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ARMY SERVICE FORCES
UNITED STATES ENGINEER OFFICE
ROCHESTER AREA
P. O. BOX 258, STATION "O"
ROCHESTER 7, N. Y.

ADDRESS REPLY TO
THE AREA ENGINEER

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MDW 33

1 October 1945

Subject: Draft of Report by Chemical Warfare Laboratories.

To: The District Engineer, Rochester District, Oak Ridge, Tenn.
(Attention: Major John A. Hall)

There is enclosed one copy of report by Chemical Warfare Laboratories, entitled, "Biologic and Health Hygiene Section".

For the Area Engineer:

H. S. Hanson,
Administrative Assistant.

Incl.:
Rpt. (Draft)

PROVENANCE

REPOSITORY:	OFFICE OF HUMAN RADIATION EXPERIMENTS (OHRE)
COLLECTION:	PLUTONIUM INJECTION INVESTIGATION FILES (OHRE 1)
BOX:	4
FOLDER:	IRRELEVANT MATERIAL

Biologic and Health Physics Section

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I.- Introduction

S.I.

The origin and growth of the research section came as a natural development ~~following~~ to the rapid progress of ~~the~~ physical research. ~~During the early days~~ Even before the responsibilities of the project were assumed by the Office of Scientific Research and Development, the ~~amount and type of~~ research carried out ~~on~~ in the isolated physical experiments ~~pointing toward the~~ concerning isolation and utilization ~~of the isotope~~ separation 235 were on a very small scale and, in reality, constituted no real medical hazard. However, as the physical phases developed, it became ~~quite~~ apparent that hazards due to the radiation from the parent substance uranium and its natural and artificial ~~daughters~~ disintegration products including radium and the fission products, could be extremely injurious to the human body. Experience had already accumulated ~~following the use of X-ray and radium~~ to show that the long lasting detrimental effects and occasional fatality ~~which occurred~~ fatalities could occur following indiscrete use ~~either~~ of radium or X-rays through ignorance or neglect. ~~Again should injury arise from experimentation on these substances by exposure to gradually increasing amounts of these substances, this damage would be incurred by that select group of scientists carrying out these investigations. Loss of such men to science would indeed constitute a damaging blow to the future of this~~

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country at any time, and in time of war might make up a definite difference between success and defeat. This concept was very apparent to those directors of the individual projects and, with the organization of the small units under O.S.R.D., caused them sufficient concern that a certain portion of the funds of one of the most advanced portions, the Chicago project, was allocated to biological research and development of methods of protection for these scientific workers. The cooperation between the medical and physical research sections even at this early date, served its purpose in the protection of these scientific observers and at the same time accumulated much valuable data.

With the continuing success of research, by the combined efforts of all personnel, the general scope of the project expanded rapidly. At that time the responsibility for the project was assumed by the creation of the Manhattan District for overall supervision. With this bringing together of all facilities directed toward a single effort, it became necessary to organize a medical section as well to supervise the activities of research and health protection on the entire project.

5.2. Purpose of Research Program

The hazard problems which arose with the growth and development of the Manhattan District into a gigantic industrial enterprise were many and have been

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as Section 2 of this Document. The primary emphasis of
reviewed under Section II. It became the prime concern of the research section also
to investigate the potential possibility of damage due to all of the uranium & other
radioactive compounds used, considering that such damage might be due either to radiation or
chemical toxicity, or both. Special materials were also developed as aids to
processing and these too constituted possible medical hazards inasmuch as likewise,
uranium, very little was known concerning their possible poisonous action on the
human body. The most important of these substances were elemental fluorine
and various compounds manufactured by reacting fluorine with hydrocarbons. If
such compounds on testing against large animal populations, showed damage against
certain of the systems in the body, this knowledge was immediately used in
plant operations for the protection of the workers by health monitoring, protective
devices and by engineering.

5-3 II. Radiation Hazard Research (Alpha, Beta, Gamma (X-ray) Neutron)

The need for medical research on an organized scale was first realized
by the University of Chicago group whose researches involved experimentation
on the pile process for the transformation and isolation of the transuranic
element, plutonium (239). For clarity, a brief review of the physical reaction

in the pile process is indicated so that the origin of the hazardous materials can be understood.

Uranium, the base material entering the pile, is a naturally unstable or radioactive material. The particles liberated in the breakdown of uranium may have a positive charge of high energy (alpha particles), negative charges (beta rays which are similar to electrons) and medium long wave rays (gamma rays). In addition to these energies liberated from the electrical orbits of the atom, the nucleus may also contribute by the loss of neutrons or particles which have mass but no electrical charge. When billets of pure uranium metal (containing 0.7% uranium 235) are placed in a predetermined geometrical arrangement and shielded by some substance which slows the speed of the neutrons, continuously being liberated from each billet, the neutrons in passing thru the surrounding metal cause by various physical phenomena new electrical imbalances which further the production of additional new neutrons. In this way the pile becomes self prepetuating in action. With the shift in atomic structure by the addition of new electrial energies, a conversion is formed so that neutrons are able to enter into the nucleus of certain atoms of uranium 238. This causes an increase in the weight and changes in the physical characteristics of the uranium 238 converting it

to another substance, plutonium 239, which has different physical and chemical properties.

As mentioned above, uranium by radioactive decay degenerates with the production of infinitesimal alpha rays or particles, beta rays and gamma rays (similar to X-rays). In uranium alone, in an undisturbed state, this radiation is quite weak, and to incur any damage, an individual would be forced to be exposed to a relatively long period of time. Hence, the radiation hazard from the uranium ores and pure uranium compounds and in the purification process necessary to isolate uranium 235, was small in magnitude when compared with that present in the pile reaction.

When such a bombardment of neutrons exists, as produced by the so-called pile reaction, and neutrons so produced collide, enter or otherwise interfere with parts of the structure of other atoms of any type, each interference will cause an instability in the electrical charges which serve to maintain the atom in stable equilibrium. As a result a tremendous discharge of particles or energies of all types, alpha, beta and gamma rays etc., takes place, depending on the nature of the reaction. Since all of these particles or rays are nothing more than expressions of different types of electrical energy of different wave lengths,

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it is ~~only~~ evident that when such rays or particles enter living tissue they will cause an additional electrical reaction ~~with the atoms or electrical systems which support life~~ in that tissue ~~in a normal fashion~~. For this reason it ~~is~~ was obviously quite important to study the biological effects of all types of radiation ~~so that~~ to determine the allowable amounts of exposure whether ~~it arises~~ arising from sources outside the body or from material taken into the body ~~can be adequately determined and~~ overexposure prevented.

To handle adequately ~~the scope of~~ this large problem Dr. R. S. Stone was designated to organize and coordinate the research work done at the University of Chicago. Dr. R. S. Stone was responsible to Dr. A. H. Compton, the Metallurgical Project Director. ~~Responsibilities of~~ Research performed by this project was subject ~~approved~~ to the District Engineer ~~thru the medium~~ of Colonel S. Warren, Chief of the Medical Section.

The research group concerned itself with attempts at development and improvement of clinical tests related to radiation exposure, so that project personnel could be followed for demonstrable signs of damage due to overexposure. To this end it has cooperated with other experimental groups in following similar tests in animals having known exposure to various radioactive and toxic substances.

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In addition certain experiments on exposures to fixed amounts of X-radiation were carried out. One might question the use of this type of technique in such a group of studies. However, it has been shown that the effect of x-rays is almost identical to that produced by gamma radiation from radioactive material. In addition the effects of x-rays on the human subject is much better known than that produced by other types. Hence, the x-ray is used by all groups on this project working with radioactivity as a standard measure of biological effects of radiation because of ~~its~~ the ease in control ~~administration, and measurement~~ measuring this type of radiation. Even so, additional data on the ~~x-ray~~ biological effects of x-rays were necessary to fill gaps existing in this rather well studied field, and additional work was carried out by this section.

In late 1942 the Chicago group completed the initial studies on the experimental uranium pile at Argonne, and were ready to start the construction of a larger production type unit at Clinton. This was to be used as a pilot plant for the development of production techniques as well as continuation of developmental physical research. This necessitated additional experimentation on many new and specific radiation problems arising from the handling of larger masses of material on a plant scale which could but be handled at the plant site. In particular much information was needed on the biological effects of radiation from

neutron and beta radiation. At this time all Chicago personnel were engaged in already assigned problems. Hence, it was necessary to build a new laboratory and organize a new research group to carry out such studies under the direction and control of the Chicago Health Physics group headed by Dr. Stone. Dr. H. J. Curtis assumed the leadership of the Clinton group being directly responsible to Dr. Stone.

Experimental work at the Clinton Laboratories commenced as soon as the facilities were available at this installation. The organization plan was somewhat similar to that of the Chicago group and carried on quite similar activities. The biological research section was primarily interested in the effects of animals to the various types of radiation emanating from the pile in operation and from the reaction products to which workers are exposed in the chemical separation of plutonium 239. These exposures are primarily those of beta and gamma ray and neutron (slow) exposures.

(2) X-radiation

Although much radiation work of a spotty nature was being carried out by the Chicago group at the Metallurgical Laboratory, it was impossible to find the space and the facility for carrying out an extensive control and experimental program on x-ray exposures. The National Cancer Institute at Washington was at

that time carrying on a similar program results of which when expanded would fulfill requirements useful to the district. So by expansion of the existing facilities at this location and close cooperation with Dr. Stone and his group a program which would give the desired results was set up in July 1943 at the Bethesda, Md., installation. This included the comparative study of continuous exposures of animals to both x-rays and gamma rays from radium at different concentration levels for specified periods of time. These animals were closely followed for the demonstration of the earliest evidence of any visible changes in the blood, and for evidences of damage at specified periods of time after the start of the exposure. Such results were of great value in the correct evaluation of all types of radiation exposure and while partially duplicated by other types of experiment filled obvious gaps in the field of information on this subject.

The Division of Radiology at Rochester University under the direction of Dr. William S. Bale was created to carry out research on the biologic effects of x-ray in various dosages to the entire body - similar to that which a worker might be exposed on radiation of his entire body surface. Various types of x-rays ranging from those of a 10,000 volts to one million volts were being

studied. This furnished check results on work carried out elsewhere. Effects of these x-rays on the tissues and blood elements of the body were studied. Extensive studies on the hereditary transmission of body characteristics or types to succeeding generations after exposure to x-ray were being carried out. Scientific studies related to the nature of these changes and their cause would serve as aids in early diagnosis of overexposures to x-ray so that individuals so exposed may be removed from such a hazard before irreversable damage is done. Other closely related problems such as the effect of chronic exposure to x-rays on specific tissues, particularly the very sensitive bone marrow were being carried out. Results of all of these studies enabled the Chief of the Medical Section and his scientific advisors to calculate tolerance limits for exposure to radiation so that exposed workers and scientific personnel would not be injured.

Early in 1944 it became apparent that information was needed on the biological effect of the fast neutron on experimental animals. In addition, since the energy produced by the neutron in its reaction had never been adequately measured, it was desirable to have investigations carried out by a recognized authority on the measurement of this energy so that neutrons

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could be standardized in known terms much as x-rays are standardized in terms of roentgens (r).

Dr. G. Failla of the Cancer Research Laboratory of Columbia University agreed to carry out this work. As noted above he has been carrying out studies aimed at such standardization using the Columbia cyclotron as a neutron source. Similarly he has been exposing mice to carefully graded amounts of fast neutrons for acute and chronic exposures. Studies are made of the biological changes induced in these mice by examination of the blood and various body tissues.

Additional results on neutron exposure to another species of animals were also desirable. Hence, another project was instituted in 1944 at the Biochemical Foundation of the Franklin Institute for the exposure of dogs to neutron radiation from the cyclotron at this installation. This work is being guided by Dr. Dowdy of the Rochester project and his aides.

Results of these exposures were used for comparison with the results of Dr. Failla at Columbia also working on fast neutrons, and the work carried out at the Clinton Laboratory on both fast and slow neutrons.

No mention has been made of the entirely different investigative program on fisheries research which has been assumed as one of the activities of the Medical Section. This program under the direction of Dr. Lauren Donaldson,

Associate Professor of Fisheries Research at the University of Washington, Seattle, was prompted by the possibility of injury to the salmon in the Columbia River by the wastes and cooling water including radioactive products issuing from the Hanford Engineering Works production piles. This program which started in 1943 anticipated the initial operation of the piles at some time in late 1944, and it was quite important to have some initial observations before the actual operations commenced. Inasmuch as certain projects such as the Bonneville and Grand Coulee Hydroelectric Power projects had already been believed to have limiting effects on the size of the salmon runs, it was imperative that no additional factors should be introduced into the river which might prove detrimental as a cause in further decrease of the salmon population. For this reason this rather extensive project was started to determine the possible presence of any such effect by the plant processes, so that suitable corrective measures could be instituted before irreparable damage was done to this very valuable and important industry.

Dr. Donaldson, therefore initiated studies concerning the effects of possible radiation (primarily x-ray radiation) on these fish.

A large series of x-ray exposures were carried out to determine the possible biological effect of comparative doses of x-ray on fish of various sizes from the egg stage through the various developmental stages to the adult fish. The adult fish after each of these exposures were bred artificially and the comparative fertility of the eggs determined against unexposed fish used as the controls. The young raised from such eggs were returned to the river after suitably marking them for ease of identification. The return of these fish with the regular salmon run in the specified period of time would determine their health and survival as compared to the normal or unmarked fish.

5.4 III. Radioactive Substances

a. Radium

Although a major quantity of this material was not used in the industrial operation of the Manhattan District, it was necessary to conduct animal studies with radium to use this substance as a base line for comparison with the other comparatively new radioactive substances. Radium was selected because it has been used widely as a standard measure of biological effects of radiation and further, because considerable data was available on toxic effects of radium for humans accumulated knowledge from animal and human exposure since its discovery. This

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work was undertaken at both the University of Rochester, Radiology Division, under the direction of Dr. William S. Bale. This substance was studied for the same reason and at by the University of Chicago group.

b. Polonium

Polonium or (Radium F) was being produced in relatively large amounts, and it was obviously important to study its toxicity. Animal experimentation was undertaken by Dr. W. S. Bale at the Univ. of Rochester to study determine the distribution of this material after being absorbed by the body. Calculations of the energies amounts necessary to damage tissues in various parts of the body were after carried out.

c. Plutonium

The University of Chicago carried out quite a large share of the specific as well as basic research on the metabolism of plutonium (239 ~~230~~) and its toxic effects on the animal organism. It was suspected early that this material might behave in some fashion similar to another heavy metal, radium, with which considerable difficulty in the form of toxicity and deaths developed after the last war. Hence parallel studies were made on radium as well as plutonium for purposes of comparison, and, therefore,

The Crocker Radiation Laboratory of the University of California under the guidance of Dr. J. Hamilton was enlisted to carry out some of the experimental

work on plutonium. Plutonium (239) was made by the cyclotron in trace (extremely minute but detectable) amounts and used in metabolic experiments. The relative effects of trace substances alone and added to regular amounts of some materials such as iodine was also tested. The general results of these tests on trace amounts of these new materials were used for comparison with the results carried out by the Chicago group on larger amounts of such materials and in a sense were used as pilot experiments for establishing the general type of observation made by the Biological Section of the Chicago group when larger amounts of these rare materials become available. Smaller phases of the work at the Crocker Radiation Laboratory included work carried out on soils of various geologic types which were artifically contaminated with plutonium (239). Tests were made on plants grown on such soils and methods of decontamination to remove such materials from the soil. Another phase included work in a small laboratory on methods of attempted decontamination of the animal body of this material. Certain chemical experiments were carried out by this group in developing new methods useful in their work.

d. Fission Products

The experimental work on these radioactive products was carried out by

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the University of Chicago group of investigators. As might be suspected, numerous other nuclear products of the same decay are formed, in certain reactions in which atoms are ruptured a large number of side products and in the chemical separation of plutonium, these substances are formed, which although not desired, do contaminate fraction products and could be hazardous. could produce a hazard. These fission products are formed by actual splitting of the uranium or plutonium atoms into two portions of unequal size as regards weight and mass. Since they are in addition radioactive, there is again the double problem of acute toxicity and radiation and the effect of chronic radiation produced by deposited material. exposure from these substances after being absorbed and stored in the body for extended periods of time. These problems also required investigation, and experiments were planned to carry them out. At first none of the calculated fission products were available and they were made for the project by the co-operative efforts of the group working with the 60 inch cyclotron at the Crocker Radiation Laboratory. The scope of the work on fission products all of these substances and types of radiation by this section included determination of poisonous or toxic levels on various species of animals, the effects of acute and chronic poisoning after exposure to them through feeding, breathing, and introduction of the substance mechanically into the blood stream or tissue spaces of the body; the effects on the various organs of the body after each type of exposure; and the rates of

elimination of substances from the body. Methods for removal of these substances from the body were investigated. ~~Applications of all these studies were of great value in attempting to follow the possible exposure in the human, and preventing any harmful effects due to the overexposure of workers on the various projects.~~

The Crocker Radiation Laboratory of the University of California also carried out work on fission products. ~~Animals were used to study~~ The metabolism in animals was studied, and the effect of of the fission products ~~A smaller phases of the work were carried out on soils~~ artificial contamination of soils of various geologic types ~~which were artificially contaminated~~ with fission products was investigated. Tests were made on plants grown on such soils and methods of decontamination to remove such materials from the soil were studied. Another phase ~~included work in a small laboratory on~~ of the problem dealt with methods or attempts at decontamination ~~of the animal body of these materials.~~ of removing the elimination of these substances from the animal body.

The University of Washington also carried out some work on fission products. Fish were raised in tanks fed by concentrations of the effluent from the piles (which contained fission products) and observations were made. To this date, no evidence has been discovered that would indicate that the amount of radiation emanating from the pile wastes or chemicals in the cooling water has had

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any detrimental effect on the salmon. Additional results are being awaited at the present time to further corraborate the the above statement.

e. Uranium

This substance, as experience has shown, rightfully belongs in the next group of section under substances of potential chemical toxicity. Tho' although it is a radioactive material, its radioactivity is very weak, and the harmful effects encountered in animals are entirely from its chemical toxicity. Because of the work on uranium in the prospective use in a variety of forms, it was considered imperative that complete data be obtained on the toxic effects which might follow exposure to the various uranium compounds, and to the pure metal.

~~Form the foregoing account it might seem to the uninitiate that the scope of the work covered by the previously discussed groups was sufficiently inclusive to solve the large percentage of problems arising in this new research. Many pressing unknowns however, still remained to be answered. Such problems as the toxic effects which might follow the exposure to the various uranium compounds, and pure metal in its preparation for installation in the uranium pile remained to be solved.~~

The Metallurgical Laboratory

Dr. Alfred Tannenbaum of the University of Chicago first attacked the problem of the toxicity of uranium and its compounds by conducting well-controlled animal experiments on the ingestion and injection of these substances in mice. It was soon apparent, however, that more information was needed and speed was imperative. The University of Rochester, Pharmacology Division under the guidance of Dr. Harold Hodge undertook the investigation of the toxicity of

The scope of this program was made greater and that a much larger material allowance would be required because of the increased need for the data. Accordingly, the Univ. of Rochester

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uranium and its compounds on a more elaborate scale.

The division of pharmacology almost entirely occupied itself with the problems related to possible hazards arising from exposure to uranium compounds used in processing in the plants. All types of exposure whether it be to breathing the dust, eating of traces of the powder, absorption of material through the skin and accidental injection into the body through injury were considered. Appropriate experiments were carried out on many species of experimental animals in order to demonstrate the effects of such exposures on the living tissue. The minimum amounts of toxic material, which when absorbed showed injury to susceptible tissues, was determined, and on such findings tolerance amounts, to which workers in the plants could be exposed safely, were determined. Experiments were carried out to determine the cause of the damaging effects on the kidney by these compounds, so that suitable measures could be taken for protective and decontamination of overexposed workers.

Protective devices, in addition, were tested and recommended for use in the areas contaminated with these materials. Findings of practical use were immediately submitted to the Office of the Medical Section for application toward protection of workmen in areas using such materials. Consultant services were

obtained from well established industrial hygiene laboratories such as the Research Division of the U. S. Bureau of Mines and the Kettering Laboratories. Later the services of Dr. Carl Voegtlin, formerly chief of the National Cancer Institute, joined the staff were obtained as scientific advisor.

5.5

W. Substances of Potential Chemical Toxicity

The Special materials which were developed for use as aids in the processing of the uranium compounds constituted potential possible medical hazards, since, like uranium, very little was known concerning their toxicity for possible poisonous action on the human body. The most important of these substances were elemental fluorine, hydrogen fluoride and various compounds manufactured by reacting fluorine with hydrocarbons (fluorcarbons - C_7F_{16}, C_8F_{16}, $C_{21}F_{44}$). The toxicity of these substances was tested on experimental animals much in the same way as is carried out in the began an experimental program similar to those used by the Toxicology Division of the U. S. Public Health Laboratories. Protective devices in addition were tested and recommended for use in areas contaminated with for installations requiring their use. these materials. Findings of practical use immediately submitted to the Office of the Medical Section for application toward protection of workmen in areas using such materials. The work on these special substances was carried out by the Pharmacology Division of the University of Rochester under the direction

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~~of Dr. Harold Hodge.~~ In this research program, as with the uranium research program, consultant services were obtained from well-established industrial hygiene laboratories such as the Research Division of the U. S. Bureau of Mines and the Kettering Laboratories. ~~Later the services of Dr. Carl Voegtlin, formerly chief of the National Cancer Institute, were obtained as Scientific advisor. That such a system has been highly effective is shown by the almost perfect record of this organization in protection of all workers against damage by any special materials.~~

5.6 Industrial Research

a) General The industrial application of results of the research programs is described elsewhere in this volume (Section 3 - Industrial Medicine). ~~It is obvious that the Manhattan District assumed tremendous responsibilities when the organization undertook to safeguard the people employed in the industrial plants against radiation and chemical hazards. Three research groups assumed this responsibility.~~ In conducting the Industrial Medical activities it was necessary to do certain non-medical research, primarily concerned with hazard control.

~~a~~ The Chicago group studied methods of monitoring and developed methods (1) Univ of Chicago adequate of procedures using ~~exposure~~ X-ray films and ionization chambers to determine the amount of radiation existing around working areas. Ventilation systems were studied and working areas were designed to offer the maximum protection.

By use of ~~all~~ the data developed by the workers in this research group and the

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animal research group, corrective measures were instituted to cover all likely possibilities of exposure and to safeguard the workers in all cases.

(2) Clinton Laboratories.

The Clinton group had an industrial research section similar to the one at Chicago. This group assumed responsibility for the medical overall supervision and protection of all workers at Clinton Laboratories both by monitoring the plant and making as well as physical and laboratory studies of the workers at frequent regular intervals.

(3) The University of Rochester

The University of Rochester group also had an industrial research section. One part concerned itself with industrial research on the uranium compounds and the new substances developed for the processing and purification procedures of uranium compounds. Toxicity studies were conducted on large animal populations in order to arrive at tolerance values to which workers in the plants could be safely exposed. Monitoring methods and protective devices were developed for the further protection of the workers exposed to uranium and other special materials. A third

The other part concerned itself in the monitoring of the plant areas under the supervision of the Medical Section was directly detailed for dangerous amounts of radioactive substances, and acted as a consultant service in the determination of the extent of the radioactive was provided hazard. Results of their studies enabled the Chief of the Medical Section and

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his scientific advisers to calculate the tolerance limits for exposure to radiation so that exposed workers and scientific personnel would not be injured.

(g) VI. Instrument Research

(1) General

Since the Manhattan District was confronted with many new and important radiological and chemical hazards in industrial operation, new instruments and devices had to be developed in order to cope successfully with the problems that arose, and the University of Chicago and University of Rochester groups organized Instrument Sections to help solve the difficulties.

(2) Activities

(a) Medical Advisor

4. The Instrument Section of the University of Chicago group designed delicate electronic indicators for various types of radiation and adapted such apparatus to the conditions necessary for either analytical work or monitoring, as the need existed. Instruments were also made for other areas.

(b) Clinton Laboratories

5. The Clinton Laboratories organized a separate instrument section which was used for the construction of instruments especially designed to meet the needs of the Clinton installation.

(c) University of Rochester

6. The Rochester University group also assigned a group of men who devoted their time to instrument research and development. Standard alpha

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meters and all purpose meters for measuring alpha, beta and gamma rays were constructed for Plan and dispensed to areas coping with hazard problems from radiation.

VII. Reports on Research Activities

The various research sections kept in close contact with the Office of the Medical Section thru the medium of progress reports.

The Chicago, Clinton group and the National Cancer Institute reports are filed with the District and are designated as the CH and CN reports.

Progress reports from the University of Rochester are designated as the H series of reports.

Reports of Dr. Failla from Columbia University are on file in the District Office under the name of the head of Radiological, Dr. G. Failla

Reports and information concerning the Franklin Institute project are contained in the Rochester series of reports.

Results of the series of investigations from the University of Washington Fisheries are on file in the District Office under that name.

VIII. Conclusion

It was thru the mutual cooperation among these various research groups and the central coordination by the Medical Section which made it possible

to put into practical application in industry the accumulated knowledge of this biological research and so to offer the research and industrial personnel of the Manhattan District a maximum factor of safety while engaged in work which carried high potential hazard.