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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

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VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

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VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

31 December 1946

FOREWORD

This volume of Book IV of the Manhattan District History presents a brief discussion of the research and development work performed under the auspices of the Metallurgical Laboratory, with headquarters at the University of Chicago, during the period from mid-January 1942 to 31 December 1946. Basic nuclear concepts and early nuclear research culminating in the discovery of neptunium and plutonium are outlined briefly to give the reader the necessary background material. Minute details and highly technical discussions have been avoided, wherever possible, in order to present a clear, comprehensive history of this unique research program.

This volume is divided into two parts, each having its own table of contents, summary, index, and appendices. The research work described in Part I is that conducted at the University of Chicago and at other laboratories under the auspices of the Metallurgical Laboratory. Part II presents a discussion of the research and development work conducted at Clinton Laboratories.

Since much of the design work for the actual production units at the Hanford Engineer Works was proceeding concurrently with the research work conducted by the Metallurgical Laboratory, a considerable amount of the research and development work which affected major design decisions is discussed in Volume 3.

The summary contains an abstract of every main subject treated in the text and is keyed to the text in such a manner that paragraph numbers and headings in the summary correspond to the various sections in

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the text.

Appendix references have been made in the text as a combination of letters and numerals; the letters denote the appendix divisions and numerals refer to the position of the item in the particular appendix. Thus (See App. A-12) would refer to Appendix A, item 12 of that appendix.

Other phases of the history of the Pile Project are described in:

Volume 1 - General Features

Volume 3 - Design

Volume 4 - Land Acquisition, HEW

Volume 5 - Construction

Volume 6 - Operation

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VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

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SUMMARY

1. Introduction. - The objectives of the research conducted by the Metallurgical Laboratory were the development of a process for the production of plutonium and the development of a process for the separation and purification of plutonium from the uranium and fission by-products. The work was authorized by the President of the United States under the First War Powers Act.

The structure of the atom is analogous to that of the solar system: the nucleus being the "sun" and the orbital electrons being the "planets." Identity of an atom is determined by the atomic number, which is the number of protons in the nucleus, and the mass number, which is the sum of the protons and neutrons in the nucleus. The periodic table lists nuclei ranging from one proton (hydrogen) to 92 protons and 146 neutrons (uranium). The nuclei of naturally occurring elements of atomic number 90 or above are characterized by instability because of unbalanced mass to charge ratios. This condition leads to radioactivity, the process by which unstable nuclei return to stable states.

In 1932, J. Chadwick's discovery of the neutron began the chain of research, which, strengthened by E. Fermi's work in Italy, finally led to the fission of uranium, announced in 1939 by Hahn and Strassmann in Germany. It was realised that the tremendous quantities of energy liberated in the fission process were potential sources of power. The problem was to make the fission reaction self-sustaining. By 1940, it was demonstrated that uranium-235 was the

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readily fissionable material in uranium which could be used for propagating a chain reaction. However, U-235 was chemically identical to other uranium isotopes and its concentration by physical methods might have been unfeasible. Therefore, the search for other more satisfactory fissionable materials was continued. In December 1940, a transuranic element of atomic mass 238 and atomic number 94, plutonium, was discovered at the University of California by G. T. Seaborg and his co-workers. A few months later, another isotope of the same element was produced, which, based on considerations of fission theory, could replace U-235 as the fissionable element in a chain-reacting system. The early work on plutonium-239 revealed that this material could be produced and separated successfully from natural uranium.

2. <u>Operating Arrangements</u>. - Prior to August 1942, Pile Project research was conducted through arrangements with OSRD at various universities throughout the country. However, in January 1942, Dr. A. H. Compton, Director of the Metallurgical Project, decided to concentrate the research at one location. To this end, certain contractual arrangements were made between the Government, represented by the OSRD and later by the Manhattan Engineer District, and the contractor selected, the University of Chicago. These arrangements included contracts No. W-7401 eng-37 for research and development and No. W-7405 eng-39 for the operation of a semi-works plant. Some research facilities were provided by the University of Chicago. However, as the Metallurgical Laboratory expanded, the need for construction of new facilities became evident. These new facilities were provided by the construction of new buildings such as those at Argonne Laboratory, and the

New Chemistry Building; and by modifications to existing buildings, such as Site B and the Armory. Upon completion of the facilities at the Argonne National Laboratory, Contract No. W-7405 eng-37 was terminated and operation under Contract 31-109 eng-38 commenced at the new location. Because of the nature of the Pile Project, substances required for research purposes were comparatively rare. The procurement of materials for research and experimental purposes was performed by the Government through the Manhattan District.

3. Development of Piles. - The understanding of how a Pile operates and the various types of Piles requires some knowledge of certain introductory concepts. In particular, neutrons are being produced continuously during Pile operation. However, many of these neutrons are ineffective for the production of plutonium. Some are lost through leakage and others are absorbed in the Pile materials in an ineffective manner. However, these Pile materials serve a definite purpose in Pile operation. The moderator reduces neutron speeds to thermal levels in order to promote the chain reaction; the coolant is required to draw off and dissipate the heat formed in the Pile by nuclear reactions; and the shield is necessary in order that personnel be protected from exposure to excessive radioactivity. The chain reaction is further sustained by placing the uranium and moderator in a geometrical arrangement called a "lattice." A lattice arrangement of the uranium and moderator is a characteristic of a heterogeneous type of Pile, in contrast to a homogeneous type in which the uranium and moderator are in a uniform mixture throughout the Pile. Within these two general classifications, Pile types can be further enumerated by

specification of moderator and coolant. In order to develop the first chain-reacting system, considerable experimental work was necessary in order to determine accurately certain nuclear constants. This experimental work utilized small laboratory Piles for the measurement of neutron intensities and various Pile factors. The first chain-reacting Pile was constructed in the latter part of 1942, and operated as a chain-reacting system early in December 1942. In the consideration of Piles for plutonium production, theoretical considerations led to the elimination of certain possible moderators and coolants, while practical considerations led to the elimination of others. These considerations narrowed the choice of moderator to graphite only, and the choice of coolant to either helium or water, with the possibility of diphenyl cooling, necessitating only slight changes to the water-cooled plant. While preliminary design problems associated with the development of a production Pile were being investigated, a program for the design and construction of certain experimental Piles at Argonne was being initiated. This program was an outgrowth of the dire need for providing Pile research facilities required for the development of larger production Piles; and also to obtain important operational data on a Pile employing heavy water as a moderator. Consequently, a uranium-graphite Pile was built at Argonne, using the materials that were employed in the first chain-reacting Pile. In addition, a uranium-heavy-water Pile was also constructed at Argonne. The experimental data and information gained through the use of these Piles were invaluable in testing materials for production Piles, and for the study of important nuclear constants. Before construction of production Piles could begin, it was necessary that a decision be made as to whether helium or water should be employed as the coolant. The selection of a graphite, water-cooled Pile for the production of plutonium was made only after careful evaluation of the advantages of helium on the one hand and water cooling on the other. With regard to this final choice, the consensus is that water cooling was the wiser.

4. Problems in Pile Design. - Pile design problems arising from nuclear phenomena were extremely complex. Other problems arose from technical, engineering, and constructional aspects of design for a production Pile operating at high power. Certain design problems, although difficult, did not involve the extensive long-term experimental research required of more intricate problems of Pile design. The problem of designing a lattice that would permit easy removal of the uranium, and provide adequate circulation of the cooling water, was solved by designing a lattice in which the uranium is in the form of slugs placed end to end in horizontal tubes. Adequate protection of personnel from dangerous Pile radiations was accomplished by use of a Pile shield made of iron and masonite. Control of the Pile was achieved by inserting into the Pile neutron-absorbing material in the form of rods or pipes. One of the difficult problems of Pile design, however, was the development of a means of retarding tube corrosion and film formation by the coolant on the inside of the tube. This corrosion and film formation is caused by oxidation of the aluminum cooling tubes by water under the effects of Pile operation. After extensive research, the solution to the problem was found in the control of the acidity of the cooling water, and the addition of certain

chemicals to inhibit the formation of film. Another difficult Pile design problem arose from the necessity of protecting the uranium slugs from corrosion and of minimizing the escape of radioactive fission products into the cooling water. To protect the uranium slugs, it was necessary to develop methods of coating or canning the slugs to insure a close continuous bond between the slug and coating. This was necessary in order to prevent contact between the water and the uranium and to provide a high rate of heat transfer from the slug to the cooling water. Early considerations of the problem led to research in various methods of applying protective coatings, and the study of various materials for possible use as a coating. Development of the canning method led to the realization that an aluminum can held many advantages. Final developments in the coating and canning program were marked by the ultimate design of a process utilizing both a coating and a can. In close coordination with the design of production Piles and chemical processes, it was necessary to investigate the metallurgy of Pile materials and the new element, plutonium. The scope and objectives of metallurgical research were determined by the needs of the Metallurgical Laboratory as emphasis on various research programs shifted from time to time. During the early stages of Pile design, the metallurgy of various Pile materials such as canning materials, coolant tubes, shield materials, and the uranium itself were investigated thoroughly. Later on, extensive studies were made of the metallurgy of plutonium and alternate Pile materials. A program as broad and varied as this utilized the facilities of other research organizations. These contractors participated actively in Project-wide metallurgical developments. The operation of a Pile and a chemical process involving the handling of highly radioactive materials required the design of considerable associated equipment and instruments. Over an extended period of time, the Metallurgical Laboratory served as a design and manufacturing center for special optical and electronic instruments.

5. Pile Operating Problems. - Piles operating at high power levels introduced problems which were not significant in the earlier work with low-power experimental Piles. The effect of radiation on solid materials in the Pile, especially graphite, received constant attention. The accumulation of fission products which reduces Pile reactivity did not cause difficulty except in the case of xenon poisoning. Also, several methods for the detection of slug swelling and can failure were investigated by various research organizations to insure a trouble-free Pile operation.

6. Development of Plutonium Separation Process. - Early tracer studies with microscopic quantities of plutonium at the University of California demonstrated the feasibility of a separation and purification process for plutonium. In 1942, organization and expansion of plutonium studies resulted in the construction of new facilities at Chicago; subdivision of the problems to include work on the radioactive fission products; and arrangements for cyclotron irradiation of several hundred pounds of uranium salts. The general problem facing the chemists was the development of a satisfactory process for the separation and decontamination of the plutonium within a time schedule which did not permit leisurely pursuit of the objectives. The concentration of plutonium and fission products in the uranium

from which they were to be separated was less than 200 parts per million. This separation was difficult, but even more formidable was the necessity of removing the fission product elements from the plutonium to such a degree that less than one part in 10 million of the original concentration of fission products remained in the plutonium. All this had to be done with remote control apparatus because of the extremely high degree of radioactivity associated with the fission products. There were four types of processes considered: volatility, adsorption, solvent extraction, and precipitation. Volatility methods depend on differences in vapor pressures between the materials to be separated. Though this process is mechanically the most simple, its development was hampered by severe corrosion problems and insufficient knowledge of the "dry" chemistry of plutonium. Adsorption methods, employing the adsorptive and desorptive properties of inert materials under varying conditions, eliminated the severe corrosion problems, but the impracticability of complete removal of the fission products from the adsorbers resulted in a severe radiation hazard. Solvent extraction processes utilize different degrees of solubility of salts of plutonium, uranium, and fission products in water and organic liquids as a means of separation. These processes provide the only completely continuous separation methods which can be developed. Although a satisfactory solvent extraction method had not been demonstrated by the time process design had to be started, laboratory investigations of these processes were continued and the solvent extraction process appeared very promising for future use. Precipitation methods involve formation of chemical compounds which are insoluble under chemically controllable conditions. The very low concentrations of plutonium and fission products can be handled efficiently by means of "carriers" in successive precipitations and dissolutions until the desired purification of plutonium is achieved. The sequence of repeated operations would simplify equipment design and permit considerable process change without equipment change. This advantage was an important factor in the selection of the separation process. Furthermore, since precipitation methods had been employed from the earliest days of plutonium research, it was logical that they were the most advanced at the time a choice had to be made. A precipitation process was outlined with two carrier materials, bismuth phosphate and lanthanum fluoride, in mind. Final decisions combined the most favorable features of both. Plant operation of this process has been more successful than had been expected and has proved beyond question the wisdom of its choice.

7. Organization and Personnel. - The Metallurgical Laboratory was formed under the directorship of Dr. A. H. Compton who later became Pile Project Director. The three original groups, nuclear physics, chemistry, and theoretical, soon were supplemented by health, engineering, and other sections for specialized work. About 2000 persons were employed at the peak of activities in July 1944. The Chicago Area Office, originally headed by Captain J. F. Grafton and later by Captain, now Lieutenant Colonel, A. V. Peterson and Captain, now Major, J. H. McKinley, was established in August 1942 to supervise the construction of new research facilities. However, when the Manhattan District assumed full responsibility for all activities of the

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Project in May 1943, the Chicago Area Office was charged with administration of certain government contacts with the Metallurgical Laboratory and associated organizations.

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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

SECTION 1 - INTRODUCTION

1-1. Objectives. - The objectives of the research and development work performed by the Metallurgical Laboratory were to procure those theoretical and experimental data necessary to develop a controllable, chain-reacting system (termed a "Pile"), producing plutonium from natural uranium, and to develop a chemical process for the separation and purification of the plutonium from uranium and the fission by-products.

1-2. Scope. - The research work necessary to make the Pile Project feasible included consideration of the following important features:

1. Development of a self-sustaining, controllable chain-reacting system.
2. Determination of the most suitable materials to be used in Pile construction as seen from the point of view of nuclear physics as well as from that of engineering. These materials were those to be used as "moderator,"* shielding, and coolant.
3. Shielding of all personnel from hazardous radiations during operation of the production and separation units.
4. Suitable and reliable means of removing heat from the

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production units.

5. Investigation and choice of the most feasible chemical separation process for extracting the plutonium from the irradiated uranium and fission by-product elements.

1-3. <u>Authorization.</u>

a. <u>General.</u> - The Manhattan District Project was authorized by the President of the United States under authority conferred on him by Public Law No. 580, 77th Congress and Public Law No. 354 (First War Powers Act) 77th Congress (See Book I, Vol. 1).

b. <u>Specific.</u> - The original specific authorization for the research and development work on the Pile Project is contained in a report to the President of the United States, dated 13 June 1942, by Dr. J. B. Conant, Chairman NDRC, and Dr. V. Bush, Director OSRD. It was approved by the Chief of Staff, the Secretary of War, and the Vice President of the United States. The report was transmitted on 17 June 1942 by Dr. Bush to the President, who approved it.

1-4. <u>Basic Nuclear Concepts.</u>

a. <u>Introduction.</u> - To aid the reader in his understanding of certain necessarily technical discussions that appear in succeeding paragraphs, a brief explanation is presented of certain fundamental concepts which form the basis of nuclear physics and its application to the Pile Project.

b. <u>Elements.</u> - Every material substance is composed of a limited number of distinct varieties of chemically-indivisible matter called "elements." An element is not to be thought of as an ultimate constituent of matter, although each element has a real chemical existence and a true order of chemical magnitude. The term "element," to this day, retains the same meaning as heretofore, but the physical conception of the element has been altered. In particular, under present concepts of the atomic theory, each element is composed of atoms, having their individual chemical and physical characteristics.

c. <u>Fundamental Concepts</u>. - Atoms, in turn, are composed essentially of three different kinds of particles, namely, neutrons, protons, and electrons. Thus, each element is made up of atoms, and all atoms are composed of the same kinds of particles. However, one element is distinguished from another by the difference between the relative quantities of neutrons, protons, and electrons in the atoms of each. For example, an atom of beryllium contains five neutrons, four protons, and four electrons; while an atom of gold contains 114 neutrons, 79 protons, and 79 electrons. Moreover, each element may exist in several different species called "isotopes." All the isotopes of any given element are chemically identical, since their atoms contain the same number of protons and electrons, making the atoms electrically neutral. However, isotopes differ physically from each other because their atoms differ in the total number of neutrons comprising each atom. Briefly, a neutron is a particle having a net electrical charge of zero, and having 1.00893 "mass units."* The proton has a positive electrical charge of unity and has a mass of 1.00757 units. The electron has an electrical charge equal to that of the proton, but opposite in sign, that is, negative; and has a mass of 0.000548 units. Thus, the mass of the electron is negligible in comparison to that of a proton or neutron.

d. Atomic Structure. - In describing the structure of the atom, the analogy of a planetary system is undoubtedly familiar to the reader. Employing this analogy, the center or "sun" of the "solar system" of the atom is the nucleus, consisting, in general, of neutrons and protons. The only exception to this is the case of the hydrogen atom, whose nucleus contains a single proton. The revolving "planets" are electrons, one to balance the electrical charge of each proton in the nucleus, revolving in orbits about the nucleus. Even though atoms are inconceivably small (diameter of an electron orbit is less than 1/100,000,000 of an inch) the atom consists mostly of empty space. To illustrate this fact, if the cross section of the nucleus of the atom were the size of a 50-cent piece, the nearest electron would be revolving in a circle of radius of one-half mile. The opposite charges (those of protons in the nucleus and electrons in the orbits) develop a force of attraction between the nucleus and the revolving electrons, but the high speed (about 1360 miles per second) of the revolving electrons keeps them in their circular orbits, in the same manner that the sun's gravitational pull on the earth is balanced by the centrifugal force of the revolving earth. As explained previously, the weight of the electron is negligible in comparison to that of the neutron or proton, so that virtually all of the weight of the atom is in the nucleus.

e. Mass Number and Atomic Number. - The mass number of an isotope is determined by adding together the number of neutrons and protons in its atom. The atomic number of an element is determined by the number of protons in its atom. Elements are known by their atomic number, while various isotopes of the same element are distinguished by the mass number. Thus gold (79 protons) is known as element 79; uranium (92 protons) as element 92. The predominantly abundant isotope of uranium is known as uranium-238 (U-238), i.e., its nucleus contains 92 protons and 146 neutrons; while other isotopes (all with 92 protons) are designated as uranium-235 (U-235) and uranium-234 (U-234). A table of naturally-occurring elements, commonly called "The Periodic Table of Elements," lists 92 elements ranging from hydrogen (element 1) with the simplest atom consisting of one electron and a nucleus comprised of only one proton; to uranium (element 92) with 92 electrons and, for U-238, a nucleus comprised of 92 protons and 146 neutrons.

f. Nuclear Stability. - While it has been correctly stated that a neutron has a net electrical charge of zero, it is important to realize that, for the purposes of clarity in further discussions, it is assumed that the neutron itself is composed of a proton and an electron more or less "bound" together. The nucleus, in turn, is subjected to two different forces: (1) the electrostatic forces of repulsion between the positively-charged protons, and (2) the mechanical forces of attraction between all the closely-packed particles. The comparative magnitude of these two opposing forces is dependent, partially at least, upon both the size and complexity of the nucleus, and upon the relative proportions of neutrons and protons. The combined effect of these forces of attraction and repulsion is such that only certain nuclei are stable. Although conditions for stability vary widely within all ranges of the periodic table, it can be stated that, in general, instability exists to a greater degree in the upper ranges of the periodic table of elements, where nuclei possess 90 or more protons and about 150 neutrons.

g. Radioactivity. - A condition of instability in a nucleus may be illustrated by considering the analogy of a hot piece of metal in a cool surrounding. An unstable condition then exists, but a stable condition is reached when the metal cools to a point where there is no transfer of energy from the metal to its surroundings or from the surroundings to the metal. An unstable nucleus may be compared to the hot metal, in which case the nucleus seeks a stable condition be emitting alpha particles (helium nuclei), beta particles (negatively charged particles or electrons), or certain radiant energy. This nuclear process of seeking stability is referred to as "radioactivity" and elements which "disintegrate" in this fashion are termed "radioactive."

h. Uranium-238 and Plutonium. - Uranium-238, to all intents and purposes, may be considered a stable isotope of uranium (actually it is not, but its rate of disintegration is so slow that, for practical purposes, it may be considered as stable), and, under proper conditions, its nucleus can be made to absorb a neutron with a result that it forms $_{92}U^{239}$. (Note: The symbol "$_{92}U^{239}$" is used to indicate the uranium isotope whose nucleus contains 239 particles of which 92 are protons.) $_{92}U^{239}$ is a radioactive isotope, each nucleus of which emits a beta particle. It is assumed that this beta particle is the negative portion of a neutron, and its emission, therefore, leaves one free positive charge, i.e., a proton. The additional proton increases the atomic number by unity, resulting in an element of atomic number 93, to which the name neptunium has been given. Thus, radioactivity accounts for the change from $_{92}U^{239}$ to $_{93}Np^{239}$. Neptunium, however, is only one stage in the disintegration. It, too, is radioactive, and emits, likewise, a beta particle, becoming another element, plutonium, with atomic number 94, and indicated as $_{94}Pu^{239}$.

1-5. Early Nuclear Research.

a. Introduction. - The discovery of the neutron by Sir James Chadwick and his associates in England in 1932 revolutionized atomic research. As explained in the preceding paragraph, the neutron became established as a fundamental particle of the atomic nucleus. Furthermore, the newly found particle was recognized as a remarkable projectile for atomic bombardment experiments. Its lack of electrical charge assured its penetration of the strong electrostatic fields within the atom.

b. First Neutron Bombardments. - In 1934, a scientific group led by Enrico Fermi in Italy started systematic neutron bombardment of practically all the elements. They showed that the nuclei of atoms were affected by neutrons in various ways. One process involved absorption or "capture" of the neutron by the nucleus. Presumably, this caused an unstable state; then the nucleus returned to stable conditions by emitting a beta particle (high-speed electron) to form a new atom, one unit greater in atomic number than the parent atom. By this mechanism, copper atoms were converted to zinc atoms, and gold atoms to mercury atoms. In other cases of neutron bombardment, other types of changes within the nucleus occurred, resulting in the formation of many radioactive isotopes of naturally occurring elements, eventually ending in a stable atom of lower atomic number than the parent atom.

c. Interaction of Uranium and Neutrons. - The question arose as to what would happen if uranium, the element of highest known atomic number, were subjected to neutron bombardment. Would a new "transuranic" element be created, or would the neutron absorption cause radioactive decay to an element a few places lower in the periodic system? When the experiment was performed, resulution of the results was extremely difficult, and even consideration of elements of atomic number up to 97 could not account for all the findings.

d. Discovery of Fission. - At the end of 1938, Hahn and Strassmann in Germany became interested in the problem and concentrated their efforts on the chemical separation of the products of reaction of neutrons with uranium. They presented indisputable chemical evidence that at least one of the products believed to have been a transuranic element was actually an isotope of the element barium, which has about half the mass of uranium. A new mechanism for the reaction of a neutron with uranium was obvious: the splitting or fission of the uranium nucleus.

e. Energy Released by Fission. - The fission of the uranium nucleus caused the release of a tremendous amount of energy. The total mass of the fragments was less than the mass of the parent atom plus the captured neutron. According to Einstein's theory, this mass was not lost but converted into energy. Measurements of photographic and electronic manifestations of fission confirmed that enormous quantities of energy were evolved in the reaction.

f. Mass Energy Relationship. - The equivalence of mass and energy is not apparent in ordinary combustion or chemical processes. As expressed by Dr. Einstein, Energy = Mass x Conversion Factor; the conversion factor is equal to the square of the speed of light, a number so large that mass changes accompanying ordinary releases of energy are too small to be detected. The energy from the usual burning of one kilogram (2.2 pounds) of coal is about 8.5 kilowatts. However, if this quantity of coal could be completely annihilated so that no ash or combustion gases remained, 4-billion times as much energy would be produced.

g. The Chain Reaction and Associated Problems. - It is easy to understand the sensation that Hahn and Strassmann's report created in the scientific world. Nuclear physicists everywhere started investigation of the fission process. Heretofore, utilization of energy from nuclear disintegration was not practical because the processes were not self-supporting. The total energy necessary to bring them about was always far greater than the total energy which resulted. The scientists reasoned that if nuclear fission was accompanied by the release of more neutrons, these could be used to propagate further nuclear disintegrations, and the reaction might become self-sustaining or "chain" in character. A chain-reacting system would make available the quantities of energy released by the individual atoms as a power source of unlimited possibilities. The following problems were attacked to determine the feasibility of a chain-reacting system:

1. How many neutrons were released by the fission of the uranium nucleus?
2. If these neutrons were available for further reaction, why was there no chain reaction under existing experimental conditions?

3. Three isotopes of uranium were known. Were all three subject to the fission reaction? Would other elements behave similarly?

4. What energies of bombarding neutrons were most efficient in producing fission? How could neutron energies be varied and controlled?

5. What were the identity and radioactive properties of the fragmentary atoms and radiation accompanying fission?

h. Development of Nuclear Theory. - Partial or complete answers to the above questions were soon known to the scientific world. In addition, the nuclear-drop model theory was developed by Niels Bohr and his associates to account for the fission process. This theory regards the nucleus as held together by cohesive forces similar to those binding the molecules in a drop of water. If an extraneous neutron is absorbed by the nucleus, equilibrium conditions are disturbed; the nucleus is distorted and eventually broken apart, just as a drop of water is affected by increasing its size. The mathematical treatment of the forces within the nuclear-drop model provided scientists with a means for correlating the vast amounts of experimental evidence that had been obtained, and deciding what information was still needed for complete understanding of nuclear fission.

i. Review of General Knowledge in 1940. - By the time organized voluntary or enforced censorship had been placed on the publication of information concerning fission, about the middle of 1940, the following facts were generally known:

1. An average of one to three high-speed neutrons are released in the fission of a uranium nucleus.
2. These fast neutrons can be slowed down or "moderated" to the speeds of gas molecules at ordinary temperatures by elastic collisions with relatively inert atoms such as carbon, helium, or hydrogen.
3. Fast neutrons cause fission in uranium-235 and uranium-238. However, slow neutrons cause fission of U-235 but do not cause fission of U-238; instead, they react with U-238 to form transuranic elements, neptunium and plutonium.
4. Fission of thorium and protoactinium, two other heavy elements, is caused only by fast neutrons.
5. Extremely high kinetic energy is imparted to the fission fragments, which are identified as radioactive isotopes of elements with atomic masses approximately half the mass of the uranium atom.

1-6. Early Plutonium Research. - Early research work on the transuranic elements (those with atomic numbers 93 and 94) was done at the University of California. Element 93, named neptunium (Np), was discovered by E. McMillan and P. H. Abelson. Element 94 was discovered in December 1940 by G. T. Seaborg, A. C. Wahl, and J. W. Kennedy by the bombardment of uranium-238 with deuterons (nuclei of the "heavy hydrogen"* atom), giving Np-238 which disintegrated to plutonium-238. Thus, the first isotope of plutonium discovered and studied was not the isotope of paramount interest, Pu-239, but, rather, the isotope Pu-238.

In March 1941, the important isotope, Pu-239, was discovered. Considerations of fission theory confirmed by experiments led to the conclusion that plutonium (Pu-239) would undergo fission when bombarded by neutrons. This conclusion led to a realization that if relatively large amounts of plutonium were available, it would be likely that a chain reaction with fast neutrons could be produced. The release of enormous energy (See Par. 1-5) would accompany such a reaction. In the meantime, however, much had been learned concerning the fission process and the isotopes U-235 and U-238. Thus knowledge lent support to the possibility of producing plutonium from uranium by means of a slow-neutron chain reaction. Furthermore, the separation of the plutonium from the uranium could be accomplished by ordinary, albeit complicated, chemical means; since plutonium, although produced from uranium, is a different chemical element. Production of the other material of possible military importance, U-235, however, would require a difficult isotopic separation of it from U-238, since these isotopes are chemically identical. By the end of 1941, it was generally recognized that, with practical certainty, an atomic bomb capable of exerting tremendous destructive force could be made from either concentrated U-235 or from the newly-discovered element, plutonium. Also, considerable theoretical progress had been made. Certain nuclear and physical constants had been determined with a relatively high degree of accuracy, and earlier estimates of properties of plutonium had been checked. On the practical side, however, little progress was recorded. Although the chain reaction had been demonstrated clearly to be theoretically possible, no self-sustaining chain reaction had been achieved. Furthermore, the establishment of a chain reaction did not necessarily insure an effective atomic bomb even though the bomb "explosion" is a nuclear chain reaction. Moreover, only microscopic amounts of plutonium (these were in the form of plutonium salts) had been produced. Virtually no uranium metal or graphite of required purity were available for construction of Piles. By the end of May 1942, however, the experimental work, for which Dr. A. H. Compton was Director, had been centered at the University of Chicago (See Par. 2-1) and considerable progress, both theoretical and practical, had been made. The most urgent problem in the production and procurement of uranium metal and graphite of high purity had been solved and initial production was getting under way. At the Metallurgical Laboratory, problems associated with the design of the first chain-reacting unit were nearing solution, and uranium and graphite were being received and processed for its construction; and for the construction of small experimental units for the study of neutron absorption and nuclear properties of Pile materials. In addition, other research required for Pile design and construction was being pushed vigorously (See App. C 1), including neutron studies and engineering aspects of Pile design. Simultaneously, research in the chemical separation and purification of plutonium was making rapid strides, even though, as pointed out previously, only microgram amounts of plutonium were available from "cyclotron"* production. The chemical properties of plutonium and chemical reactions between plutonium and chemicals possessing required characteristics for separation processes were being actively investigated (See App. C 2). Having available only minute amounts of plutonium, the achievements of microchemists in their studies of chemical properties of plutonium and the evolution of likely separation and purification processes was, indeed, a remarkable achievement. The results of their studies proved invaluable in the complete development and refinement of large-scale separation processes when more plutonium became available, early in 1944, from operation of the Clinton Laboratories Pile (See Vol. 2, Part II). It is to be remembered that, although the Metallurgical Laboratory of the University of Chicago, under arrangements with the Office of Scientific Research and Development, served as the nerve center of this broad program of research, considerable theoretical work was being done at other universities and laboratories under similar arrangements with OSRD (See Par. 2-1).

SECTION 2 - OPERATING ARRANGEMENTS

2-1. Arrangements with OSRD. - Government sponsored research directed toward the development of chain-reacting fissions was inaugurated under contracts of the Office of Scientific Research and Development by small groups of scientists at the University of Chicago, Columbia University, Princeton University, the University of California, the University of Virginia, Cornell University, the National Bureau of Standards, and the Naval Research Laboratory. In January 1942, Dr. A. H. Compton, who had been appointed Director of the Project for studying controlled chain reactions and the measurement of nuclear properties, decided to concentrate the studies, insofar as possible, at one location. These were centered at the University of Chicago under OSRD Contract No. OEM sr-410. The Manhattan District of the Corps of Engineers, following its establishment effective 16 August 1942, coordinated the work and pushed plant construction while the OSRD continued to supervise the research and development work on atomic fission under its existing contract. This arrangement continued until 1 May 1943 when the Manhattan District then and since September 1942 under the command of Major General (then Brigadier General) L. R. Groves, assumed full responsibility for all phases of the atomic bomb program.

2-2. Contractual Arrangements with the University of Chicago.

a. Selection of Contractor (See App. D 1). - As pointed out in the preceding paragraph, it was decided to concentrate the research and development work for the Pile Project at one location in order to coordinate and expedite its completion. The University of Chicago had been selected because of (1) its nationally central location and distance from the sea coasts, (2) the facilities available for immediate use and future expansion, (3) the supply of trained physicists and chemists available in the Midwest, and (4) housing facilities, which were not as critical in Chicago as in some other locations. Consequently, in the spring of 1942, the research groups from the various universities were moved to Chicago and organized under the name of the "Metallurgical Laboratory." Therefore, at the time that the Manhattan District assumed full responsibility for the administration and supervision of the research and development work, the facilities and personnel were already established at the University of Chicago and it was economically sound to continue the work at this location.

b. Contract No. W-7401 eng-37. - On 1 May 1943, the University of Chicago entered into a contract, No. W-7401 eng-37 (See App. B1), with the Manhattan District for conducting research and development work leading toward the design, construction, and operation of chain-reacting production units and chemical separation plants. The work was undertaken by the University on a non-profit basis, the contractor being reimbursed for all costs incurred in connection therewith.

The total cost to 31 December 1946 under this contract was $27,933,134.83, of which $647,671.80 represents the cost for remodeling existing facilities and new construction. In addition, construction completed under prime contracts and including Government Purchase Orders, amounted to $2,154,912.36. None of the funds of this contract were spent for restoration of facilities, and the net cost for

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operating the Laboratory under the contract was $27,285,463.03.

Contract No. W-7401 eng-37 was terminated as of 30 June 1946, the research work continuing under Contract 31-109 eng-38, with the name of the Laboratory changed to the Argonne National Laboratory.

c. Contract 31-109 eng-38. - The new contract covering research and development work on chain-reacting units and chemical separation plants was initiated upon completion of the Argonne Laboratory facilities and became effective 1 July 1946. For the period ending 31 December 1946, the new contract costs were $2,756,730.54, of which $161,688.10 represents cost for remodeling and new construction, and the balance of $2,595,042.44 represents the cost of operating the Laboratory.

As of 31 December 1946, lump sum settlements for a total value of $49,509.83 were made with the University of Chicago, for restoration of facilities. Payment of the settlements will be made with funds from Contract 31-109 eng-38 which includes provisions for all restoration in connection with the old and new contracts.

d. Contract No. W-7405 eng-39. - The Metallurgical Laboratory of the University of Chicago also undertook the operation of a semi-works or pilot plant at Oak Ridge, Tennessee, to be designed and constructed by E. I. du Pont de Nemours and Company under another contract. This operation was covered by Contract No. W-7405 eng-39, which also became effective on 1 May 1943 (See Vol. 2, Part II).

2-3. Provision of Research Facilities. - When the Metallurgical Laboratory was established, space for the necessary offices and laboratories was provided by the University of Chicago in campus buildings

(See App. A 2). The administrative offices were located in a part of Eckhart Hall (See App. A 4); the physics group was assigned space in the West and North Stands of Stagg Field (See App. A 5) and in the Service Building (See App. A 10) for use of the cyclotron located there; and the chemistry group was allocated laboratory space in Jones and Kent Laboratories. This last space was vacated when the New Chemistry Building (See App. A 6, 7) was completed. As the Project grew, the University withdrew its activities from Eckhart Hall and the adjoining Ryerson Hall (See App. A 8) and these two buildings were almost entirely occupied by the Metallurgical Laboratory. Later, space was assigned in the Anatomy Building and Billings Hospital (See App. A 8, 9) and the buildings now known as Drexel House (See App. A 9) and Ellis Laboratory (See App. A 10) were turned over entirely for the use of the health group. In all, the Metallurgical Laboratory occupied approximately 205,000 square feet of space in campus buildings (See App. B 3). From time to time, modifications and alterations to these campus buildings had to be made in order to adapt them to the needs of a concentrated, everchanging research and development program, and to make all of the space occupied a "Restricted" area for obvious security reasons (See Book I, Vol. 14). In addition, interior modifications were made in the Reynolds Student Clubhouse, Barnes Laboratory, the Botany Building, the Alpha Delta Phi fraternity house, and the Museum of Science and Industry to adapt them for the use of University functions displaced by the taking over of other campus buildings by the Metallurgical Laboratory. This work was accomplished originally by the University's Buildings and Grounds Department, and later by

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Laboratory subcontracts and purchase orders supervised by the Chicago Area Office of the Manhattan District. The cost of these alterations amounted to approximately $131,000 under subcontracts and purchase orders (See App. D 2) and an estimated $300,000 for work done by University forces.

2-4. Construction of New Facilities.

a. General. - In the summer of 1942, it became evident that more research facilities would be required in order to expedite accomplishment of the objectives of the Metallurgical Laboratory. Since the facilities that the University of Chicago was able to supply had been overtaxed by the rapid expansion of the Metallurgical Project, it was decided to construct several new buildings. The Manhattan District established the Chicago Area Office in August 1942 to lease the property required and to supervise the construction work. The Stone and Webster Engineering Corporation had accepted a contract, No. W-7401 eng-13, to perform architect-engineer-management services for all construction required by the Manhattan District. (It was later determined that it would be necessary for other contractors to take part in this work if the Project was to be completed on schedule.) Plans to construct a pilot plant near Chicago for small scale production and separation of plutonium were reconsidered and it was decided to construct this plant at a more remote location under another contractor (See Vol. 2, Part II). Stone and Webster then prepared the design and supervised the construction of an experimental Pile building with related laboratories, and a chemistry laboratory building. It was later found necessary to more than double these facilities to take

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care of the growing program.

b. Argonne Laboratory (See App. D 2). - For security reasons, it was felt that experimental work in a Pile laboratory could best be handled away from population centers. A decision was made to construct the laboratory in an isolated area on a site, selected in June 1942 by Colonel Marshall, District Engineer, about twenty miles southwest of Chicago in a Cook County Forest Preserve known as the Argonne Forest. This location was chosen because it was sufficiently isolated and yet within easy commuting distance of the University campus (See App. A 1, 3). With the assistance of the Real Estate Branch of the Great Lakes Division, U. S. Engineers, a lease was negotiated between the Forest Preserve District and the War Department for the use of 1088 acres of this area at a rental of one dollar, for the duration of the war and one year (See App. C 19). The construction of the original laboratory building, service buildings, an access road and protective security fencing was initiated in September 1942 and completed in the early part of 1943. In August 1943, construction was started on a new laboratory for a "heavy water"* Pile and necessary service buildings at this site involving the erection of eight buildings including a dormitory and mess hall for resident members of the Contractor's staff. In addition, a 328-foot well was drilled to provide adequate water supply and a 75,000-gallon steel water tank was erected for storage capacity. This work was completed in October 1944 (See App. A 3, A 11-15; D 2).

c. New Chemistry Building. - To take care of the expanding chemistry group it was found necessary to provide 20,000 square feet of laboratory space specially equipped for developing separation and purification processes for uranium-235 and plutonium-239. The University offered to lease to the Government, for this purpose, 0.73 of an acre of land located at 56th Street and Ingleside Avenue (See App. A 2), then occupied by tennis courts, for a one dollar rental fee (See App. C 20). Stone and Webster also acted as architect-engineers for this construction under Contract No. W-7401 eng-13. Work was initiated in August 1942 and completed in December 1942 (See App. A 6, 7; D 2). In May 1943, the chemistry program had been increased to the point where it was necessary to provide additional facilities for this work. Action was taken to supplement the above lease to include an additional 0.85 of an acre of land adjacent to the New Chemistry Building on which to construct a 30,000-square foot annex (See App. A 16, 17). This New Chemistry Annex was completed in November 1943. Extensive modifications to the New Chemistry Building were also necessary and were started in February 1944. This work included the installation of a complete ventilation system to provide dust free laboratory space for research on plutonium. This work was completed in October 1944 (See App. D 2).

d. <u>Site B</u>. - In April 1943, the University made available to the Metallurgical Laboratory an ice house and stables that it owned at 6111 University Avenue in Chicago (See App. A 1, 2, 18). This location, known as Site B, was remodeled and enlarged to provide laboratory, shop, and service facilities for the rapidly growing metallurgy and health divisions of the Project. These facilities were completed for occupancy in June 1943. As the technical

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and health programs continued to expand, it was necessary to double these facilities in the fall of that year. In all, approximately 62,670 square feet of facilities were provided at this location (See App. B 3; D 2).

e. Armory. - To solve the critical space problem a lease (See App. C 21) was negotiated in March 1944, between the State of Illinois and the U. S. Government, for the use of the 124th Field Artillery Armory located at 52nd Street and Cottage Grove Avenue in Chicago (See App. A 1, 2, 19). Extensive alterations and modifications were made to convert the space taken over to laboratories, shops, stock rooms, and offices for the Laboratory administrative personnel and the staff of the Chicago Area Office (See App. B 3; D 2).

f. Construction Costs. - All of the above construction was accomplished under lump sum contracts let by the Government or under subcontracts of the University. A total of 360,000 square feet of new facilities were constructed and/or leased at a cost of approximately $2,000,000 (See App. B 3; D 2). Since September 1944, no major construction has been undertaken. However, some alterations and modifications to existing facilities were continually being made. This work was carried out under the supervision of the Chicago Area Engineer by means of University of Chicago subcontracts.

2-5. Procurement of Materials. - The subject of the procurement of feed materials for the atomic bomb program is given complete treatment in Book VII. However, the procurement of the special materials required to initiate and carry out the research program of the

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Metallurgical Laboratory is worthy of mention here. In 1942, procurement of uranium and graphite was primarily the responsibility of the OSRD S-1 Section Planning Board. Small amounts of uranium oxide and metal were purchased by the Laboratory with the assistance of OSRD from Westinghouse Electric and Manufacturing Company, the Metal Hydrides Company, the Mallinckrodt Chemical Works, and the Canadian Radium and Uranium Company. With the technical assistance of the National Bureau of Standards, graphite of sufficient purity was obtained from the National Carbon Company and the Speer Carbon Company. In the fall of 1942, production facilities for producing uranium metal of sufficient purity were established at Iowa State College under an OSRD contract. This work was continued under Manhattan District Contract No. W-7405-eng-7. Arrangements also were made late in 1942, by the Manhattan District, for the increased production of metal by the Mallinckrodt Chemical Works as well as the Union Carbide and Carbon Corporation and the du Pont Company. Early in 1943, the Manhattan District took over all procurement of such materials for the Metallurgical Project. In addition to the above, the following materials were procured by the Government for the contractors: radium, platinum, iridium, fluorine, and hydrogen fluoride, calcium, tungsten, thorium, and beryllium. The University of Michigan under Contract W-7401-eng-92 prepared a number of pure chemicals for use in the purification research program being done at Metallurgical Laboratory and elsewhere.

SECTION 3 - DEVELOPMENT OF PILES

3-1. Types of Piles.

a. Introductory Concepts. - Certain fundamental considerations of fission and the chain reaction have already been presented (See Par. 1-5). The fission process, and the formation and "non-fission" loss of neutrons within a Pile, requires some amplification in order that the reader may appreciate the problems involved in designing a Pile. Within the Pile Project, the primary purpose of the Pile is to produce plutonium by a nuclear reaction which sustains itself. Unfortunately, many of the neutrons produced in the Pile by fission processes are nonproductive from this viewpoint. Some of the neutrons are absorbed in the Pile materials other than the uranium; others are lost by leakage; still others are absorbed by the uranium or impurities in a manner such that (1) radioactive by-products, and not plutonium, result or (2) no fission (to continue the reaction) occurs. If too many neutrons are absorbed without fission occurring, or, even though fission does occur, if the number of neutrons emitted by the fission process is too small, the reaction will not sustain itself and will die out. Thus, in a Pile, if a specific number of first-generation neutrons is produced by fission, a certain number of them will be ineffective for the reasons just described. Some of them, however, will be effective and will cause fission, thereby producing more (next generation) neutrons. If these fissions are sufficiently numerous and effective, this next generation will have an equal number of neutrons and the system is chain reacting. This change in the number of neutrons from one generation to the next is described, mathematically, by a factor called the "multiplication factor" or "reproduction constant," and is designated by the letter "k." It is the factor by which the average number of neutrons in a Pile changes during one generation. Thus, if 100 neutrons at the start of a generation cause fission that produce 105 new neutrons available to cause additional fission, the multiplication factor is 105/100 or 1.05. Clearly, "k" must have a value equal to unity, or the system would not be a self-sustaining, chain-reacting unit. Within a Pile, a myriad of factors affect the value of "k" and all of them have to be taken into account in the design of a chain reaction that would maintain itself. At the outset, the ultimate success of the entire Pile Project was synonymous with the construction of the first chain-reacting unit (See Par. 3-2) in order to demonstrate clearly that such a unit or system was actually attainable—not just theoretically possible.

b. Pile Materials. - The materials that comprise a Pile may be divided into five categories in accordance with their purpose. Briefly, these categories are the uranium, the moderator, the coolant, the Pile shield, and the auxiliary equipment, including control devices, equipment for insertion and removal of the uranium, and recording instruments. The part that uranium plays as the "raw material" in the production of plutonium in the Pile has been amply described (See Sec. 1).

(1) Moderator. - It has been mentioned (See Par. 1-5) that fast neutrons can be slowed down or moderated by certain substances. The slowing down of these neutrons is a result of a series of elastic collisions between high speed particles and particles virtually at rest. The more nearly identical the mass of the fast-moving neutron and the

particle that is struck by it, the greater is the loss of kinetic energy by the neutrons. Consequently, substances or elements with nuclei of low mass are most effective as moderators. These elements are the so-called "light" elements such as hydrogen, helium, lithium, beryllium, boron, carbon (graphite), and deuterium oxide (heavy water). In addition to the requirement of low atomic weight, another requirement (among many) of a moderator is that its tendency to absorb neutrons be very low—too high an absorption of neutrons by the Pile moderator may cause the Pile multiplication factor "k" to be less than unity, thus making the chain reaction impossible. Thus, by a series of elastic collisions between the fast or high energy neutrons, resulting from fission in the Pile, and the nuclei of the moderator, the energy of the neutrons is reduced to very low or "thermal" energies. This reduction in energy of neutrons to thermal levels is required in order to establish a favorable balance between the relative number of neutrons absorbed by the uranium-235 (resulting in fission to produce more neutrons) and those captured by the uranium-238 to produce plutonium, since low-energy neutrons are more effective than fast neutrons in the fission of U-235. Conditions for this favorable balance must be created within the Pile by use of a moderator and other means, otherwise there would exist an unfavorable condition in which neutrons would be more readily absorbed by the 140 times more abundant U-238, with a consequent reduction in the number of neutrons available to cause fission in the rare isotope U-235, resulting in the discontinuance of the chain reaction and the cessation of Pile activity. Consequently, major problems associated with the design of the Pile, as for example, the moderator, arose from the primary necessity of promoting fission to sustain the chain reaction.

(2) Coolant. - Since the production of appreciable amounts of plutonium in a Pile is accompanied by the continuous liberation of energy in the form of heat, a cooling system is required to draw off and dissipate this heat in order that the Pile may operate for extended periods of time. Substances used for cooling may be divided into three classes; namely, gases, liquids, and molten metals. Nuclear, physical, and engineering considerations established the following criteria for a Pile coolant:

1. Low absorption of neutrons.
2. Chemical stability.
3. Desirable thermodynamic properties.
4. Resistance to radioactive disintegration.
5. Simplicity of design of cooling system which includes pumps, heat exchangers, circulatory system, and auxiliary equipment.

No one coolant satisfied these criteria completely. Among the gases, air or helium could be employed. In the case of liquids, ordinary water and heavy water (deuterium oxide) offered possibilities of use. Other possible coolants included liquid bismuth and alloys of lead and bismuth. Each of these coolants had certain advantages and disadvantages for use in a Pile (See Vol. 3).

(3) Shield. - While in operation, a Pile emits radiations of various types. These radiations are definite health hazards to operating personnel, since they are somewhat similar to X-rays. To prevent

personnel from being exposed to this hazard, a Pile requires a shield to confine these radiations safely within the structure. The shield also serves as a major structural member of the Pile. Various materials or combinations of materials could be used as a shield. Thick walls of concrete appeared the obvious and best, although concrete and water, "masonite,"* or lead could also be used; as could also a combination or "sandwich" type shield of masonite and iron or other materials.

e. Lattice. - The essential Pile ingredients for production of plutonium by nuclear reactions are the uranium and the moderator. The extent and nature of nuclear reactions that occur within the Pile are dependent upon the manner in which the uranium and moderator are placed or distributed in the Pile with respect to each other; upon the comparative volume and weight of the uranium and moderator; and also upon the physical shape of the pieces of uranium metal and the moderator. The geometrical arrangement of pieces of uranium in the moderator is termed the "lattice."* However, to describe a specific lattice uniquely requires a precise delineation of considerably more factors than those just described (See App. C 3). A Pile employing a fissionable material such as uranium in the form of either lumps or definite shapes (cylindrical, spherical, or cubic) imbedded in a moderator is termed a Pile of the "heterogeneous" type. This type of Pile is to be contrasted to a type termed the "homogeneous" type, in which the uranium is in the form of fine particles mixed with the moderator; or in which the composition of the material within the Pile is uniform throughout. Like the moderator, the general purpose of the precise arrangement in a heterogeneous Pile, in contrast to a homogeneous Pile, is to promote fission to sustain the chain reaction.

d. Description of Pile Types. - Within each classification as to type (heterogeneous vs. homogeneous), Piles are customarily described with respect to coolant and moderator. For example, a Pile could be described as an air-cooled, graphite-moderated, heterogeneous type; or a water-cooled, heavy water-moderated, homogeneous type. Thus, various coolants could be combined with different moderators to form different combinations such as the following: graphite-moderated, with helium, air, or water as a coolant; or heavy water-moderated, with air, helium, water, or heavy water as a coolant. While these substances can be easily enumerated for possible use in a Pile, obvious nuclear physical engineering considerations led to the elimination of some of them at the outset. Other possibilities were investigated to a considerable extent before they, too, were discarded for less obvious reasons (See Par. 3-3). As has been pointed out above, the primary purpose of both the moderator and lattice is to promote fission in order to sustain the chain reaction. The likelihood of effective fission may be increased by still another method which is a characteristic of a type of Pile known as an "enriched" Pile (See Vol. 3). It is the isotope uranium-235 that is the highly fissionable material in uranium, but it exists in uranium only in about one part in 140. Also, the abundant isotope U-238 captures neutrons, without fission resulting. If the U-235 could be separated from the U-238, and a Pile using a high concentration (enrichment) of U-235 could be constructed, the probability of fission occurring to sustain a chain reaction would be greatly enhanced.

3-2. First Chain-Reacting System.

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a. Introduction. - It was recognized in the early stages of investigation that a mathematical analysis of the processes involved in neutron absorption and reproduction could not give the degree of accuracy required for actual construction of a high power, chain-reacting unit. The varied factors to be considered were so complex that experimental determination of neutron reproduction constants of suggested systems was necessary.

b. Laboratory Piles. - The first experimental Piles which were constructed at the Metallurgical Laboratory were heterogeneous systems of uranium metal, uranium oxide, and graphite. Many such systems (called lattices) were subjected to neutron irradiation from external "radium-beryllium sources"* and the University of Chicago cyclotron. Then, by means of probing channels through the lattices, measurements of neutron intensities within the systems were made. Theoretical calculations of Pile factors were thus checked against experimental findings. The experimental lattice work provided essential information on the following major problems:

1. The multiplication constant "k" was shown to be greater than unity for certain lattices of uranium metal, uranium oxide, and graphite of the purity available to the Project.

2. "Thermal stability"* experiments indicated that the "reactivity"* of the systems under investigation became less as temperatures increased. Therefore, an accidental rise in temperature was not likely to increase the development of energy, causing a further

rise in temperature, and a probable catastrophe.

3. The value of using large lumps of uranium, instead of relatively small pieces, for optimum neutron utilization was established.

4. The importance of delayed neutrons in controlling Pile operation was confirmed. A small percentage of the neutrons available for uranium fission are delayed for periods ranging up to a few seconds after the splitting of the uranium nucleus. This phenomenon produces a lag in reactivity of a Pile instead of a rapid multiplication of energy which would result if all fission neutrons were instantaneously liberated. The experimental Piles, in particular the first chain-reacting unit described below, measured the effects of delayed neutrons on Pile reactivity and control.

c. First Chain-Reacting Pile. - By October 1942, sufficient materials were available to attempt the construction of a self-sustaining, reacting unit. It was designed as a spheroid of graphite blocks containing bricks of uranium and uranium oxide in the proper geometrical spacing. Movable strips of neutron-absorbing cadmium metal were inserted in the Pile as construction advanced to keep the neutron radiation low enough to prevent accidental attainment of the chain reaction. Measuring instruments were also placed at strategic points for purposes of constantly checking neutron intensities and energies. Thus, it was discovered that critical conditions were attained before the lattice was completed, i.e., the multiplication factor exceeded unity. As a result, the final shape of the Pile approximated a flattened sphere with a polar diameter of about 20 feet and an equatorial diameter of about 26 feet (See App. C 4). On 2 December 1942, operation of the Pile was started at an energy level of ½-watt by careful partial withdrawal of the cadmium metal strips. On 12 December 1942, the power level was raised to 200 watts. However, the latter power level could not be maintained because of the radiation hazard to people in the vicinity. Therefore, the testing was continued at the ½-watt level until the Argonne Laboratory (See Par. 2-4) was constructed. In the early part of 1943, the first chain-reacting unit was dismantled at its campus site and reassembled with proper "biological shielding"* for higher power outputs at the Argonne Laboratory.

3-3. Piles Considered for Plutonium Production.

a. Theoretical Considerations. - Certain types of Piles and various possible coolants and moderators have been enumerated in the previous paragraph. Early considerations, however, led either to the outright elimination of certain materials, or to the determination that definite advantages accrued in the use of one type of material over another. Late in 1941, it was shown that the heterogeneous type of Pile, employing a lattice, possessed definite advantages over a homogeneous type (See App. C 5). Of the possible moderators, lithium and boron were quickly discarded because of their high tendency to absorb neutrons. Helium, likewise, was struck from the list of likely moderators since, being a gas, its neutron moderating properties were relatively low under normal pressure, and also, being chemically inert, helium forms no compounds. In the case of the coolants—air, water, helium, bismuth, and heavy water—none was eliminated solely on the basis of theoretical considerations. Thus, early considerations narrowed the choice of moderators to either water (a compound of hydrogen), beryllium, carbon in the form of pure graphite, or heavy water; the choice of coolants lay in either air, water, helium, bismuth, or heavy water. It is to be realized that no one choice of moderator and coolant was better in every respect than all the others, and certainly none of them could be guaranteed to give smooth, trouble-free operation.

b. Practical Considerations. - In addition to the theoretical considerations, certain practical considerations led to the further elimination of certain pile types and materials. Such practical considerations included the complexity of a cooling system for a specific coolant; Pile efficiency; relative plutonium production rate; safety of operation; ease of insertion and removal of the uranium; speed of construction; availability of materials; and status of knowledge (in mid-1942) of Pile design in foreseeing possible trouble and complications. The enriched Pile was eliminated at this time because of the scarcity of uranium-235 (See Book VII). The use of heavy water as a moderator or coolant for a production Pile was eliminated on the same count as there were only a few kilograms of heavy water available and it was estimated that two years would be required to supply adequate amounts. Heavy water and the heavy-water Pile, however, offered distinct advantages that warranted the continued production of heavy water and development of heavy-water Piles in the event that insurmountable difficulties arose in the use of other Piles for plutonium production. Actually, a comparatively small heavy-water Pile was built (See Par. 3-4) and has proved to be an invaluable instrument in the study of nuclear physics. Beryllium appeared to be considerably less advantageous than heavy water and just as difficult to obtain. In the case of gaseous coolants, helium offered many advantages over air. In particular, the inert quality of helium lessened corrosion problems arising from chemical reaction of the coolant with the Pile materials. Bismuth as a coolant had certain advantages in comparative plutonium yield and rate of plutonium production. These advantages, however, were more than offset by the difficulties in handling an intensely radioactive molten metal; and also by the fact that the use of bismuth as a coolant would require the use of "uranium carbide"* in the Pile instead of uranium (the melting point of uranium metal being lower than that of molten bismuth), and the manufacture and fabrication of uranium carbide presented many serious problems that would require long-term study.

c. <u>Statement of Problem at End of 1942</u>. - Thus, for the purposes of designing a plutonium-producing Pile of high output in as short a time as possible, theoretical and practical considerations, by the end of 1942, had narrowed the choice of a moderator to one, namely, graphite; and the choice of a coolant to two--helium or water. It is to be realized, however, that the elimination of certain possibilities--for example, enriched Piles and heavy-water Piles--from a role as high-power plutonium-production Piles was a result of a situation existing in 1942. Questions of whether or not a graphite-moderated, water- or helium-cooled heterogeneous Pile was the best type of Pile from all points of view, could be answered only as a result of considerably more research after alternative Pile materials became available. In the meantime, however, a plutonium-producing Pile had to be built. Before construction could start, however, there remained the one question as to whether it should be water- or helium-cooled.

3-4. Argonne Experimental Piles

a. Introduction. - The first chain-reacting unit constructed in the West Stands was dismantled early in 1943 (See Par. 3-2) and its materials were used in the construction of a uranium-graphite Pile in an isolated location about 20 miles southwest of Chicago (See App. A 1). Early investigations of possible plutonium-production Piles revealed that the use of heavy water as a moderator had certain advantages, but the amount of heavy water then available was negligible, and graphite moderation was chosen for production Piles. However, a program was established for the production of heavy water (See Book III) for possible alternative use in production Piles, and also for use in low-powered experimental Piles that would serve as a source of valuable information on this type of Pile and also as a valuable experimental instrument for use in the design of production Piles. A heavy-water-moderated Pile was constructed early in 1944 at the same isolated location to which the graphite Pile was moved. This location is known as "Argonne" and the two Piles and experimental facilities are known as the "Argonne Laboratory" (See App. A 3).

b. Argonne Uranium-Graphite Pile. - The greater part of the materials used in the Argonne uranium-graphite Pile was taken from the West Stands Pile after the latter was dismantled. However, the Argonne Pile, known as the CP-2 Pile, was built substantially cubical in shape, instead of spherical, and contained considerably more uranium. This CP-2 Pile is about 30 feet square in plan and about 25 feet high (See App. A 20). The lattice consists of a geometrical arrangement of graphite blocks, bored with cylindrical recesses in which small uranium cylinders are inserted. The Pile is shielded on all sides by a concrete wall 5 feet thick, and on the top by a six-inch layer of lead and 50 inches of wood. The Pile contains about 52 tons of uranium and 472 tons of graphite, and first became chain reacting in May 1943. Its overall multiplication constant "k" is about 1.055 (See App. C 6). No cooling system was provided for this Pile so that it is normally operated at a power level of only a few kilowatts, although the power level has been raised for brief intervals. This Pile has been used extensively for determining the "neutron-capture cross sections"* of many elements which might be used in future Pile construction or might be present as impurities in Pile materials. It has also been used for studies of shielding, controls, thermal stability, and instruments, as well as a training school for production operations.

c. Argonne Uranium-Heavy-Water Pile. - The reacting unit of this Pile, known as the CP-3 Pile, is a cylindrical aluminum tank with a diameter of six feet, in an upright position (See App. A 21-23). The tank is filled with heavy water. The cover of the tank is pierced with holes regularly spaced, through which aluminum-sheathed uranium rods project vertically into the heavy water in the tank. The system (including tank and cooling system) requires approximately 6.5 tons of heavy water, and 121 rods suspended vertically in the heavy water. The tank itself is surrounded by a graphite "reflector" which serves to reflect

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neutrons back into the reacting unit. A lead shield surrounds the reflector. The usual biological shield of concrete surrounds the entire structure. The top of the structure is shielded by several layers of thick, one-foot square removable "bricks" composed of alternate layers of iron and masonite. Various holes for experimental purposes traverse the shield. Control is achieved by rods of neutron-absorbing material which are pivoted so as to swing down and dip into the heavy water. Cooling of the Pile is accomplished by circulating the heavy water through an external water-cooled heat exchanger system. Safety features for emergency purposes include an automatic mechanism which can plunge the control rods into the heavy water; and also a subterranean tank into which the heavy water in the reacting unit may be dumped rapidly. The CP-3 Pile became chain reactive in May 1944 and was operated at full power (300kw) in July 1944. Both the CP-2 and the CP-3 Piles at Argonne have proven to be extremely valuable instruments in the general study of nuclear physics and in the testing of materials for use at other sites (See App. C 7).

3-5. <u>Selection of Graphite, Water-Cooled Production Pile</u>. - By the end of 1942, it had been determined that a plutonium-producing Pile of the heterogeneous type employing graphite as a moderator appeared the best from most theoretical and practical viewpoints. Actually, scientific design and technical data regarding various types of Piles was incomplete, and it was not possible to make a carefully weighed decision as to the best type of plant. Yet a decision was necessary in order that full scale design and construction could get under way. The one decision remaining was whether helium or water should be used as a

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coolant.

a. Helium Cooling. - The Metallurgical Laboratory favored helium cooling during the early stages of investigation. Preliminary plans for such a plant were drawn up, and it was felt that full scale design could be achieved more rapidly for the helium-cooled plant than for the water-cooled plant. Among the many recognized problems inherent in helium cooling were:

1. The large quantity of helium required.
2. The early procurement of high-capacity blowers.
3. The relatively low power output per kilogram of uranium metal.
4. The difficulty of charging and discharging the Pile, especially if the helium were under considerable pressure.
5. The removal of neutron-absorbing impurities from the large quantity of helium.
6. The hazards resulting from leakage of the radioactive gas.
7. The relatively low heat-absorbing capacity of helium, making it desirable to maintain the helium under pressure with the attendant need for an enclosing pressure tank.

In spite of these evident difficulties, however, a design for a helium-cooled Pile was prepared by the Metallurgical Laboratory in considerable detail (See App. C 8). This design was submitted to the du Pont Company who initially accepted it.

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b. Water Cooling. - While the designs of the helium-cooled plant were being worked out, further experimental results indicated that water cooling was possible and tentative plans were prepared (See App. C 9) on a water-cooled production Pile. These plans made provision for the use of either of two coolants--water or "diphenyl"*--necessitating only minor changes to the plant in going from one type of cooling to the other. The only construction change that would be necessary in the Pile proper in going from water cooling to diphenyl cooling would be to increase the thickness of the annular space between the slugs and the aluminum tubes (See Vol. 3). Disadvantages in this type of Pile were also apparent. The advantage of a lesser volume of coolant was partially offset by problems of corrosion caused by the water or diphenyl in contact with the Pile materials, and the radioactivity "pick-up" of the coolant in passing through the Pile. It was known also that the internal complexity of the Pile would be considerably greater if a liquid were employed as a coolant.

c. Final Choice. - Early in 1943, however, after the du Pont Company had studied the proposed designs for a helium-cooled plant and the tentative plans submitted by the Metallurgical Laboratory for a water-cooled plant, including the possibility of a diphenyl-cooled unit, it favored the water-cooled plant in view of the engineering problems involved in the design of the other two types. The consensus now is that water cooling was the wisest choice.

SECTION 4 - PROBLEMS IN PILE DESIGN

4-1. Introduction. - Early in 1943 the first objective of the Metallurgical Laboratory, i.e., the design of a plutonium-producing Pile, had been reduced to the design of a graphite-moderated, water-cooled Pile (or several such Piles). Also, the objective had been further delimited by decisions as to the rate of production (See Vol. 6) and the location of the plant site (See Vol. 4). Clearly, speed of construction was necessary to provide the United States with a military weapon of unprecedented power for use in current military engagements. The complexity of problems in the design of a Pile, mainly from the nuclear physics viewpoint, has been implied by previous discussions of nuclear theory (See Par. 1-4) and certain preliminary considerations (See Sec. 3). These problems were further complicated and new problems were introduced by technical, engineering, and constructional aspects of Pile development. Moreover, in a production Pile, operating necessarily at high power, the dissipation of considerable heat was a problem which was not present to such a great degree in low-power experimental or semi-works Piles. It has been calculated that the production of one gram of plutonium in a Pile would be accompanied by as much heat as the burning of three tons of coal. The solution of each of these problems required considerable concentrated research. Some of these problems, such as problems of the lattice, shielding, and control rods, turned out to be less troublesome than others. Other problems, particularly those arising from the need of cooling the Pile, proved extremely difficult, and their solutions required, over a period of time, the concentrated efforts of both the Metallurgical Laboratory and other research organizations. Other problems, too, such as effects of radiation on Pile materials, the design of Pile control instruments, optical instruments, and "remote control" devices required extensive study and development.

4-2. <u>Certain Design Problems</u>.

a. <u>Lattice</u>. - The lattice has been described previously as consisting of lumps of uranium imbedded at specified "points" in a graphite moderator. There were several objections to this point lattice for use in a production Pile. First, the Pile would have to be almost completely disassembled in order to remove the uranium; secondly, concentration of the coolant at the uranium lumps (which are points of maximum production of heat) would be extremely difficult. In order to overcome these difficulties, it was decided to have the uranium in the Pile in the form of "cylindrical slugs"* approximately eight inches in length and 1.4 inches in diameter placed end to end in horizontal, internally-ribbed tubes with the water coolant flowing in the annulus between the surface of the slugs and the inner surface of the tube. When the uranium slugs had been in the Pile long enough so that a predetermined amount of plutonium had been formed, the slugs could be pushed out of the Pile by forcing fresh uranium slugs into their place. In addition, this "rod" lattice would be superior structurally. However, it became necessary then to determine whether such a rod lattice could be built with a multiplication factor greater than unity. The calculations made by the theoretical physicists were confirmed by the experimental physicists, with the result that this form of lattice was adopted.

b. Shield. – As has been mentioned previously, dangerous and very intense radiations are emitted by the Pile reacting unit when in operation. This radiation is, in fact, so intense that if no precautions were taken, it would be fatal to remain in the neighborhood of a Pile for as short a time as one second. Furthermore, this radiation, particularly neutrons, has a pronounced capacity for leaking out through holes, cracks, or other faults. It was necessary, therefore, to interpose between the chain-reacting unit and the operating personnel a shield to absorb the dangerous radiations. The shield had to be not only impervious to dangerous radiations, but also gastight to prevent escape of radioactive gases. The problem was further complicated by the fact that the tubes in which the slugs were placed and which carried the coolant had to traverse the shield in order to permit the removal of uranium slugs. The material to be used in the shield, the thickness of the shield, and a multiplicity of other problems required full investigation in order that the shield would satisfy nuclear physics and engineering criteria. It was decided to use a shield of about six-foot thickness containing alternate layers of iron and a hydrogenous material. Water was first considered for the hydrogen-containing layers, but masonite was the final choice because of the greater ease and speed with which an iron-masonite shield could be erected.

c. Control and Safety Rods. – It was necessary to control the nuclear reaction so that the multiplication constant "k" would remain equal to unity. If this were not done, the reaction would become divergent with consequent destruction of the Pile due to excessive temperatures and exposure of surrounding areas to excessive heat and radiation hazards. Control was achieved by inserting into the Pile a neutron-absorbing material in the form of rods or pipes. The extent to which these control rods were inserted into the Pile was automatically regulated by instruments in such a manner that "k" was held at or just above unity. In order to design a control rod it was necessary to first determine what neutron-absorbing substance was to be used, how much of it would be required, and how much heat would be generated in the control rods by their absorption of neutrons. Furthermore, the number, placement, and degree of control of the rods had to be determined (See Vol. 3).

4-3. Tube Corrosion and Film Formation. - The selection of water as a coolant, and the use of a "rod" lattice, required that water be conveyed to the uranium through tubes or pipes. Nuclear physical considerations (low neutron absorption), and relative stability and strength in the presence of high radiation limited the choice of tube materials at the outset. Further requirements of availability of materials, relative resistance to leakage, warpage, and corrosion led to the selection of aluminum as a material for coolant tubes, although it was realized that, even using aluminum, the problem of corrosion and oxidation of the aluminum by water under the effects of Pile operation would not be solved easily. The problem of corrosion of the aluminum tubes and the formation of a film by chemical action on the inside of the pipe was an important one; for leakage of water through openings caused by corrosion might stop the chain reaction, and the formation of a thick film could retard coolant flow to such a point that excessive heating might result. Either of these conditions, also, would require

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the removal of the tube from the Pile—an arduous task that would first require shutting down the Pile, and allowing time for decay of radioactivity, thus seriously impeding production and exposing personnel to possible radiation dangers. It was recognized early that the method of solution lay in the control of the chemical makeup of the cooling water. However, it was not a case of merely adding certain fairly obvious chemical ingredients that would retard corrosion, and others that would reduce film formation. The problem was soon found to be extremely complex and required extensive work for a period of about two years—right up to the time that the production units went into operation. Many chemicals were investigated. Some, while tending to reduce corrosion, would have undesirable tendencies under intense radiations, or, while effective at one rate of flow, would be considerably less effective at another. Others, while reducing film formation at certain temperatures, would be comparatively ineffective at other temperatures, or would form corrosive compounds under the effects of radiation. In addition, not only was it necessary to investigate various chemicals, but also various concentrations of them. "Synthetic" water of the natural composition available at the plant site was prepared in the laboratory; tests were run employing various minerals, acids, and alkalies at various temperatures, rates of flow, and concentrations; and the effects under radiation were noted. The corrosion studies showed that optimum conditions were achieved with respect to the corrosion of the tubes when the water was only slightly acid ("pH"* of 6.5). This effective acidity is controlled by treating the cooling water with dilute sulphuric acid before it enters the Pile. Other chemicals are also added to inhibit

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the formation of flow-retarding film. These chemicals include sodium silicate, sodium dichromate, oxalic acid, and certain insoluble "scouring" solids. Many scientific reports on this problem of corrosion and film formation have been written and are in the files of the Metallurgical Laboratory (See App. C 10).

4-4. <u>Coatings and Canning.</u>

a. <u>Introduction.</u> - In order that corrosion of the uranium slug by the cooling water be eliminated and the radioactivity of the cooling water be lessened, it was necessary to develop a protective coating for the uranium slug. This work involved investigations of possible materials for coatings, and also, means of applying the coatings. It was necessary that the substance selected for the coating not only protect the uranium from corrosion but also be relatively non-corrodible itself. Furthermore, it was required that the coating prevent radioactive "fission products"* from entering the cooling water, and also be gastight. These requirements were over and above the ever-present nuclear physical requirement of low neutron absorption. Moreover, it was vital that the method of applying the protective coating be such as to provide a close, continuous seal to prevent water from leaking into the can and to insure a high rate of heat transfer from the uranium slug to the cooling water. The problem was critical, as a failure of the coating or jacket not only would increase the radioactivity of the water discharged from the Pile, but probably would cause the slug to swell and bind in the tube. Were this to occur, the flow of cooling water would be impeded or perhaps stopped entirely, and the removal of the swollen slug would be exceedingly difficult. It was believed conceivable at the outset that failure of the coating on a single slug might require shutdown of the entire Pile. Several processes were ultimately developed, but there was no certainty that any of them would prove entirely satisfactory. In fact, some modifications were made in the process in August and September 1944 just before the first production Pile was placed in operation (See Vol. 6). All in all, the development of a satisfactory slug closure was perhaps the most difficult of all research and development problems undertaken in connection with Pile design and development (See Vol. 3). The complete development of a "canning"* process required a broad program of research including such lines of investigation as the following:

1. Nuclear physical requirements.
2. Analysis of requirements and limitations imposed by Pile design.
3. Intensive and critical appraisal of the general field of protective coatings and their application.
4. Investigation of the metallurgy of uranium.
5. Study of corrosion problems.
6. Development of testing methods.
7. Process development and manufacture.

b. Early Considerations. - In surveying the general field of applying protective coatings, the following general techniques were studied and experimental work carried out on all of them: electroplating; hot-dipping; spray coating; cementation coating; and mechanical jacketing or canning (See App. C 11). In addition, the possibility of developing corrosion-resistant alloys of uranium was investigated. The work on electroplating methods revealed that a variety of suitable metals could be applied to the uranium but to achieve adherence and continuity of the electroplate was extremely difficult, although an electroplate coating consisting of alternate layers of nickel, copper, and lead appeared not too objectionable. The hot dip method, however, appeared better than the electroplating. Mechanical jacketing or canning also revealed definite advantages, largely dependent upon the quality of the final closure, which was to be accomplished by some welding technique. Of the large number of materials studied for possible use as a protective coating, comparatively few proved to be practical. These included copper-tin alloys, zinc, zinc-aluminum alloys, aluminum-silicon alloys--all of which appeared likely for use in the hot dip method. For the canning method the aluminum can appeared to offer many advantages. As a result of further investigations, the canning method employing an aluminum can proved definitely superior and was selected for use in the air-cooled pilot plant erected at Oak Ridge, Tennessee (See Vol. 2, Part II).

c. Final Developments. - As work progressed toward the final choice of a coating for slugs in a water-cooled production Pile, the aluminum jacket remained the chief candidate. However, it was recognized that a can and canning procedure that proved suitable for a low-powered pilot plant in all likelihood would be inadequate for the production Pile because of the vastly greater amount of heat developed in this unit. The magnitude of this heat is such that, in the central portion of the production Pile, the heat equivalent of approximately 13 kilowatts must be transferred from each slug to the cooling water.

To insure that this heat be removed from each slug continuously during the life of the slug in the Pile, it was necessary to achieve a positive and uniform contact between the cylindrical slug and the can, and tests indicated that the simple canning procedure developed for the Clinton pilot plant would be inadequate. These considerations led to a program of research to develop a method of bonding the aluminum can to the uranium slug. Previous experimental work in hot dipping and the aluminum can suggested possible methods for bonding a can to the uranium cylinder. In particular, two methods were investigated simultaneously. One of these methods employed sine, containing a small amount of aluminum for the bonding. This method proved satisfactory from the point of view of corrosion resistance and mechanical requirements but tests on the canned slug in the Argonne Pile revealed undesirable nuclear physical properties. The second method employed an alloy of aluminum and silicon for the bonding agent. Severe mechanical difficulties were encountered in the development of this process due to the comparatively small difference between the melting point of the alloy and the aluminum can, causing penetration of the bond into the can. However, it was felt that this difficulty could be overcome and the development of the aluminum-silicon bond and canning procedure was pushed vigorously through the summer and into the fall of 1944, and was finally adopted for use in the production Piles (See Vol. 6). The development of the canning procedure, however, required thorough investigations into possible methods of final closure of the can so as to be gastight, waterproof, corrosion-resistant, and durable under Pile operation. Early experimental work on welded closures did not reveal clearly that a completely satisfactory welding method could be attained. Consequently, two canning methods obviating the use of a weld were considered (See App. C 12). However, a suitable welding technique was developed by the use of electric welding (with tungsten electrodes) in an atmosphere of argon gas (See Vol. 6). In order to insure a sufficient number of slugs for the initial charging of the Piles, 152 tons of unbonded slugs were procured and tested. A very small fraction of this total was found unsuitable for operation (See Vol. 6). The extensive program of research required in the development of a satisfactory canning method utilized the facilities, equipment, and trained personnel not only of the Metallurgical Laboratory, but also of other universities, Government and industrial research organizations, and other sites (See Vol. 2, Part II) of the Manhattan District Project. Worthy of particular mention are the valuable contributions made by the National Bureau of Standards, Iowa State College, Massachusetts Institute of Technology, and Battelle Memorial Institute in the studies of the metallurgy of uranium and the development of canning testing methods; and by the Grasselli Chemicals Division of the du Pont Company in the investigations of possible canning materials and methods (See App. B 1).

4-5. Metallurgy.

a. Scope and Objectives. - The program of metallurgical research conducted by the Metallurgical Laboratory was unusually broad in its scope and varied in its objectives. The metallurgical research activities at all times were coordinated closely with other research programs. During the early stages of Pile design, it was necessary to investigate thoroughly the metallurgical properties of various materials proposed for use in the Pile, including the canning materials, metals for use as coolant tubes, shield materials, and the uranium itself. Various methods of fabricating Project materials were investigated. These methods included hot piercing, extrusion, casting, drawing, and rolling. The final purification of plutonium and the handling of the pure plutonium were beset by problems of a metallurgical nature. For example, it was necessary to develop suitable materials from which to make crucibles to handle the highly reactive plutonium, and success in the development of such materials was dependent upon a sound knowledge of the chemical and metallurgical properties of the new element, plutonium. A considerable portion of the metallurgy research program was devoted to a thorough study of the alloy systems of uranium and the metallurgy of alternate Pile materials.

b. <u>Contractors (See App. D 1)</u>. - A program as broad as this and as varied in its objectives required special facilities and highly specialized technical skills. This work, therefore, was conducted not only at the Metallurgical Laboratory, but also at other Project sites. In addition, the facilities of several industrial research organizations were utilized. The Massachusetts Institute of Technology performed considerable work in the development of crucibles and the manufacture of experimental quantities of plutonium; and some work also in studies of the alloy systems of uranium and the metallurgy of materials of construction, particularly beryllium. The group at Iowa State College, in addition to their fundamental research in the production of uranium (See Book VII), carried out excellent work in regard to uranium alloys, the metallurgy of thorium in connection with its use as a possible primary fissionable material, and preliminary work in the metallurgy and production of beryllium. The work of the Grasselli Chemicals Division has been described previously in connection with the canning program with which considerable metallurgical research was coordinated. The Battelle Memorial Institute participated actively in the development of methods of fabricating uranium in slug (cylindrical) form suitable for canning. These and other organisations performed this research and development work under contracts with the Government (See App. B 1). The scope and objectives of the research programs under these contracts were established by the Government through representatives of the Metallurgical Laboratory; and the progress of the work was checked periodically. By these means, the work of each individual contractor was carefully integrated with the research objectives of the Pile Project. Other facilities were utilized by subcontracts between the Metallurgical Laboratory and other organisations. In particular, aluminum fabrication studies were carried out through this arrangement by the Wolverine Tube Division of the Calumet and Hecla Consolidated Copper Company, the Aluminum Corporation of America, and other organizations (See App. B 2).

4-6. Associated Equipment. - While performing research associated with the design of a production Pile and the development of a chemical separation process, it was necessary to carry on a vigorous program for the design and development of certain auxiliary equipment required in Pile operation and chemical processes. Some of this equipment was available commercially and could be adapted to Project use with comparatively few modifications. However, the need for most of the equipment arose from the health hazards present in the processing of highly radioactive substances and the necessity of determining the strength and nature of radioactive emanations. These hazards required the use of remote control techniques which in turn, required special equipment. For these reasons it was necessary for the Project to design, test, and manufacture equipment and instruments. A predominant role was played by the Metallurgical Laboratory in the design and manufacture of these instruments, in particular, optical and electronic instruments. The optical instruments included boroscopes (for examination of Pile tubes), periscopes, telescopes, extensoscopes, peritelescopes, "fly-eye" viewers, and other inspection devices (See App. C 13; Vol. 6). The main problems in the development of these instruments arose from the coloration and other effects of radiation on their materials of construction. This complication necessitated thorough investigations and testing of various types of glass, cements, and plastics. During 1942 and the forepart of 1943, the Metallurgical Laboratory was the design center for the electronic instrument program. As the activities increased at other Project sites, the demand for electronic instruments grew rapidly. During this period of Project development, the Metallurgical Laboratory continued research to improve electronic circuits and to design new instruments, and also expanded its facilities for the production of instruments. During the year 1944-1945 the Metallurgical Laboratory served as the main source of supply for electronic instruments. Many instruments were developed for experimental use and for use in conjunction with Pile operation. However, the majority of these electronic instruments were built for the primary purpose of measuring radiation levels in order to protect personnel from excessive radiation of various types (See Book I, Vol. 7). Instruments have been constructed for the detection and measurement of specific types of radiation such as "alpha radiation,"* "beta radiation,"* gamma radiation, and slow neutron radiation. Other instruments can be used for detection of several types of radiation. These instruments also have various applications such as surveying of large areas, surveying of confined areas (probe type), and monitoring of air, hands, equipment, and clothing. Additional research facilities for the development of special electronic devices were obtained through Government contract with the Victoreen Instrument Company. Demand for new Pile Project instruments and the increasing stringency of specifications required a continuous instrument research program (See App. C 14).

SECTION 5 - PILE OPERATING PROBLEMS

5-1. General. - Concurrently with the design and construction of plutonium producing Piles, the research and development program concerned itself with problems associated with successful and uninterrupted operation of the Piles. However, there were many troublesome factors which did not loom into significance until Pile operation at high power levels was actually attained. Extrapolation of small scale data did not guarantee perfect evaluation of results under enormously magnified circumstances, although allowances for all foreseeable variables were made in design and construction. Therefore, research and production facilities were organised to collaborate on any operating problems that developed.

5-2. Effect of Radiation on Solids (Wigner Effect) (See Vol. 6). - Atoms of solid Pile materials are dislodged from their normal lattice positions by the constant bombardment of high energy neutrons during Pile operation. Interatomic forces prevent a fraction of the displaced atoms from returning to their normal lattice positions. The unchecked development of this phenomenon of atomic displacement (generally termed the "Wigner Effect") is deleterious to the physical and structural properties of the Pile materials affected. Any adverse changes in densities, elastic moduli, or heat conductivities of the Pile contents would endanger successful Pile operation. Since atomic displacement is accompanied by a storing of the energy absorbed in the process, the sudden accidental release of this energy during Pile operation is another factor to be considered. Furthermore, graphite which comprises the bulk of the Pile materials, is particularly susceptible to atomic displacement because of its rigid crystalline structure. Consequently, the Metallurgical Laboratory, in collaboration with Clinton Laboratories and Hanford Engineer Works, undertook the development of methods for measuring and controlling the Wigner Effect in the Hanford Piles. Specialized facilities at the Carnegie Institute of Technology and the National Bureau of Standards also were pressed into service. To date, it has not been necessary to reduce internal stresses caused by atomic displacement in the Hanford Piles. Nevertheless, research has provided the means to follow conditions very carefully, and methods for controlled stress and energy relief have been devised.

5-3. Xenon Poisoning (See Vol. 6). - Many of the radioactive fission elements produced in an operating Pile are parasitic to the chain reaction. That is, they compete against uranium-235 for the capture of slow neutrons, thereby "poisoning"* Pile reactivity. Extensive research prior to the design of production Piles revealed several fission elements which were recognized as potentially troublesome. Fortunately, the extremely short half lives of most of them prevented accumulation of dangerous concentrations in an operating Pile. However, when the first Hanford Pile became reactive, and a certain power level was reached, the Pile reactivity suddenly began to decrease, until after a few hours operation the Pile shut itself down. The fact that after a short shutdown period the Pile again could be started only to repeat this mysterious behavior suggested the accumulation and decay of some unfamiliar radioactive poison. Operating records of the Piles at Chicago and Clinton were searched for evidence of the same difficulty, but apparently the effect at lower Pile levels was negligible. However, under carefully controlled conditions, the phenomenon was identified in the Clinton Pile and attributed to a radioactive isotope of the rare gas xenon. This poisoning effect due to xenon was not eliminated in the Hanford Piles. However, the poisoning effect was overcome by increasing the excess (the amount above 1.00) multiplication factor "k" by increasing the number of slugs in the Pile and by proper adjustment of control rods. This procedure, however, would not have been possible had the original Pile designs provided for the availability of only slight excess "k" (See Vol. 2, Part II; Vol. 6).

5-4. Detection of Slug Swelling and Can Failure. - It has been pointed out previously that failure of the jacket surrounding the uranium slug would seriously imperil Pile operation. A broad program of research had evolved a slug-canning process which withstood all tests to which it had been subjected. However, to insure minimum interruption of Pile operation, it was necessary to take into account the possibility of can failure under conditions of high-power Pile Operation. There is no indication of failure in a can until a swelling of the uranium slug caused by water penetrating the can and reacting chemically with the uranium restricts the flow of cooling water. Also, imperfections in the bond cause variations in temperature at the surface of the slug. These variations cause some distortion of the slug. Advanced stages of can deterioration are marked by excessive swelling and distortion of the slug, causing the slug to bind in the tube and preventing the easy removal of the slug. For these reasons it was necessary to investigate possible methods of detecting can failure in its early stages (See App. C 15). Among various methods investigated were the following:

1. Optical Methods. - The decrease in intensity of light transmitted through the annulus from one end of the tube to the other would indicate the presence of blisters on one or more slug surfaces. Considerable difficulties were introduced by the turbidity of the flowing water, and the turgidity in the water caused by the presence of impurities. The method was not explored further after the initial tests with flowing water in the tubes.

2. Sliding Collar Method. - A curved plate, with horseshoe shaped cross section, is allowed to float downstream through the tube. The fit of the plate over the slugs is such that the presence of a blister which attains appreciable size will bind the plate, and can be detected when the plate is drawn back to its starting point by means of a wire. This method produced good results in that early detection was possible. However, the induced radioactivity in the wire and reel mechanism contributed some difficulties. The investigation was discontinued in favor of other methods.

3. Feeler Method. - A taut wire attached to spokes at each end of the tube rotates in the annulus

parallel to the center line of the slugs. A blister will cause the wire to catch and the effect may be felt by stress on the rotating mechanism. The inherent difficulties were caused by the extreme length of the annulus with reference to its clearance, and the ambiguity of interpretation of the effects contributed by slight bowing of the tube and misalignment of the slugs.

4. <u>Slug Pusher Methods</u>. - The entire row of slugs is pushed a short distance through the tube and then returned. Increase in the amount of pressure necessary to accomplish the task would indicate obstructions on the surface of the slugs. The method also gave good results, but the constant pushing of the row showed signs of wearing through the can and increasing the oxidation rate of the aluminum. The method was adapted and incorporated into the "W" Pile operations as an auxiliary test for detection of can swelling.

5. <u>Radioactivity of the Water</u>. - This is the method which was finally adapted for use in the Piles. The water discharged from the tubes is monitored through a proportional counter placed at a distance such as to give the number of neutrons present at a specific time interval after discharge. A simple automatic alarm indicates neutron density rates

suddenly increasing over the normal background, which in turn reflects the baring of as little as 25 mm.^{2} of uranium due to a break in the can.

6. Supersonic Reflection. - Investigation was made of the possibility of sending supersonic waves through the entire tube, thus detecting can failures by the changes in transmission. The method did not prove practical for the purpose (but was better adapted to the testing of the soundness of individual slugs, and the effectiveness of the bond).

SECTION 6 - DEVELOPMENT OF PLUTONIUM SEPARATION PROCESS

6-1. Background Research.

a. Early "Tracer"* Studies. - Although the available quantities of plutonium were extremely small for many months after its discovery in December 1940, chemists at the University of California were able to study its chemical properties by utilizing its radioactive emanations (alpha rays) to trace it through various reaction processes. In this way, the solubilities of many plutonium compounds in several liquids were determined, even though only microscopic quantities of the substances were in existence. It was also shown that plutonium, like many other elements, had at least two oxidation states or combining ratios with markedly different chemical properties.

b. Organization and Expansion of Plutonium Studies. - At a conference held in Chicago in April 1942, the main task of plutonium chemistry was stated as the separation and purification of plutonium in the amounts required for war purposes. Subsequently, chemistry groups were organized at Chicago to study separation, fission products, and analytical problems; and a new building was erected with the necessary facilities. In order to supply research workers with weighable quantities of plutonium and fission products, several hundred pounds of uranium salts were exposed to neutron irradiation in cyclotrons at Washington University and at the University of California. About 500 micrograms (500-millionths of a gram) of plutonium salts were obtained from these sources by the end of 1942. By means of special microchemical and remote control techniques, sufficient information about plutonium and fission products was secured for the development of the separation processes discussed in the following paragraphs.

6-2. General Problems.

a. Separation and Decontamination. - Both the plutonium and the fission products,* from which it was to be separated, were present in the uranium in extremely small concentrations—less than 200 parts per million. The design of an industrial process for the concentration of such relatively small quantities of desired materials in itself was an extremely difficult task. The formidable feature of the undertaking, however, was that the minute amounts of fission product elements would in turn have to be separated from the plutonium ("decontamination"*) to an extent such that only about 1 part per 10 million of the fission products would remain. To add to the complications, the separation process would have to be carried out entirely by remote control because of the deadly levels of radioactivity associated with the fission products. It was imperative, therefore, that the process be adaptable to equipment that would require a minimum of maintenance and that process control limits be not too stringent.

b. Time Factor. - Another important factor that influenced the nature of the development program was the necessity of maintaining time schedules. Whenever a decision had to be made regarding a course of action, the approach taken was that which showed promise of producing results with the greatest certainty in the time allotted. As a result, indirect methods were sometimes chosen instead of attempting more direct ones, because the former seemed to be the more certain approach.

[redacted]

6-3. Processes Considered (See Vol. 3).

a. Introduction. - The most promising processes for separating plutonium from uranium and associated fission products may be divided into four categories: volatility ("dry"); adsorption; solvent extraction; and precipitation (See App. C 16). In all processes except those involving volatility, it is necessary first to dissolve the uranium metal containing the plutonium and the fission products.

b. Volatility Processes. - These methods of separation of plutonium depend on differences in vapor pressures between plutonium or a plutonium compound and uranium and fission products (metal or compounds). The only system investigated extensively involved the fluorides of plutonium, uranium, and fission products. In this process, the uranium slugs from the Pile would have their aluminum jackets broken and then be exposed to hydrogen to form finely powdered hydrides of all the constituents. The hydride would then be converted to a tetrafluoride by treatment with hydrogen fluoride gas at elevated temperatures. Some of the fission products would form volatile fluorides at this stage and be carried away from the plutonium and uranium. Fluorine would then be passed through the residual material to convert the uranium and plutonium to the hexafluorides, which, in turn, could be vaporized from the remaining fission products and be collected separately. This process is mechanically the most simple, and the uranium and plutonium are recovered in relatively pure, concentrated forms. However, the use of fluorides at high temperatures presents severe corrosion problems in large scale operation. Furthermore, complete development was impossible without a thorough knowledge of the dry chemistry of

[redacted]

plutonium. Insufficient quantities of plutonium were available to permit completion of such studies in time to develop a volatility process for large scale use.

c. Adsorption Processes. - Some minerals and certain synthetic materials have the property of adsorbing foreign substances on their surfaces. The use of activated charcoal to remove undesirable gases from the atmosphere is a well known application of adsorption properties. Similarly, a synthetic resin, called Amberlite IR-1, has been shown capable of completely adsorbing plutonium from a solution of uranium salts. In practice, the solution of irradiated slugs is passed through a column containing the resin. The plutonium and fission products are completely adsorbed from solution but most of the uranium passes through the column. Then the resin column is treated with suitable solutions to remove successively the little uranium that was adsorbed, most of the fission products, and finally the plutonium. Further decontamination of the plutonium can be effected by subjecting the dissolved material to another cycle of adsorption and desorption in a second column. This process has the advantage over the volatility methods of eliminating the severe corrosion problems. Among the disadvantages appears the difficulty of obtaining the complete removal of the fission products from the resin. Successive accumulations of these products produce a severe radiation hazard. At the time it became necessary to select a process, high yields of plutonium and high decontamination factors had not as yet been demonstrated for adsorption methods.

d. Solvent Extraction Processes. - This type of process depends on degrees of solubility of salts of plutonium, uranium, and fission products in organic liquids and aqueous solutions. The earlier work on plutonium extraction and decontamination was done with ether as the extracting agent. Time did not permit a demonstration of the feasibility of complete decontamination or complete separation of plutonium from uranium. Furthermore, the explosion hazard associated with the use of ether made this process appear almost prohibitive. The facts that solvent extraction is the simplest and the only completely continuous process for separation and decontamination of plutonium have convinced research workers of the desirability of its development. Consequently, even after the choice of a production process had been made, solvent extraction studies continued. With the present knowledge of the chemistry of the materials involved, a solvent extraction method now in laboratory development (See App. C 17) is likely to replace present methods in efficiency and simplicity of operation.

e. Precipitation Processes. - Precipitation methods involve the formation of chemical compounds which are insoluble under chemically controllable conditions. The insoluble compound, called the precipitate, can then be separated from the materials still in solution by filtration, centrifugation, or settling. The extremely low concentration of plutonium resulting from Pile operations makes separation and purification of the element by ordinary precipitation methods very difficult because the precipitated particles are too dispersed and minute for efficient processing. For this reason a relatively large quantity of a substance known as a "carrier"* is added to the solution. This material can be precipitated satisfactorily, and, when its insoluble compound is formed, atoms of plutonium are preferentially adsorbed and occluded by its particles while the bulk of uranium and fission products remains in solution. The carrier and carried material can then be redissolved in smaller quantities of solution and treated under another set of chemical conditions. Thus, by successive precipitations and dissolutions, the plutonium can be separated successfully from uranium, fission products, and, finally, from carrier material. The distinct advantage of the precipitation methods lies in the sequence of repeated operations, thereby limiting the number of different equipment pieces requiring design, and allowing considerable process change without equipment change.

6-4. <u>Selection of Process (See Vol. 3)</u>.

a. <u>Choice of Precipitation Methods</u>. - In the preceding paragraph the principal advantages and disadvantages associated with the various separation processes were cited. The early work in plutonium chemistry consisted largely of precipitation reactions involving radiochemical carrying from which solubility properties were deduced. It was logical, therefore, that precipitation methods were the most advanced and were chosen for production units at the time plant design had to be started (June 1943). Furthermore, it was felt that if it were necessary to develop any separation process on a partly empirical basis, there would be less risk in the scale-up of a precipitation process than in one which had not been completely proved in the laboratory.

b. <u>Outline of Process</u>. - Final choice of a separation method lay between the use of "lanthanum fluoride"* or "bismuth phosphate"* as a carrier. In both of these methods, plutonium is precipitated from the initial solution of irradiated slugs with one of the above compounds as the carrier; some fission products accompany the plutonium as contaminants. The precipitate is then separated from the solution and redissolved under another set of conditions such that reprecipitation of the carrier will leave the plutonium in solution and remove the remaining fission products. This single process does not separate completely the plutonium and the fission products, but the cycle can be repeated successively until the desired decontamination is achieved.

c. Final Decisions. - Lanthanum fluoride appeared to have some advantage chemically over bismuth phosphate, so the basic plant design was made with the "lanthanum fluoride"* method in mind. However, there were two factors favoring the "bismuth phosphate"* process which out-weighed those favoring the lanthanum fluoride process. One was the fact that bismuth phosphate was more readily soluble than lanthanum fluoride. The other, and most important for large scale operations, was the problem of corrosion. Fluoride solutions presented many more corrosion problems than did the nitrate-phosphate solutions involved in the bismuth phosphate process. The process, as finally chosen, actually represented a combination of the bismuth phosphate and lanthanum fluoride processes with a final precipitation of plutonium peroxide (See App. C 18). Details of the process as developed on a semi-works scale are presented in Volume 2, Part II and as developed on a production basis in Volume 6. The behavior of the precipitation process in production has exceeded all expectations. The high yields and decontamination factors and the relative ease of operation have demonstrated amply the wisdom of its choice. Further developments may make the present process obsolete, but the principal goal, which was to have a workable and efficient process for use as soon as production Piles were delivering plutonium, was attained.

SECTION 7 - ORGANIZATION AND PERSONNEL

7-1. Metallurgical Laboratory. - The Metallurgical Laboratory was formed with Dr. A. H. Compton in the position of Laboratory Director. Three divisions were established—the nuclear physics group which concerned itself with initiating a chain reaction; the chemistry division which conducted research on the chemistry of plutonium and on separation methods; and the theoretical group which was interested in the design of production Piles. In March 1942, an engineering division (later to be known as the technical division) was added. In the summer of 1942, the importance of health problems became apparent and a division to study these problems was organized. Under these major divisions the work was subdivided into various sections and groups (See App. B 4, 5). As the Pile Project grew in size and scope, Dr. Compton was appointed Director of the Metallurgical Project with N. Hilberry as Associate Director. R. L. Doan succeeded Dr. Compton as Laboratory Director at Chicago. The shifting of emphasis on various phases of the Project necessitated changes from time to time in key personnel. S. K. Allison, J. C. Stearns, and F. Daniels, successively, were Directors of the Metallurgical Laboratory.

Effective 1 July 1946, the Argonne National Laboratory was established under Contract 31-109 eng-38. Twenty-five mid-western educational and research institutions participated in the organization. The council composed of representatives, one from each institution, meets annually and elects a Board of Governors, who advise the Laboratory Director and the Contractor (the University of Chicago) on matters of programs and policies. Because of security restrictions, active participation of the institutions has not yet been initiated. As of 31 December 1946, the Argonne National Laboratory was devoting about 10% of its research efforts to problems of Hanford operations, specifically to development and improvement of the Redox separation processes and to the study of the effects of irradiation upon Pile graphite.

From a small group of technical personnel in the spring of 1942, the Laboratory developed into an organization of 2008 technical, administrative, shop, and service personnel in July 1944 (See App. B 6). As of 1 July 1945, there were 1444 employees in the organization (See App. B 7). The changeover to operation at the Argonne National Laboratory made practically no difference in personnel utilization and, as of 31 December 1946, the total number of employees was 1278 (including 46 part-time employees who devoted an average of 59.2% of their time to work for the Laboratory) (See App. B 7a).

7-2. <u>Chicago Area Office</u>. - When the Chicago Area Office was established in August 1942, Captain J. F. Grafton was appointed Area Engineer. He was succeeded by Captain, now Lieutenant Colonel, A. V. Peterson in December 1942. In October 1944, Captain Peterson was transferred and was succeeded by Captain, now Major, J. H. McKinley, the Area Engineer as of 1 July 1945. The Area Office's first function was to supervise construction of the research facilities. When the Manhattan District assumed full responsibility for the research and development work in May 1943, the Area Office was charged with all functions necessary to administer Contract No. W-7401 eng-37 and the associated contracts. The organization (See App. B 8) expanded with the Metallurgical Laboratory, from a handful of personnel in the fall of 1942 to a total of 243 in July 1945. As the Area Office assumed responsibility for Contract 31-109 eng-38, little change in numbers of personnel resulted so that, on 31 December 1946, the total number of employees was 176, which included 5 officers and no enlisted personnel (See App. B 8a).

7-3. Acknowledgments. - In addition to those individuals mentioned above, the following are deserving of special mention for their individual contributions to the Metallurgical Project: E. Fermi, G. T. Seaborg, E. P. Wigner, R. S. Stone, W. H. Zinn, F. H. Spedding, C. M. Cooper, P. E. Church, L. Szilard, T. R. Hogness, J. Frank, A. J. Dempster, and J. Chipman. The several contractors associated with the Metallurgical Project that made great contributions to its success are: Iowa State College, Columbia University, Massachusetts Institute of Technology, University of California, Carnegie Institute of Technology, Washington University, Princeton University, Brown University, Battelle Memorial Institute, Grasselli Chemicals Division of the du Pont Company, and the National Research Corporation. Contributing research was also conducted by the National Bureau of Standards.

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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

APPENDIX A

MAPS AND PHOTOGRAPHS

No.	Description
1	Map - Vicinity Map for Metallurgical Laboratory
2	Map - Location of Metallurgical Laboratories
3	Map - Plot Plan - Argonne Laboratory
4	Photo - Eckhart Hall
5	Photo - West Stands, Stagg Field
6	Photo - New Chemistry Building
7	Photo - Interior of New Chemistry Building
8	Photo - Ryerson Hall
9	Photo - Drexel House; Billings Hospital in Background
10	Photo - Ellis Laboratory; Service Building in Background
11	Photo - Argonne Laboratory from West
12	Photo - Argonne Laboratory from South
13	Photo - Argonne Laboratory from Southeast
14	Photo - Dormitory and Mess Hall, Argonne Laboratory
15	Photo - Fence Line Protection at Argonne Laboratory
16	Photo - New Chemistry Annex
17	Photo - Typical Laboratory - New Chemistry Annex
18	Photo - Site B - 6111 University Avenue
19	Photo - 124th Field Artillery Armory
20	Photo - Argonne Uranium-Graphite Pile (CP-2)
21	Photo - Argonne Uranium-Heavy-Water Pile (CP-3)
22	Photo - Nuclear Control Panel for CP-3 Pile
23	Photo - Physical Control Panel for CP-3 Pile

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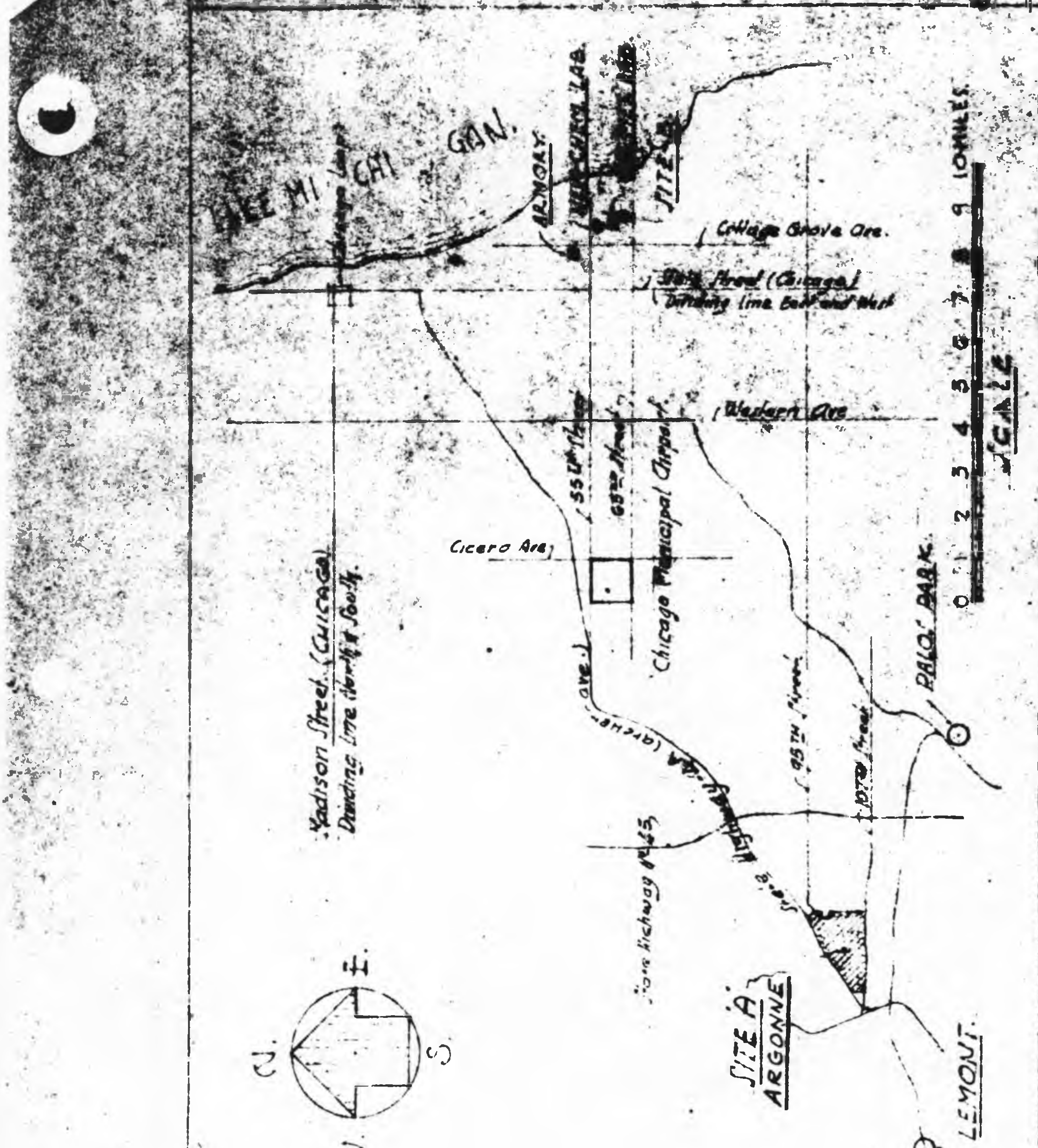
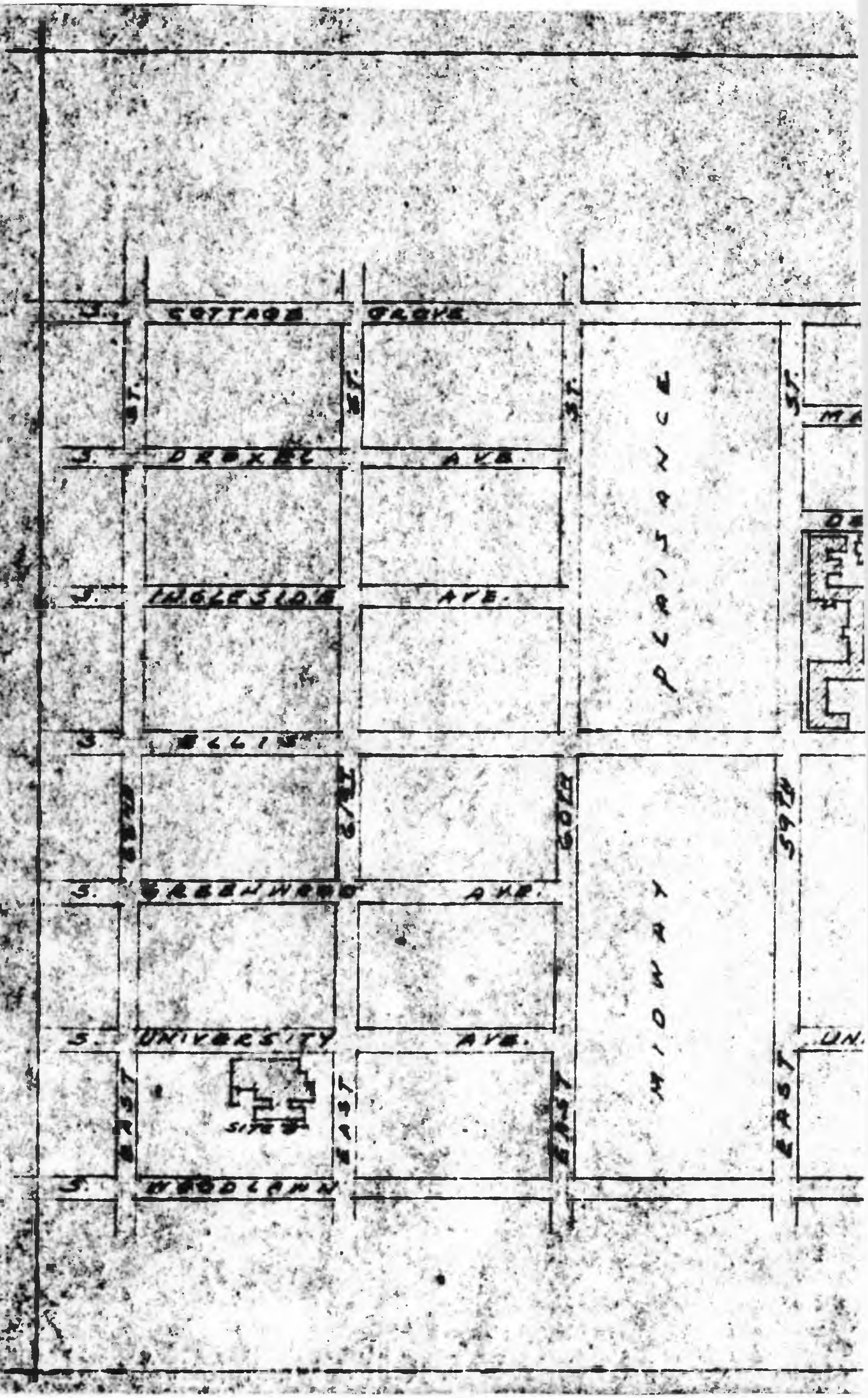
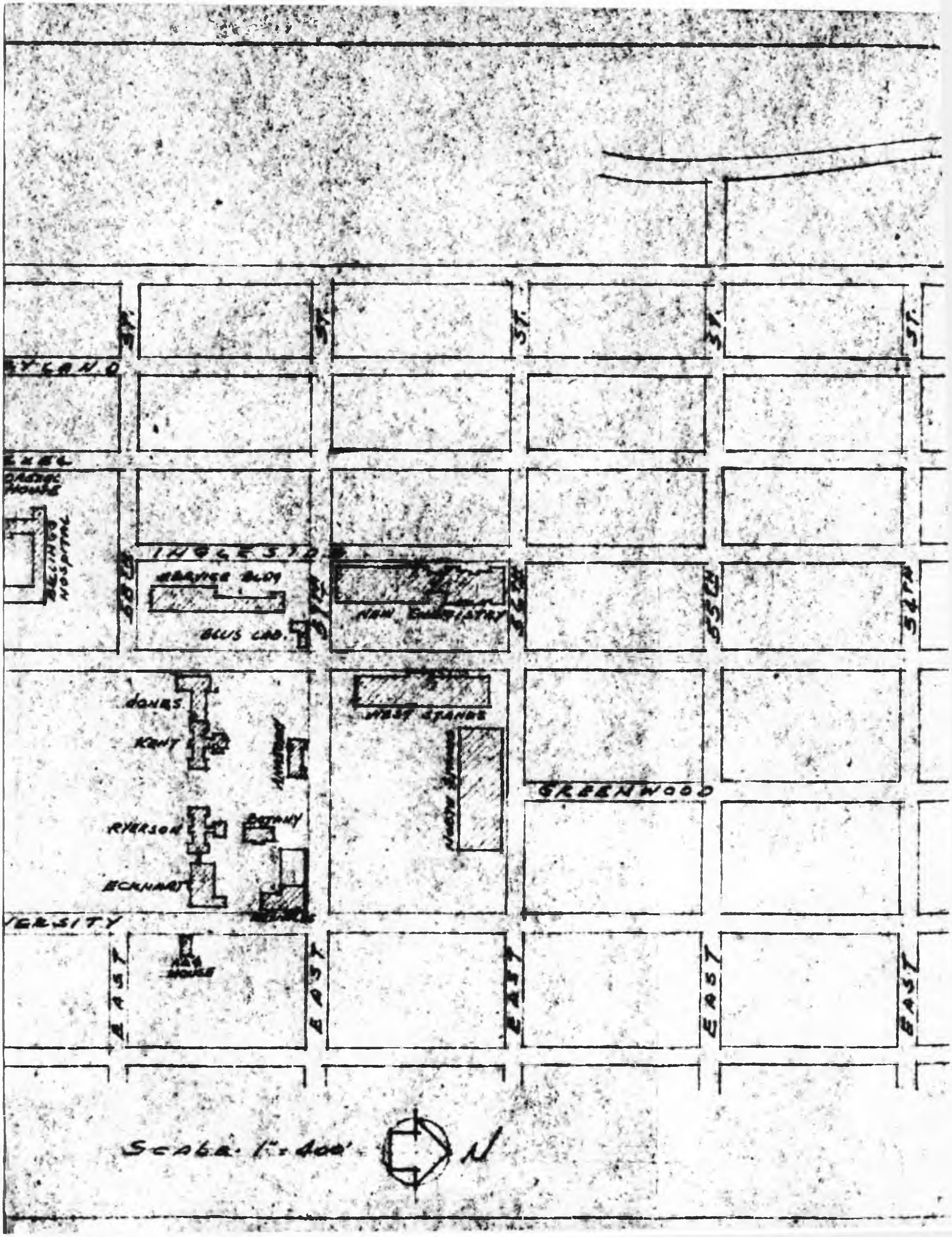


VICINITY MAP
FOR
METALLURGICAL
LABORATORIES

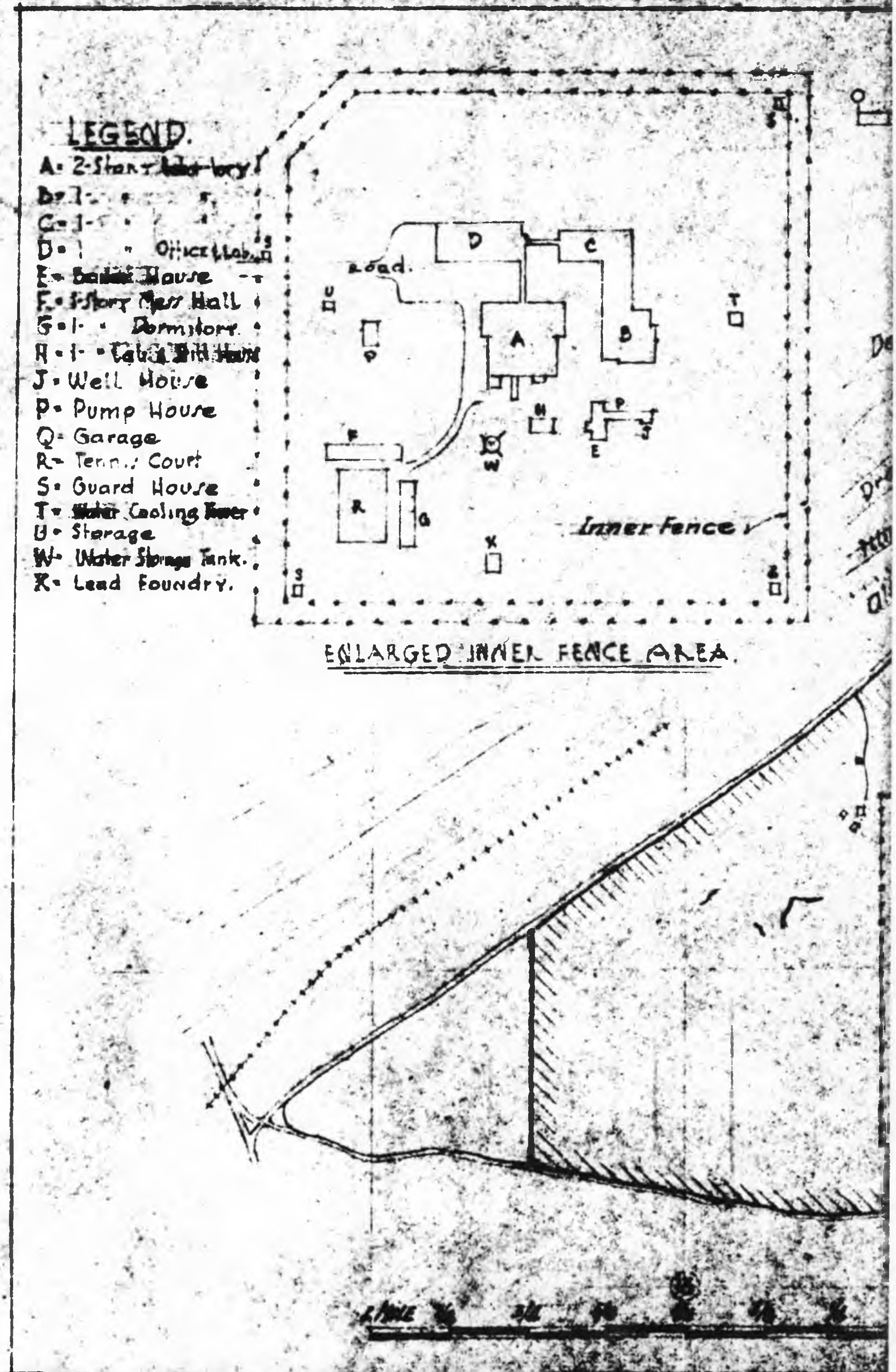
A-1

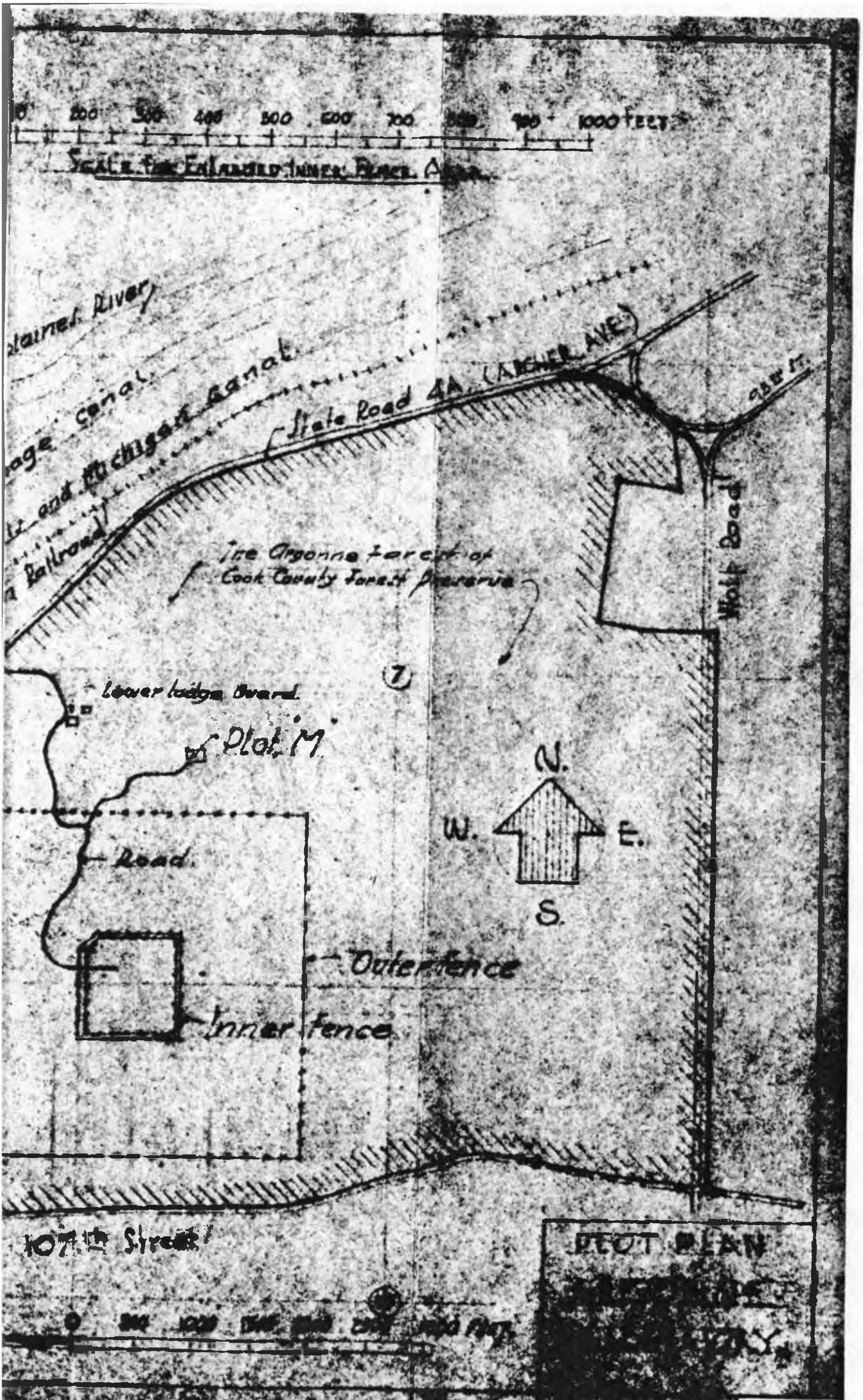


S. COTTAGE GROVE
S. DREXEL AVE.
S. INGLESIDE AVE.
S. ELLIS
S. GREENWOOD AVE.
S. UNIVERSITY AVE.
S. WOODLAWN
MIDWAY PLAISANCE
SITE


INGLESIDE
SERVICE BLDG
NEW DORMITORY
WEST STANDS
JONES
KENT
RYERSON
BOTANY
ECKHART
GREENWOOD
EAST
Scale 1" = 400'
N

ARMORY
AVE.
800 EAST
ST.
54TH
53RD
52ND
51ST
1000 EAST
EAST
OF

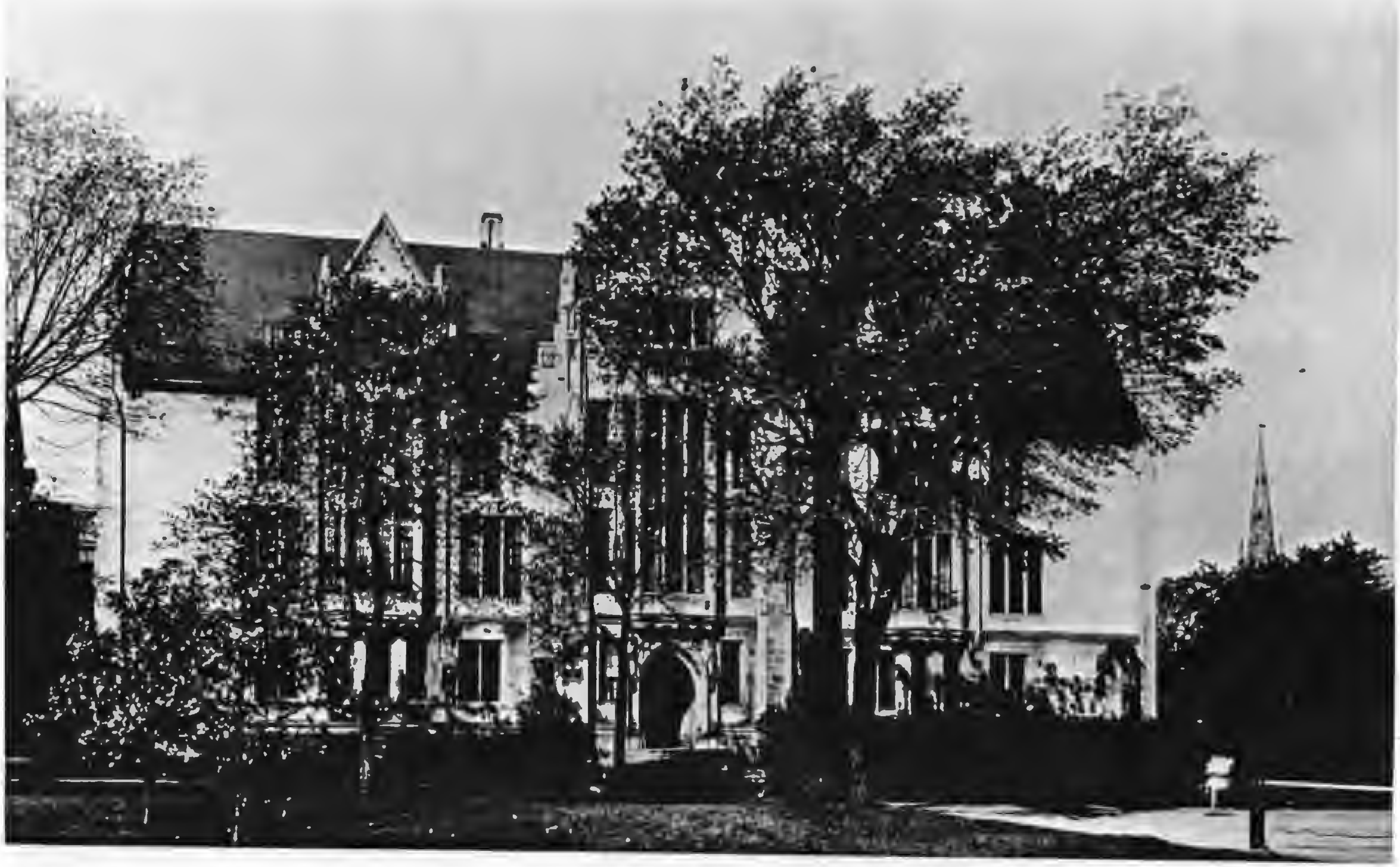

LEGEND.
D = 1 " Office & Lab.
E = Boiler House
F = 1-Story Mess Hall
G = 1- " Dormitory
J = Well House
P = Pump House
Q = Garage
R = Tennis Court
S = Guard House
T = Water Cooling Tower
U = Storage
W = Water Storage Tank.
X = Lead Foundry.
Road.
Inner Fence
ENLARGED INNER FENCE AREA.


1000 FEET
State Road 4A (Archer Ave)
Wolf Road
The Argonne Forest of Cook County Forest Preserve
Lower lodge Guard
Plot M
Road
Outer fence
Inner fence
N.
W.
E.
S.
PLOT PLAN

A-3

APPENDIX A 4

ECHKART HALL



APPENDIX A 5

WEST STANDS, STAGG FIELD

APPENDIX A 6

NEW CHEMISTRY BUILDING

[redacted]

APPENDIX A 7

INTERIOR OF NEW CHEMISTRY BUILDING

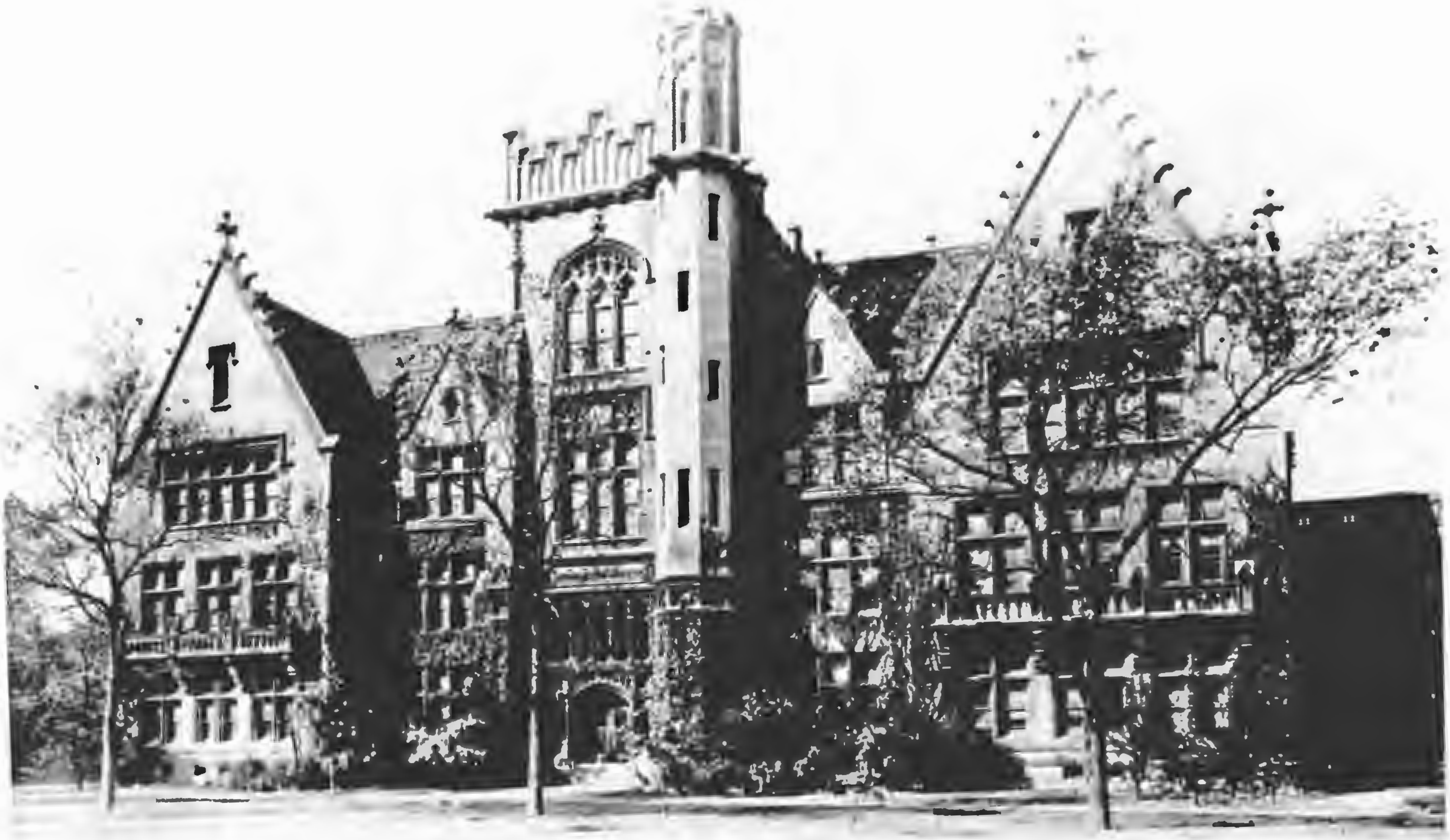
[redacted]

[redacted]

[redacted]

APPENDIX A8

RYERSON HALL



APPENDIX A 10

ELLIS LABORATORY; SERVICE BUILDING IN BACKGROUND

APPENDIX A 11

ARGONNE LABORATORY FROM WEST

APPENDIX A 12

ARGONNE LABORATORY FROM SOUTH

APPENDIX A 13

ARGONNE LABORATORY FROM SOUTHEAST

APPENDIX A 14

DORMITORY AND MESS HALL, ARGONNE LABORATORY

APPENDIX A 15

FENCE LINE PROTECTION AT ARGONNE LABORATORY

APPENDIX A 16

NEW CHEMISTRY ANNEX

SECRET

APPENDIX A 17

TYPICAL LABORATORY - NEW CHEMISTRY ANNEX

SECRET

APPENDIX A 18

SITE B - 6111 UNIVERSITY AVENUE

APPENDIX A 19

124TH FIELD ARTILLERY ARMORY

APPENDIX A 20

ARGONNE URANIUM-GRAPHITE PILE (CP-2)

[redacted]

[redacted]

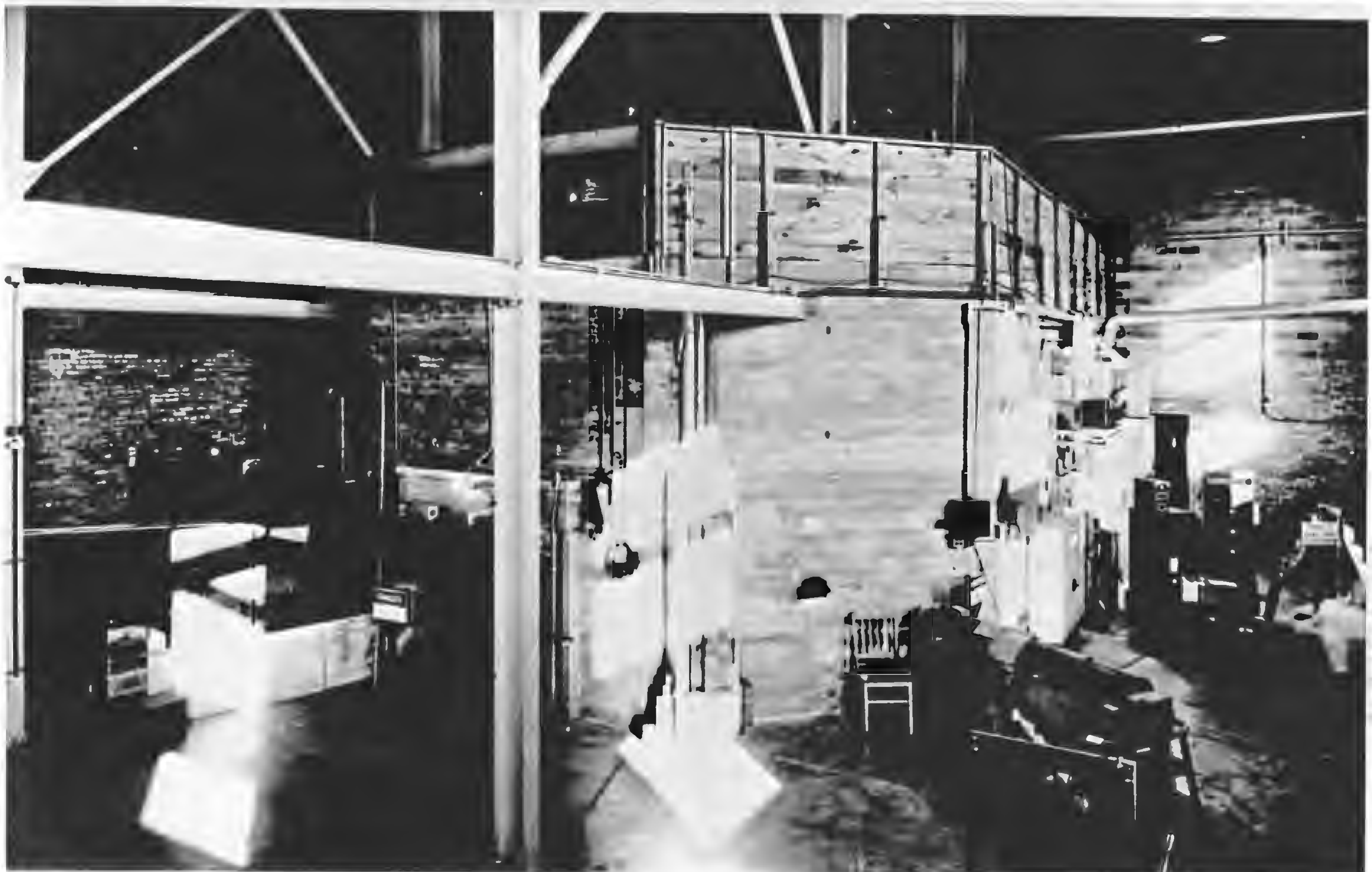
[redacted]

[redacted]

APPENDIX A 21

ARGONNE URANIUM-HEAVY-WATER PILE (CP-3)

[redacted]



APPENDIX A 22

NUCLEAR CONTROL PANEL FOR CP-3 PILE

[redacted]

[redacted]

[redacted]

APPENDIX A 23

PHYSICAL CONTROL PANEL FOR CP-3 PILE

[redacted]

[redacted]

MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

APPENDIX B

CHARTS AND TABULATIONS

No.	Description
1	Prime Research and Development Contracts Associated, in Whole or in Part, with the Activities of the Metallurgical Laboratory.
2	Subcontracts under Metallurgical Laboratory Contract W-7401 eng-37.
3	Areas Occupied by the Metallurgical Laboratory.
4	Metallurgical Laboratory Organization Chart (5 July 1944).
5	Metallurgical Laboratory Organization Chart (5 July 1945).
6	Monthly Force Report for Month Ending 30 June 1944.
7	Monthly Force Report for Month Ending 30 June 1945.
7a	Argonne National Laboratory Organization Chart (31 Dec. 1946).
8	Chicago Area Engineer's Organization Chart as of 1 July 1945.
8a	Chicago Area Engineer's Organization Chart as of 31 December 1946.

PRIME RESEARCH AND DEVELOPMENT CONTRACTS ASSOCIATED, IN WHOLE OR IN PART, WITH THE ACTIVITIES OF THE METALLURGICAL LABORATORY

Contractor	Contract Number	Term of Contract	Approx. Total Cost	Purpose
University of Chicago (ML)	W-7401 eng-37	5/43 - 6/46	$28,000,000	Provide for the successful operation of "W."
University of Chicago (ANL)	31-109 eng-38	7/46 - 12/47*	2,757,000	* see footnote
University of California	W-7405 eng-48b	7/43 - 12/46	50,000	Separation processes.
Indiana University	W-7401 eng-82	8/43 - 4/44	25,000	Use of cyclotron to determine cross sections of pile materials.
University of Michigan	W-7401 eng-92	1/44 - 8/44	11,500	Perfection of a supersonic method for testing soundness of slugs and quality of bonds.
	W-7401 eng-127	8/43 - 2/44	29,000	
Victoreen Instrument Co.	W-7401 eng-135	8/43 - 5/45	784,000	Design and development of electronic instruments and assemblies.
University of Notre Dame	W-7405 eng-49	3/43 - 6/45	99,000	Use of electrostatic generator to study the effects of intense irradiation on pile materials.
Columbia University	W-7405 eng-50	12/43 - 6/45	40,000	Use of cyclotron to determine cross sections of pile materials.
Washington University	W-7405 eng-83	5/43 - 10/44	140,000	Use of cyclotron to provide product in weighable amounts for chemical research.
Battelle Memorial Inst.	W-7405 eng-92	4/43 - 6/45	235,000	Development of methods of fabrication and coating of metal for use in piles.
Mass. Inst. of Technology	W-7405 eng-175	5/43 - 6/45	1,032,000**	Development of Frost Test Method for quality of cans and bonds.

Carnegie Inst. of Tech.	W-7405 eng-277	1/44 - 6/45	$ 90,000	Effect of intense irradiation upon pile construction materials.
du Pont (Grasselli)	W-7412 eng-24	5/43 - 1/45	275,000	Development of coatings and testing methods.

* Contract 31-109 eng-38 for operation of the Argonne National Laboratory from July 1, 1946 to December 31, 1947 was negotiated by the Manhattan District. For the period ending December 31, 1946 approximately $2,757,000 was spent of which approximately 10% represents a continuation of efforts for improvement of "W" operations. The balance of effort was assigned to new research and development in connection with the theory and design of piles for production of usable energy.

** Only a small percentage of M.I.T.'s effort was directed to the testing procedures.

SUBCONTRACTS UNDER METALLURGICAL LABORATORY CONTRACT NO. W-7401 eng-37

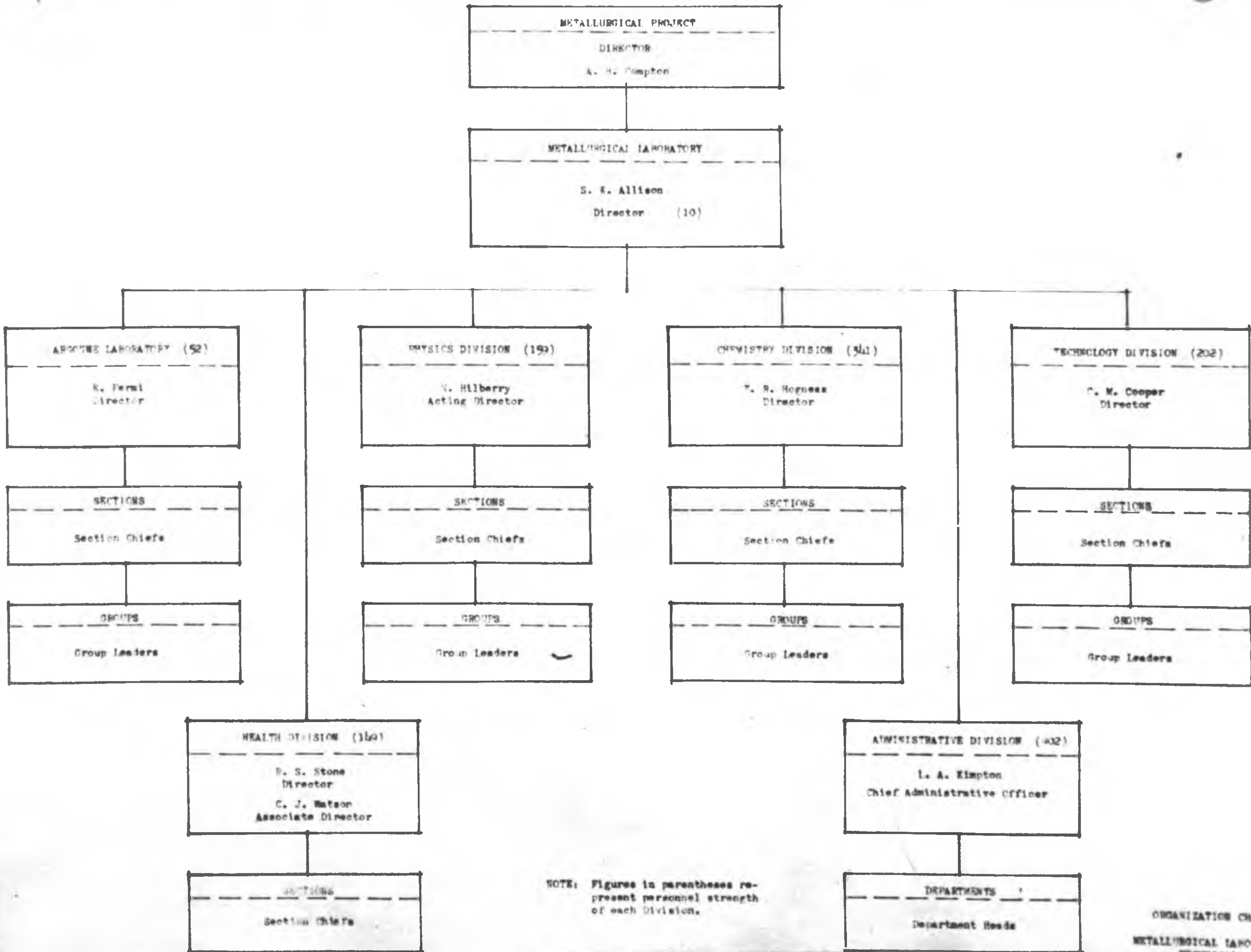
Subcontractor	Subcontract Number	Duration	Est. Cost	Purpose
Wolverine Tube Div.	4	6/43 - 1/46	$ 36,000	Development of ribbed tubes, methods of extrusion of alloys.
Joslyn Mfg. Co.	9	8/43 - 6/46	15,000	Method for fabricating slugs by rolling.
Michael Reese Hospital	13	7/43 - 6/46	40,000	Metallic toxicology experiments.
W. E. Pratt & Co.	52	4/44 - 6/46	7,500	Machining and grinding of slugs.
Protectoseal Co.	106	6/44 - 8/45	37,500	Fabrication of optical instruments for use in pile operation.

AREAS OCCUPIED BY THE METALLURGICAL LABORATORY

LOCATION	SQUARE FEET
1. Campus Research Facilities	
Eckhart Hall	58,650
Ryerson Hall	71,175
West Stands, Stagg Field	29,600
North Stands, Stagg Field	9,000 *
Service Building	6,165 *
Jones Laboratory	5,755
Kent Laboratory	12,155
Anatomy Building	1,280
Billings Hospital	4,900
Drexel House	4,830
Ellis Lab. (5700 Ellis Avenue)	1,750
TOTAL	205,260

*Space released and returned to University of Chicago.

LOCATION	SQUARE FEET
2. New Facilities, Constructed and/or Leased	
Argonne Laboratory	54,200
New Chemistry Building and Annex	54,255
Site B	62,670
Armory, 124th Field Artillery	188,000
TOTAL	359,125



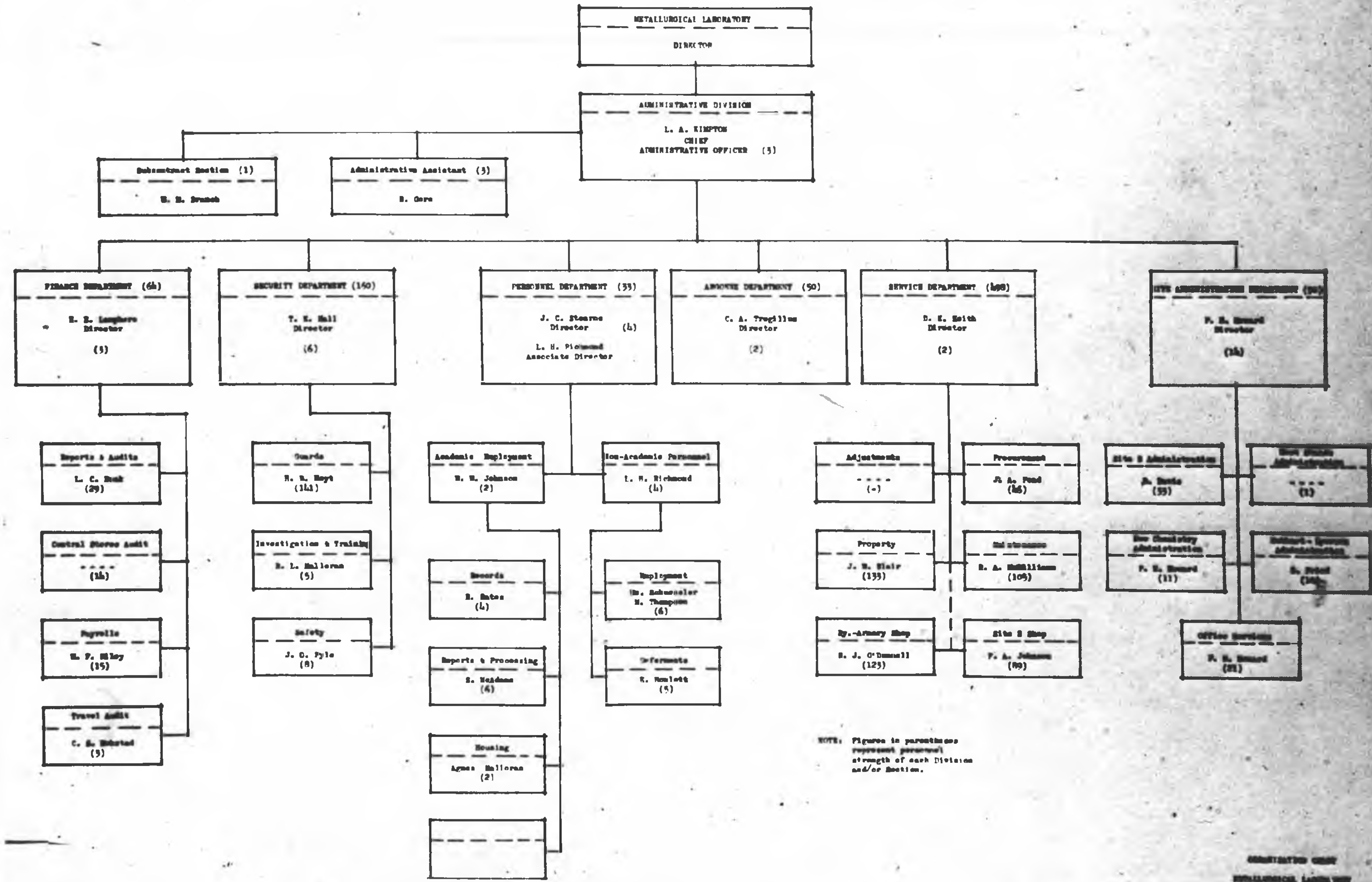
NOTE: Figures in parentheses represent personnel strength of each Division.

ORGANIZATION CHART

METALLURGICAL LABORATORY
TECHNICAL

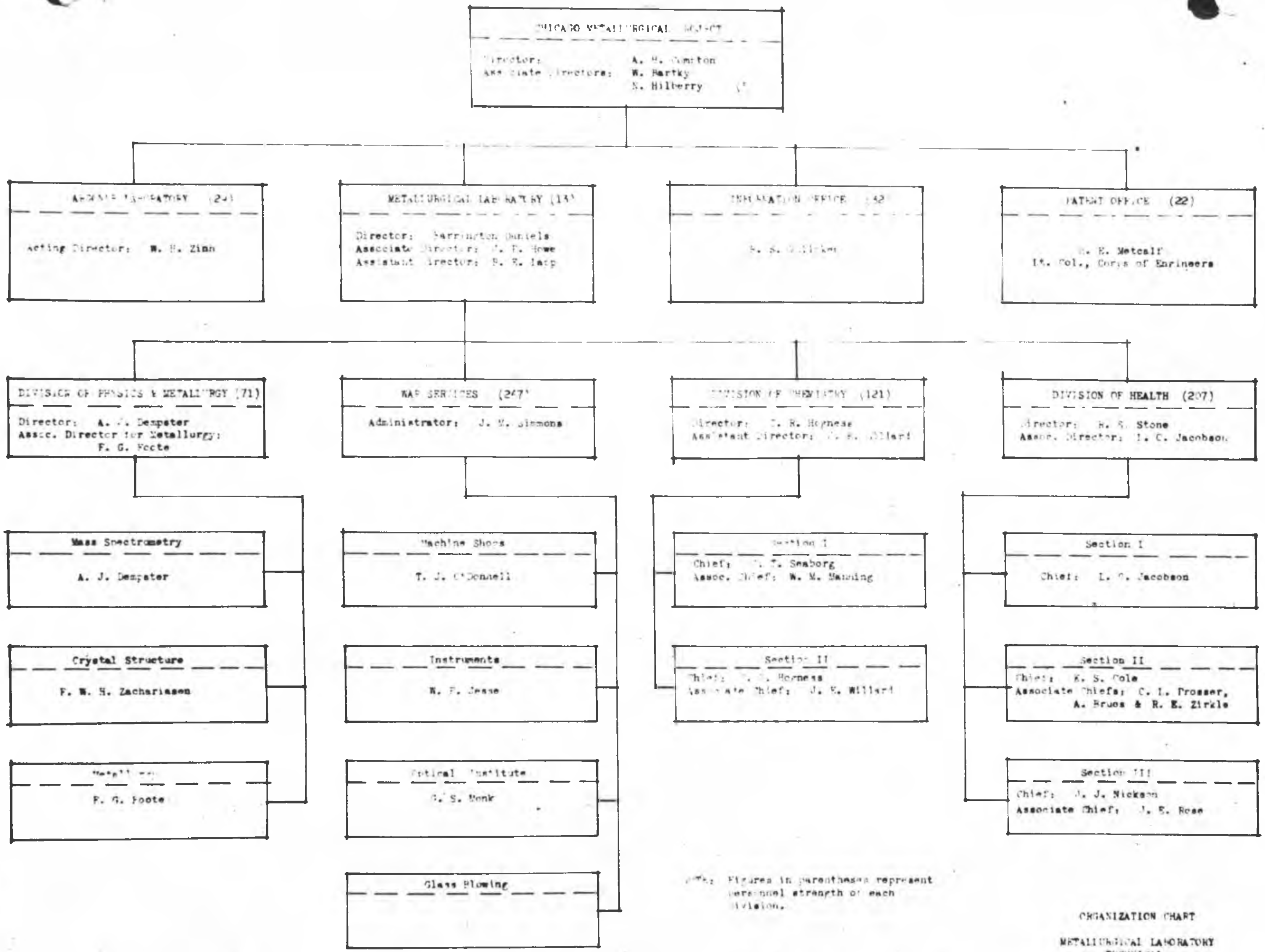
5 JULY 1944

B-4



NOTE: Figures in parentheses represent personnel strength of each Division and/or Section.

Sheet No. 2 of 2 sheets.



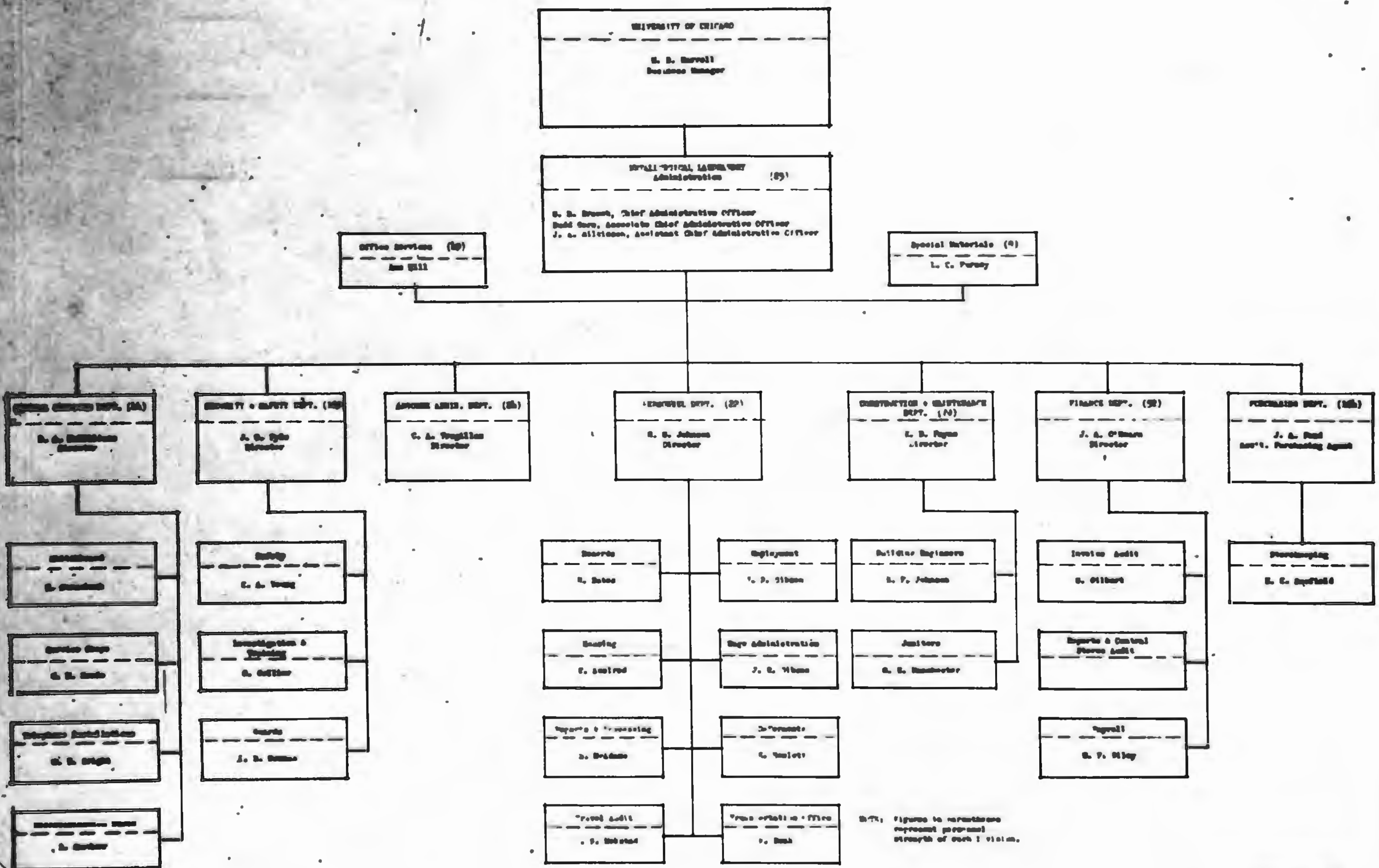
NOTE: Figures in parentheses represent personnel strength of each division.

ORGANIZATION CHART

METALLURGICAL LABORATORY
TECHNICAL

5 JULY 1945

Sheet No. 1 of 2 sheets.



Sheet No. 2 of 2 sheets.

MONTHLY FORCE REPORT	(1) Contractor: University of Chicago Metallurgical Laboratory	Reports Control Symbol EIDMP 7-4
		(2) Month Ending: 30 June 1944
To: District Engineer Manhattan Engineer District Attention: EIDMP-7	(3) Location: Chicago, Illinois	(4) Contract No.: W-7401-eng-37

	Departments (5)	No. on Payroll End of Month (6)	Average Daily Absentee Percent (7)	Number of New Hires (8)	Number Terminated (9)	Immediate Needs (10)	Anticipated Releases (11)
Operations & Research	(a) Total	1872	6.8	241	153	387	0
	(b) Office	550	8.0	93	50	100	0
	(c) Plant Operation	190	9.4	29	30	27	0
	(d) Plant Maintenance	329	9.7	51	36	69	0
	(e) Lab. & Research	745	3.6	66	37	191	0
	(f) All Others	58	12.0	2	0	0	0
Construction	(g) Total						
	(h) Labor						
	(i) Crafts						
	(j) Non-Manual						

Reported by:	Telephone Number:	Date:

EIDM Form 40
8 October 1943

(Letter of Transmittal Unnecessary)

MONTHLY FORCE REPORT	(1) Contractor: University of Chicago Metallurgical Laboratory	Reports Control Symbol EIDMP 7-4
		(2) Month Ending: 30 June 1945
To: District Engineer Manhattan Engineer District Attention: EIDMP-7	(3) Location: Chicago, Illinois	(4) Contract No.: W-7401-eng-37

	Departments (5)	No. on Payroll End of Month (6)	Average Daily Absentee Percent (7)	Number of New Hires (8)	Number Terminated (9)	Immediate Needs (10)	Anticipated Releases (11)
Operations & Research	(a) Total	1397	7.4	77	156	235	271
	(b) Office	412	8.0	24	34	29	60
	(c) Plant Operation	195	4.1	28	11	149	0
	(d) Plant Maintenance	292	10.2	18	23	38	1
	(e) Lab. & Research	452	5.9	7	87	19	208
	(f) All Others	46	13.0	0	1	0	2
Construction	(g) Total						
	(h) Labor						
	(i) Crafts						
	(j) Non-Manual						

Reported by:	Telephone Number:	Date:

EIDM Form 40
8 October 1945

(Letter of Transmittal Unnecessary)

[redacted]

ARGONNE NATIONAL LABORATORY

ORGANIZATION CHART

(as of 12/31/46)

LABORATORY DIRECTOR
Assistant to the Director

ASSOCIATE DIRECTOR

Pile Research & Development Division
Four Groups
Metallurgy Division
Three Groups
Shops

ASSOCIATE DIRECTOR

Theoretical Physics Division
Two Groups
Experimental Nuclear Physics Division
Nine Groups
Chemistry Division
Section I
Fourteen Groups
Section II
Five Groups
Biology Division
Fifteen Groups
Mass Spectroscopy & X-Ray Division
Two Groups
Instrument Research & Development Division
Six Groups
Medical Division
Four Groups
Health Physics Division
One Group
Information Division
Two Groups
Patents Division
One Group

BUSINESS MANAGER
Assistant Business Manager (Staff Capacity)
Assistant Business Manager
Personnel Officer
Chief Accountant
Purchasing Agent

[redacted]

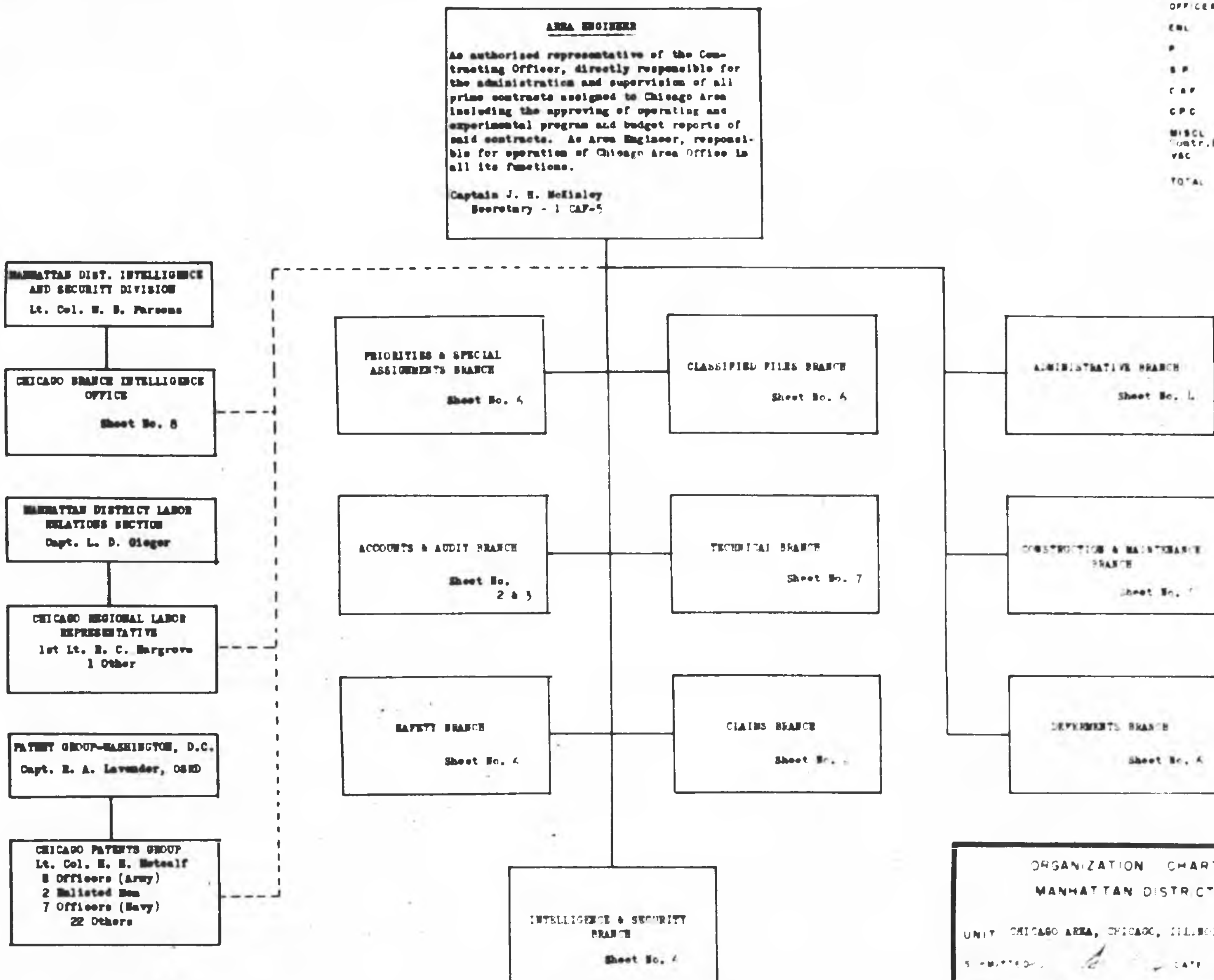
Capt. Chapman

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

PERSONNEL		
OFFICERS	Army	27
	Navy	7
ENL		18
P		8
SP		5
CAF		114
CPC		54
MISCL	Ungr.	4
	Contr. Payroll	25
VAC		4
TOTAL		268

[redacted]



[redacted]

ORGANIZATION CHART

MANHATTAN DISTRICT

UNIT CHICAGO AREA, CHICAGO, ILLINOIS

SUBMITTED BY: DATE 7-1-45

RECOMMENDED DATE

APPROVED DATE

SHEET NO 1 OF 8 SHEETS

B-8

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

[redacted]

PERSONNEL
OFFICERS
ENL
P
SP
CAF
CPC
MISCL.
VAC.
TOTAL

ACCOUNTS AND AUDIT BRANCH

As Chief Project Auditor, directs and administers functions of Accounts and Audit Branch through section supervisors.

Mr. J. R. Barbour CAF-11 Auditor
Secretary - 1 CAF-4
1 CAF-3 Clerk-Typist
1 CAF-3 Clerk

FISCAL AND AUDIT SECTION

As Supervising Accountant, supervises and coordinates activities necessary to insure control of flow of audit and documentary data pertaining to reimbursement of prime contracts under administration of Chicago Area.

Miss B. Castleberry CAF-6 Clerk

REPORTS & STATISTICS SECTION

Records certain historical data pertaining to all phases of contract expenditures; maintains log of recurring reports, expediting those from other sections; prepares special reports.

Mrs. F. R. Rasmussen CAF-5 Clerk
1 CAF-3 Clerk-Typist

FISCAL SECTION

Records and maintains control of funds allocated for administering prime contracts and related sub-contracts under administration of Chicago Area; sets up subsidiary control accounts of all funds encumbered by purchase orders, sub-contract commitments and miscellaneous encumbrances; prepares all fiscal and analytical reports; maintains control of all incoming and outgoing vouchers, summaries and supporting documents.

Mrs. P. L. Churchill CAF-4 Clerk
2 CAF-2 Clerk-Typist
1 CAF-3 Clerk
1 CAF-3 Clerk (V.)

COST SECTION

Maintains accountability of proper cost distribution and control, recording funds expended on prime contracts and sub-contracts administered by Chicago Area; maintains control of cost records of Government vouchers; controls expenditures of Contractors as vouchers are reimbursed.

Miss C. E. Allen CAF-4 Clerk
1 CAF-3 Clerk

MATERIAL & OTHER AUDIT SECTION

Audits public vouchers submitted for reimbursement by prime contractors under Chicago Area covering material, supplies, equipment, services, travel and utilities; reviews all items of expendable and non-expendable supplies and equipment, unauthorized procurement of items appearing on mandatory schedule or restricted and prohibited list; institutes control and records for partial shipments, concurrent services and rentals.

Miss J. A. Abrams CAF-4 Clerk
2 CAF-2 Clerk
2 CAF-3 Clerk (1e)

SUB-CONTRACT RECORDS & INSURANCE SECTION

Edits sub-contracts and amendments thereto; prepares special reports covering status of same; maintains card system control of all information in connection with sub-contracts; maintains files to control expenditures of all types of insurance.

Miss F. R. Riley CAF-7 Adm. Asst. *
1 CAF-3 Clerk-Steno.

SUB-CONTRACT AUDIT SECTION

Audits all sub-contract vouchers submitted by prime contractors for reimbursement; reconciles bank accounts and ledgers of two prime contractors and prepares evidence of payment reports for General Accounting Office.

Mrs. G. Sorkin CAF-7 Adm. Asst. *
1 CAF-3 Clerk**

PAYROLL POST AUDIT SECTION

Audits Contractors' payrolls; verifies leave; audits leave record cards; checks overhead percentages, annuities and accident cases involving compensation payments.

Miss E. Mandler CAF-4 Clerk
1 CAF-3 Clerk
1 CAF-2 Clerk-Typist

CONTRACTORS' PERSONNEL RECORDS SECTION

Establishes and maintains complete payroll card system for all employees of various Contractors; audits all WLB 100 forms for adherence to limitations initiated by War Labor Board, Treasury Department and Labor Acts.

Miss F. I. Piasecki CAF-3 Clerk-Typists
1 CAF-3 Clerk
1 CAF-2 Clerk-Typist

[redacted]

* To be recommended to next highest grade.
** To be recommended to CAF-5.

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT Accounts & Audit Branch, Chicago Area
SUBMITTED — DATE 7-1-45
RECOMMENDED — DATE
APPROVED — DATE

[redacted]

PERSONNEL
OFFICERS
ENL.
P
S P
CAF
SPO
MISCL.
VAC.
TOTAL

ACCOUNTS & AUDIT BRANCH

Mr. J. W. Barbour

ACCOUNTABLE PROPERTY OFFICER

Captain P. Baranowsky

PROPERTY SECTION

Supervises all activities of Property Section.

Mr. [illegible] Quinlan CAF-[illegible] Adm. Asst.#
Mr. J. W. [illegible] CAF-7 Adm. Asst.*

#Designated Agent for Accountable Property Officer

[illegible] ACCOUNTABILITY SUBSECTION

Supervises preparation of reports and correspondence pertaining to Property Accountability.

Miss M. [illegible] CAF-[illegible] Clerk

RECORDS AND REPORTS SUBSECTION

Maintains control over property accountability of equipment received on Government procurement and transfer; supervises preparation of reports of survey; transmits Salvage and Scrap checks.

Mrs. [illegible] Pinan CAF-5 Clerk
1 CAF-3 Clerk

ENGINEER WAREHOUSE SUBSECTION

Supervises inspection and inventories of Surplus Stock and Standard Machine Tools; handles special assignments and inspects materials where knowledge of specialized experience in scientific equipment is necessary.

Mr. [illegible] Hanson SP-6 Inspector (Matl.)*
1 CPC-4 Chauffeur (Mech. Rep.)

CLASSIFICATION UNIT

Reviews Central Stores vouchers of prime contractors; classifies contractors' purchase orders; checks classification of receiving reports, shipping tickets and [illegible] of shipments; maintains register of property voucher numbers; applies proper nomenclature to all documents; posts items of property to card records; keeps register of cylinders and other containers on deposit; maintains perpetual inventory of [illegible] items.

Mrs. [illegible] Wright CAF-2 Clerk**
[illegible] CAF-1 Clerk
[illegible] CAF-[illegible] Clerks
[illegible] CAF-[illegible] Clerk-Typists

PRIME CONTRACTS UNIT

Audits Documents Approved Summaries and Public Stores vouchers of prime contractors; posts items of property to permanent card records for ready reference as to acquisition and disposal; reconciles property records with inventory at termination of contracts.

Miss [illegible] Rogers CAF-3 Clerk*
1 CAF-[illegible] Clerk-Typist
2 CAF-2 Clerks

RECEIVING UNIT

Maintains accountable records of surplus materials; prepares surplus lists and reports; maintains advance information files and logs governing all transactions of material, supplies and equipment received; prepares correspondence necessary to complete transfer of accountability.

Miss S. [illegible] CAF-4 Clerk
2 CAF-3 Clerk-Typist
1 CAF-2 Clerk-Typist
2 CAF-2 Clerks

SHIPPING UNIT

Issues Government bills of lading and documents of transfer; maintains control files of advance information and logs governing records of all transactions; advises consignee of shipment; transmits Government bills of lading on incoming and outgoing shipments.

Miss M. [illegible] Franson CAF-3 Clerk
1 CAF-3 Clerk-Typist
3 CAF-2 Clerk-Typists

RECEIVING & SMALL STORES UNIT

Receives and inspects equipment, materials and supplies procured or transferred to this station; in charge of small stores and of receiving, inspecting and tagging of equipment being declared surplus.

Mr. J. T. Hartley SP-6 Inspector (Matl.)*
1 CAF-4 Storekeeper
1 SP-6 Insp.(Matl.)(New)
1 Laborer ‡

TRAFFIC UNIT

Inspects, packs, crates, ships and expedites equipment being transferred, reconsigned and shipped to other stations; arranges for shipment by most expeditious method.

Mr. J. P. Cox SP-6 Inspector (Matl.)
1 Wrhse. Lab. (V.)
2 Laborer ‡

* To be recommended to next highest grade.
** To be recommended to [illegible]
‡ [illegible] Payroll

[redacted]

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT Accounting & Audit Branch, Chicago Area
SUBMITTED [signature] DATE 7-1-45
RECOMMENDED ______ DATE ______
APPROVED ______ DATE ______

PERSONNEL
OFFICERS
ENL
P
SP
CAF
CPC
MISCL
VAC
TOTAL

[redacted]

CHIEF OF BRANCH

Supervises and coordinates administrative matters between various branches of Chicago Area; issues travel orders for temporary duty travel of civilian and military personnel; certifies vouchers; establishes air priorities for movements of personnel and shipments.

Is Accountable Property Officer and War Bond Officer for Area.

Captain Paul Baranowsky
T/3 J. T. Harris
Secretary - 1 CAF-4

PROCUREMENT SECTION

Locates supplies, material and/or equipment; secures bids and quotations; expedites deliveries; issues purchase orders; receives invoices; procures mandatory and/or controlled items from other Government agencies; processes contractual documents between District Legal Section and Contractor.

Miss M. K. Clarey CAF-6 Clerk
1 CAF-4 Clerk
1 CAF-3 Clerk-Typist
1 CAF-2 Clerk-Steno.

CIVILIAN & OFFICER PERSONNEL SECTION

Processes all civilian personnel actions; maintains 201 and general personnel files; maintains records and rosters on military personnel; submits reports of assignments, leaves of absence and transfers of Officer Personnel to higher authority.

Miss D. H. Cassedy CAF-6 Clerk
1 CAF-3 Clerk-Typist
1 CAF-2 Clerk-Typist

MAIL & RECORDS SECTION

Receives, routes and dispatches all mail; maintains record of correspondence received and dispatched; provides messenger service; maintains office supplies; maintains all files.

Mrs. V. E. Kingius CAF-4 Clerk*
1 CAF-3 Clerk-Typist
1 CAF-3 Clerk
1 CAF-2 Clerk-Typist
2 CPC-2 Messenger (1*)

SPECIAL ENGINEER DETACHMENT

Administers all military matters pertaining to enlisted men assigned to Chicago Area; maintains military records of enlisted men; submits to higher authority all required reports, including daily morning reports.

M/Sgt. R. E. Bidleck
1 CAF-4 Clerk-Steno.

TRAVEL & VOUCHER SECTION

Makes reservations; issues transportation requests; plans itineraries; issues OPA forms for official travel; prepares travel and public vouchers.

Miss V. A. Clarke CAF-4 Clerk
2 CAF-3 Clerk-Typist
2 CAF-2 Clerk-Typist (1*)

TRANSPORTATION SECTION

Provides transportation for Area; maintains vehicles in safe operating condition; plans routes and itineraries for out-of-town trips; trains new Chauffeurs.

Mr. G. M. Maronde CPC-5 Motor Veh.Disp.
2 SP-4 Inspector (Equip.)
17 CPC-4 Chauffeur (Mech. Rep.)

* To be recommended to next highest grade.

[redacted]

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT Administrative Branch, Chicago Area
SUBMITTED [signature] DATE 7-1-45
RECOMMENDED DATE
APPROVED DATE

PERSONNEL
OFFICERS
ENL.
P
S P
C A F
C P C
MISCL.
VAC.
TOTAL

[redacted]

CONSTRUCTION AND MAINTENANCE BRANCH

Assists contractor under Contract W7401-eng-37 in determination of requirements for construction modification and restoration, preparation of plans and specifications and supervision of construction; also approves plans, specifications, work orders, costs and completion of above work within limits determined by Area Engineer; supervises maintenance of Government-owned or leased facilities.

Mr. C. H. Teutsch P-4 Engr. (Mech.)
1 CAF-2 Clerk-Steno.

DRAFTING SECTION

Prepares designs, working and record drawings for modification of sites and construction of special equipment.

Mr. H. C. Litt P-3 Engr. (Arch.)

OFFICE ENGINEER

Maintains card index system for work completed and work now in progress regarding restoration of contractor-owned buildings; check drawings completed by draftsmen against rough sketches; prepares engineering correspondence, reports and estimates to sub-contractor.

Mr. H. L. Davis P-3 Engr. (Civil)*

SITE ENGINEER SECTION

Makes recommendations to Branch Head regarding feasibility of work requests; coordinates plans and specifications for construction and issuance of work orders to contractors; supervises construction operations; checks cost estimates; assists in procurement of materials by contractors; recommends acceptance of completed work.

Acts as consultant to Division Head on all electrical matters.*

Mr. P. C. Moon P-3 Supt. (Constr.)
Mr. N. F. Krol P-3 Engr. (Arch.)
*Mr. E. J. Solem P-3 Engr. (Elec.)
Mr. G. B. Thorgney P-3 Engr. (Arch.)
4 Ungr. Bd. Maint. Laborers

CONTROL SECTION

Records and routes work orders; formalizes work orders prepared by Site Engineers; receives proposals; distributes work orders; types all correspondence and reports for Construction Branch.

Miss E. V. Furney CAF-4 Clerk-Steno.
1 CAF-2 Clerk

* Recommended for reassignment to Engineering Aide SP-7

[redacted]

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT Construction and Maintenance Branch, Chicago Area
SUBMITTED [signature] DATE 7-1-45
RECOMMENDED ______ DATE ______
APPROVED ______ DATE ______

[redacted]

AREA ENGINEER

Captain J. E. McKinley

CHICAGO BRANCH INTELLIGENCE OFFICE

Major G. C. Thompson, Jr.

INTELLIGENCE & SECURITY BRANCH

Initiates personnel and firm clearances; investigates delays in work, espionage, sabotage and subversion in collaboration with Branch Intelligence Office; reviews local publications for disclosures of classified information; provides protection for special material and certain personnel; advises contractors on security matters; sends and receives all classified and unclassified teletype messages; maintains cryptographic security.

Mr. E. G. Hawkins, Jr.
  Mr. J. H. Boruzecki
  Mr. J. H. Fiscell
  1 CAF-4 Clerk-Steno.
  2 CAF-3 Clerk-Steno. (1*)
  1 CAF-2 Clerk *
  1 CAF-4 Teletype Oper.

SAFETY BRANCH

Supervises Safety Program for all activities under jurisdiction of Area Engineer; prepares and transmits compensation claims and reports for Government employees to District Safety Section for review and submission to U. S. Employees' Compensation Commission; reviews Workmen's Compensation and other insured claims of contractors for compliance with security regulations.

Captain Paul Baranowsky - Area Safety Officer
  1 CAF-4 Clerk-Steno.

PRIORITIES & SPECIAL ASSIGNMENTS BRANCH

In charge of priorities, WPB allocations and expediting for Chicago Area; expedites delivery of material from midwest region for other Areas and M.E.D.; acts as special assistant to Area Engineer on assignments requiring technical background; controls inter-project and/or inter-Area requests for equipment and materials; arranges loans of special equipment from other agencies; responsible for justification of air priorities requested locally.

Mr. E. L. Fleury Sub Engineer (Civil)
  1 CAF-4 Clerk-Steno.

DEFERMENTS BRANCH

Consults with Personnel Directors of Contractors' and sub-contractors' organizations regarding hiring, terminating and transferring male employees in accordance with Selective Service requirements; processes deferment requests through necessary channels; requests assignment of men to Special Engineer Detachment and SDC.

Miss M. D. Goldberg CAF-6 Clerk
  1 CAF-3 Clerk-Steno.

CLAIMS BRANCH

Investigates and reports all facts and circumstances relating to service-connected accidents, incidents and happenings which are required by the 25 series of Army Regulations to be investigated. Immediate responsibility for these investigations rests upon Area Engineer.

Captain Paul Baranowsky - Area Claims Officer
  1 CAF-4 Clerk-Steno.

CLASSIFIED FILES BRANCH

Receives, routes and dispatches all classified mail; maintains files on all classified material; maintains record of incoming registered mail; keeps detailed accounting records on all classified correspondence.

M/Sgt. D. Henry
  T/5 M. L. Gottschall
  1 CAF-3 Clerk-Typist
  1 CAF-2 Clerk
  1 CAF-2 Clerk-Typist

[redacted]

* To be recommended to next highest grade

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT Chicago Area, Chicago, Illinois

[illegible]PARTMENT

CORPS OF ENGINEERS, U.S. ARMY

[redacted]

PERSONNEL	
OFFICERS	
ENL.	
P	
S P	
CAF	
CPC	
MISCL.	
WAC.	
TOTAL	

CHIEF OF BRANCH

Aids and advises Area Engineer on technical phases of program; consults with contractors' technicians on problems of policy and procedure; supervises all activities of Branch.

Captain [illegible] Chapman
Secretary - 1 CAF-[illegible]

T[illegible]AL LIAISON SECTION

A[illegible] between Chicago Area and a[illegible] informing [illegible] between Chicago Area and [illegible] are dependent, [illegible] information [illegible] between the [illegible] Area and [illegible] scientific reports [illegible] compliance with [illegible] information; [illegible] Area for compliance with [illegible] policies.

[illegible]
CAF-[illegible]

SPECIAL MATERIALS

Furnishes unique technical information concerned with preparation, handling and disposal of special materials; expedites movements of special materials of high classification and great urgency in Chicago Area and associated areas; delivers routine metal and chemical samples to contractor personnel for subjection to functional tests and also for disposal of material after testing; processes procedures, developments and special tests under direction of Area Engineer; maintains all records; assists in procuring and re-allocating supplies for associated contractors; controls movements of special materials made by contractors under administration and/or technical jurisdiction of Chicago Area.

T/Sgt. M. B. Hodin
1 CAF-4 Clerk *
2 CAF-3 Checker
1 CAF-3 Clerk *
1 CAF-2 Clerk *

STATISTICS, REPORTS & CONTROL SECTION

Reviews inter-area distribution of certain reports for compliance with District directives and security measures; maintains file and index of technical reports from various contractors under jurisdiction of Chicago Area; maintains liaison with issuing offices, patent group and military intelligence for purpose of recovery and retirement of classified documents under contract termination proceedings; prepares narrative reports to District Office; also prepares reports to Patent Group and Military Intelligence concerning visitors from certain locations outside the Area.

T/Sgt. H. M. Stewart

* To be recommended to next highest grade.

[redacted]

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT Technical Branch, Chicago Area
SUBMITTED [signature] DATE 7-1-46
RECOMMENDED ______ DATE ______
APPROVED ______ DATE ______

PERSONNEL
OFFICERS
ENL.
P.
S P
C A F
C P C
MISC.
VAC.
TOTAL

[redacted]

MANHATTAN DISTRICT INTELLIGENCE & SECURITY DIVISION
Lt. Col. W. B. Parsons

CHICAGO BRANCH INTELLIGENCE OFFICE

Supervises Intelligence and Security matters of Manhattan District in Illinois, Wisconsin, Michigan, Minnesota, Iowa, Missouri and Lake, Porter, LaPorte and St. Joseph counties of Indiana.

Major G. C. Thompson, Jr.
2nd Lt. C. F. Clarke, Jr.
Secretary - 1 CAF-4

SPECIAL ASSIGNMENTS

1st Lt. C. F. Wendt
2nd Lt. A. H. Madigan

ADMINISTRATIVE SECTION

Responsible for administration of personnel attached to Chicago Branch Office; assists Chicago Area in administrative details on civilian and officer personnel; responsible for maintenance, operation and assignment of vehicles; procures supplies and equipment; maintains all files of Chicago Branch Office.

Is Property Officer and Cryptographic Security Officer.

2nd Lt. J. H. Mahoney
Mrs. G. H. Greene CAF-5 Clerk
1 CAF-3 Clerk-Steno.
1 CAF-3 Clerk
2 CAF-2 Clerk
1 CPC-4 Chauffeur (Mech. Emp.)
2 EM

SHIPMENT SECURITY SECTION

Guards all shipments of MED materials originating in the Fifth, Sixth and Seventh Service Commands while enroute from point of origin to ultimate destination; makes shipment surveys within Fifth, Sixth and Seventh Service Commands; handles all courier movements either originating out of this office or trans-shipment courier movements; transmits Top Secret documents and materials from Chicago to their ultimate destinations.

2nd Lt. D. A. Metzger
Mr. J. B. Henderson
1st Lt. J. A. Moran
2nd Lt. F. H. Bolton
2nd Lt. J. F. Carr
2nd Lt. T. B. Guilfoyle
2nd Lt. E. Koranda
2nd Lt. R. G. Hadden
2nd Lt. L. A. Seminara
2nd Lt. J. L. Weingarten

1 CAF-5 Clerk
1 CAF-3 Clerk-Typist
1 CAF-2 Clerk-Typist
23 CPC-7 Patrolman
9 CPC-8 Patrolman

COUNTER INTELLIGENCE SECTION

Supervises investigations made by the Chicago Branch Office.

Captain J. S. Murray
2nd Lt. D. W. Collins
2nd Lt. A. H. Madigan
2nd Lt. V. K. Schumann
1 CAF-4 Clerk-Steno.
3 CAF-3 Clerk-Steno.
1 CAF-3 Clerk-Typist
1 CAF-2 Clerk-Typist
1 CAF-3 Clerk-Steno. (V.)
Agents

PERSONNEL CLEARANCE SECTION

Responsible for personnel and firm clearance, clearance of transfers on personnel employed on MED work.

2nd Lt. J. H. Mahoney
Miss M. B. Lee CAF-3 Clerk-Typist
1 CAF-3 Clerk-Steno.
1 CAF-2 Clerk-Typist

SAFEGUARDING MILITARY INFORMATION SECTION

Responsible for SMI policies, Security education, censorship, SMI violations, procurement and distribution of SMI supplies.

Mr. G. A. Mayer
Miss F. Seidel CAF-3 Clerk-Steno.
1 EM

PLANT SECURITY SECTION

Supervises plant surveys, visitor control, fire protection, continuity of production, maintenance of responsibility list of MED facilities; liaison with Area Engineer on Security recommendations.

Mr. G. W. Wheaton
Mrs. B. W. Milburn CAF-4 Clerk-Steno.
Agent

[redacted]

ORGANIZATION CHART
MANHATTAN DISTRICT

UNIT CHICAGO BRANCH INTELLIGENCE OFFICE
SUBMITTED ______ DATE 7-1-45
RECOMMENDED ______ DATE
APPROVED ______ DATE

[redacted]

PERSONNEL	
OFFIC	5
ENL.	
P	12
S P	6
C A F	106
C P C	42
Ungr.	5
MISCL. Proposed	5
VAC.	12
Contr.	3
TOTAL	197

PATENT GROUP - WASHINGTON, D. C.

Capt. R. A. Lavender, OSRD

CHICAGO PATENT GROUP #

Mr. F. W. Test

AREA ENGINEER

As Area Engineer, responsible for operation of Chicago Area in all its functions, including general administration, maintenance, intelligence and security and patent activities in compliance with broad policies and objectives. Administers the cooperative research program embracing 25 participating institutions. Approves operating and experimental programs and budget estimates. As authorized representative of the contracting officer, is directly responsible for administration and supervision of all contracts in the Chicago Area.

Colonel Arthur H. Frye, Jr.
(Civilian position: Engineer (Civil), P-7, Chic. 368 (NR)
1 Secretary (Stenography), CAF-5, (V) (NR) *

EXECUTIVE OFFICER

As Executive Assistant to the Area Engineer, responsible for the execution of all operations of the Chicago Area.

Major Donald F. Wood
1 Clerk-Steno., CAF-3

As Asst. to the Executive Officer, performs with broad discretionary powers such duties as directed by the Executive Officer. Authorized representative of the Contracting Officer; Certifying Officer; Deferment Investigation Officer; Savings Bond Officer; Claims Officer.

1st Lt. H. B. Phillips, Asst.
1 Clerk-Typist, CAF-3 **

CHIEF PROJECT AUDITOR
W. L. Phillips
Sheet No. 2

ADMINISTRATIVE DIVISION
J. T. Harris
Sheet No. 3

OPERATIONS DIVISION
E. R. Fleury
Sheets No. 4 & 5

SECURITY DIVISION
J. H. Mahoney
Sheet No. 6

PROPERTY & SUPPLY DIVISION
R. L. Quinlan
Sheet No. 7

* Vera M. Funk detailed to this position for a period of 6 months from PN 38-1 (Clerk-Steno., CAF-4) in Security Division.

** Employee holding this position as Clerk-Typist, CAF-2 due to proposed cancellation of position.

\# All personnel of Patent Group employed under Contract No. W31-109-eng-38.

[redacted]

ORGANIZATION CHART

UNITED STATES ATOMIC ENERGY COMMISSION

UNIT CHICAGO AREA, CHICAGO, ILLINOIS

SUBMITTED Donald F. Wood DATE 1-1-47

RECOMMENDED Arthur H. Frye Jr. Col. DATE 1-1-47

APPROVED DATE

SHEET NO 1 OF 7 SHEETS

B8a

[redacted]

PERSONNEL

OFFIC.	
ENL.	
P	
S P	
C A F	18
C P C	
MISCL. Proposed	1
VAC.	1
TOTAL	20

CHIEF PROJECT AUDITOR

Directs and administers audits, accounts and fiscal.

Chief - Auditor, CAF-11, Chic. 8
(Mr. W. L. Phillips)
1 Secretary (Stenography), CAF-4

ASSISTANT PROJECT AUDITOR

Under general supervision of the Chief Project Auditor but with considerable individual responsibility for the proper function of audit procedures in the administration of two prime contracts and all sub-contracts thereunder, within the jurisdiction of the Chicago Area Office, supervises under authority and direction of the Chief Project Auditor, through subordinate supervisors, all employees in the home office, engaged in audit procedures for the above contracts.

Chief - Auditor, CAF-9, Chic. 385
(Miss G. Sorkin)
1 Clerk-Typist, CAF-4

SUPERVISING AUDITOR

Supervises and coordinates all activities pertaining to Fiscal and internal audit.

Chief - Auditor, CAF-7, Chic. 11
(Miss B. Castleberry)

PAYROLL POST AUDIT SECTION

Responsible for post audit of contractor's payrolls.

Chief - Clerk, CAF-5, Chic. 498
(Miss L. M. Schmidt)
1 Clerk, CAF-3
1 Clerk-Typist, CAF-3
1 (PP) Clerk-Typist, CAF-3

CONTRACT SECTION

Edits all negotiated documents and amendments thereto. Responsible for historical and cost data on restoration and remodeling as substantiation in any negotiation settlements.

Chief - Clerk, CAF-4, Chic. 248
(Mrs. M. L. Rago)

COST & FISCAL SECTION

Responsible for maintenance of fiscal and cost accountability records and controls.

Chief - Clerk, CAF-6, Chic. 387
(Miss C. E. Allen)
1 Clerk, CAF-4
1 Clerk, CAF-3
2 Clerk-Typist, CAF-3
1 (V) Clerk-Typist, CAF-3 (RR)

VOUCHER AUDIT SECTION

Audits public vouchers submitted for reimbursement by prime contractors under Chicago Area covering material, supplies, equipment, services, travel and utilities.

Chief - Clerk, CAF-5, Chic. 17
(Mrs. J. S. LeGuire)
1 Clerk, CAF-4
1 Clerk, CAF-3
1 Clerk-Typist, CAF-3

[redacted]

ORGANIZATION CHART

UNITED STATES ATOMIC ENERGY COMMISSION

UNIT CHIEF PROJECT AUDITOR, CHICAGO AREA

SUBMITTED [signature] DATE 1-1-47
RECOMMENDED [signature] DATE 1-1-47
APPROVED DATE

[redacted]

PERSONNEL	
OFFIC.	
ENL.	
P	
S P	
C A F	30
C P C	23
Ungr.	1
MISCL.	
VAC.	4
TOTAL	58

ADMINISTRATIVE DIVISION

Plans, directs and coordinates all activities of the division. Delegated authority as Contracting Officer and Transportation Officer. Authorized to sign travel orders. Responsible for Work Measurement Program and Service Control.

Chief - (V) Adm. Asst., CAF-11, Chic. 346 (NR)
(Mr. J. T. Harris) *
1 Clerk-Steno., CAF-3

PERSONNEL BRANCH

Responsible for processing all civilian personnel actions within authority delegated by the District Office. Maintains records and files. Submits reports of actions affecting Officer personnel. Prepares pay and allowance vouchers.

Chief - Clerk, CAF-6, Chic. 15
(Miss D. H. Cassady)
2 Clerk-Typist, CAF-4
1 Clerk-Typist, CAF-3

MOTOR POOL

Responsible for all phases of operation and maintenance of vehicles, supply of vehicles and spare parts, training of all personnel, maintenance of required records, inspection of personnel and equipment, prompt and accurate submission of all required reports.

Chief - Motor Vehicle Dispatcher, CPC-7,
(Mr. G. M. Maronde) Chic. 504
3 Inspector (Auto Equip.), CAF-5
19 Chauffeur, CPC-3
2 Clerk-Typist, CAF-3
1 (V) Clerk-Typist, CAF-2, (NR)

TRAFFIC BRANCH

Responsible for all activities of branch. As civilian transportation agent, furnishes Government bill of lading and other shipping documents to cover all movements over common carriers in accordance with existing regulations. Advises Area Engineer, Division and Branch Chiefs on important traffic matters.

Chief - Adm. Asst., CAF-7, Chic. 12
(Mr. M. W. Ellen)
2 Clerk-Typist, CAF-3
1 Clerk-Typist, CAF-2
1 Truck Driver (Med.), Ungr.

FILES BRANCH

Responsible for the operation of Mail & Records and Classified Files Sections. Responsible for disposition and retirement of all record and non-record material.

Chief - Mail & File Supervisor, CAF-5, Chic. 436
(Mrs. V. B. Ringius)

MAIL & RECORDS SECTION

Receives, routes, classifies, dispatches and files all unclassified mail for Area. Maintains record of mail received. Provides messenger and reproduction service. Maintains stock of office supplies. Maintains library.

Chief - (V) Clerk, CAF-4, Chic. 40
(Mrs. P. F. Roos)**
1 Clerk-Typist, CAF-3
1 Clerk, CAF-3
1 Clerk-Typist, CAF-2
1 Messenger, CPC-3
2 Messenger, CPC-2
1 (V) Messenger, CPC-3 (NR)

CLASSIFIED FILES SECTION

Receives, routes, classifies, dispatches and files all classified material for the Area. Keeps record of receipt of incoming special delivery, registered and insured mail; keeps detailed accounting records on all classified correspondence.

Chief - Clerk, CAF-4, Chic. 186
(Mrs. K. P. Caveney)
1 Clerk-Typist, CAF-3
1 Clerk, CAF-3
1 Clerk-Typist, CAF-2

VOUCHER BRANCH

Responsible for preparation of commercial and travel vouchers; maintains records in connection therewith.

Chief - Clerk, CAF-4, Chic. 449
(Miss K. C. Rea)

WAGE ADMINISTRATION BRANCH

Responsible for administration of Contractors' wage rates and the audit of applications for salary approval.

Chief - Clerk, CAF-4, Chic. 27
(Mrs. V. J. Mortara)
3 Clerk-Typist, CAF-3

PROCUREMENT BRANCH

Locates supplies, material and/or equipment; secures bids and quotations; issues purchase orders; receives invoices; procures mandatory and/or controlled items under TPS contracts; processes contractual documents between District Legal Section and Contractor.

Chief - Clerk, CAF-4, Chic. 178
(Miss J. R. Kulp)
1 Clerk-Typist, CAF-2

* Employee presently holding PM 200 (Adm. Asst., CAF-9) and will be recommended for promotion to PM 346.
** Promotion to PM 40 pending. Presently holding PM 104 (Clerk-Typist, CAF-2).

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ORGANIZATION CHART

UNITED STATES ATOMIC ENERGY COMMISSION

UNIT ADMINISTRATIVE DIVISION, CHICAGO AREA

SUBMITTED [signature] DATE 1-1-47
RECOMMENDED [signature] DATE 1-1-47
APPROVED DATE

[redacted]

PERSONNEL	
OFF	
ENL.	
P	3
SP	1
CAF	6
CPC	
MISCL.	
VAC.	2
TOTAL	12

OPERATIONS DIVISION

Supervises all operations of Technical, Construction and Maintenance and Safety Branches. Reviews for and advises Area Engineer on technical phases of research and development program, on approval of construction programs and safety programs. Controls inter-project and/or inter Area requests for technical material. Acts as assistant to Area Engineer handling special assignments requiring technical background and handles contacts with participating institutions of Argonne National Laboratory.

Chief - Engineer (Civil), P-5, Chic. 290
(Mr. E. R. Fleury)
1 Clerk-Steno., CAF-4

TECHNICAL BRANCH

Aids and advises Area Engineer, through Division Chief, on technical phases of programs; consults with Contractors' technicians on problems of policy and procedure. Performs in liaison capacity between other Areas and Contractors under jurisdiction of Chicago Area in progress of research programs and technical matters concerned with scientific fields. Establishes administrative procedures for Technical Branch. Supervises all activities of Information and Special Materials Sections including maintenance of records. Arranges all matters with Argonne National Laboratory pertaining to participating institutions.

Chief - Engineer (Chem.), P-4, Chic. 229
(Mr. M. B. Rodin)
1 Adm. Asst., CAF-9
1 Clerk-Steno., CAF-4

INFORMATION SECTION

Reviews inter-Area distribution of certain reports and correspondence for compliance with District directives on information interchange and security regulations. Processes and distributes technical information which involves contacts between the Chicago Area and other sites. Approves and fills requests from the District and other sites for classified documents. Maintains current file and index of technical reports of prime contractors as well as records of all documents declassified in the Area. Prepares monthly narrative report for transmittal to District Office and other special reports as required by the Area Engineer. Transmits reports from other sites to their consultants in this location. Assists in distribution of information to participating institutions.

Chief - (V) Engineer (Chem.), P-3, Chic. 230 (NR)

SPECIAL MATERIALS SECTION

Furnishes unique technical information concerned with preparation, handling and disposal of special materials; expedites procurement and release of special materials of high classification and great urgency in Chicago Area and associated Areas; schedules routine metal and chemical samples to Contractor personnel for subjection to functional tests and disposal of material after testing; administers development and special test problems under direction of Area Engineer; maintains all records; assists in procuring and reallocating supplies for associated Contractors; authorizes movement of special materials made by Contractors under administration and/or technical jurisdiction of Chicago Area. Advises Traffic Branch in all technical matters.

Chief - Aide, Scientific, SP-8, Chic. 308
(Mr. H. E. Armstrong)
1 Checker, CAF-3
1 Clerk-Typist, CAF-3

SAFETY BRANCH

Inspects all projects for safety and fire protection; cooperates with all Contractors to promote services for safety and fire protection; provides consultation service on safety; cooperates with Engineering sections, arranges for showing of safety motion picture films; provides posters and other bulletin service; checks construction plans to include safety; works on traffic problems.

Chief - Engineer (Safety), P-4, Chic. 1
(Mr. J. T. Faust)
1 (V) Engineer (Safety), P-2, (NR)
1 Clerk-Typist, CAF-3

CONSTRUCTION & MAINTENANCE BRANCH

Chief - Supt. (Constr.), P-5, Chic. 328
(Mr. P. C. Moen)

Sheet No. 5

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ORGANIZATION CHART
UNITED STATES ATOMIC ENERGY COMMISSION

UNIT OPERATIONS DIVISION, CHICAGO AREA

SUBMITTED DATE 1-1-47
RECOMMENDED DATE 1-1-47
APPROVED DATE

[redacted]

PERSONNEL

OFFI.	
ENL.	
P	9
S P	5
C A F	3
C P C	
Ungr.	3
MISCL.	
VAC.	2
Contr.	1
TOTAL	23

OPERATIONS DIVISION

Chief- Engineer (Civil), P-5, Chic. 290
(Mr. E. R. Fleury)

CONSTRUCTION AND MAINTENANCE BRANCH

Assists Contractor under Contract W31-109-eng-38 in determination of requirements for construction, modification and restoration, preparation of plans and specifications and supervision of construction; also approves plans, specifications, work orders, costs and completion of above work within limits determined by Area Engineer; supervises maintenance of Government-owned or leased facilities.

Chief - Supt. (Constr.), P-5, Chic. 328
(Mr. P. C. Moen)
1 Clerk-Steno., CAF-4

ARGONNE NATIONAL LABORATORY SECTION

Assists Branch Chief in securing necessary information for planning and construction for all new buildings and sites. Makes preliminary sketches, plans and specifications for the above and reviews the final drawings, specifications and bids; recommends acceptance to Branch Chief. Assists building contractor in locating and procuring materials for construction.

1 Engineer (Elec.), P-4
1 Engineer (Arch.), P-4
1 (V) Engineer (Mech.), P-4, (RR)
1 (V) Draftsman (Arch.), SP-8, (RR)

CONTROL SECTION

Records and routes work orders; formalizes work orders prepared by Engineers; receives proposals; distributes work orders; types all work orders and reports pertaining to Control Section.

Chief - Clerk-Steno., CAF-3, Chic. 384
(Miss T. S. Piorkowski)
1 Photostat & Blueprint Operator, CAF-2

SITE MODIFICATION, MAINTENANCE & RESTORATION SECTION

Makes recommendations to Branch Chief regarding feasibility of work requests; prepares plans and specifications for construction and issuance of work orders to contractors; receives bids and checks cost estimates; assists in locating and procuring materials by contractors; assists Branch Chief in negotiations with property owners with regard to restoration; prepares plans and specifications and secures costs for restoration; recommends acceptance to Branch Chief.

Chief - Engineer (Arch.), P-4, Chic. 329
(Mr. W. C. Litt)
1 Engineer (Mech.), P-3
1 Engineer (Elec.), P-3
1 Draftsman (Arch.), SP-8
1 Draftsman *

SUPERVISION OF CONSTRUCTION

Under Branch Chief, supervises field operations pertaining to new construction and modification and changes to existing sites, including restoration of such sites. Makes topographical surveys, runs control levels and sets building locations and grades.

1 Engineer (Arch.), P-4
3 Road Maintenance Laborer, Ungr.
1 Engineer (Civil), P-2
1 Engineering Aide (Civil), SP-6
1 Engineering Aide (Civil), SP-5
2 Engineering Aide (Civil), SP-3

OFFICE ENGINEER

Maintains card index system for work completed and work now in progress regarding restoration of contractor-owned buildings; checks drawings completed by Draftsmen against rough sketches; prepares engineering correspondence, reports and estimates to sub-contractor.

Chief - Engineer (Civil), P-2, Chic. 383
(Mr. H. L. Davis)

* On Contractor's payroll

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ORGANIZATION CHART

UNITED STATES ATOMIC ENERGY COMMISSION

UNIT OPERATIONS DIVISION, CHICAGO AREA

SUBMITTED ______ DATE 1-1-47
RECOMMENDED [signature] DATE 1-1-47
APPROVED ______ DATE ______

[redacted]

PERSONNEL	
OFFICERS	3
ENL.	
P	
S P	
C A F	17
C P C	19
MISCL.	
VAC.	1
TOTAL	40

SECURITY .ISION

Supervises Manhattan District Security and Intelligence activities in North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Wisconsin, Illinois, Michigan, Indiana and Ohio.

Chief - Sec. & Intel. Officer, CAF-12, Chic. 250
(Mr. J. H. Mahoney)
1 Investigator (Intel. & Sec.), CAF-11
2 Clerk-Steno., CAF-4 (1*)

VISITOR CONTROL BRANCH

Administers the issuance of visitor permits to intra District visitors; maintains close liaison with Contractors in visitor control; keeps records of visitors; reports to District Office on foreign visitors.

Chief - Investigator (Intel. & Sec.), CAF-11, Chic. 294
(Mr. J. J. Lannon)
1 Clerk-Steno., CAF-4 (Partial)

PLANT SECURITY BRANCH

Responsible for inspection of all facilities engaged in MED work under Chicago Area prime and sub-contracts. Writes reports for transmission to District Office on inspections. Makes recommendations for improvement of security conditions at each installation when deemed necessary. Responsible for contract termination security surveys.

Chief - Investigator (Sec. & Intel.), CAF-10, Chic. 350
(Mr. E. W. Healy)
1 (V) Clerk-Steno., CAF-4 (NR) **

MAIL & FILE BRANCH

Responsible for administration and maintenance of all Security Division files. Responsible for collection and dispatch of all Security Division mail. Keeps pending mail system for Security Division. Screens current newspapers for news pertinent to security of Chicago Area.

Chief - Clerk-Steno., CAF-4, Chic. 35 (Partial)
(Miss E. D. Herro)
1 Clerk-Typist, CAF-3
1 Clerk, CAF-3 (Partial)

INVESTIGATIVE BRANCH

Responsible for all intelligence and counter-intelligence activities. Supervises and conducts all investigations made by the Chicago Area Office as office of origin and for other Area Security Offices in the Manhattan District. Supervises activities of Resident Security Officer in Centerline Area.

Chief - Intel. & Sec. Officer, CAF-11, Chic. 293
(Mr. D. J. Harley)
1 Investigator (Intel. & Sec.), CAF-10
1 Clerk-Steno., CAF-4 (Partial)
1 Clerk-Steno., CAF-3

CRYPTOGRAPHIC BRANCH

Responsible for sending all classified and unclassified teletype messages. Responsible for cryptographic security pursuant to AR 380-5 in transmission and reception of messages.

Chief - 1st Lt. H. B. Phillips, Cryptographic Officer
1 Teletype Operator, CAF-4
1 Clerk-Steno., CAF-4 (Partial)
1 Clerk, CAF-3 (Partial)

SHIPMENT SECURITY BRANCH

Responsible for all guarded shipments of MED materials originating in the Fifth Army when enroute from point of origin to ultimate destination; makes shipment surveys within the Fifth Army; handles all courier movements; transmits top secret documents and materials from Chicago to their ultimate destinations.

Chief - 1st Lt. T. L. Aton
1st Lt. H. K. Doty
1 Clerk, CAF-6
1 Clerk-Typist, CAF-4
4 Patrolman, CPC-8
14 Patrolman, CPC-7
1 Chauffeur (Mech. Rep.), CPC-4

PERSONNEL CLEARANCE BRANCH

Responsible for personnel and firm clearance for transfers on personnel employed on MED work for Chicago Area, Site Y and related installations.

Chief - Investigator (Intel. & Sec.), CAF-11, Chic. 294
(Mr. J. J. Lannon)
2 Clerk-Steno., CAF-4 (1 partial)
1 Clerk-Steno., CAF-3

* Detailed to PN 402 for a period of 6 months.

** Allocation of grade CAF-4 presently under question. Duties being performed by Lillian J. Horvat who is holding PN 69 (Clerk-Steno., CAF-3 in Personnel Clearance Branch).

ORGANIZATION CHART

UNITED STATES ATOMIC ENERGY COMMISSION

UNIT SECURITY DIVISION, CHICAGO AREA

SUBMITTED [signature] DATE 1-1-47
RECOMMENDED [signature] DATE 1-1-47
APPROVED ______ DATE ______

[redacted]

[redacted]

PERSONNEL
OFFIC
ENL.
P
S P
C A F 30
C P C
Proposed 5
MISCL.
Ungr. 1
VAC.
Contr. 2
TOTAL 38

PROPERTY & SUPPLY DIVISION

Coordinates, plans and directs the activities of the various branches of the division. Accountable Property Agent.

Chief - Adm. Asst., CAF-9, Chic. 503
(Mr. R. L. Quinlan)

REQUIREMENTS, STORAGE & ISSUE AND WAREHOUSE BRANCH

Responsible for locating scarce mandatory or controlled items through other Government agencies, arranges for procurement of purchase of such items and of those acquired by WAA site sales. Advises and informs scientific and construction personnel of availability of such equipment. Receives Contractor's purchase requisitions. Expedites deliveries. Reviews WAA and District surplus lists. Arranges for attendance of interested personnel at WAA site sales. Supervises functions of Receiving, Small Stores and Warehouse Section.

Chief - Storekeeper, CAF-7, Chic. 427
(Mr. J. P. Cox)
1 Clerk-Steno., CAF-3

RECEIVING, SMALL STORES AND WAREHOUSE SECTION

Responsible for receiving equipment, packing and crating outgoing shipments and preparation of transfer documents. Arranges for adequate warehousing. Controls operations regarding maintenance of office furniture and equipment. Provides labor, makes local deliveries and pick-ups for Area. Operates small stores stockroom; maintains stock records.

Chief - Clerk, CAF-4, Chic. 347
(Mr. D. F. Greig)
1 Storekeeper, CAF-4
3 Clerk-Typist, CAF-3 (1 partial)
1 Clerk-Typist, CAF-2
1 [illegible] (PP) TRUCK DRIVER (MED)
1 Warehouse Laborer (Partial)
1 Laborer *

REPORTS & SPECIAL ASSIGNMENT BRANCH

Responsible for reports required by regulations. Conducts research of records and correspondence on unique problems. Makes continuous selective audits of records of receipt and issue of Special Materials Section. Maintains records covering receipt and issue of oil and gasoline procured for and consumed by Area Motor Pool.

Chief - Clerk, CAF-5, Chic. 438
(Miss S. A. Druktenis)
1 Clerk-Typist, CAF-2 (Partial)
1 (PP) Clerk-Typist, CAF-2

PROPERTY RECORDS (CONTRACTOR) BRANCH

Responsible for maintaining property records in accordance with regulations of all Government-owned property in possession of Contractors under jurisdiction of Chicago Area.

Chief - Clerk, CAF-6, Chic. 349
(Miss M. R. Sack)
2 Clerk-Typist, CAF-4
3 Clerk-Typist, CAF-3
2 Clerk, CAF-3
2 (PP) Clerk-Typist, CAF-2

PROPERTY DISPOSAL & INVENTORY BRANCH

Responsible for declaration of excess property to District Office and of surplus property to WAA. Makes small lot sales. Obtains scrap determination from WAA for disposition of excess scrap items. Disposes of nominal quantities of scrap by bid locally. Controls activities of Inventory & Excess Material Storage and Real & Installed Property Records Sections.

Chief - Clerk, CAF-6, Chic. 114
(Mr. J. T. Hartley)
3 Clerk-Typist, CAF-3 (2 partial)
1 Clerk-Typist, CAF-2

INVENTORY & EXCESS MATERIAL STORAGE SECTION

Arranges for and is responsible for inventory of all Government-owned property and for assignment of USA numbers. Makes arrangement for adequate storage space for excess and surplus property.

Chief - Clerk, CAF-6, Chic. 261
(Mr. J. P. Duffy)
1 Procurement Inspector, CAF-5
1 Clerk-Typist, CAF-2
1 Warehouse Laborer, Ungr. (Partial)
1 Laborer *

REAL & INSTALLED PROPERTY RECORDS SECTION

Maintains Accountable Property records of Real and Installed Class "A" Property.

Chief - Clerk-Typist, CAF-3, Chic. 382 (Partial)
(Miss C. S. Burke)

MILITARY PROPERTY RECORDS & CONTRACTOR'S AUDIT BRANCH

As Special Assistant to Division Chief, establishes and/or recommends improvements in procedures. Designated Agent. Supervises activities of Selective Audit and Property Records (Station Military Acct.) Sections.

Chief - Clerk, CAF-6, Chic. 435
(Mrs. G. C. Finan)

SELECTIVE AUDIT SECTION

Makes continuous selective audit of Contractors' records. Conducts inventories of items in stock and submits to Contractor for adjustment, if necessary. Conducts unanticipated checks of Contractors' receiving activities to insure conformance with procedures.

Chief - Clerk, CAF-5, Chic. 262
(Mr. J. Makipaa, Jr.)

PROPERTY RECORDS (STATION MILITARY ACCT) SECTION

Responsible for maintaining property records in accordance with regulations of all Government-owned property in possession of Station Military Account.

Chief - Clerk, CAF-4, Chic. 305
(Miss M. M. Pokarney)
2 Clerk-Typist, CAF-2 (1 partial)
1 (PP) Clerk-Typist, CAF-2

* On Contractor's payroll.

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ORGANIZATION CHART
UNITED STATES ATOMIC ENERGY COMMISSION
UNIT PROPERTY & SUPPLY DIVISION, CHICAGO AREA
SUBMITTED [illegible] DATE 1-1-47
RECOMMENDED [illegible] DATE 1-1-47
APPROVED ____ DATE ____

SHEET NO. 1 OF 1 SHEETS

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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

APPENDIX C

REFERENCES

REPORTS

(Note: References listed immediately below are Metallurgical Laboratory reports on file in the library of the Metallurgical Laboratory.)

No.	Report No.	Title
1	C-101	"Report for Week Ending May 30, 1942"
2	A-135	"The Chemical Properties of Elements 93 and 94", G. T. Seaborg and A. C. Wahl. (March 19, 1942)
3	CP-1136	"Loading for Hanford 305 Pile", H. L. Anderson. (December 11, 1943)
4	CP-413	"Experimental Production of a Divergent Chain Reaction", E. Fermi.
5	A-55	"Reaction in Systems Composed of Metal and Carbon", L. Szilard
	C-1	"Discussion of the Homogeneous and Lattice Arrangements for Power Plants", E. P. Wigner
6	CP-2459	"A Brief Description of the Argonne Uranium-Graphite Pile (CP-2)" H. E. Metcalf. (December 20, 1944)
7		Monthly reports, as indicated, of research at Argonne Laboratory.
	CP-1965	July, 1944
	CP-2301	October, 1944
	CP-2749	February, 1945
	CP-3195	June, 1945

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Appendix C (Cont'd)

No.	Report No.	Title
8	CE-277	"Preliminary Process Design of Power Plant", T. V. Moore, M. C. Leverett. (September 25, 1942)
9	CE-407	"Preliminary Process Design of Liquid Cooled Power Plant Producing 5×10^5 KW", M. G. J. Boissevain, E. P. Wigner, et al. (January 9, 1943)
10	CN-1188	"Report for Month Ending January 3, 1944; General Engineering Section, Technical Division", G. E. Kidd, J. O. Maloney.
	CT-2524	"Film Formation in "W" Annulus", R. E. Larson, M. J. Szulinski. (December 23, 1944)
	CE-2818	"Radiation vs. Corrosion", R. Briggs (April 7, 1945)
11	N-1299	"Comments on Proposed Canning Procedures", S. K. Allison, E. C. Creutz. (January 12, 1944)
12	N-1145p	"Work on Long Cartridge Jacket at Aluminum Company", (MUC-EC-102) (July 12, 1944)
	CP-1940	"Warping in Long Cartridges", G. Young. (July 25, 1944)
	CP-2798	"Experimental Production of Die Cast Slug Coatings", J. H. Chapin. (March 27, 1945)
13	N-1375	"Discussions Concerning Design and Use of Project Instruments", G. S. Monk.
	CP-1680	"All-Plastic Optical System for Project Purposes", G. S. Monk. (May 6, 1944)
	CP-1687	"Notes on Coloration of Optical Materials", G. S. Monk. (May 11, 1944)
14	MUC-WPJ-134	"Catalog of Instruments", P. A. Dana, D. L. Collins, H. Palevsky. (June 1, 1945)

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Appendix C (Cont'd)

No.	Report No.	Title
15	N-1306	"Reports to Swell Committee", E. C. Creutz.
	CT-2633	"Supersonic Flaw Detector, Model IT", R. F. Platt.
	CT-1897	"Supersonic Transmission Measurements on Various Samples", F. A. Firestone, W. G. Langton. (July 4, 1944).
	CP-2774	"Final Report on Swell Detection by Pusher Method", W. B. Shank, M. Krankel. (November 11, 1944)
16	CN-1017	"Survey of Separations Processes", W. W. Armstrong, E. R. Gilbert, J. O. Maloney. (October 29, 1943)
	CN-1315	"A Brief Summary of Methods for Extraction, Decontamination, Concentration and Isolation of Product", (January 28, 1944)
	CN-2519	"Survey of Separations Processes", R. E. Clark. (August 1, 1944)
17	CN-3000	"Separations Processes for Plutonium", G. T. Seaborg and associates. (May, 1945)
18	CS-2124	"Information Meeting (Chemistry)", Project Council. (August 22, 1944)

LEASES

No.		Description	Location
19	W-2288 eng-523	Lease for use of 1088 acres of Argonne Forest, Chicago	File 601.53 Chicago Area Office
20	W-2288 eng-149	Lease for use of area at 56th St. and Ingleside Avenue, Chicago	File 601.53 Chicago Area Office
21	W-11-114 eng-570	Lease for use of 124th Field Artillery Armory, 52nd St. and Cottage Grove Avenue, Chicago	File 601.53 Chicago Area Office

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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

APPENDIX D

DOCUMENTARY FORMS

No.	Description
1	General Contractual Information
2	Extracts from Construction Completion Report

[redacted]

[redacted]

GENERAL CONTRACTUAL INFORMATION

Government research and development contracts in connection with the Pile Project research program at the Metallurgical Laboratory are on a cost plus overhead basis. In the case of each contractor, proportional allowances for overhead are not in excess of those normally charged by the contractor as evidenced by the records of the contractor over a period of two years prior to the effective date of the contract.

Payment to the contractor is accomplished by reimbursement on vouchers submitted by the contractor only after such vouchers have been approved for payment in accordance with standard Government accounting procedures.

The specialized nature of the Pile Project research work limited the choice of contractors. Primary considerations in the final selection of a contractor for specific research work are the contractor's experience, facilities, and trained personnel. Other factors, such as prior relations with the OSRD and the Manhattan District, location, and considerations of security also play an important part in the final selection.

[redacted]

[redacted]

ARMY SERVICE FORCES
United States Engineer Office
Manhattan District
Chicago Area Office

EXTRACTS FROM CONSTRUCTION COMPLETION REPORT

[redacted]

[redacted]

EXPENDITURE SUMMARY OF CONSTRUCTION WORK FOR METALLURGICAL LABORATORIES OF THE UNIVERSITY OF CHICAGO

Site "A" ----------------------------------	$ 609,400.02
Site "B" ----------------------------------	583,858.92
New Chemistry and Annex ------------------	668,126.41
Armory ------------------------------------	162,196.58
The University of Chicago Laboratories ---	131,330.43
Total	$2,154,912.36

[redacted]

[redacted]

COMPLETION REPORT
SITE "A"

SECTION I

1. This project, known as Argonne or "Site A," is located in the southwest part of Cook County, Illinois, Palos township, on the south side of State highway #4A, also known as Archer Avenue, approximately 5 miles northeast of the village of Lemont, Illinois, in the area known as Argonne Forest of Cook County Forest Preserve.

The project is constructed for and is being used for laboratory investigation by the Metallurgical Laboratory of the University of Chicago. Access to the site is provided by a crushed stone and cinder road approximately 3/4 mile long. This access road begins at highway #4A, in an easterly direction at a point approximately 1 - 1/8 mile southwest of the triangular intersection of highway #4A and 95th Street South, Chicago, Illinois.

Transportation facilities include the State highway #4A, the Chicago and Alton Railroad, the Atchison, Topeka and Santa Fe Railroad, and the Illinois and Michigan ship canal. The railroads and canal lie immediately northwest of State Highway #4A with terminal facilities in the village of Lemont.

2. The area consists of approximately 1088 acres, leased from the Forest Preserve District of Cook County, Illinois. The area of the building site is approximately 16 acres and is located within an inner double fence at an approximate elevation of 742 feet above sea level. Flood lighting is provided to illuminate the inner fence at night. An outer fence comprising an area of approximately 202 acres encompasses the inner fence area. A lower lodge guard house is located at the access road approximately 1000 feet southeast of highway #4A. The terrain is hilly and heavily wooded with hardwood trees and hawthorne brush, with the exception of the southeast corner of the 1088 acres, on which is located an abandoned 18 hole golf course. A disposal pit for contaminated property brought to Argonne from other sites is located approximately 3/8 mile northeast of the building site at an elevation of nearly 700 feet above sea level. This plot is designated as plot "M" on the plot plan. It is 90 ft. x 150 ft. and is enclosed by a concrete curbing 3' deep into the ground and a cyclone type wire fence 7' high.

All the buildings except Building "A," the lower lodge and the lead foundry, were constructed under government contract and are located as shown on plot plan Drawing No. A-48.

Building A is a two story and basement structure, masonry - first story, stud and wood siding - second story. A guard sentry cupola located on the roof of this building is manned continuously. Part of Building B and Building E are of masonry construction, the other buildings and connecting passages are wood stud and cement asbestos siding construction except the Mess Hall and dormitory which are standard T.O. series 700 construction.

The Dormitory building G consists of 3 units of 2 bedrooms, 2

[redacted]

toilet rooms with shower and one living room combined, to accommodate single men and scientists requiring overnight stay on the site.

A tennis court is provided for the recreation of academic personnel.

Facilities for making special apparatus for the scientists are provided for by the installation of a carpenter shop, machine shop, lead foundry, and a glass blowing shop. A stock room carries a small supply of expendable items most likely needed for laboratory research work and upkeep.

The total floor area of all site buildings is 54,200 sq. feet.

3. The following contracts were negotiated for the construction of "Site A."

Number	Contractor	Amount	
	Lump Sum Government Contracts		
W-7401 eng-8	E. L. Lonergan	$152,191.47	
W-7401 eng-10	Bar Brothers	8,125.65	
W-7401 eng-11	L. E. Meyers & Co.	10,978.00	
W-7401 eng-16	Piping Contractors	8,429.00	
W-7401 eng-17	Davies Electric	12,246.89	
W-7401 eng-18	E. S. Claffey Co.	15,675.71	
W-7401 eng-28	E. L. Lonergan	24,496.22	
W-7401 eng-114	E. L. Lonergan	266,318.55	
W-7401 eng-147	Water Cooling Equipment	2,695.00	
W-7405 eng-253	Permutt Co.	5,580.00	
W-7409 eng-40	Chicago Bridge & Iron	8,020.00	
W-7421 eng-3	S. B. Geiger Co.	2,140.60	
W-7401 eng-146	Skidmore, Owings & Merrill	15,200.00	
W-7401 eng-13	Stone & Webster	38,967.35	575,064.44
	Subcontracts to 7401 eng-37		
7401-37-81	Samuel R. Lewis	904.00	
7401-37-80	H. P. Reger & Co.	2,360.73	
7401-37-79	Bulley & Andrews	5,050.56	8,315.29
	Metallurgical Laboratory Purchase Orders		
P. O. MO-3347	Ernest Freeman & Co.	95.95	95.95
	Government Purchase Orders		
P. O. 3148	H. P. Reger & Co.	220.00	
P. O. 3475	H. P. Reger & Co.	162.50	
P. O. 3470	Davies Electric Co.	457.90	
P. O. 3474	Davies Electric Co.	483.05	
P. O. 3473	Davies Electric Co.	52.00	
P. O. 3472	Davies Electric Co.	439.35	
P. O. 3471	Davies Electric Co.	175.81	

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P. O. 2712	Westerlin & Campbell	$ 1,163.00	
P. O. 3450	Westerlin & Campbell	375.00	
P. O. 970	E. L. Lonergan	516.43	
P. O. 7962	E. L. Lonergan	1,976.95	
P. O. 3356	Thomson Engineering Co.	1,728.90	
P. O. 3745	Illinois Window Shade Co.	23.13	
P. O. 11136	Davies Electric Co.	81.39	
P. O. 11140	Davies Electric Co.	155.44	
P. O. 11150	Davies Electric Co.	358.51	
P. O. 11168	Davies Electric Co.	296.17	
P. O. 7476	Davies Electric Co.	1,469.28	
P. O. 12002	Davies Electric Co.	807.23	
P. O. 12578	Davies Electric Co.	823.85	
P. O. 27116	Davies Electric Co.	1,193.37	
P. O. 28119	Davies Electric Co.	749.39	
P. O. 28823	Davies Electric Co.	476.29	
P. O. 12723	Davies Electric Co.	1,794.45	
P. O. 3719	H. P. Reger & Co.	310.00	
P. O. 7411	H. P. Reger & Co.	180.00	
P. O. 7475	H. P. Reger & Co.	595.18	
P. O. 7795	H. P. Reger & Co.	74.79	
P. O. 7796	H. P. Reger & Co.	1,829.01	
P. O. 12381	H. P. Reger & Co.	1,761.13	
P. O. 11903	Ostberg Seed Co.	66.00	
P. O. 12010	Schuckmell Co.	481.18	
P. O. 8420	L. E. Meyers Co.	290.00	
P. O. 12493	L. E. Meyers Co.	94.25	
P. O. 28337	Voss Belting & Spec. Co.	94.71	
P. O. 8469	Bulley and Andrews	139.90	
P. O. 7637	Westerlin & Campbell	865.00	
P. O. 7165	J. I. Reeves	247.80	
P. O. 7123	Boom Elec. & Amp. Co.	1,290.00	
P. O. 7832	Boom Elec. & Amp. Co.	3,622.00	27,924.34

Grand total up to 1 October 1945 $609,400.02

Name	Address	Type of Contractor
E. L. Lonergan	203 N. Wabash	General Contractors
Bar Brothers	Mazon, Ill.	Fence Contractors
L. E. Meyers & Co.	53 W. Jackson	Building
Davies Elect. Co.	126 N. Jefferson	Electrical Contractors
E. S. Claffey Co.	8 W. Illinois	Heating
Permutt Co.	407 S. Dearborn	Water Conditioning
Chicago Bridge & Iron Co.	332 S. Michigan	Bridge & Iron
S. B. Geiger Co.	37 W. Van Buren	Well Contractors
Skidmore, Ownings & Merrill	104 S. Michigan	Architects
Stone & Webster	33 S. Clark St.	Engineering

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Samuel R. Lewis	407 S. Dearborn	Engineering
H. P. Reger & Co.	1501 E. 72nd Place	Heating & Plumbing
Bulley & Andrews	2040 W. Harrison St.	General Contractors
Ernest Freeman & Co.	416 W. Erie	Elec. Contractors
Westerlin & Campbell	1113 W. Cornelia	Ice Machinery
Thomson Engineering Co.	205 W. Wacker	Pump Contractors
Illinois Window Shade Co.	4524 S. Cottage Grove	Window Shades
Ostberg Seed Co.	7301 S. Woodlawn	Grass
Schucknell Co.	3757 S. North	Window Shades
Voss Belting & Spec. Co.	5301 N. Ravenswood	Belting & Spec. Co.
J. I. Reeves	1547 W. Ardmore	General Contractor
Boom Elec. & Amp. Co.	1227 W. Washington	Electric & Amplifier

4. No unusual conditions occurred during the period of construction. The architect-engineers and the contractors executed the work satisfactorily and with dispatch. It is recommended that these firms be given favorable consideration for other Government construction work.

5. Starting date of construction work was 14 September 1942. The operator started to work in December 1942. Completion of construction work was 1 October 1944, with the exception of Contract No. 7401-37-79 which is incomplete and still active.

6. Job records comprising legal description of property, maps, layouts, record drawings, and completion reports are available in the office of the Area Engineer, Chicago Area Office.

7. Water for the site is pumped from a drilled well 508 feet deep into an elevated steel storage tank of 75,000 gallon capacity. The overflow of the water storage tank is located 134' above the pump head, and an average water pressure of 58 pounds per square inch is maintained. A motor driven chlorinator feeds a chlorine solution into the pump header. Periodically samples of water are sent to the Illinois State Department of Public Health for analysis. The weekly quantity of water pumped is approximately 115,000 gallons.

No gas line is extended into the Site.

Electricity is supplied by the Public Service Company of Northern Illinois, to a transformer bank of 1500 kilowatt capacity, 440/220 volt, 3 phase, 60 cycle A.C. and 110 volt, single phase, 60 cycle A.C. is available at inner site Area. An emergency power plant of 10 kilowatt capacity is automatically put into service, should the power company service fail.

Heating is provided by one 100 H.P. high pressure Keewanee boiler located in Building E. This boiler is equipped with an underfeed bin stoker, and connected through piping to Buildings A-E and H. A high pressure heat exchange provides recirculated hot water for heating Buildings B, C and D. The Mess Hall and Dormitory are heated by individual coal stoves. The original low pressure boiler in Building A serves as a standby unit in case of failure of main heating plant.

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For fire protection, six (6) standard fire hydrants with hose are installed. A fire squad of non-academic personnel is trained by the operators of the site and in the event of a large fire, arrangements have been made to call the Lemont fire department.

Sewerage disposal is provided for by the installation of a septic tank, located east of site, outside the inner fence, underground piping extends from the septic tank to the various buildings on the site proper.

SECTION II

1. All the above contracts were lump sum agreements, without any additional cost to the government, other than the Area Engineers and District Office overhead, and this figure is not available.

2. No government materials were transferred in to this site from any other project.

[redacted]

COMPLETION REPORT
SITE B

SECTION I

1. This project, known as "Site B", is an addition and alterations to two University of Chicago owned buildings located at 6111 University Avenue, Chicago, Cook County, Illinois, and is in an apartment house district. It is being used for laboratory investigation by the Metallurgical Laboratory of the University of Chicago. There are no railroad connections directly with the project, but is easily accessible by truck or van.

2. Work consisted of the construction of a two story addition and alterations to the two buildings already on the site (a plot of ground 250' x 175'). There was a total of 31,619 sq. ft. floor space before and 62,671 sq. ft. floor space after construction. The site is Government controlled under the terms of Contract No. W-7401-eng-37.

3.

Number	Contractor	Amount	
	Lump Sum Government Contracts		
W-7401-eng-146	Skidmore, Owings & Merrill	$ 22,300.00	
W-7401-eng-132	Bulley & Andrews	161,427.62	183,727.62
	Subcontracts to 7401-eng-37		
7401-37-61	Bulley & Andrews	88,929.82	
7401-37-62	Ernest Freeman & Co.	21,979.22	
7401-37-63	Phillips, Getschow Co.	45,141.63	
7401-37-64	O'Callaghan Brothers	21,840.63	
7401-37-78	Skidmore, Owings & Merrill	14,000.00	
7401-37-77	O'Callaghan Brothers	11,020.10	
7401-37-74	Ernest Freeman & Co.	40,280.92	
7401-37-70	Bulley & Andrews	42,491.81	
7401-37-71	Phillips, Getschow Co.	45,628.92	
7401-37-75	Narowetz, Htg. & Vent. Co.	11,058.91	
7401-37-79 *	Bulley & Andrews	52,649.28	
7401-37-81	Samuel R. Lewis	1,700.66	396,720.80
	Metallurgical Laboratory Purchase Orders		
P.O. 40735	Narowetz Htg. & Vent. Co.	3,273.00	3,273.00
	Government Purchase Orders		
P.O. 8343	National Electric Tool Co.	37.50	

* Incomplete - Still Active

[redacted]

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P.O. 12153	Cert. Burg. Alarm Systems	$	100.00	137.60
Grand Total up to October 1, 1945				$583,858.82

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Name	Address	Type of Contractor
Skidmore, Owings & Merrill	104 S. Michigan Ave.	Architects
Bulley & Andrews	2040 W. Harriston St.	General Contractors
Ernest Freeman & Co.	416 W. Erie Street	Electrical Contractors
Phillips, Getschow Co.	32 W. Hubbard	Heating Contractors
O'Callaghan Brothers	21 S. Green Street	Plumbing Contractors
Narowetz Htg. & Vent. Co.	1722 W. Washington	Heating & Ventilating
Samuel R. Lewis	407 S. Dearborn	Engineering
National Elec. Tool Co.	1915 S. State St.	Electrical Contractors
Cert. Burg. Alarm Systems	1418 W. Augusta	Burglar Alarms

4. There were no unusual conditions during the period of construction, and the contractor executed the work satisfactorily and with dispatch.

5. The starting date of the construction work was 1 May 1943 and the completion date was 1 October 1944, except for contract No. 7401-37-79 which is incomplete and is still active.

The operator started using the building on 10 June 1943.

6. Job records, including layouts and record drawings, are available in the office of the Area Engineer.

7. A 450 KVA 120V-208V, 4 wire service was installed for electrical power facilities and later was increased to a 600 KVA 120V-208V, 4 wire service in order to accommodate the increased demand of the laboratory installations.

The water facilities were extended from the existing 4" water service at 80# pressure.

The gas facilities were extended through a new 3" line from gas main in street.

The drainage facilities were extended from existing 4" cast iron and 4" vitreous tile lines under floor and rerouted to meet the demands of the laboratories.

The building is heated with cast iron direct steam radiators. Steam enters the building from the University of Chicago 6" main through a new 4" main at 150 p.s.i. It is reduced in pressure to about 5 p.s.i. for use in the radiators, to about 25 p.s.i. for heating domestic water and for special uses, and part is transmitted at initial pressure for laboratory uses.

SECTION II

1. All the above contracts were lump sum agreements and there

[redacted]

was no additional cost to the government other than the Area Engineers and District Office overhead and that figure is not available.

2. There were no materials transferred in from any other project.

[redacted]

COMPLETION REPORT
NEW CHEMISTRY BUILDING AND ANNEX

SECTION I

1. The New Chemistry Building and Annex, whose entrance address is 5625 S. Ingleside Avenue, Chicago, Illinois, faces west along Ingleside Avenue from 56th Street on the north to 57th Street on the south and an alley on the East.

It is used for laboratory investigation by the Metallurgical Laboratory personnel of the University of Chicago. The closest railroad is located approximately one mile east, however, automobile or truck transportation is convenient. The project is located in the midst of multiple apartment buildings. A street car line is located about 700' north.

2. The entire building, which is one story high, covers a rectangular area approximately 597.0' x 115.0' which equals 68,823 sq. feet, or 1.58 acres. Before construction, the grounds were vacant and formerly used as tennis courts. The land was acquired from the University of Chicago under Lease No. W-2288-eng-149 and is government controlled under the terms of Contract No. W-7401-eng-37.

3.

Number	Contractor	Amount	
W-7401-eng-13	Stone & Webster	$ 28,412.62	
W-7401-eng-1	E. L. Lonergan	57,326.39	
W-7401-eng-2	E. L. Lonergan	4,550.67	
W-7401-eng-3	H. P. Reger & Co.	29,064.00	
W-7401-eng-5	Hoffman Electric Co.	11,656.67	
W-7401-eng-6	W. W. Kimball Co.	24,351.30	
W-7401-eng-7	H. P. Reger & Co.	28,748.24	
W-7401-eng-59	E. L. Lonergan	178,427.93	
W-7401-eng-66	Skidmore, Owings & Merrill	13,561.60	
W-7401-eng-166	E. L. Lonergan	225,349.77	
W-7401-eng-165	Skidmore, Owings & Merrill	19,200.00	
W-7401-eng-177	P. Nacey Co.	13,023.00	633,892.19
	Subcontracts to 7401-eng-37		
7401-37-79 (Still Active)	Bulley and Andrews	19,181.32	19,181.32

Metallurgical Laboratory Purchase Orders

P.O. MO-3326	H. P. Reger & Co.	19.00
P.O. MO-3347	Ernest Freeman & Co.	38.28
P.O. MO-3885	Reynolds Corp.	64.21

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P.O. MO-3345	Bulley & Andrews	$ 59.35	
P.O. MO-3340	Phillips, Getschow Co.	229.18	
P.O. MO-44993	Refrigeration Systems, Inc.	1,365.00	1,775.02

Government Purchase Orders

P.O. 2773-3147	Acme Sheet Metal Works	294.85	
P.O. 7131	Hoffman Electric Co.	138.00	
P.O. 29085	Hoffman Electric Co.	30.80	
P.O. 28955	Hoffman Electric Co.	739.75	
P.O. 12692	Hoffman Electric Co.	1,688.77	
P.O. 7017	Otto M. Stein	150.00	
P.O. 28930	H. P. Reger & Co.	1,748.36	
P.O. 27323	H. P. Reger & Co.	747.55	
P.O. 12748	H. P. Reger & Co.	1,553.97	
P.O. 11805	Schuckmell Co.	391.10	
P.O. 11214	Weber Costello Co.	36.30	
P.O. 12223	Reynolds Corp.	878.00	
P.O. 27037	Reynolds Corp.	59.20	
P.O. 29466	Reynolds Corp.	1,303.39	
P.O. 8469	Bulley & Andrews	473.79	
P.O. 28889	Bulley & Andrews	30.89	
P.O. 11996	Phillips, Getschow Co.	81.19	
P.O. 8487	O'Callaghan Bros., Inc.	5.28	
P.O. 12465	Ernest Freeman & Co.	14.69	
P.O. 7159	E. L. Lonergan	1,812.00	
P.O. 7164	E. L. Lonergan	1,100.00	13,277.88

Grand Total up to 1 October 1945

$668,126.41

Contractors:

Name	Address	Type of Contractor
Stone & Webster	33 S. Clark St.	Architects & Engineers
E. L. Lonergan	203 N. Wabash St.	General Contractors
H. P. Reger & Co.	1501 E. 72nd Place	Plumbing & Heating
Hoffman Electric Co.	2525 W. Van Buren	Elect. Const.
W. W. Kimball Co.	306 S. Wabash	Lab. Furniture
Skidmore, Owings & Merrill	104 S. Michigan Ave.	Architects & Engineers
P. Nacey Company	927 S. State St.	Sprinklers
Bulley & Andrews	2040 W. Harrison St.	General Contractors
Ernest Freeman Co.	416 W. Erie St.	Electrical Contractors
Reynolds Corporation	4228 S. Lowe Ave.	Ventilating
Phillips, Getschow Co.	32 W. Hubbard	Heating Contractors
Refrigeration Systems, Inc.	646 W. Washington Blvd.	Engineers
Acme Sheet Metal Works	1121 E. 55th St.	Sheet Metal Works

Otto E. Stein	14 E. Jackson	Landscaping
Schuckmell Co.	3757 W. North	Window Shades
Weber Costello Co.	12 & McKinley Chg. Hts.	School Supplies
O'Callaghan Brothers	21 S. Green St.	Plumbing Contractors

4. There were no unusual conditions occurring during the period of construction that would give cause for delaying factors. All work progressed satisfactorily to all concerned.

5. Construction was started 22 August 1942. All contracts have been completed as of or before 1 October 1944, with the exception of Contract No. 7401-37-39, which is still active. Operators occupied premises as work was being completed.

6. Job records, including completion reports, maps, layouts, record drawings, catalogs, guarantees, etc., are in possession of the Chicago Area Office.

7. The utilities on the premises include:
Water (City of Chicago) 2" line and 2 - 6" lines serving sprinkler system, 30# pressure.
Gas (People's Gas, Light and Coke Co.) 3" line 3/4" pressure
Electricity (Commonwealth Edison Co.) 4 wire 3 phase 60 cycle 208 Volt (for both lighting and power) from 3 - 100 KVA transformer, 1200 Amperes.
Sewerage 8" & 6" waste lines into city disposal system
Heating Steam from a Central heating system of the University of Chicago, 4" line, 80 to 85# pressure.

SECTION II

1. All the above contracts were lump sum agreements and there was no additional cost to the government other than the Area Engineers and District Office overhead and that figure is not available.

2. There were no materials transferred in from any other project.

[redacted]

COMPLETION REPORT
ARMORY

SECTION I

1. This project, known as the "Armory", is an alteration and addition to the 124th Field Artillery Armory located at 52nd Street and Cottage Grove Avenue, Chicago, Cook County, Illinois. The east side of this project is facing Cottage Grove Avenue, the North, South and West sides are facing Washington Park. The project is accessible by Cottage Grove Avenue Street car and by truck or van. The Site is used jointly by the Metallurgical Laboratory of the University of Chicago and the Area Engineer for the Chicago Area Office as follows:

The second, third and fourth floors at south end, also the shed in the southwest corner of yard area, are used for laboratory investigation. The first floor at south end, north part of the arena, east side battery section and yard area, are used by the Metallurgical Laboratory as stock room, storage, receiving and shipping rooms, special material and carpenter shop. The south end of Arena and cubicles facing the Arena are used by the Area Engineer as material and car storage. The Metallurgical Laboratory and the Area Engineer are occupying the offices on the first, second, and third floor north end, and also the rooms in the west side battery section.

2. Work consisted of remodeling and erecting partitions to suit the requirements of the laboratories and offices, installing new overhead electric power wiring throughout the second, third and fourth floors south end, installing a new boiler and steel stack. A storage shed and laboratory shelter was constructed in the yard area. The approximate floor area is as follows: laboratory and shop space in south end and east battery section - 78,000 square feet; Office space in north end and west battery section - 60,000 square feet; Storage space in Arena - 50,000 square feet. The property is leased under lease No. W11-114-eng-570 dated 1 March 1944, from the State of Illinois and is government controlled under the terms of contract No. W-7401-eng-37.

3.

Number	Contractor	Amount	
	Lump Sum Government Contracts		
W-7401-eng-99	Skidmore, Owings & Merrill	12,000.00	
W-7401-eng-171		123,207.73	135,207.73
	Subcontracts to 7401-eng-37		
7401-37-79	Bulley and Andrews	10,928.87	10,928.87
	Metallurgical Laboratory Purchase Orders		

[redacted]

P.O. MO-3341	Bulley and Andrews	1,610.19	
P.O. MO-3347	Ernest Freeman & Co.	1,494.08	
P.O. MO-1545	Narowetz Htg. & Vent. Co.	418.00	
P.O. MO-3329	Phillips, Getschow Co.	774.36	4,296.63

Government Purchase Orders

P.O. 12680	Lammert & Mann	895.00	
P.O. 28455-29835	Ernest Freeman & Co.	3,396.04	
P.O. 28956-28871	Phillips, Getschow Co.	5,442.73	
P.O. 28866	O'Callaghan Brothers	556.58	
P.O. 29831	Narowetz Htg. & Vent. Co.	1,473.00	11,763.35

Grand Total up to October 1, 1945 $ 162,196.58

*Incomplete - Still Active

Name	Address	Type of Contractor
Skidmore, Owings & Merrill	104 S. Michigan	Architects
Bulley and Andrews	2040 W. Harrison St.	General Contractors
Ernest Freeman & Co.	416 W. Erie	Elec. Contractors
Narowetz Htg. & Vent. Co.	1722 W. Washington	Heating & Ventilating
Phillips, Getschow Co.	32 W. Hubbard	Heating Contractors
Lammert & Mann	221 N. Wood	Engineering Contractors
O'Callaghan Brothers	21 S. Green Street	Plumbing Contractors

4. There were no unusual conditions during the period of construction, and the contractors executed the work satisfactorily and with dispatch.

5. The starting date of the construction work was 11 March 1944, and the completion date was 1 October 1944, except for contract No. 7401-37-79 which is incomplete and is still active. The Metallurgical Laboratory was using part of the building for shipping and storage purposes before March 1944, and the offices and laboratories were being occupied from March 1944 as rapidly as the alteration work progressed.

6. Job records comprising legal description of property, layouts, and record drawings are available in the office of the Area Engineer, Chicago Area Office.

7. The existing fire pump standpipes were used to supply water for the laboratory requirements.

Gas facilities were extended through the south end of the building from the existing gas main located in the first floor southeast corner of the building.

Electric power is furnished by the Commonwealth Edison Company's installation of three 150 KVA transformers located on a pole mounted platform outside the building at the southeast corner. An overhead four wire, three phase 208 Volt 60 Cycle feeder system, was extended throughout the second, third and fourth floors at south end of building to accommodate the laboratory installations.

High pressure steam facilities for laboratory purposes were provided for by the installation of one 30 H.P. scotch marine type portable steel boiler 100 p.s.i. working pressure. This boiler was equipped with a pressurestat controlled blast power type gas burner with thermostatic type safety cut-off.

A steel stack 139' high was erected outside the building and connected through breeching to the boiler. Instantaneous type transfer heaters using steam under thermostatic control were installed to provide heated water for laboratory requirements. The original building boilers are operated for heating purposes.

A 15 H.P. air compressor was installed and compressed air lines were extended throughout the second, third and fourth floors at south end of building.

The existing drainage facilities were used except one drain line located in the yard area, which was rerouted to meet the demand of the laboratories.

SECTION II

1. All the above contracts were lump sum agreements. There was no additional cost to the government other than the Area Engineers and District Office overhead, which cost is not available.

2. The value of materials transferred in to this site from other projects is approximately $8000.00.

[redacted]

REPORT ON UNIVERSITY-OWNED BUILDINGS USED BY METALLURGICAL LABORATORY

The Metallurgical Laboratory took over some of the buildings and facilities of the University of Chicago and used them for laboratory investigations. Under the supervision of the Area Engineer Office, the Metallurgical Laboratory made some modifications and additions to the existing facilities, and the following is a list of the buildings and amount of money spent for alterations, which totals $131,330.43.

ECKHART HALL

Number	Contractor	Amount	
7401-37-60	Bulley & Andrews	$ 3,998.62	
7401-37-79 (still active)	Bulley & Andrews	11,118.72	
P.O. 3344	Johnson Electric Co.	357.59	15,474.93

RYERSON HALL

Number	Contractor	Amount	
7401-37-66	Bulley & Andrews	12,602.41	
7401-37-79 (still active)	Bulley & Andrews	8,474.16	
P.O. 3345	Bulley & Andrews	170.21	
P.O. 4437	Ernest Freeman Co.	161.89	
P.O. 3344	Johnson Electric Co.	1,628.55	
P.O. 4449	Johnson Electric Co.	558.33	23,595.55

MICHAEL REESE

Number	Contractor	Amount	
P.O. 4437	Ernest Freeman	276.35	
P.O. 3884	L.J. Graf Construction Co.	644.49	
P.O. 1545	Narowetz Mfg. & Vent. Co.	392.13	
P.O. 3342	O'Callaghan Bros.	1,117.04	
7401-37-79 (still active)	Bulley & Andrews	200.76	2,630.77

WEST STANDS

Number	Contractor	Amount	
7401-37-60	Bulley & Andrews	3,030.69	
7401-37-79 (still active)	Bulley & Andrews	10,644.97	
P.O. MO-3345	Bulley & Andrews	665.23	
P.O. MO-4437	Ernest Freeman Co.	65.90	
P.O. MO-3344	Johnson Electric Co.	272.82	
P.O. MO-3340	Phillips, Getschow Co.	1,490.77	16,170.38

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ELLIS LABORATORY

Number	Contractor	Amount	
P.O. 3349	O'Callaghan Bros.	$ 22.12	
P.O. 3345	Bulley & Andrews	384.03	
7401-37-79 (still active)	Bulley & Andrews	2,153.16	2,559.31

DREXEL HOUSE

Number	Contractor	Amount	
P.O. MO-3345	Bulley & Andrews	126.26	
P.O. MO-4437	Ernest Freeman & Co.	51.49	
P.O. MO-3884	L. J. Graf Construction Co.	644.18	
P.O. MO-3349	O'Callaghan Bros.	1,131.76	
7401-37-79 (still active)	Bulley & Andrews	3,270.91	5,224.60

BILLINGS HOSPITAL

Number	Contractor	Amount	
7401-37-79 (still active)	Bulley & Andrews	228.17	228.17

REYNOLDS CLUB

Number	Contractor	Amount	
7401-37-65	Bulley & Andrews	12,378.93	
7401-37-79 (still active)	Bulley & Andrews	242.45	12,621.38

JONES LABORATORY

Number	Contractor	Amount	
7401-37-79 (still active)	Bulley & Andrews	149.52	149.52

NORTH STANDS

Number	Contractor	Amount	
7401-37-76	Bulley & Andrews	922.73	
7401-37-112	Holabird & Root	5,000.00	5,922.73

BARNES LABORATORY

Number	Contractor	Amount	
7401-37-66	Bulley & Andrews	625.02	625.02

BOTANY LABORATORY

Number	Contractor	Amount	
7401-37-72	Bulley & Andrews	9,101.15	9,101.15

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ALPHA DELTA PHI

Number	Contractor	Amount	
7401-37-73	Bulley & Andrews	$ 1,526.65	1,526.65
	MUSEUM OF SCIENCE & INDUSTRY		
7401-37-67	Bulley & Andrews	34,818.12	34,818.12
	KENT LABORATORY		
P.O. 8471	Bulley & Andrews	682.15	682.15
	Grand Total up to October 1, 1945		$131,330.43

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MANHATTAN DISTRICT HISTORY

BOOK IV - PILE PROJECT

VOLUME 2 - RESEARCH

PART I - METALLURGICAL LABORATORY

APPENDIX E

GLOSSARY

Alpha Radiation. - Alpha radiation is that radiation composed of alpha particles. The alpha particle is the nucleus of the helium atom. Consequently, it is composed of two protons and two neutrons and has an atomic number of two and an atomic mass of four.

Beta Radiation. - Beta radiation is one of the types of emanation from a radioactive substance. The beta ray is an electron which, for convenience, may be assumed to have been associated with a proton in the nucleus of an atom in the form of a neutron. Thus, when a beta ray is emitted, the nucleus contains one more proton than before, resulting in transmutation to a new chemical element one number higher in the scale of elements.

Biological Shielding. - A biological shield is necessary in Pile design in order to reduce the strength of radiations emanating from the Pile to a safe level as determined by health and safety standards. Such materials as steel, iron, concrete, and masonite, alone or in combination, form effective biological shielding.

Bismuth Phosphate. - Bismuth phosphate is the chemical compound used as a carrier in the initial steps of the separation of plutonium from the uranium and by-product elements. It carries the

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plutonium at a weight ratio of 90 parts of bismuth phosphate to one part of plutonium phosphate.

Canning. - Canning is that step in the preparation of uranium for use in a Pile, in which the uranium slug is coated with a bonding material and encased in an aluminum sheath or can, and hermetically sealed.

Carrier. - The term carrier refers to an insoluble compound which possesses the ability to remove from a solution minute quantities of another solid even though the second solid may remain partly in the undissolved state.

Cyclotron. - The cyclotron is a complex electromagnetic device developed to accelerate charged subatomic particles to the velocities and energies required to penetrate the powerfully repellent and positively charged atomic nucleus.

Decontamination. - Decontamination is a series of steps which form a part of the separation process for recovering plutonium from large quantities of uranium and small quantities of many other elements. It is a series of steps carried out to decrease the fission products and their associated radioactivity to the extent that further processing may be accomplished without massive protective shielding.

Diphenyl. - Diphenyl is a white, crystalline hydrocarbon, melting at 160° Fahrenheit and having a high thermal conductivity making it an excellent coolant.

Fission Products. - The splitting of the atoms of such substances as uranium or plutonium results in the formation of chemical elements

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intermediate in the scale of the chemical elements. These are called fission products or fission by-products.

<u>Graphite</u>. - Graphite is a form of the chemical element carbon, of atomic number 6, and possesses the property of reducing the energy and velocity of neutrons to that which will permit capture or absorption by atoms of uranium or plutonium.

<u>Heavy Hydrogen (or Deuterium)</u>. - Heavy hydrogen is that isotope of atomic number 2. Its symbol is H^2 or D and it is the principal component of heavy water. Deuterium has a neutron-capture cross section of only 0.0009×10^{-24} square centimeters.

<u>Heavy Water</u>. - Heavy water is the isotopic compound of heavy hydrogen of mass 2 (deuterium) with oxygen and is denoted by the symbol D_2O. Heavy water is the most advantageous moderator yet investigated since the light elements are the most effective in slowing down neutrons and the neutron-capture cross section of deuterium is very much smaller than that of hydrogen. Heavy water is manufactured by one of two methods, the fractional distillation of water or the hydrogen-water catalytic exchange reaction.

<u>Lanthanum Fluoride</u>. - Lanthanum fluoride is the chemical compound used as a carrier in the latter steps of the separation of plutonium. It is a more efficient carrier than bismuth phosphate in that it carries the plutonium at a weight ratio of 5 parts of lanthanum fluoride to one part of plutonium fluoride.

<u>Lattice</u>. - The uranium lumps of considerable size imbedded in a moderator and in a regular pattern constitute a lattice.

<u>Masonite</u>. - Masonite is the trade-name applied to various fiberboards

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made from steam-exploded wood fiber. Masonite is an effective means of shielding since it is rich in hydrogen which, being a light element, is effective in retarding neutrons.

Mass Unit. - The unit of mass employed in nuclear physics is 1/16th of the mass of the predominant oxygen isotope O^{16}, and is equal to 1.6603×10^{-24} grams.

Moderator. - Neutrons emitted in the process of fission of Uranium-235 have high speeds. Before these neutrons can be effectively used for further fission, their speeds must be reduced to that of slow neutrons. The process of slowing down or moderation is simply one of elastic collisions between high-speed particles and particles practically at rest. The more nearly identical the masses of the neutron and struck particle, the greater the loss of kinetic energy by the neutron. Therefore, the light elements are the most effective moderators.

Neutron-Capture Cross Section. - The neutron-capture cross section of a substance is the term used by physicists to refer to the relative dimensions of an atomic nucleus of the substance as a target for various subatomic particles and the possible types of nuclear reactions. It permits the evaluation of the probability of any specific reaction taking place, and is usually expressed as an area in units of 10^{-24} square centimeters.

pH. - The pH of a solution is a measure of its acidity. Actually, the pH is the logarithm of the reciprocal of the hydrogen iron concentration of the solution. A neutral solution has a pH of 7.0.

Poisoning. - Poisoning is the term applied to the formation of

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substances within the Pile structure, especially within the slugs, which, due to their high neutron-capture cross section, tend to decrease the reproduction factor to below the critical value with the possibility of making the Pile inoperative. The most prominent of poisoning agents is xenon.

Radium-Beryllium Source. - A radium-beryllium source is used as a source of neutrons. These are liberated from the beryllium through the bombardment of the beryllium by the alpha particles emitted spontaneously by radium.

Reactivity. - The ability of a Pile to increase the number of free neutrons within it by multiplication, generation by generation, is called its reactivity.

Slug. - Slug is the non-descriptive term used to refer to the pieces of metallic uranium which are prepared for charging into Piles for the manufacture of plutonium.

Thermal Stability. - A Pile in which the reactivity decreases with increasing temperature is said to be thermally stable. If the reactivity increases with increasing temperature, the system would be thermally unstable because an accidental rise of the temperature would develop increased energy and consequently determine a further rise in temperature.

Tracer. - A tracer is a radioactive substance, used to detect small quantities of its isotope in chemical analysis. It is mixed in minute amounts with the isotope, and the resulting mixture behaves as a single chemical substance, although the former may always be detected by its radioactivity.

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Uranium Carbide. - Uranium carbide was suggested for use in the molten bismuth-cooled plant since its melting point is so high (about 2300° Centigrade).

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INDEX
(See also page 7.3, "Acknowledgments", for additional names of persons and institutions)

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