.Sacher

A preliminary analysis has been made of the erythema data of Quimby and Reisner. Both sets of data are satisfactorily expressed by

$$Z = Q \left[A \exp(-at) + B \exp(-bt) \right]$$

where Z is the tissue injury at time t days after exposure Q. The best fit is obtained for A = 2.3 B, a = .37 day -1 and b = 0 for times up to 28 days.

16. Work for the Coming Month

A considerable part of the month will be required to establish the work of the section in the Biology Laboratory at Area B.

The necessary activity of UX_1 should become available for external beta radiation and dust experiments. Some Ce and Ru may be obtained to start fish experiments. The primary work on Cd^{115} will be completed.

The work on the effect of filtered cyclotron radiation on Drosophila eggs will be completed. The new x-ray equipment will be installed and in use. The lethal effects on rabbits will be nearly completed. Sufficient Xe^{127} is expected to start another exposure. The Xe extraction work will continue. An investigation of methods of dust exposure and analysis will be well under way.

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D. HEALTH PHYSICS
E. O. Wollan, Section Chief

17. Radioactivity in River from Pile Cooling Water at W.

A brief summary is given here of a report being prepared with Coryell and Howe on the radioactivity which will be discharged from one 2.5×10^5 kw. pile into the river at Site W. The main sources of radioactivity going from the pile into the cooling water are: (1) Fission recoil from uncoated metal, (2) Erosion of uncoated metal, (3) Production of radioactive elements in the water and dissolved substances by the neutrons in the pile and (4) recoil of radioactive elements produced in the aluminum tubes. Approximate figures for the concentration of activity in the river water (flow = 10^9 cm3/sec) are given below for an 8 hour holdup.

(1) 2×10^{-12} watts/cm3
(2) 1×10^{-13} watts/cm3
(3) 3×10^{-14} watts/cm3
(4) 3×10^{-16} watts/cm3

(1) and (2) correspond to an uncoated pile and (2) is based on Howe's corrosion data. These figures indicate that (1) is the worst source of activity but with 10^{-11} watts/cm3 (equivalent to 0.1 r/24 hours) as the tolerance concentration a completely uncoated pile would not give a tolerance concentration of radioactive products in the river after an 8 hour holdup assuming complete mixing of the cooling water in the river.

18. Use of F.Products

A report on this subject has been prepared at Mr. Allison's request in conjunction with Messrs. Peterson, Stone, Cole, Coryell, Apple, Turkevich and others.

19. Radiation Monitoring and Instrument Coordinating Committee.

Preliminary recommendations for radiation monitoring of the Site W area and neighboring centers of population has gone out through Dr. Stone and Mr. Compton as MUC-HG-136. The final report on monitoring at the Clinton Laboratories is embodied in MUC-HG-143.

20. Recording Integron Meters.

The Integron furnished us by Victoreen with a full scale of 0.1 r has been operated on a recorder as a test of its operating characteristics. It is found that the insulation leakage with no drying agent in the chamber is very small in dry weather. The new instruments being made for use at X will be well sealed with a drying agent inside. A meter of this type has not yet arrived here for test. The charging voltage from the set is not absolutely constant, variations over an eight hour period amount to about 5%. This could be overcome by the use of a stabilizer on the primary but a 5% variation in this voltage can probably be tolerated in this service. Aside from this point the instrument seems to work very satisfactorily.

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21. Progress on Film Radiation Meter - Wollan and Goldstein

The pocket type ionization chamber is more ideally suited to the accurate measurement of exposure to radiation than photographic films but since there are some advantages in the latter method it was thought worth while to investigate its possibilities. Only preliminary results have been obtained so far.

If photographic films are to be of any value as a radiation meter they must be sufficiently sensitive to measure with some precision a tolerance dose of x- and gamma-radiation in a reasonable time and the response of the film should be such that the blackening is expressible in roentgens.

In the tests so far made duPont D 1 dental x-ray safety film has been used. The development of the film is carried out in a tank and the time and temperature is maintained the same. The blackening is measured on a photocell densitometer. The scale of the meter is adjusted to zero blackening with a clear film in place.

The film gives a readable blackening with 0.1 r of Radium gamma-rays. With 1/16" of bakelite over the film the meter readings for various gamma-ray exposures with the mean deviations for 5 films developed at the same time is given below:

Exposure	Blackening
0.25 r	.36 ± 0.01
0.50 r	.17 ± 0.01
1.00 r	.07 ± 0.02

When a set of films was developed on succeeding days with reasonable care in maintaining the conditions of development the same, the variations in the average of five films for each development was 8%. This error does not, however, have to enter when the films are used as a meter because then a standard film can always be developed with each batch of films to be measured. The blackening is linear with exposure when all films are developed at the same time. It is necessary that a standard exposure be used with every batch because large errors in absolute blackening would result from the continuous weakening of the developer.

The worst handicap with film as a radiation meter is the fact that the blackening per roentgen of exposure increases rapidly as the energy of the radiation decreases. It is hoped that a proper type and thickness of absorber over the film will give a sufficiently satisfactory linear relation between blackening and energy of radiation. So far lead has been the only absorber which has been studied with any thoroughness. To make this test stepped wedges of lead on a 1/16" bakelite sheet were made in which the lead varied in thickness between 0 and 2 mms. in gradations of 1/4 mm. These plates were placed over a dental film in its wrapping and with the 1/16" bakelite sheet nearest the film. Exposures of various amounts of radiation were made for Ra gamma-rays, 400 kv, 250 kv, and 140 kv x-rays. These kilovolts quoted for the x-rays correspond to the maximum, the average energies would probably be about 1/2 of these figures. The film blackening for 1 r (as measured on a Victoreen condenser r-meter) of the above radiations is plotted in the curves below. It will be seen that the blackening per roentgen is reasonably alike for all radiations used at a lead filter thickness of 0.6 mm. The inserted plot gives blackening vs. average energy (the average energies for the x-rays being taken as one half the maximum.)

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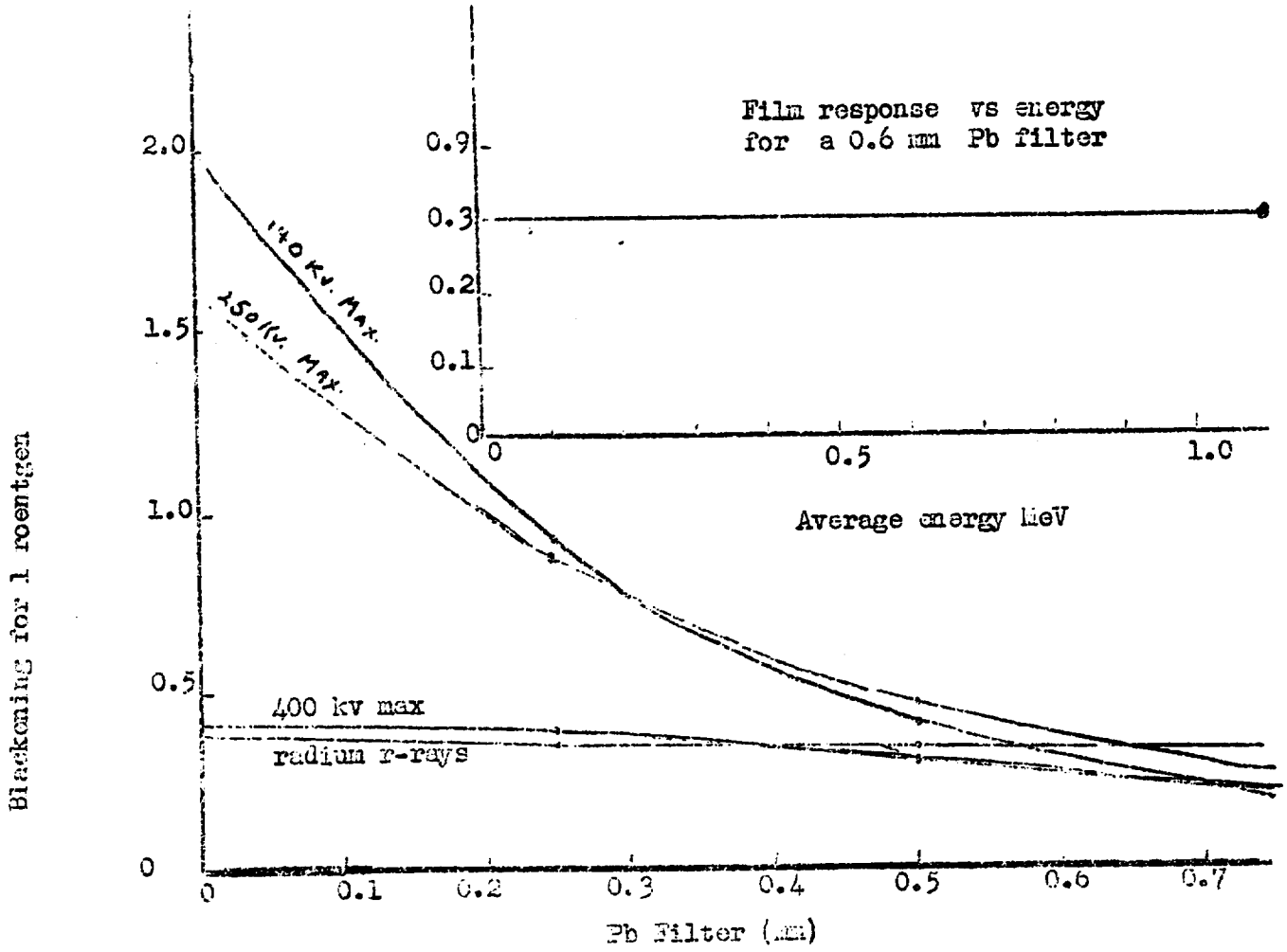


These results would be satisfactory for a film meter with an accuracy of ±10% at 1 roentgen except that the response for radiations less than about 70 kv would probably be too small with this filter. If part of the film were uncovered except for a sheet of bakelite, a measure of the amount of soft radiation present could be estimated.

Such a film meter can probably best be used to give the exposure received during one week. Further measurements are being made with Cu and Ag filters to see if the response can be made approximately linear to lower energies.

22. Radiation Instruments - H.A. Wilson

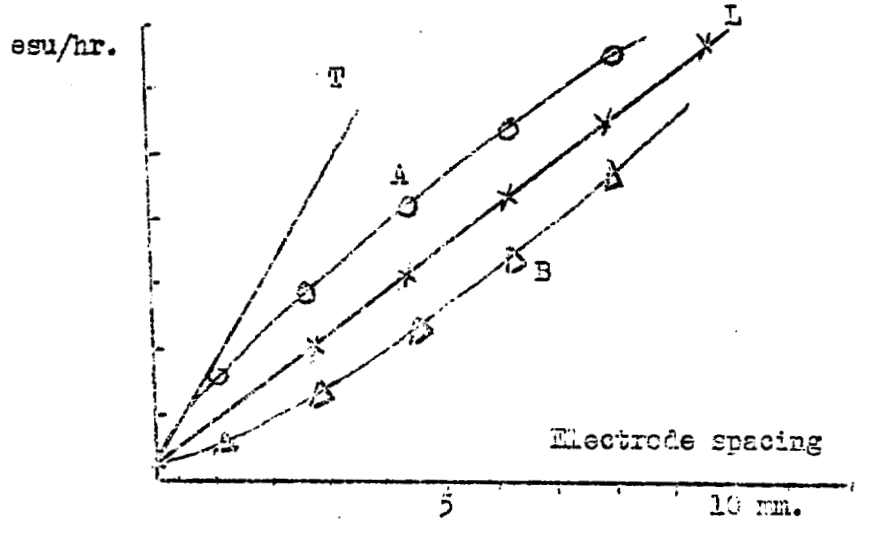
A report on this subject has been prepared [illegible]. An analysis is made of instruments which are now available and some suggestions

as to improvements on these are given. Some ideas on other types of instruments not previously considered here are brought out.

Radiation Hazard Problems. Some of the several letters which are being circulated on shielding and other radiation problems are being checked over and points not covered by these are being investigated. This material will be organized in a later report.

23. Accurate Measurement of β -radiation from x-metal.** Parker and Gemertsfelder

The β -ray emission from x-metal has been measured by Dr. G.Failla by the extrapolation method. This method is clearly the nearest approach to a measurement of the ionization in a skin surface close to the metal. The value reported by him was 0.22 r/hour through an undetermined absorber (approximately 30 mg/cm^2). This figure was much higher than the one derived from our pocket chambers. A critical review of those measurements led to a value of about .165 r/hr. Before proceeding to extensive β -ray readings it was deemed advisable to attempt to reconcile the two types of measurements. We therefore constructed an extrapolation chamber in which the chamber spacing could be varied from 1 mm to 10 mm.



The method depends on a plot of the ionization current against electrode spacing'extrapolated'to zero spacing. Under favorable conditions this plot is a straight line as L in the figure. The ionization per unit volume is then unambiguous However, curves of type A or B can arise. For example with incident quantum radiation the curve will resemble A or B according as the electrode material has effective atomic number greater or less than that of air.

With the β -rays from the metal, Failla obtained a curve like A for which a convincing physical explanation could not be given. With such a curve the true leakage rate is obtained from the slope of the curve at the origin.

The determination of this tangent T is not precise as it depends greatly on the reading at smallest spacing, necessarily the most inaccurate. In Failla's work T gave .22 r/hr. and the main portion of A a slope of .16 r/hr. The latter would be in agreement with pocket chamber results. Hence it was expected that we might find a curve more like L. Our results exactly confirmed Failla's, the final dosage rate being 0.23 r/hour through 32 mg/cm^2, with a curve like A.

In comparing pocket chamber and extrapolation readings, it should be noted that the latter includes "back scatter', ie. a component due to electrons scattered back from the thick electrode. Pocket chamber readings made with back scattering material give 0.2 ± 0.01 r/hr. This agreement is considered satisfactory when one recalls that the pocket chambers are long cylinders (length 50 mm. diameter 7 mm) while the extrapolation chamber is a flat cylinder (spacing 0 - 10 mm. diameter 25 mm).

The extrapolation chamber has been used to measure the alpha-radiation which amounts to 14.5 r/hour in contact (Failla gives 14.4 r/hr.). Also a test has been made with gamma-radiation. This gave a curve of the type L in the figure as it should. The quantitative result was .150 r/hr. against a calculated .135 r/hr. No allowance has yet been made for scatter which could well increase the calculated value by 5 - 10%.

**Errata. In CH-630 p6. paragraph 4(4) line 5 write ~0.2r/hr instead of ~ 0.09 r/hr. Also p.16, line 1, write .2 r instead of .1 r.

24. <u>Secondary β-radiation.</u> - Parker and Gamertsfelder.

The assembly of radium sources in hospital practice should give information concerning the amount of radiation required to produce skin changes on the hands. Unfortunately we have normally measured only the gamma-radiation. With reasonable care the dose to the hands in a single operation does not exceed 0.25 r. A technician would certainly average less than 10 operations per week. If now one measures the ratio of ($\beta + \gamma$) to gamma under comparable scattering conditions the clinical figures can be corrected. It appears that this ratio is

Walls near operator's hand lined with -	$\frac{\beta+\gamma}{\gamma}$ Solid angle 2π	Estimated 4π
Bakelite	1.05	1.11
Al	1.14	1.27
Fe	1.33	1.66
Pb	1.81	2.7

In a standard aluminum-lined lead bench the secondary β-ray effect is thus relatively insignificant. Since minor skin damage has been demonstrated in technicians who have been exposed only under these conditions (say 4 r per week maximum) these figures should be weighed against the results of x-ray fluoroscopy where the weekly hand exposure is alleged to be 5 to 20 r per week. The radium conditions are very different if unfiltered sources are used. Through a fairly thick glass wall radium tube we find $\frac{\beta+\gamma}{\gamma}$ = 7.6 and this would be increased for the thin glass capillaries used as radon containers.

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25. Survey at Argonne.

Summarised measurements of the gamma-radiation around the pile are -

On top: .0012 r/ kw.hour
On balcony: .0013 r/ kw. hour
Guard station: .0002 r/ kw. hour

In regions near the experimental holes values up to .06 r per kw. hour were found.

The Argonne electroscope was calibrated against two of ours, so that future checks in the vicinity of holes, etc., could be made there.

26. Meteorological Program for Site W. - P.E.Church

After an initial survey of the possible meteorological hazards which might be encountered at Site W, it was deemed advisable to have a field party of meteorologists make certain observations at various designated places within the area. Further, it was decided to start the observational program as quickly as feasible.

The program of the meteorologists calls for making observations on -

(1) The general horizontal and vertical wind pattern over the whole area.

(2) The micro-meteorology of the wind pattern during conditions which may be critical for operation. (a) These include periods of calm or very low velocities (less than 2 m.p.s.) within the lower layers. (b) The possible stagnation of air into localized pools at various places over the site. (c) The direction of air drainage and volume of the drainage currents.

(3) Certain features of inversions that develop among these are -

(a) Height to the "lid" (where there is a marked change in the stability of the air)

(b) The thermal gradient within the inversions in relation to water vapor in the air, cloudiness ground temperatures, and the wind gradient.

(c) The degree of turbulence and lateral spreading under various lapse rates, especially when the wind velocity is less than 2 m.p.s. at the surface.

(4) Later [illegible] relation to the vertical wind and thermal gradients. This phase will be observed after a stack has been built and before actual operation begins.

Since the last report, four meteorologists have been employed by the Metallurgical Laboratories. The men have been trained in the techniques they will use, especially on determining the wind gradient, and nearly all the essential

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equipment has been assembled. The meteorologists left Chicago on June 5th and will be making observations at Site W on about June 10th.

Simultaneous observations will be made at the main meteorological station and at one of some twenty other key locations. In this manner the local wind pattern can be worked out in an efficient manner. Especially important is the vertical wind gradient at these various other locations in relation to that at the main observatory. The wind gradient in the lower layers will be observed by the double theodolite method using slowly ascending balloons. The thermal gradient will be recorded during inversions and calms by meteorographs developed by the Metallurgical Laboratories. These instruments will be carried aloft by captive balloons.

Routine meteorological observations will also be carried on at the main observatory.

27. Work for the Coming Month

Refer to report CH-632, pages 13 and 14 for items on which investigation will be continued during the coming month.

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E. U. C. RADIATION LABORATORY

J. G. Hamilton

a. Cerium: The Cerium studies have now been completed for the entire sixty-four day period and will be presented shortly in a complete report.

b. Unseparated F-products: The studies with unseparated F-products freed from x-metal have now been completed for the one, four, and sixteen day intervals on animals receiving solutions of this material intramuscularly, interperitoneally, orally and directly into the lungs. The intramuscular results closely parallel the intraperitoneal data previously listed in a Chicago report which noted that most of the activity was found to be localized in the skeleton and liver. The sixteen day pulmonary experiment indicated that at sixteen days from 1/5 to 1/3 of the mixture introduced into the lungs was retained and that almost all of that absorbed was present in the skeleton at this interval. The sixteen day oral studies reveal that 3% to 5% of the activity was absorbed and approximately 70% of the absorbed activity was found in the skeleton.

c. Ruthenium: Radio-Ruthenium without carrier has been prepared by distillation of the volatile tetroxide. Its identity and purity have been confirmed by adequate chemical and physical processes on the separated sample. A large group of animals have been injected by the different routes of administration previously listed for the raw fission products. Thus far only sufficient time has elapsed to enable us to describe the preliminary results on the four day groups. At this interval the intraperitoneal and intramuscular animals revealed a high concentration in the kidney and none of the other tissues of the body demonstrated any marked tendency for selective deposition. This is of interest in that all of the studies with the alkaline earth and rare earth groups show a high degree of selective deposition in the skeleton. The chief channel of elimination for Ruthenium is by way of the kidneys which is again in direct contrast to elements of the fission group previously studied. When introduced directly into the lungs at the four day interval a large proportion of the administered dose remained there unabsorbed. Here again no striking deposition was noted in any of the tissues with the exception of the kidney. In this case, as in the other Ruthenium experiments, it is probably related to the fact that the urine is the chief channel of elimination. No significant absorption takes place from the gastro-intestinal tract after administration by mouth.

d. Barium: Radio-Barium without carrier (Ba^{135}) has been prepared by the deuteron bombardment of Caesium Bromide. Its identity and purity have been established by adequate chemical and physical procedures. The Ba^{135} has now been turned over to Professor Chaikoff for metabolic studies.

e.* A sample group of rats has been exposed to the gaseous components of the short-lived F-products. This was accomplished by bombarding UO_2 with deuterons in a small ball jar and pumping off the recoil by means of a continuously operating Toepler pump. This system was calculated to remove the short-life F-products in an average time of 30 seconds after their formation on the target surface.

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The gases were pumped into a 4 liter bell jar containing four rats, three of which were maintained in this atmosphere for three hours. Preliminary results secured from one animal, after one hour exposure, revealed that the short lived activities were distributed throughout all of the tissues, the highest concentration being noted in the kidney, fat, liver and blood. The remainder of the animals are to be sacrificed later in order to ascertain the distribution of the long life descendents.

f. Radio-Autographic Studies: A series of preliminary experiments on the distribution of the raw fission mixture, Cerium, and Ruthenium have been undertaken. The initial results at four days show that Ruthenium is retained by the lungs to a high degree and that it is distributed quite evenly throughout the pulmonary tissue. The F-mixture, on the other hand, revealed a very spotty distribution which was not related to the principal structure within the lung such as the bronchial tree, air sacs, lymphoid tissue, and blood vessels. The Cerium sections must await longer exposures of the films.

g. Proposed work for the month of June: A) Completion of metabolic studies of the raw F-mixtures. B) Continuation of experiments with Radio-Ruthenium. C) Metabolic studies on Radio-Barium to be carried out by Professor Chaikoff. D) Repetition of experiments with short-lived volatile components of deuteron induced fission. E) Continuation of Radio-Autographic studies with the items listed above. F) Continuation of tracer studies with Zirconium. G) Initiation of tracer studies with Columbium, and Praesodymium if time permits.

*This experiment was greatly facilitated by the collaboration of Dr. Waldo Cohen from the Metallurgical Laboratory.

F. REPORTS FROM THE SUB-PROJECTS

28. N.C.I.

A. Acute Doses - Henshaw and Nettleship.

As has been indicated previously, our experiments on repeated acute doses is well along. No new impressions have been gained from the blood counting during the past month. Several cycles of rise and fall of blood level have now been observed and it seems likely that not much more information is to be obtained from the hematological work. It is possible that some of the animals will flop over into leukemia at some stage during the next year but we have considerable information on this already.

Our histological preparations are now quite extensive and are becoming fairly complete in some parts. Examination can probably be started with profit during the coming month. Much additional information should come from this source.

In regard to the dosage-rate problem, discussed several times recently, I should like to call attention to our report of Nov. 18, 1942, mailed to Dr. Cantril. There it was shown that acute doses of [illegible] r applied to the whole body of guinea pigs is lethal. This has been confirmed by later experiments and in that acute doses as low as 150 r have in some instances been lethal.

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These experiments are going according to schedule. The one of the 0.1r level has been going for four months, the others for 2½ months. One group of mice and one group of guinea pigs were removed from the 8 r level after five and four weeks respectively. Two female and two male mice, each from a group on the 8 r level and also from a group on the four r level were killed and autopsied after two months' exposure. All single acute exposures of 12.5 and 50 r (x-rays) (rate of administration of dose: 2.4 r/hour and 11.0 r/hour) have been given. In addition groups of mice for the breeding experiment as outlined in the last report are being exposed on the different levels to varying total doses.

Results: The blood counts show the following picture: In all control mice and some experimental mice there is a downward trend of the total white count at the beginning of the experiment, from above 10,000 to approximately 7,000 for which no reason can be given. Although some of the mice have received so far a total dose of 500 r, the counts have remained above 5,000 on all levels except of those that received additional acute exposures. Likewise the differential count, the red count and hemoglobin determinations remained within normal limits. Those mice, receiving a single acute exposure of 12.5 r (rate of administration of dose = 2.4 r/hour) show practically no effect of this exposure; this holds for the control mice (receiving no other exposure) as well as for the experimental mice (being exposed on the different levels). Those mice, receiving a single acute exposure of 50 r (rate of administration of dose = 11.0 r/hour) show a total white count drop (to below 5,000 in some cases) at one week and two weeks following the acute exposure, but returning to normal by the fourth week. This holds for the control mice as well as the experimental mice. Again here the differential count, red count, and hemoglobin determination were within normal limits. All control and experimental guinea pigs show essentially a normal blood picture with the exception of a few animals on the 8 r level (total dose up to the present approximately 500 r) in which the total white count dropped slightly below 5,000. Differential and red count and hemoglobin determination appear normal. No statements can be made as yet as to the effects of the acute exposures as most of these were finished only during last week.

The growth rate of the experimental animals has been comparable to that of the control animals so far. It may be stated that one group of male mice on the 8 r level (total dose so far approximately 500 r) shows uniform greying of the coat. It cannot be explained why this greying is limited to only one group of this level.

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III. Continuous exposure for 24 hours daily.

Daily doses: 8 r, 4 r, 2 r, 1 r, and 0.5 r

Rate of administration of dose: 0.33 r/hour, 0.165 r/hour, 0.082 r/hour 0.041 r/hour, and 0.020 r/hour.

Since the last report the following groups have been added to the different levels:

8 r/day total dose: 600 r
4 r/day total dose: 500 r
2 r/day total dose: 500 r

Results of the breeding of these mice are the following:

8 r level

Total dose:	300 r	Average	litter	size:	7.6	
" "	400 r	"	"	"	7.3	
" "	500 r	"	"	"	7.7	(incomplete)

4 r level

Total dose:	100 r	Average	litter	size:	8.4	
" "	200 r	"	"	"	8.5	
" "	300 r	"	"	"	8.6	
" "	400 r	"	"	"	8.4	(incomplete)

2 r level

Total dose:	100 r	Average	litter	size:	8.3

1 r level

Total dose:	100 r	Average	litter	size:	7.7	
" "	200 r	"	"	"	4.3	(incomplete)

Controls of comparable age were run for all mice. The range of the average litter size of the control was from 6.1 to 8.7. In only one case did the average litter size of the experimental mice show a drop below the range of the controls. This was in the group receiving 200 r on the 1 r level. This group is still incomplete. As all mice were started at 28 days of age this group was 256 days old when bred (breeding was done in all cases 28 days after finishing the exposure).

It was previously reported that female CBH mice exposed on the 4 r level beginning at the age of 3 months became sterile after a total dose of approximately 400 r. These findings are in disagreement

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with the above results. Whether this disagreement is due to an age or strain factor cannot be decided at present. Further experiments, as outlined previously, are necessary.

A group of maleC3H mice conceived and born on the 4 r level were killed at the age of 17 months after having received a total dose of approximately 2,000 r. Blood counts made priorto death gave a blood picture comparable to that of controls of the same age. At autopsy all organs appeared normal with the exception of the testes which showed atrophy. Microscopic sections of the organs of two animals which have come through so far show reduction of spermatogenesis compared with controls. Tissues of the other organs were essentially comparable to those of normal controls of the same age.

IV. Continuous exposure for 8 hours daily plus daily acute exposures of 1 hour.

A new experiment was set up during the last month in which two groups of female mice are being exposed to a daily dose of approximately 5 r the rate of administration of the dose being approximately 5 r/hour. One of these groups is given in addition 0.1 r/day, rate of administration of dose = 0.0125 r/hour. This experiment was outlined in a letter to Dr. Stone, April 24. This experiment will be important to clarify the effect of the rate of administration of the dose by comparing its results with the results of the experiments in which the same daily dose is given with a rate of administration of the dose of 0.5 r/hour for 8 hours and 0.165 r/hour for24 hours. All experimental results obtained so far seem to indicate that relative to certain effects (survival age, blood count) the total dose is much less important than the rate of administration of the dose.

39. U. C. Hospital

Preliminary results are available now from the total body irradiation of 8 incurable patients with fractional doses ranging from 10 r to 50 r and total doses up to 390 r.

One [redacted] Ca of kidney with metastasis) given 4 x 50 r of 200 kv x-rays between 10/21/42 and 10/24/42 and again between 12/14 and 12/17/42 showed a satisfactory blood count on 3/1/43. He was subjectively upset at the time of each treatment but worked hard between treatments and since the conclusion.

One [redacted] Lymphosarcoma) who was given 244 r (200 kv) between 1/8/43 and 2/1/43 in 15 treatments of about 10 r each and 6 treatments of about 30 r each showed a leukocytosis at the beginning of treatment but a definite leucopenia on 2/13/43

[redacted] (Cancer of breast with metastacis) was given five treatments of about 36 r each between 11/9 and 11/20/42 to a total of 221 r (200 kv). By 2/4/43 she had developed a marked leucopenia but a new series of treatments was instituted consisting of 7 x 20 r plus 13 x 10 r between 2/4/ and 2/27/43. This caused an initial leucocytosis followed by a leucopenia down to 3000 on 4/15/43 but on 4/29/43 the white blood count had recovered to a total of 6000.

[redacted] (cancer of toe with metastacis) was treated from 1/25 to 2/15/43 with doses of about 16 r to a total of 300 r (200 kv). His white blood count fluctuated from 9500 to a high of 15,400 on 2/5/43, a low of 3,200 on 3/13/43 and back to 5,200 on 4/9/43.

[redacted] (Hodgkins Disease) was treated from 1/19 to 2/12/43 with treatments of about 15 r to a total of 320 r (200 kv). The white blood count fluctuated between 9000 and 20,000 but went to a temporary low of 5,500 on 4/1/43 with a recovery to 12800 on 4/26/43.

[redacted] (Spondylitis) was treated from 1/7/43 to 3/6/43 with treatments of about 10 r to a total of 290 r, the first 10 with 100 kv and the second 18 with 200 kv. His white blood count fluctuated around 9,000 r from an initial count of 9,500 to a final on 4/10/43 of 7,600.

[redacted] (Lymphoblastoma) was treated irregularly from 10/13/42 to 1/9/43 receiving a total of 367 r but her general condition from her disease became so bad that her blood count is of little significance.

[redacted] (Spondylitis) was treated from 1/13/43 to 2/18/43 with daily doses of about 10 r each to a total of 297 r (100 kv). His white blood count fluctuated a great deal but never went down below 7,400 and on 2/18/43 was 10,200.

Conclusions:

(1) None of these patients have been followed long enough as yet to establish the first effects of the treatments.
(2) Individual doses of 10 r even when given daily had little if any subjective effect on the patients; nor did doses of 20 r. Those in the neighborhood of 30 r occasionally caused temporary weakness and very occasionally, nausea.
(3) The doses of 100 kv unfiltered radiation had much less effect than similar doses of 200 kv filtered through 5 mm Al.
(4) Nearly all the doses affected the white blood count in one way or another but to date recovery has occurred in all except the one debilitated by her disease.