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MANHATTAN DISTRICT HISTORY

BOOK VIII, LOS ALAMOS PROJECT (Y) - VOLUME 3, AUXILIARY ACTIVITIES

CHAPTER 4, DAYTON PROJECT

December 1948

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MANHATTAN DISTRICT HISTORY

BOOK VIII, LOS ALAMOS PROJECT (Y)

VOLUME 3, AUXILIARY ACTIVITIES

CHAPTER 4, DAYTON PROJECT

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APPENDIX

1. Subject and Make-Up of this Chapter.

This chapter of the Manhattan District History deals with the auxiliary activity of the Los Alamos Project which was call "Dayton Project"; it consisted of the work of the Monsanto Chemical Company at Dayton, Ohio, primarily concerned with the purification and production of polonium, for delivery to Los Alamos, including research in connection therewith.

There is incorporated in this chapter, as an appendix, a document entitled "Historical Report - Dayton Project", dated 31 October 1947, prepared by personnel of the Monsanto Chemical Company and approved by Dr. Carroll A. Hochwalt, Project Director, and Dr. Malcolm M. Haring, Laboratory Director, for that Company. Excellent descriptions of the major features of the project may be found in that document, and, to avoid repetition, most of the details therein have been omitted here. This part of this chapter is, in effect, therefore, an outline or summary only. It contains, however, frequent references to the appendix (and also Volume 2 of this Book VIII), which will enable the reader to turn to any of the details desired. Further references, principally to reports on the accomplishments of the project, located in the project files, will be found in the appendix. A Top Secret Supplement to the Historical Report in the appendix contains production figures; this supplement, because of its high security classification, is not included with this chapter, but is filed in the Area Manager's Office.

Both this chapter and its appendix cover the history of the Dayton Project from its inception through 31 December 1946, when the Manhattan District relinquished control to the Atomic Energy Commission.

2. Purpose and General Development.

As explained in Volume 2 (the "Technical" History of the Los Alamos Project), during the "first period" of the work of the Los Alamos Laboratory, April, 1943, to August, 1944, the radiochemists at Los Alamos were seeking means of development of an initiator for the gun assembly. They realized early in their investigations that polonium would be the best material to use, in combination with beryllium, but were in doubt as to whether polonium could be purified sufficiently to meet the tolerances for neutron backgrounds, and in consequence steps were taken to use radon as a possible substitute. This alternative was abandoned later, however, after successful polonium production was assured. (Vol. 2, par. 4.47, 7.40.)

The two successive problems, of polonium purification and of polonium production in the required quantities, became primarily the responsibility of the Monsanto Chemical Company (Vol. 2, par. 17.41, 4.47). Both problems were solved by that company, in close cooperation with the radiochemists at Los Alamos, under a contract which was administered by the Chicago Area Engineer of the Manhattan District, Contract No. 7407-eng-18. The laboratory for research and development and the plant for production of the polonium were established by the Monsanto Chemical Company on rented properties in Dayton, Ohio. When the Monsanto Company assumed responsibility for the operation of Clinton Laboratories, a new contract was made, and the operations in Dayton were continued under a modification of that new contract: Modification No. 2, effective 1 August 1945, to Contract No. W35-058-eng-71, effective 1 July 1945. (App., p.4.4.) Thereafter, the Dayton

Project was administered by the Office of the District Engineer in Oak Ridge, and the Chicago Area Engineer transferred his records to Oak Ridge (14 September 1945).

The research, development and production work on polonium for the gun initiator program was of incalculable value in the later development of the initiator (or "urchin") for the implosion bomb, and was perhaps essential to the success of that bomb (Vol. 2, par. 7.41). The use of polonium for the implosion initiator is described in Volume 2 as representing a major technical achievement (Vol. 2, par. 17.38).

3. Production Methods.

At the beginning of the Dayton Project it was known that neutron-bombarded bismuth metal was the most satisfactory source of polonium, but the material had been produced in this manner theretofore only in minute quantities in the cyclotron, and no method of concentration and purification had been developed. In order that all major possibilities might be explored, therefore, much of the early research and experimentation by the Monsanto Company was directed toward various methods of extraction of polonium from lead dioxide, which was immediately available in residues from the radium refinery at Port Hope, Canada. The method finally developed and used in production was the neutron-bombarded bismuth method, revised by many refinements and improvements during the period covered by this history. The raw material for use in this method was produced by subjecting very pure metallic bismuth to an intense neutron flux, first in the Clinton pile, at the Clinton Laboratories in Oak Ridge, and later, after June, 1945, in a pile at Hanford. (App., pp.5.1ff.)

The complicated nature of the process may be illustrated briefly

by enumerating the various steps listed in the final flow chart, for the production procedure in use from September 1945 throughout the year 1946, as follows:

(a) Decanning of Bismuth Metal; (b) Solution of Bismuth Metal; (c) Initial Bismuth Scrub; (d) Secondary Bismuth Scrub; (e) Volatilization from Scrub Powder; (f) Removal of Silver from Solution; (g) Assay of Gamma Count; (h) Micro-Purity Assay by weighing; (i) Electrolysis of Solution; (j) Calorimeter Assay of Plated Foil; (k) Gamma Assay of Plated Foil; (l) Neutron Assay of Plated Foil. (App. pp.5.30, 5.31.)

The first shipment of polonium to Los Alamos was made on 15 March 1944 (App. p.3.3).

The development of production methods, and the research work involved, are ably described in Chapter V of the Appendix.

4. Health Hazards.

The hazards produced by polonium, to which laboratory and production workers were exposed, have been described briefly in Volume 2. They are in many ways parallel to those produced by plutonium and are nearly, if not quite, as dangerous per unit of radioactivity (Vol. 2, par. 9.33, and Supplement to Vol. 2, par. 6.18). Polonium has high alpha activity and spreads around a laboratory very readily. It was virtually impossible to work with polonium and avoid entrance of the material into the system, but polonium is also eliminated rapidly and does not settle in dangerous concentrations in the bone, as do radium and plutonium. (Vol. 2, par. 17.39.)

Great care was exercised on the Dayton Project to protect workers from the polonium hazards (as well as other hazards incident to

their work), insofar as the current knowledge of these hazards would permit. At the very beginning of the project, after consultation with Colonel Stafford L. Warren and Colonel H. L. Friedell, of the Medical Section of the Manhattan District, safety measures were instituted. Estimated safe tolerances were established and means were developed for detecting the presence of polonium in the human body. Between April, 1945, and June, 1946, Captain B. S. Wolf, of the Medical Section, directed the health efforts of the Project. (App., Chap. VII.) Despite the great increase in output during the year 1946, health conditions were vastly improved in the period (App., p.5.31).

The safety tolerances under which the project was operating were based on analogous estimates only, with no definite experimental data to back them up. This became the subject of considerable concern to those in charge, and it was felt that a program of biological research on polonium should be instituted at Dayton. The Monsanto Company, after extended investigation and after consultation with a specialist in industrial toxicology, presented to the District Engineer a plan for such a program. This program was approved in principle and authorized by the Manhattan District in October 1946. (App., p.7.3ff.)

5. Preparations for Urchin Production.

The initiators for the gun assembly, and the initiators for the implosion bomb - the so-called "urchins" - were developed and manufactured at Los Alamos, with polonium produced in Dayton incorporated in them (Vol. 2, par. 7.41, 17.38ff). In September 1945, Production of urchin initiators was moved to the new laboratory on DP East Site, and, particularly during 1946, the methods and techniques were steadily im-

proved, despite the dangerous hazards and the difficulties involved in this work. As stated in Volume 2, the initiators finally produced had neutron backgrounds only one-third of the best of those produced during the war. (Vol. 2 Supplement, par. 6.17, 6.18.)

During 1946, in line with the Manhattan District's program for conversion of the Los Alamos Laboratory to a peace-time basis, plans were started to transfer the manufacture of the urchin initiators to the Monsanto plant in Dayton, and this transfer had been almost accomplished by 31 December 1946. Monsanto personnel obtained full information from Los Alamos and from equipment manufacturers; materials and equipment were ordered; an additional building (a Stransteel Quonset Hut) was erected; and the design of dry-boxing for all the hazardous operations was vigorously pushed. (App. Chap. VIII.)

6. New Plant.

Toward the latter part of 1945, the Manhattan District began consideration of plans for the construction of a new polonium production plant, to supersede the plant then in operation in Dayton. Partly because of the importance of the polonium production and the key position of this material in relation to the manufacture of bombs, and partly because it was desired to test the possibilities of plant construction with protective cover, the plans contemplated that the new plant would be built underground. It was therefore not practicable or desirable to use a rented site, as was done for the plant in Dayton.

At first it was proposed that the new plant would be designed by the Clinton Laboratories and would be erected at the Clinton Engineer Works, but this proposal was finally abandoned, for various reasons,

including anticipated difficulty in persuading the personnel in Dayton to move to Oak Ridge, and concern at the introduction of polonium contamination in the neighborhood of a plutonium plant.

The Manhattan District, on 19 July 1946, authorized design of the new plant, for construction somewhere in the Dayton area. The site was finally selected in August, and area of about 160 acres near Miamisburg, Ohio, about 15 miles southwest of Dayton. The firm of Giffels and Vallet, of Detroit, Michigan, was engaged as Architect-Engineer, and began work on 24 September 1946. Their contract was signed 26 December 1946, to be effective as of 9 September 1946. The plant was to be an underground structure, proof against a 2000 lb., armour-piercing, jet-assisted bomb, and was also to be protected against biological and chemical warfare. Colonel R. J. Kaspar was appointed Area Engineer in August 1946 and he moved to the project in September. The Maxon Construction Company, Inc., was selected as the construction contractor and although their contract was not signed until 24 February 1947, it became effective as of 22 November 1946. These contracts were negotiated in the District Engineer's Office in Oak Ridge. (App., Chap. IX.)

7. Cost.

The total expenditures for the Dayton Project, from its inception through December 1946, when the period covered by the Manhattan District History terminated, amounted to $3,866,507, exclusive of surplus material furnished by the Government (App., p.4.7).

8. Personnel.

a. Manhattan District - For the Manhattan District those principally concerned with the Dayton Project, in addition to the

personnel at Los Alamos (who are named in Vol. 2). were:

Major General L. R. Groves, Commanding General of the Manhattan Project;

Colonel K. D. Nichols, District Engineer;

Colonel E. E. Kirkpatrick, Deputy District Engineer;

Major A. V. Peterson, Chicago Area Engineer, succeeded, 15 October 1944, by Captain J. H. McKinley;

Colonel R. J. Kasper, Dayton Area Engineer.

b. Monsanto Chemical Company - For the Monsanto Chemical Company, those principally concerned with the project were:

Dr. Charles A. Thomas, Executive Vice-President and Technical Director, in charge of research (also, Deputy Chief of Division 8 of NDRC);

Dr. C. A. Hochwalt, Director of Central Research and Project Director;

Dr. J. H. Lum, Laboratory Director, July 1943, to November 1945; Assistant Director of Central Research, June 1945, to November 1945;

Dr. W. C. Fernelius, Professor of Inorganic Chemistry, on leave of absence from Purdue University; Assistant Laboratory Director, August, 1943, to July, 1945; Associate Laboratory Director, July, 1945, to November, 1945; Laboratory Director, November, 1945, to June, 1946.

Dr. M. M. Haring, Senior Research Chemist and group leader in Fundamental Research, August, 1944, to July, 1945; Assistant Laboratory Director, July, 1945, to June, 1946; Laboratory Director, June, 1946, to date. (App. pp.2.1, 10.1, 10.1A, 10.2.)

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HISTORICAL REPORT

DAYTON PROJECT

Approvals:

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31 October 1947

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CHAPTER I - INTRODUCTION

1-1. General. - The fashion among historians in recent years has been to depart from attempts to divide history into sharply defined periods. They prefer to describe it as a seamless robe in which the pattern of individual lives is discerned with difficulty, leaving the things that stand out as long run trends and basic forces.

1-2. Purpose. - The purpose of this report is to describe the scientific and technical progress directed toward the governmental use of energy from atomic nuclei by the Central Research Department of the Monsanto Chemical Company, located in Dayton, Ohio. It is neither a fully documented official history nor a technical treatise. It presupposes an elementary knowledge of atomic research and a familiarity with related pertinent scientific information.

1-3. Origin. - A General Account of the Development of Methods of Using Atomic Energy for Military Purposes under the Auspices of the U. S. Government as presented by the 1945 H. D. Smyth report on page 92, par. 7.48, "Organization of Project" states, "Later the Monsanto Chemical Company did some work on problems arising in connection with the Los Alamos work." It is here that this report begins.

1-4. Style. - It is to be noted that there is little correlation between the space devoted to the work of a given group and the ability or importance of that group. Also, some developments of great technical importance are of little general interest; others, both interesting and important, are still undergoing development. Wherever the term Unit 1, Unit 2, Unit 3, Unit 4 or Unit 5 is used, it refers to the Unit described as a part of Monsanto's Central Research Department at Dayton, Ohio.

1-5. Time. - This report covers the time interval from May 1943 to Dec. 31, 1946, the date of inception to the effective date of this presentation.

1-6. Order. - In so far as is possible, the information is given in chronological or topical order.

1-7. References. - Unless otherwise indicated, references are to documents in Unit 3, Central Files.

CHAPTER II - CONCEPTION OF THE DAYTON PROJECT

2-1. Dr. Charles Allen Thomas, Executive Vice-President and Technical Director of Monsanto Chemical Company in charge of research, has furnished some interesting facts leading up to the establishment of the Dayton Project.

a. Early in 1943, as Deputy Chief of Division 8 of NDRC, he had gone East with James Conant and Richard Tolman to witness the test of a new under-water explosive. During their brief association his companions took pains to investigate his background without arousing suspicion. Shortly thereafter he received a telephone call from Brig. Gen. Groves requesting a conference in Washington at his earliest convenience. At the time he had no idea what the significance of this might be. However, on entering the General's office, he found Conant there also. After swearing him to secrecy they revealed the plan to build an atomic bomb. He and Conant spent the day discussing the technical aspects of the question and the probabilities of success.

b. It appeared that the amount of chemistry involved in the project had been underestimated. They urged him to become codirector of Los Alamos with Oppenheimer and to be responsible for the chemistry of the entire project. To aid him in reaching a decision, a two-day conference was set up at Los Alamos between Conant, Groves, Oppenheimer and himself. To accede to their request would have involved a leave of absence from Monsanto. For various reasons a compromise proposal seemed better. This put Thomas in charge of the final chemistry and metallurgy of plutonium, taking such time from the Company as seemed necessary for the work. This program was approved by Charles Belknap and Edgar Queeny on behalf of Monsanto.

c. Thomas immediately proceeded to coordinate the work between the University of California, the University of Chicago, Los Alamos and the University of Iowa. Monthly meetings were set up at the University of Chicago with representatives of each site in attendance. J. C. Warner became his deputy in Chicago. He was especially helpful in preparing the agenda of the meetings and making decisions in Thomas' absence. Joseph Kennedy was made director of chemistry at Los Alamos with Cyril Smith as associate director in charge of metallurgy. This program necessitated a monthly visit by Thomas to Los Alamos with frequent visits to the other sites. In addition he consulted with Gen. Groves each week and with Conant and Tolman quite often. He also lent a helping hand with activities at other sites. Naturally all this required his withdrawal from NDRC activities in that summer.

d. Early in the Summer of 1943 it became obvious that someone had to produce large quantities of polonium. This was undertaken by Monsanto at Dayton. Dr. Carroll Hochwalt, Dr. James Lum and Dr. Nicholas Samaras were cleared for the project and taken to Los Alamos for a better picture of requirements. Thomas became Project Director, Hochwalt Assistant Project Director and Lum, Laboratory Director.

CHAPTER III - THE PERIOD OF ORGANIZATION

3-1. Introduction. - This chapter is a continuation of Chapter II and discusses the period of organization from July 1943 through March 1944.

3-2. Organization. - Very early in July, Thomas, Hochwalt and Lum conferred on the general plan of attack. It was decided that about twelve chemists would be needed for the job and that other quarters, entirely separate from Unit 1, would be essential. It was fortunate, indeed, that the true magnitude of the problem could not be envisioned at that time. The supply of trained chemists was already nearly exhausted by the demands of the Manhattan District, defense programs and essential war industries. Moreover, time and materials were lacking to build a new laboratory and rental space was almost non-existent. Yet, the selfless efforts of such a small group, that refused to be discouraged, have brought about the establishment of the present vigorous research and production plant. Even so, without the highest priorities it would have been impossible.

3-3. Recruitment. - Lum began immediately to visit various Universities as the most likely recruiting grounds, but did not neglect other possibilities. His ability as a salesman and organizer was well demonstrated by the speed with which he assembled the desired group and put them to work. Professors, graduate students and commercial chemists were enlisted. It must be remembered that all had to enter upon the adventure without knowing its real nature. It is worth pointing out, that practically none had any prior experience in radiochemistry; therefore, must acquire these techniques, even as they worked on the problem. The first recruit, J. J. Burbage, reported for work 21 August, 1943.

3-4. Quarters. - In June of 1943, Hochwalt investigated the possibility of carrying on the work at Oak Ridge. However, no suitable building was available and this location would have been undesirable from an administrative standpoint. Temporarily, Room 30 at Unit 1, Dayton, Ohio, was set aside for interviews, conferences, ordering supplies, a library and some very small scale laboratory work. Despite the almost total lack of knowledge of the equipment necessary for a radiochemical production and research laboratory, almost no mistakes, except those of underestimation, were made in this direction. Nevertheless, it was felt that a first hand knowledge of these matters was vital, so Fernelius spent the period 1 September to 9 October at the University of California in training. He brought back, in addition to techniques, an idea for a process and a valuable recruit. Meanwhile, Thomas, Hochwalt and Lum had determined that the old Bonebrake Seminary at First Street and Euclid Avenue, later known as the Green Normal School, and at that time a somewhat battered warehouse belonging to the Dayton School Board, was available on a rental basis and could be made serviceable. It came into the hands of the Project 15 October, at which time a guard was mounted. All activities were transferred to it 25 October, 1943. Renovation, remodelling and new construction have not ceased since that time.

3-5. "Conference Period." - October, November and December might be termed the conference period of the Project. So much had to be learned quickly, that numerous visits back and forth were essential. As examples of the more important ones, the following may be mentioned: 12-15 October, Prestwood from Los Alamos visited Dayton to acquaint the Project members with their specific requirements; 22-25 October, Thomas, Lum and Fernelius conferred with Paneth and Goldschmidt in Chicago on

the properties of polonium; 1 November, Fernelius and Silverman conferred with Major Friedell and Lt. Col. Warren in Chicago on health matters; 11-24 November, Scott, of the Metallurgical Laboratories, came to Dayton to instruct Project members, notably D. L. Woernley, in the setting up, calibration and use of electronic counters; 21-23 December, Lum, Fernelius and Col. Ruhoff visited the radium refinery at Port Hope, Canada, to confer with Dr. Puchon on the recovery of polonium from the residues; 31 December, Lum, Fernelius and Col. Ruhoff visited officials of the Firestone Metal Products Co. to learn the details of the Dillon-Firestone process for obtaining polonium for use in spark plugs.

3-6. Sequence of Events. - Meanwhile, the stay-at-homes had been very active. On 10 November about 3-1/2 tons of radioactive lead dioxide were received. On 11 November, health and safety measures were instituted. On 13 November, laboratory work was started on the lead dioxide. By 8 December, the first 500 pound batch was processed. On 15 December, 30 microcuries of polonium were available for electroplating experiments. All newcomers spent many days perusing the available literature on polonium and any spare moments of the staff were devoted to library research.

3-7. Additional Space Needed. - It was speedily realized that Unit 3 would not suffice for production, so a further search was made for space. On 15 February, 1944, the Runnymede Playhouse at Runnymede Road and Dixon Avenue was obtained and a guard posted. This site was chosen because it was the only suitable structure in Dayton ready for immediate use. Construction and remodelling began 17 March, and the Production Group moved from Unit 3 on 1 June.

3-8. Production. - The first shipment of polonium to Los Alamos was made 15 March, 1944. It should be recorded that schedules were always met and quotas exceeded.

CHAPTER IV - GROWTH OF THE PROJECT

4-1. Introduction. - This chapter deals primarily with the physical growth of the project by enumerating the properties acquired, remodelling of such properties, additional construction, number of personnel and operating costs and has been reviewed in the light of production research needs. The duplication of information contained in other chapters is reviewed here for continuity rather than emphasis.

4-2. Negotiations and Acquisitions. - The original Prime Contract No. W7407 eng 18, covering research and development, became effective 24 May 1943. When the first group of scientists began the initial work on the contract early in September, Room 30 at the Central Research Department, Unit 1, was used as an office and laboratory. Here the ordering of equipment, abstracting of literature, recruiting and preliminary organization were instituted. It soon became evident that considerably more space would be required than could be furnished at Unit 1 so the early staff members looked about the city of Dayton and environs for a suitable building. Space for housing such a project that would be acceptable as a laboratory and meet the necessary security regulations was extremely difficult to find. Other war projects had utilized practically all of the available space. However, a suitable building was located on property owned by the City of Dayton, Board of Education. The three story brick building located at 1601 West First Street, was built in 1879 by the Bonebrake Seminary, later occupied by the Grace A. Greene Normal School, and prior to the time it was acquired by Monsanto, was used for warehousing purposes by the Board of Education. Arrangements for leasing the building and grounds were made the early part of September and work immediately started to place the building in condition to be used for

laboratory purposes. This site was identified as Unit 3. Beneficial occupancy of the building was made about 1 November. Considerable remodelling was required to place the building in useable condition. New floors were laid, many rooms replastered, all windows and sash replaced and entirely new systems for heating, lighting, power and outside lighting installed. In addition, two guard houses, designated as Buildings "J" and "K", a small chemical storage shed known as Building "F" and a fence surrounding the main building were erected (See plot plans, Unit 3). In the beginning, only two floors of the building were to be used, but a few months later, the third floor was renovated and necessary changes made to provide services. As the magnitude of the problem unfolded and the staff enlarged, it became apparent that additional space would be required for production.

In February 1944, negotiations acquired the Runnymeade Playhouse in Oakwood, a suburb of Dayton. This location was called Unit 4. Since this building is located in one of the finest residential sections of the city, some difficulty was encountered in leasing negotiations by Monsanto. However, condemnation proceedings were instituted and the property was obtained ~~leased~~ by the Government. This location was chosen primarily because it was the only building in Dayton that could be occupied immediately. It afforded sufficient floor space, head room, necessary services and, also, was approved by the security officials. It is owned by the Talbott Realty Company whose holdings are, primarily, the estate of the Talbott family. The building was erected about 1927 to provide recreational facilities for the family. It is a beautiful, well-built structure. Its many features include a corrugated glass roof, several greenhouses, a tennis court with cork floor, a stage, a squash court, along with lounges and boiler room and an outdoor swimming pool. In addition to the main building, is a one and one half story garage, the main floor of which was converted into a carpenter shop

and locker rooms.

a. Work was immediately started to erect three guard houses, buildings 4, 5 and 7, and a fence. Alterations to the main building were not extensive, but the interior presented many problems in constructing process facilities and laboratories. Care was exercised in making as few changes as possible in the building and the existing services to alleviate the problem of restoration upon vacating this site. Details of the first process equipment will be covered in Chapters V and VI. Careful consideration was given in order to minimize annoyances such as noise, smoke and dirt so as not to incur undue criticism from the residential area. In the face of the ever present obstacles of obtaining skilled craftsmen, equipment and building materials, work on initiating the process was expedited. Operations began in May 1944.

b. In November 1944, a small wooden building, 15' by 50', designated as Warehouse No. 1, was erected at Unit 3.

In May 1945, it was decided that the Bismuth Process was superior to the lead dioxide process for the manufacture of polonium. Consequently, numerous changes were made in the production facilities located on the main floor of Unit 4. The equipment used in the lead dioxide process was dismantled and shipped to Oak Ridge. In its place small laboratories designed for the Bismuth Process were constructed.

Early in 1945, as the scope of the work increased and additional services became necessary, it was decided to construct several temporary buildings on the land leased from the Board of Education. Plans were made and on 2 July 1945, the Charles H. Shook Construction Company was authorized to proceed with the construction of five structures: Building "A"*, Offices and Cafeteria; Building "B", Physics Laboratory and Locker Rooms; Building "D", Laundry and Glass Blowing Shop; Building "E", Machine

*See plot plans, Unit 3.

Shop; and Building "G", Power Plant. Due to the location of the temporary buildings, the main guard station was removed from the entrance of Building "M" (Schoolhouse Building) and a new main guard house erected near the southeast corner of the property. This was designated as Building "H". A cyclone fence was erected, following the boundary of the property, except on the east side. This was changed and will be noted later. Although hostilities ended, construction of these buildings was continued and beneficial occupancy made during November 1945. At the same time, a fire-proof storage vault was erected on the grounds at Unit 4 for storage of classified materials.

c. It was during this period that Monsanto assumed responsibility for the operation of Clinton Laboratories. To facilitate handling of contractual matters, the operation of the Dayton Project was incorporated in the Clinton Contract. Operations in Dayton were continued under Modification No. 2, effective 1 August 1945, to Prime Contract W35-058 eng 71, effective 1 July 1945.

d. Considerable difficulty was experienced in the proper operation of balances and electronic equipment so a very definite need for an air conditioned building became evident the early part of 1946. Accordingly, plans were made for such a building and a contract let to the F. X. Minnigan Company on 8 April 1946. This Building was numbered "C". Beneficial occupancy was made in October of the same year. Space for stockroom and warehousing was constantly becoming inadequate. A discussion of this problem with representatives from Oak Ridge indicated that portable, aluminum buildings were available from surplus stocks. Accordingly, two portable buildings known as buildings 2 and 3, 20 feet wide by 54 feet long, were requisitioned and placed on the premises of Unit 3. One was utilized as a stockroom and the other as storage for bulk materials.

e. Sensing the need for additional equipment required for the construction of the proposed new plant, several members of the staff were authorized to select equipment and operating supplies available at the SAM Laboratories in New York which was closing down the early part of 1946. A study of the equipment indicated a worthwhile portion of the material made available could be utilized. Arrangements were made for its transfer to Dayton and a search for proper warehouse space began. Such space was found at the General Electric Supply Corporation, 601 East Third Street. Arrangements were made to lease the fourth, fifth and sixth floors in May 1945, for the receiving, sorting and storage of surplus equipment. This is known as Warehouse "A". About this time, serious consideration was given to location of the Urinalysis Laboratory in an area most unlikely to become contaminated. It was agreed that Warehouse "A" would be a suitable location for this work. Consequently, the needed facilities were constructed on the fifth floor of this building and a sizeable portion of the sixth floor made available for the repair and storage of electronic equipment.

f. Upon the advent of the Area Engineer's Office, temporary office quarters were provided on the fourth floor of Warehouse "A" in October 1946. Later, additional office space was made available for the employees required by Monsanto and the Manhattan District to initiate the design and construction of Unit 5.

g. On 4 December 1945, work was started by the F. X. Minnigan Company to erect, on the Unit 3 site, a Stransteel Quonset Hut, 40 feet by 100 feet, to afford sufficient space to carry on Urchin Production. This building is designated as "L", and a portion of it allocated for much needed office space. Design of the production lines and construction of the building ~~was~~ were well under way by the end of the year. The construction of Building "L" also necessitated additional change of the fence which was

relocated to surround the entire property of Unit 3; the moving of guard house, Building "K", to a position next to the truck entrance, and the erection of four additional tropical hut buildings numbered 4, 5, 6 and 7, to house heavy machinery, maintenance supplies and miscellaneous material.

4-3. Personnel. - Concomitant with the acquisition of properties, personnel requirements increased. From a force of 46 full time employees at the end of 1943, the requirements increased to 101 employees at the close of 1944; to 201 employees at the close of 1945; and by the close of 1946, 334 employees were on the payroll. It should be noted that in addition to these figures, there were several employees of Unit 1 who devoted part of their time to this Project and designated as "loaned employees". Neither do the above figures reflect personnel assigned by the Special Engineer Detachment. The number of personnel in this category varied. A peak of approximately 34 were assigned during 1945 and 1946. To illustrate the division of personnel, the following breakdown appears on the Personnel Force Report as of the end of December 1946:

Administration	37
Research	49
Operations	68
Maintenance	12
Protection	43
Services	113
Craftsmen	12
Total	334

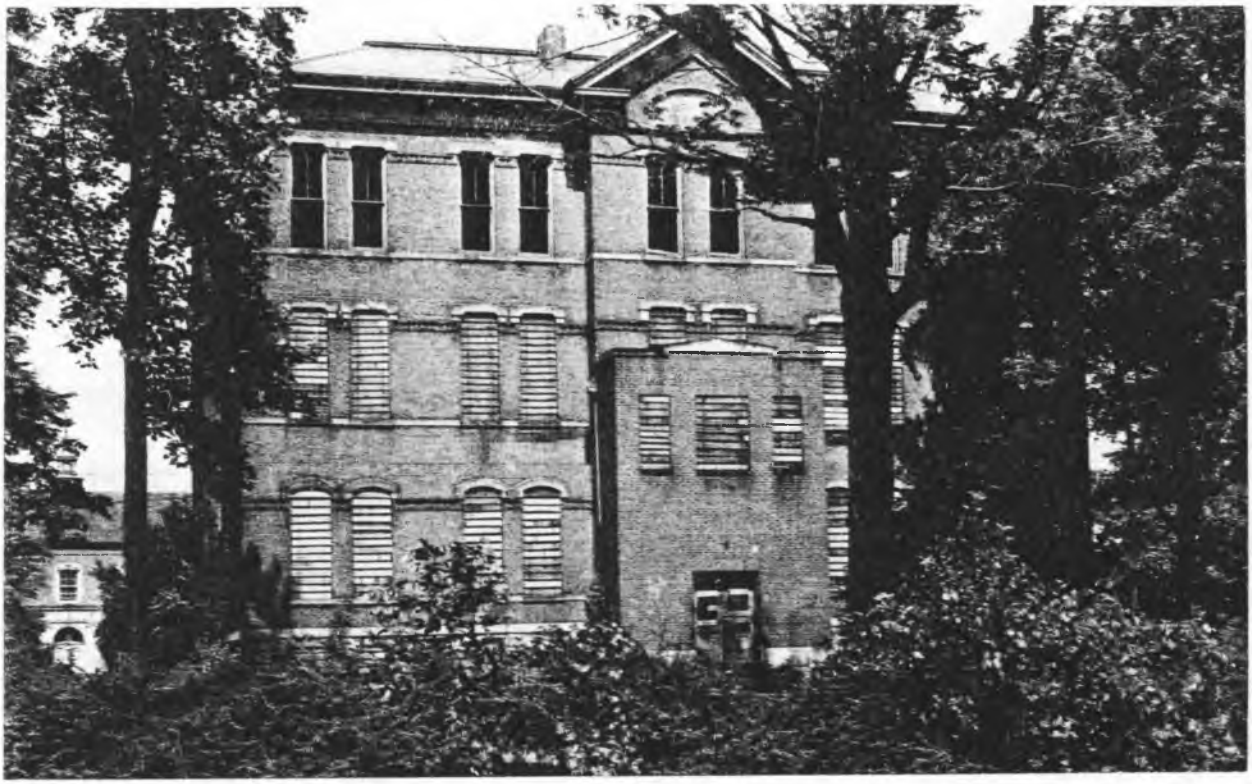
4-4. Costs. - The growth of the Project is reflected in the monies expended for operation, construction and remodelling, as follows:

1943	May thru December	$ 133,275.42
1944	Jan. thru December	996,538.41
1945	Jan. thru December	1,131,644.59
1946	Jan. thru December	1,605,048.93
	Total	$3,866,507.35

This total figure does not reflect surplus material furnished by the Government. Of the above amount, it is estimated that $450,000 was expended for remodelling of existing buildings at Units 3 and 4, installation of process equipment at Unit 4 and the construction of new buildings at both locations.

a. To better visualize the various properties and the growth of the Project, the following plot plans and photographs are submitted:

1. Plot Plan, Unit 3, dated 9/15/43, Rev. 10/5/43.
2. Plot Plan, Unit 3, dated 9/10/46.
3. Plot Plan, Unit 4, dated 7/28/47.
4. Photograph, Unit 3, 9/43
5. Photograph, Unit 3, 10/47
6. Photograph, Unit 4, 10/47



UNIT 3 STRUCTURE PRIOR TO OCCUPANCY SEPTEMBER 1943

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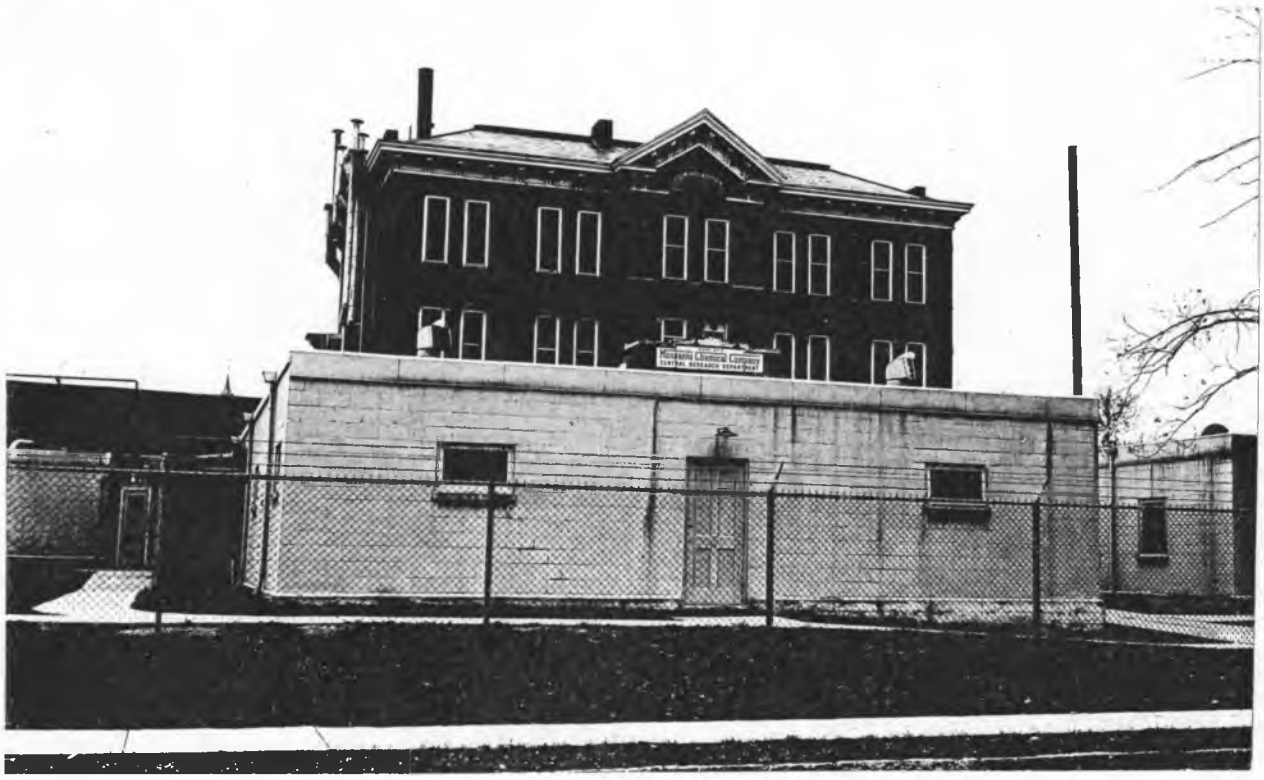

UNIT 3 AREA OCTOBER 1947

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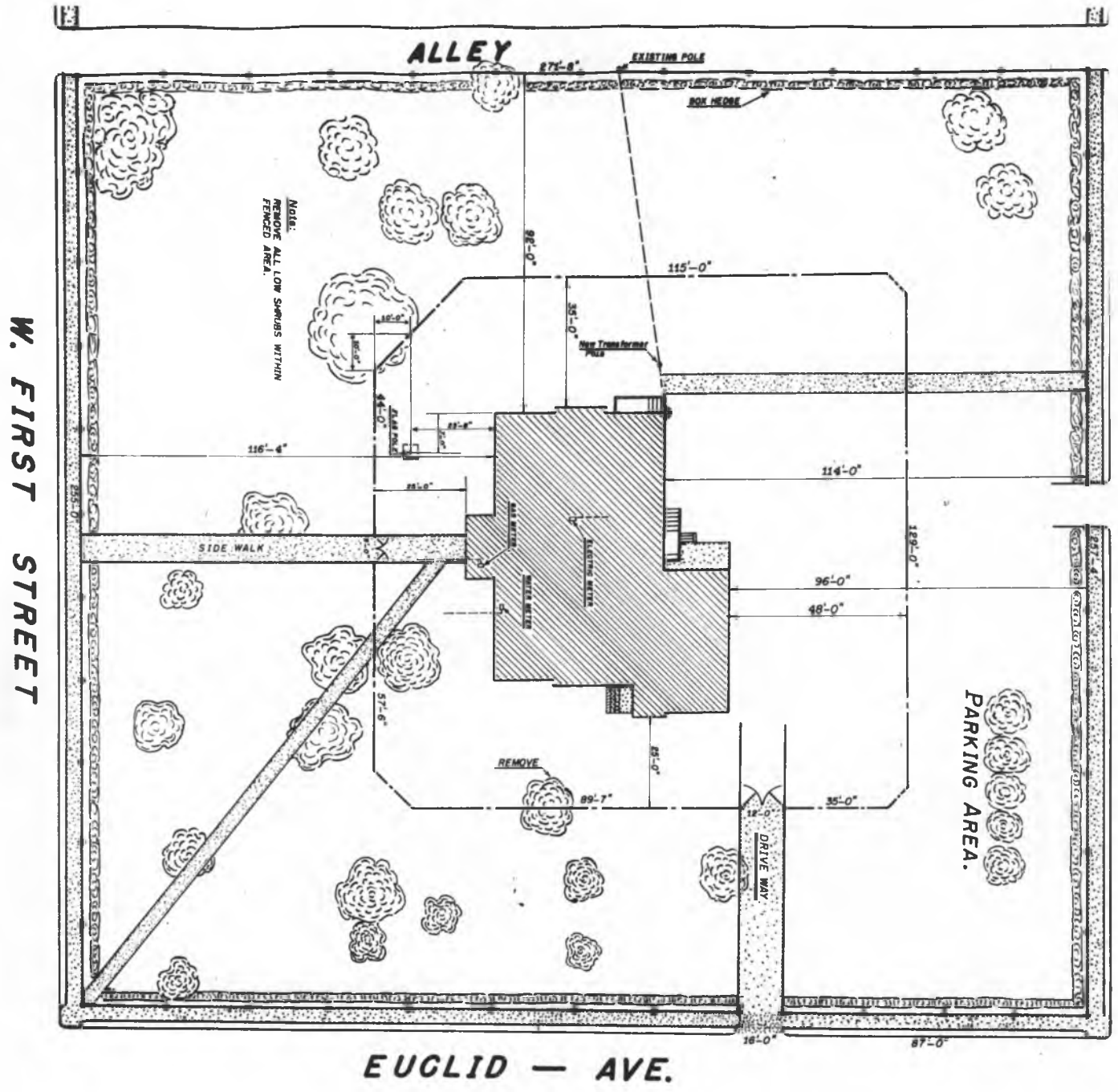

PLOT PLAN UNIT 3 PRIOR TO OCCUPANCY SEPTEMBER 1943

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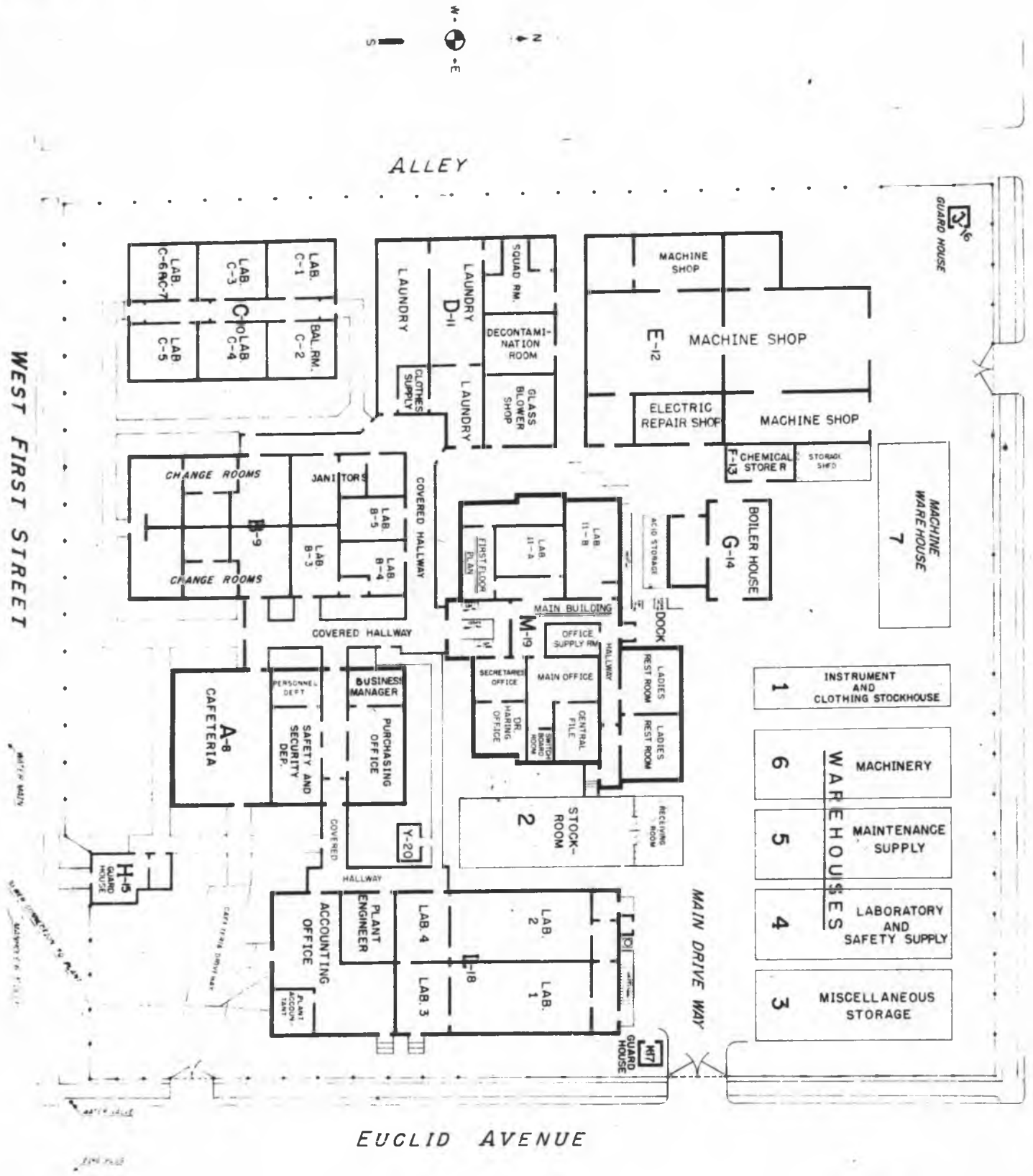

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4-5. Unit 5. - Chapters VIII and IX discuss in detail the foundation for "Y" work and the background and history of Unit 5. They are referred to here to insure continuity and coherence.

CHAPTER V - THE DEVELOPMENT OF PRODUCTION METHODS

5-1. Introduction. - An attempt to write this chapter in such a way as to give a true chronological picture of the various steps involved in the development of production methods would only result in mental chaos to the uninitiated reader. Each process and/or section of a process has been written as a chronological story followed by a series of flow charts which show the time and reason for the introduction of new steps in the process. This chapter completely ignores two problems which have, at times, been major considerations in process developments: (1) the almost continuous expansion program involving both personnel and plant facilities necessary to meet increased production schedules; and (2) the ever present difficulty of preventing personnel and material contamination involved in the production of polonium. Of primary importance to production, at the beginning of this Project, was the question: What is the easiest method of meeting production quotas during the first few months? A study was made(1) which indicated that:

(1) neutron-bombarded bismuth metal was the most satisfactory source of polonium (while the theorists promised that polonium could be produced in this manner, such polonium had been produced only in the cyclotron, and no method of concentration and purification had been developed);

(2) the most satisfactory natural source of polonium was the lead residues from the Port Hope refinery. These residues, containing RaD, RaE and RaF, were available as a by-product, after the removal of uranium and radium from natural ore. As a result of this study, it was decided to obtain some of this immediately available

lead dioxide and seek to remove the polonium from it. 7250 pounds of this material were received by 10 November 1943.

5-2. The Lead Dioxide Processes.

a. Introduction. - Research pointing toward the recovery of polonium from lead dioxide was started immediately using two methods of attack:

(1) a Wet (or Chemical) Process, and

(2) a Dry (or Kiln) Process.

Preliminary experiments indicated recovery by either process would take considerable time. To better insure the possibility of obtaining the polonium needed for the monthly quota, it was decided to, also, use another lead dioxide process, developed by J. H. Dillon of the Firestone Tire and Rubber Company of Akron, Ohio.

b. The Lead Chloride Process. - Literature on Dillon's patents indicated that polonium could be concentrated on metal foils by immersing them in saturated solutions of lead chloride, which had been prepared by digesting active lead dioxide in concentrated hydrochloric acid. The principal advantage of this process was that it could be put into operation in a minimum of time. Also, further concentration steps seemed to offer no major difficulties. Since the proper large, glass-lined equipment was not available in Dayton, the Monsanto "B" plant at Monsanto, Illinois, was chosen. At that site, the most important pieces of apparatus were present in an appropriate arrangement requiring a minimum of change for production by the Lead Chloride Process. Using the recommendations of the Dillon patent as a guide and applying the restrictions necessitated by the existing apparatus in the "B" plant, small scale experiments at Unit 3 indicated success. As a result, three tons of active lead dioxide were processed at the "B" plant. Approximately 2.50 Curies

of polonium (theoretical content was 3.15 Curies) were recovered in the form of material deposited upon copper or nickel sheets. Attempts to remove the material from these sheets were partially successful, but however, by this time (March 1944), other processes had proven more fruitful.

c. The Kiln Process. - It was hoped that, by utilizing the volatility of polonium or its compounds, a simple roasting and collecting operation could be developed for its recovery. Consequently, the development work on the kiln was first carried out in a laboratory-type, tube furnace, then, in an agitator-type kiln, and finally, in a rotary-type, pilot plant kiln. The first work in the laboratory-tube furnace concerned the study of conditions necessary for the vaporization of polonium from lead dioxide. Then, a study was made of the best type of condenser to collect the volatilized material. Before the completion of the experimental work on the tube furnace, a continuous, rotary-type, electrically heated kiln was designed, with the vaporized polonium flowing counter current to the cold lead dioxide. These two features, and the intricate mechanical design of the kiln were considered so unfavorable that its construction was never attempted. A pilot plant, agitator-type kiln was placed into operation to continue the development work on the process. In the first runs, lead dioxide was used. Volatilization of the polonium was poor. Lead dioxide slagged badly and fused at a temperature of about 700°C. - too low for a Kiln Process. Lead orthophosphate, prepared by a direct mix of lead dioxide and phosphoric acid, gave a salt that did not fuse below 900°C. Tests in the laboratory-tube furnace showed that the polonium could be readily volatilized from this compound. Pilot plant runs made in the kiln, indicated that 750°C. was the minimum temperature under which polonium could be volatilized from lead orthophosphate. In order to facilitate showering, a mechanical rapper was installed on the

agitator shaft. Different rates of gas flow did not seem to change the ease of volatilization. It was necessary to heat the material for four hours at 750°C. Various types of condensers for polonium collection were tried. A water-cooled, glass-enameled, finger-type condenser was tried (unsuccessfully). Finally, a water-cooled, brass finger, containing a Pyrex-glass-wool filter, was tried (successfully). However, the results obtained were not consistent. Steel wool, mineral wool and other types of filters were used (without success) to eliminate the collection of foreign dust on the condenser. With the data obtained, a large, rotary-type kiln was designed. Before it was built, another rotary-type, pilot plant kiln was constructed of a high temperature, stainless steel to make further studies and was used for several unsuccessful runs. Since a Wet (or Chemical) Process had been developed in the meantime, further work on the kiln was discontinued. The gross contamination of personnel and machinery was another major reason against the use of a dry process.

d. The Wet Process. - This process represents the best method developed for removal of polonium from radioactive lead dioxide. Research initiated in November 1943, indicated that it would be necessary to select a site, other than Unit 3, for full scale operations, because of space requirements. By February 1944, research had so developed that a new site of operations, Unit 4, was selected for production. Throughout the next year (until June 1945) production of polonium from radioactive lead dioxide was actively exploited. The process is based on the fact that RaD is still present in the lead dioxide by-product remaining after the uranium and radium have been removed from naturally occurring ore at the Port Hope refinery. The RaD (lead) disintegrates first into RaE (bismuth) and then to RaF (polonium). Sixty days was determined to be the optimum

time for extraction of RaF from a RaD source. The RaF content is approximately 25% of its equilibrium value.

1. The first step in the chemical process for the recovery of polonium was to dissolve the crushed and screened lead dioxide in nitric acid and hydrogen peroxide. After the solution had been filtered free of insoluble residue, lead carbonate was added to the filtrate (a nearly saturated lead nitrate solution). The resulting mixture was filtered, the precipitate discarded, and the purified lead nitrate (RaD) solution stored for periodic recovery of RaF.

2. The polonium originally associated with the ore could be tediously recovered from the solid residues of the acid-peroxide digestion by leaching in concentrated hydrochloric acid. The extract solution was filtered free of solid, the washed filter cake discarded and the filtrate, (a concentrated hydrochloric acid solution of polonium and many other elements) further processed. A large amount of tellurium was present. It could be removed by reduction with sulfurous acid. Unfortunately, a rather large amount of polonium coprecipitated with the tellurium instead of remaining in solution.

3. Each sixty days, the purified lead nitrate solution was "milked" for polonium by the addition of ammonium chloride and bismuth nitrate. Polonium was coprecipitated with bismuth oxychloride. The mixture was then filtered and the filtrate returned to storage. The precipitate of bismuth oxychloride, containing polonium, was washed and dissolved in concentrated hydrochloric acid. This solution was then similar to an original solution of irradiated bismuth metal but much more dilute. Scrubbing with metal powders and certain other absorbing agents could also be used to remove polonium from the nitrate solution.

4. Approximately 70,000 pounds of lead dioxide were processed in the plant at Unit 4 by this method and several Curies of polonium

extracted from the residues, further processed and finally shipped to Los Alamos.

5. At the time of procurement, the lead dioxide was rented from a Canadian citizen. Ownership of the material was transferred to the Canadian Government in the early stages of the war. By June 1945, it was clearly evident that polonium could be obtained much more easily and in much greater quantities by using the Bismuth Process. Since there was then no further need of the purified lead nitrate solution, the lead was precipitated as a carbonate slurry and shipped to the Madison Square Area. It was understood that the Madison Square Area would dry the carbonate and return it to the custody of the Canadian Government.

5-3. The Bismuth Process

a. Introduction. - The raw material is produced artifically by subjecting very pure metallic bismuth to an intense neutron flux in a pile. The stable isotope $^{209}_{83}Bi$ captures a neutron, becoming beta-active $^{210}_{83}$ Bi (RaE). This RaE decays to polonium, which is itself primarily an alpha emitter. The maximum polonium content of the bismuth coming from the pile in 1946 was roughly three parts per million. Thus, a tremendous concentration was required, since the material needed for urchin production must be polonium of greater than eighty-percent-weight-purity. Since the raw material was easily available and quite free from interfering foreign metals, it was, from the very first part of 1944, the source of practically all of the polonium produced by the Project. All bismuth used in the early stages of the project was bombarded in the Clinton pile. These batches of material contained an amount of polonium ranging from 0.032 to 0.083 millicuries of polonium per gram of bismuth content. After construction of the Hanford pile, it became the source of supply (June, 1945) of the material used. By the end of 1946, this latter site was supplying raw material that contained as much as 13.2 millicuries of polonium per gram of bismuth. Unfortunately, material containing this higher level of activity was much more dangerous to handle because of the higher magnitude of beta and gamma radiation associated with it, due to small amounts of heavy metal impurities present in the bismuth. However, by this time, much progress had been made in developing safer and better production techniques and the Production Group was able to handle the more dangerous material in a manner less dangerous to the personnel. Bismuth metal, of as great a purity as it is possible for the American Smelting and Refining Company to produce, was shipped to the Hanford Engineer Works.

Here, it was placed in a can, made of 2 S aluminum alloy. After neutron-pile bombardment for approximately 100 days, the canned bismuth slugs were shipped to Unit 4. The canned slugs were treated with hydrochloric acid which completely dissolved the can and resulted in the formation of an aluminum chloride solution. This solution was immediately discarded to free the process of much of the source of strong beta and gamma radiation inherent, due to the presence of iron and copper in the 2 S aluminum alloy. The decanned slugs were then dissolved in aqua regia. This solution produced a total volume much too large and of too low a specific activity to allow electrolysis of the activity on a platinum electrode. For this reason, it was necessary to effect a further concentration of the polonium without the introduction of interfering impurities.

b. Concentration Methods. - The reduction of polonium to the metallic state in the presence of ionic bismuth had been described in the literature for the separation of these two elements. Such processes, consisting of electrochemical deposition of polonium from solution on various metals, had been used successfully to separate RaF (polonium) from RaE (bismuth) where the polonium-bismuth concentration ratio was more nearly unity and where the total quantity of polonium dealt with was considerably smaller. Several metals have the appropriate redox potential necessary to reduce ionic polonium without reducing ionic bismuth. One of these metals is bismuth. This would be particularly desirable as a reducing agent. Its addition to the system would be introducing no new contaminant from which polonium need be purified. If the amount of metallic bismuth required, for this reduction, in a reasonably short time, could be made small, as compared to the bismuth in solution, a considerable concentration might be effected.

(1) The Bismuth Scrub.[5] A plan of operation was developed, which, during 1944, led to the following procedure: (1) Solution of the raw material in aqua regia; (2) Denitration of the solution; (3) Deposition on bismuth of the polonium in the solution by agitation of a small amount of finely powdered bismuth throughout the solution, thus effecting a 100/1 concentration; (4) Separation and resolution of this coated bismuth in aqua regia, followed by denitration; (5) Redeposition of the dissolved polonium, on approximately one gram of bismuth, thus effecting a further 1000/1 concentration; (6) Solution of the highly concentrated polonium (and bismuth) in acid; (7) Electroplating of the polonium from this final acid solution on platinum foils. It was necessary to remove the nitric acid remaining, after solution in aqua regia, so that the bismuth powder used as the concentrating agent would not be dissolved. This was originally accomplished (early 1944) by complexing the nitric acid, by the addition of urea to the solution. This method was soon discarded in favor of a more simple procedure involving the addition of formaldehyde to the aqua regia mixture after it had been heated to 85°C. This process remained the fundamental chemical method used for polonium concentration. Many refinements leading to greater purification have been added. Techniques pointing toward more efficient and safer handling of the procedures have been constantly developed. Much difficulty was encountered in the aquisition of glass-lined equipment and in the engineering of methods for the safe transfer of active material. Metallic containers could not be used because of the action of aqua regia. Also, the metals of construction used would, therefore, electrodeposit the polonium from the solution.

(2) The Tellurium Scavenge.[6] This process was developed, as an alternate method to the Bismuth Process, for concentrating polonium from solutions of the irradiated bismuth. Preliminary investigation of the

use of tellurium as a scavenger, based on information obtained from the literature, was started in April, 1944.

Polonium was coprecipitated together with tellurium by reduction with stannous chloride. To separate the tellurium from polonium several methods were investigated, namely - chromatographic adsorption, preferential reduction and liquid extraction. The procedure finally adopted was the separation of polonium from tellurium by preferential reduction. The tellurium is reduced to the metal with hydrazine leaving the polonium in solution. The final step consisted of the conversion of the hydrochloric acid solution to a nitric acid solution suitable for electrolytic recovery of the polonium on platinum foils. The first production operation was started in October 1944. Two months later, it was necessary to adapt the tellurium process to the recovery of polonium from the lead dioxide residues, due to the presence of excessive amounts of impurities. During this investigation, a method for removing silver was developed. It will be discussed in another section in detail. Briefly, the procedure consisted of precipitating tellurium dioxide by the addition of ammonium hydroxide to an acid solution of the tellurium; the polonium co-precipitated while the silver remained in solution as the silver ammonia complex. Eleven production runs were made during the period of October 1944 to February 1945, at which time the process was discontinued. The overall recovery of polonium from the aqua regia solution of bismuth to the final concentrate was ultimately brought to 98% or better, with foils of satisfactory purity. The process was discontinued, chiefly, because of the objectionable physiological effects of tellurium and the production of hyrazoic acid in the final conversion step. This latter product, a gas, was highly toxic to personnel. Also, the development of a volatilization procedure (described

elsewhere) gave a high degree of purification when it was used in conjunction with the bismuth process. This resulted in additional refinements which precluded the further use of the tellurium process.

(3) The Silver Scrub.[7] This process was developed as still another method for purifying polonium. The first work, done in June 1944, was based on information obtained from the literature. In this work, the polonium was scrubbed on silver powder or silver foil. The silver and polonium were then dissolved and the silver separated by precipitating it as silver chloride. In the face of production difficulties in September 1944, a test foil was prepared by this method. The production of this foil indicated a relatively simple and rapid method for purifying polonium. In February 1945, a full scale investigation was started. Reconsideration of the problem led to scrubbing the polonium on silver, by recirculating the solution through a tower, in which the silver was placed in such a manner as to obtain the maximum area per unit weight of silver. Initially, the tower was packed with silver coated glass wool. Other runs were made with the tower packed with silver coated glass wool and silver leaf. The disadvantage of the latter type of packing was that it increased the pressure drop through the tower. The next alternative was the use of silvered beads in the tower. The beads were silvered by roughening the surface and depositing the silver on them by spontaneous deposition. In the use of the silvered beads in the tower, it was necessary to use a considerable amount of acid to dissolve the silver and polonium, thus making it impractical to separate the silver and polonium by the precipitation of silver chloride. An alternate method of separating the silver and polonium was then developed. It consisted of the co-precipitation of polonium with aluminum hydroxide in an ammoniacal solution. Overall yields by this

process were as high as 98% and the purity of the final product compared favorably with present production. Because the beads could not be silvered in the tower, it was necessary to dismantle the tower after each run. This made it impractical to carry out the process by remote control, as would be desirable in production work. This process is, however, a workable alternative of the Bismuth Process.

c. Purification and Electroplating

(1) Volatilization.[8] Experiments, started in January 1944, showed that polonium could be volatilized at high temperatures from nearly all metal surfaces, whereas the deposition of the volatilized material on a specified surface was exceedingly difficult. Work until May 1944 was directed toward the volatilization of polonium from copper and nickel foils on which polonium had been deposited by electrochemical replacement from radioactive lead chloride solutions. A large volatilization furnace was constructed and tested with these foils, but satisfactory recovery of the polonium could not be obtained. Between July and October 1944, experiments were carried out on the volatilization of polonium from plated platinum foils prepared by the Electrolysis Group to permit reworking of the polonium. This procedure was found to be of considerable use in production since the complete removal of polonium, plated on platinum foils by chemical or electrolytic means, was difficult to carry out and generally resulted in the contamination of the solution with platinum. This operation was turned over to the Electrolytic Group for production work in October 1944. Current methods follow the stripping of production foils for reprocessing. Volatilization has been used successfully as a method of assaying insoluble or only partially soluble materials for polonium. Silicious residues and lead phosphate were analyzed by direct volatilization. Lead dioxide was analyzed by converting it to lead sulfate (by heating in an atmosphere of sulfur

dioxide) and then volatilizing the polonium from the lead sulfate (May, July, December 1944). Further work was done on the determination of the RaD content of radioactive lead dioxide (January, April, September, November 1945). Since considerable success had been obtained in the production process with the use of bismuth powder for the concentration of polonium from solution by electrochemical replacements, in June 1944,[8] work was started on the separation of polonium from bismuth by volatilization. The bismuth powder was converted to bismuth oxide by heating in an atmosphere of oxygen. The polonium was then volatilized from the bismuth oxide by heating to a higher temperature in a vacuum. The polonium was volatilized and collected on the inner walls of the quartz tube. The polonium was then dissolved from the walls of the tube by refluxing with acid. The experimental conditions for carrying out this operation were investigated between June 1944, and March 1945. Experimental production runs were carried out by the Research Group between April and July 1945. Since that time this process has been employed by the Production Group.

(2) Removal of Silver. - In September 1944, a gamma emitting impurity was separated from a production solution. In January 1945, measurements were completed on the half-life and energy of this impurity which, together with chemical tests, showed it to be silver. Experiments on the presence of radioactive impurities in a freshly activated bismuth slug failed to show the presence of any radioactive impurity other than silver. In April 1945, an investigation of suitable steps for the removal of silver in the production process was started. The procedure adopted was the use of ammonium hydroxide to precipitate the bismuth and polonium leaving the silver in solution.[9] Aside from the difficulties encountered with silver as an impurity, the hazards arising from the gamma radiation from irradiated bismuth

slugs of high silver content, presented a serious problem. One shipment of bismuth, during April 1945, was found to contain approximately 40 ppm of silver. As a result of requests for bismuth of lower silver content, shipments made during April and May 1945, contained 3.7 and 11-15 ppm of silver respectively. In the meantime, radiation to which the slugs were being subjected was greatly increased; therefore, the problem was little improved. By special request, the bismuth suppliers further reduced the silver content, by employing a special process with the result that bismuth shipments after January 1, 1945 were found to be spectrographically free of silver. By measurement of the gamma radiation of irradiated slugs, it was found that the silver content of the "desilverized" bismuth was between 0.1-0.2 ppm of silver. Thus, the gamma radiation hazard in handling irradiated slugs was practically eliminated.

(3) Electroplating.(10) Preliminary experiments, early in 1944, demonstrated that polonium could be separated from both hydrochloric and nitric acid solutions. The first solutions for plating from the Bismuth Process were obtained in February 1944. These were the most concentrated solutions obtained up to that time (~ 2 c/1200 ml., 3.2 M HCl). The polonium was successfully separated from these solutions, but, so many impurities were codeposited, it became apparent that improved methods of purification should be developed. A portion of this material was finally purified by repeatedly plating and stripping the electrodes. The first shipment, 20 March 1944, included two platinum foils prepared from this material. It was impossible to prepare the total shipment on foils, in the time available, so in addition to the two foils, two solutions were included to make a total of 2.4 Curies. Hydrochloric acid proved to be an un-

satisfactory medium for plating. The platinum anodes were corroded and the solutions were contaminated with platinum. A search for other, more suitable, anodic materials was not too successful. Work was started in the spring of 1944 on the critical deposition potentials in nitric acid in the presence of bismuth. This lead to the use of 1.5 N nitric acid with a controlled cathode potential of $+ 0.1E_c$. Additional work was done on the use of other media, but none was found completely satisfactory for production work. Subsequent investigation of deposition potentials have validated the $+ 0.1E_c$ for 1.5 N nitric acid solutions, but indicated separation from bismuth could still be made at a slightly higher potential. A potential of $0.0E_c$ was adopted in June 1945 and continued to be used at the close of 1946. Impure solutions for plating in the early days of the Project were the source of much trouble, causing repeated platings and strippings in an attempt to improve the quality of the final deposit. A second bismuth scrub was introduced in the Bismuth Process in an attempt to improve this condition. The first of these super-scrubbed solutions were delivered for plating in June 1944. Although solutions prepared by the super-scrub procedure were an improvement over previous solutions, trouble was still experienced in plating. It was then suggested that the bismuth powder from the super-scrub be oxidized and then volatilized. The first foils were plated from such a solution in September 1944. This operation was so successful that it remains a part of the production process. In May 1945 the first foils were made from solutions which had been freed of silver (see Removal of Silver). Adequate analytical methods were not available for determining the purity of these early solutions and plates, so the appearance and the neutron count of the plated foils were used as criteria of purity. Attempts made to weigh the final foils

resulted in the development of the micro-foil technique for solution assay. In an effort to control the neutron counts on the plated foils, various techniques and procedures were developed. The use of platinum containers, sealed in glass in an inert atmosphere, as now used in production work, resulted from this early work. In early 1945, request was made to deposit, by electrolysis, small quantities of polonium on the inside walls of small platinum-gold cups supplied by Site "Y". Extreme difficulties were encountered in meeting the neutron specifications on these cups. However, efforts were successful in supplying the quantity required in accordance with the specifications.

5-4. Assay.

a. Assay for Quantity.

1. Introduction. - Two procedures for the quantity of polonium are possible.

(a) The polonium nucleus decays by the emission of an alpha particle with an associated gamma ray. The half-life (time required for one half of polonium to decay) of this nucleus is 140 days (figure accepted by the Atomic Energy Commission for inventory purposes). In this decay each microgram of polonium emits 9.91 times 10^9 alpha particles per minute. Thus, a measure of the disintegration rate of a sample by electronic counting devices is a means of determining the weight of polonium present. It is to be noted that either the alpha or gamma radiation may be counted to assay polonium for quantity.

(b) Each alpha particle ejected from a polonium nucleus has an energy of 5.401 MEV. Each microgram of polonium gives off 122 kilogram-microcalories of heat per hour. This heat may be measured quite accurately with sensitive calorimeters, giving a second means of determining the weight of polonium present.

2. Electronic Counting. (11, 12, 13, 14, 15) - Early in 1944, alpha counters, alpha monitors, Geiger-Mueller counters, and electroscopes were in operation. Chemists were doing a large part of the counting, a function which later was performed by the organized Counting Group. The number of counting instruments increased so that by mid-year many additional alpha and beta counters were in use. Alpha chambers were used for thick sample (pellets) counting and also adapted for low geometry counting. Another alpha circuit was installed for use with various long tube, vacuum, low geometry chambers. Limited alpha counting was started at Unit 4 (production unit). Standardization and crosschecking of instruments was progressing at the close of 1944.

1945 marked several improvements and refinements of counting. Techniques in sample preparation were improved. Refinements in circuits and component parts markedly increased the reliability of counters. With the introduction of methane flow, proportional counters and the development of vacuum, low-geometry attachments, all desired ranges of alpha activity were counted. It was now possible to more accurately check the counting instruments against calorimetric measurements and make indicated corrections. With the expansion of counting facilities at the production scene, crosschecking was made so that routine counting became accurate to $\pm$ 2%. Most of this error occurred in sampling and in statistical variations rather than in instrumentation. Some expansion of facilities and improvement of instruments was made during 1946. Procedures were devised to minimize chamber contamination. With the establishment of the reliability of the regular methane flow, proportional counter, a single sample method for the determination of coincidence corrections (tau) of standard alpha chambers was instituted. This permitted daily and weekly checks encompassing two activity levels over a wide range of counting rates. Thus, incipient trouble in standard alpha counters could be detected and their reliability improved. Since tau could now be determined much more accurately and easily, higher activities could be counted in the standard alpha chamber. This resulted in higher statistical accuracy and reduced the amount of dilution required for sample preparation.

3. Calorimetry. (16, 17) - The usefulness of calorimetry in the assay of polonium depends upon the following properties: polonium decays into inert lead by the almost unique emission of alpha particles; the rate of decay is proportional to the amount present. The alpha

particles are mono-energetic to a high degree. The amount of decay energy appearing in other forms such as gamma rays is negligible. The alpha particles are very easily absorbed and their kinetic energy thereby converted into heat. The energy of a single disintegration has been accurately measured. The calorimetric method of assay is unaffected by self-absorption, diffusion into the support, geometry, statistical errors, or loss of polonium by recoil - all of which can lead to errors in electronic counting. In 1944 all quantity assay was made by electronic counters. It was realized that there would soon be a need to measure activities several thousand times more intense than the upper limit of these counters. At that time it was recommended that: two sizes of adiabatic calorimeters be used to measure smaller and larger quantities of heat covering the expected extension range; that temperature changes be measured with a platinum resistance thermometer and Mueller bridge; that calorimeters be calibrated by an electrical heater whose current and voltage drop were measured with a Wenner potentiometer and standard resistors. It was believed that errors might be limited to 1% or less for measurements extending up to two days in time. In 1945, two calorimetry programs were in operation. A group was established to study the optimum adaption of the calorimeter to production needs. The aims of this group were to produce faster, more accurate calorimeters, and whatever auxiliary equipment necessary to achieve these two aims. The direction of research soon turned from adiabatic to steady state, differential calorimeters, which, with errors of 1-2% and one hour span, were built. Closer control of room temperature, $\pm$ 2°C, and bath temperature, $\pm$ 0.003°C., were needed. Calorimetric measurements offered a means of very accurately determining the half-life of polonium. An accurate

value of this quantity was of vital interest to the entire project. This study was begun. A Production Group also was established to use for production assay the calorimeters which had been designed and constructed by the Research Group. Low-activity and high-activity calorimeters were put into routine production operation. During this year it was the recommended and accepted practice for all electronic counters to be calibrated by samples which had been measured calorimetrically. In 1946, again the efforts of the Calorimetry Group were divided between Research and Production. The research on the steady state, differential calorimeters concentrated on the elimination of the heat distribution error which arose because the heat flow of the calibration heater did not exactly duplicate that of the sample. It was believed that this was the limiting factor on the accuracy of the calorimeter. During the course of the year, a very accurate, ($\pm$ 0.15% error), but slow, calorimeter was built. A series of measurements extending over a period of four or more months were started with this calorimeter in order to get an accurate determination of the half-life of polonium. During the year, bath temperature control to $\pm$ 0.005°C. was achieved by means of a resistance bridge, galvanometer, photo relay, thyratron amplifier, and heater system. This year of research led to the belief that a steady state calorimeter of 0.1% error and half-hour speed, to operate over a larger range of sample sizes, might be achieved. In production the speed of the assay work was accelerated by the use of calibration curves. An examination of all the previous heater calibrations showed that 90% of all runs lay within 0.3% of a straight line when bridge potentials were plotted against Curie equivalents. Accordingly, curves, to be used in evaluating the samples, were drawn for each calorimeter. One heater

calibration per calorimeter per week was made to determine that the operation was being maintained on the calibration line. A production calorimeter was used in a determination of 136.7 days for the half-life of polonium. This value was considered the best thus far obtained but not of ultimate accuracy. The calorimeter had a 1.6% heat distribution error, considerably larger than that of the research instrument constructed for a most precise half-life measurement. The accuracy of production calorimeters was increased by constructing heaters to duplicate as closely as possible the geometry of the samples.

b. Assay for Quality.

1. Introduction. - Two important quality factors of a polonium preparation are the determination of: (1) light element impurities and (2) heavy or "noble" element impurities. The polonium alpha radiation can react with certain light elements producing neutrons. This phenomenon is to be avoided. The heavy element impurities codeposited with or superdeposited on polonium reduce its efficiency as an alpha emitter.

2. Light Element Impurities. (17, 18) - The neutron emission of a polonium plate is an accurate measure of the amount of light element impurities. This phase of assay became a problem in neutron measurements.

a. History of Neutron Measurement. - Neutron counting is required for three purposes: evaluation of neutron sources, detection of health hazards due to neutrons and determination of the presence of neutron emitting impurities in purified polonium. The range of values extends from 10^8 neutrons per second to substantially zero. In 1944, equipment was set up for neutron detection by the Szilard-Chambers process in calcium permanganate. The specimen was placed in the center of a 12 liter spherical flask surrounded by paraffin and after overnight

exposure, the manganese dioxide (MnO_2) which had been separated from the permanganate and activated by neutron capture was collected by filtering, and evaluated by measurement of the beta activity of the 2.5 hour (Mn^{56}) manganese isotope 56. This method is sensitive with neutron emissions varying from 33 to 500 per second, but it is slow and subject to a large probable error. A boron counter (BF_3) tube was put into use in August 1944; this allowed measurements to be made rapidly, but required a standard or independently evaluated neutron source with which to compare the unknown. Counting in a tub of paraffin by means of a boron walled proportional counter was begun in May 1945 with the receipt of two tubs from Chicago, one with a single tube and one with four boron-lined tubes. It was found that the counts obtained with the tubs were higher than with the Szilard-Chalmers method. A radium-beryllium neutron source containing 1 mg. radium was used as a standard.

1) Difference in energies of neutrons from the standard and those from our sources are responsible for differences in sensitivity or efficiency of the tub counters. Considerable uncertainty existed as to the correct sensitivity factor to use. Eventually a factor of 1.477 was adopted, to correct the values obtained by comparing a (Po-Be) polonium-beryllium source with the (Ra-Be) radium-beryllium standard in a tub. Various changes were made in the geometry, from time to time, without knowledge of the effect of these changes on the factor. When very strong sources were first made in 1946, the pulse rate produced by the B-wall tube in a tub was too high for the Higinbotham scaler to follow. Consequently a high speed counter was requested from the Electronics Group. Concurrently, measurements were begun on Hanson's arrangement, consisting of a B-lined tube mounted in a paraffin cylinder

with the source located on the prolonged axis of the tube. It was found that an inverse square response existed when the source was moved along this axis, if referred to a point approximately 8 cm. inside the face of the paraffin cylinder. This distance depends on the energy spectrum of the neutrons, indicating that this detector, too, responds unequally to sources of different energy. A program of investigation was set up with the purpose of establishing reliable technique for evaluating neutron sources over a wide range of intensities, regardless of the neutron energies involved.

3. Heavy element impurities.[19, 20] - Counting or calorimetric techniques give a measure of the weight of polonium in a sample by measurement of its radiation. If the total weight of the preparation could be obtained by other means, a mass purity of the sample could be calculated. The impurities detected in this fashion would be the socalled heavy element impurities if the sample had passed the neutron tolerance test for light element impurities. In 1944, the first attempt to detect heavy element impurities was not a weighing method. A special technique was tried using a low geometry alpha counter. The technique involved the determination of an activity-range curve for each polonium plate (the range is a function of air pressure in counter). Theoretically, for a pure deposit which is not too thick, the measured activity should remain constant with increasing pressure (decreasing range) to a definite pressure (range) and then be reduced abruptly. If codeposited or superdeposited impurities are present this reduction in measured activity should occur gradually. The method was abandoned when it was found impossible to obtain sufficiently high precision. In the latter part of 1945 the first attempts were made to weigh the polonium plate. An Ainsworth Microbalance was used and seemed to behave quite erratically in the presence of activity.

a. Early in 1945 the first attempt was made to weigh a polonium plate on a quartz-fiber torsion microbalance. This instrument worked very satisfactorily. A great deal of research followed to work out the details of this new "purity assay". Of course, the most direct method would have been to weigh the product plates, but the load capacity of the Kirk-Craig Quartz-fiber Balance was not great enough. Hence, it was decided to plate a small foil from the same solution as the large product foil and determine the product weight of this smaller piece. Because of the difficulty in reproducing exact plating conditions, it was decided to plate all the metals from the aliquot which would plate under specified potential conditions. This would give a minimum purity value for any product foil plated from the same solution under the same specified potential conditions. The details of plating apparatus, design, volume and concentration of solution, and optimum plating time were investigated. The method of alpha assay of the plates caused some trouble at first but alterations in low geometry counter design largely eliminated these difficulties.

b. The design of quartz-fiber balances was an ever present problem in this work. In cooperation with the Chicago University Metallurgical Laboratories Instrument Shop under T.J. O'Donnell, the entire mechanical design of the "Kirk-Craig" balance was altered. The Dayton project provided the ideas for making the balance more easily operated with greater precision and the Metallurgical Laboratories Shops worked out details and constructed the instruments.

c. The Dayton group proposed the construction of a balance to directly weigh the product foils and such a heavy duty quartz-fiber unit was begun by O'Donnell's group.

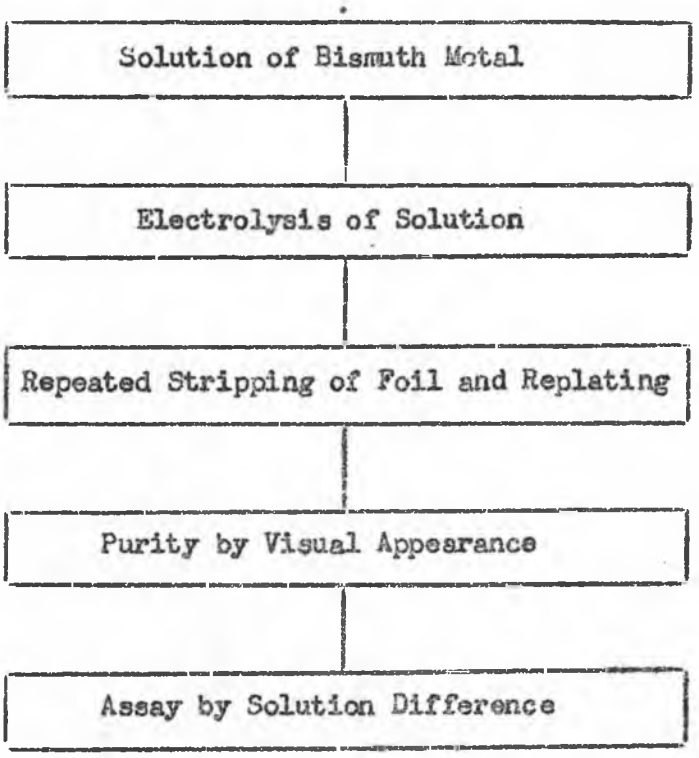
d. In 1946, small details in the purity assay test were altered to obtain greater accuracy and precision. It was felt that the accuracy of the method at this time was about ± 5%. The possible need for still greater accuracy stimulated more work in direct weighing of polonium plates. The work on the heavy duty quartz-fiber balance was progressing very slowly, so a new project was begun to again attempt to use a standard microbalance such as the Ainsworth. Preliminary work indicated that accuracies to 1% were possible but handling and shielding difficulties were tremendous.

e. Because the change to direct weighing seemed so remote, more effort was expended to redesign all apparatus used in the aliquot method with view to increasing this precision.

5-5. Chronological Flow Charts.

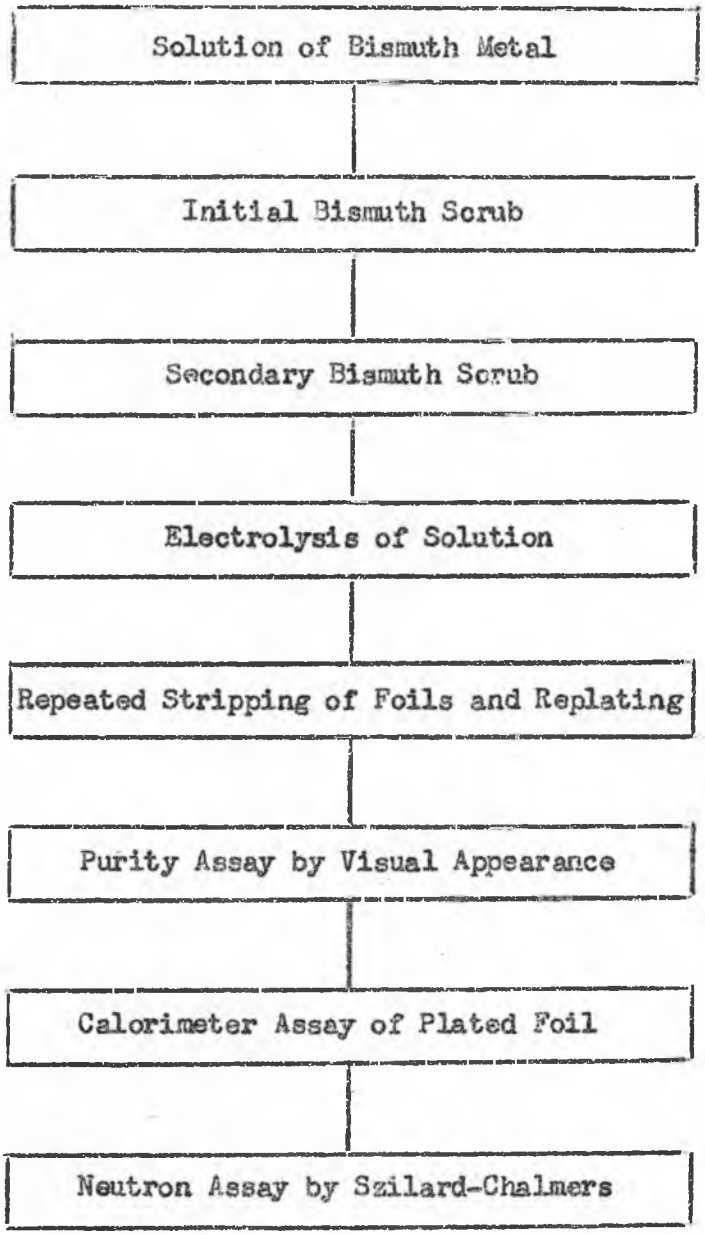
In the following flow charts no attempt is made to give processing details. The various descriptive phrases used will indicate the production procedure being practised by the Production Groups on the date given. These phrases are more fully described under the sections 5-1 through 5-4.

a. March 1944.



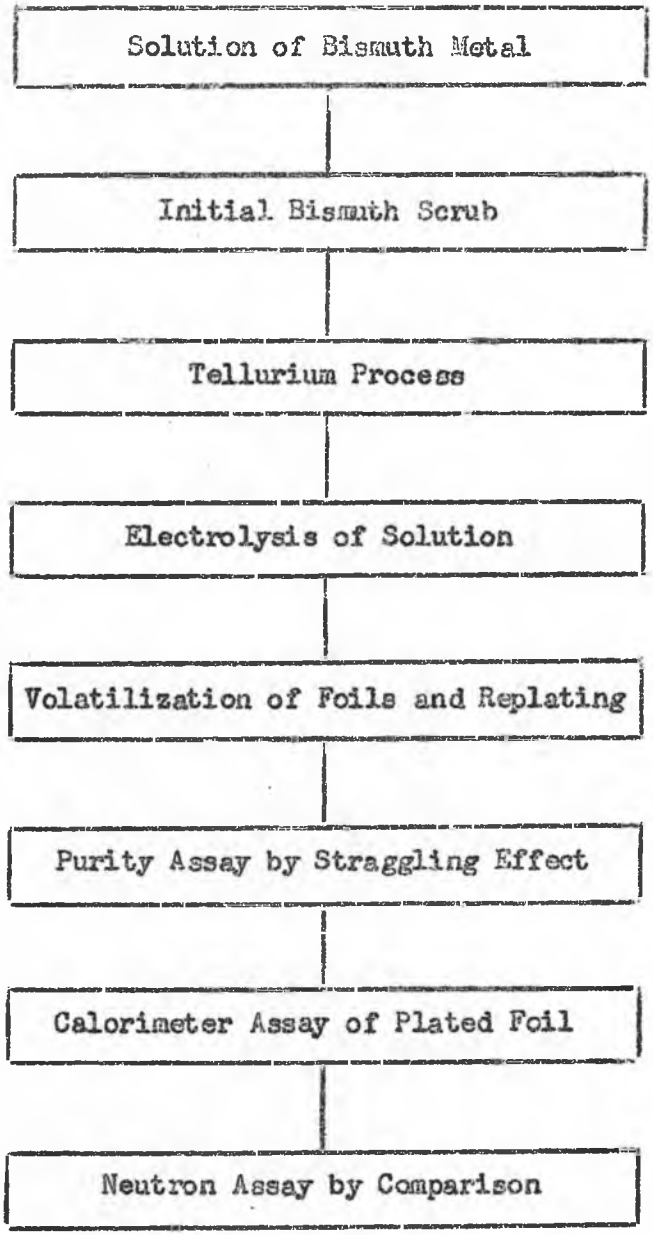
Electrolysis of the original solution was a very long, time-consuming process. Removal of the original plate by an acid leach and replating ~~was~~ were sometimes repeated as much as ten times. Repetition of this procedure ceased when a firmly adhering, metallic-like plate was obtained.

b. June 1944.



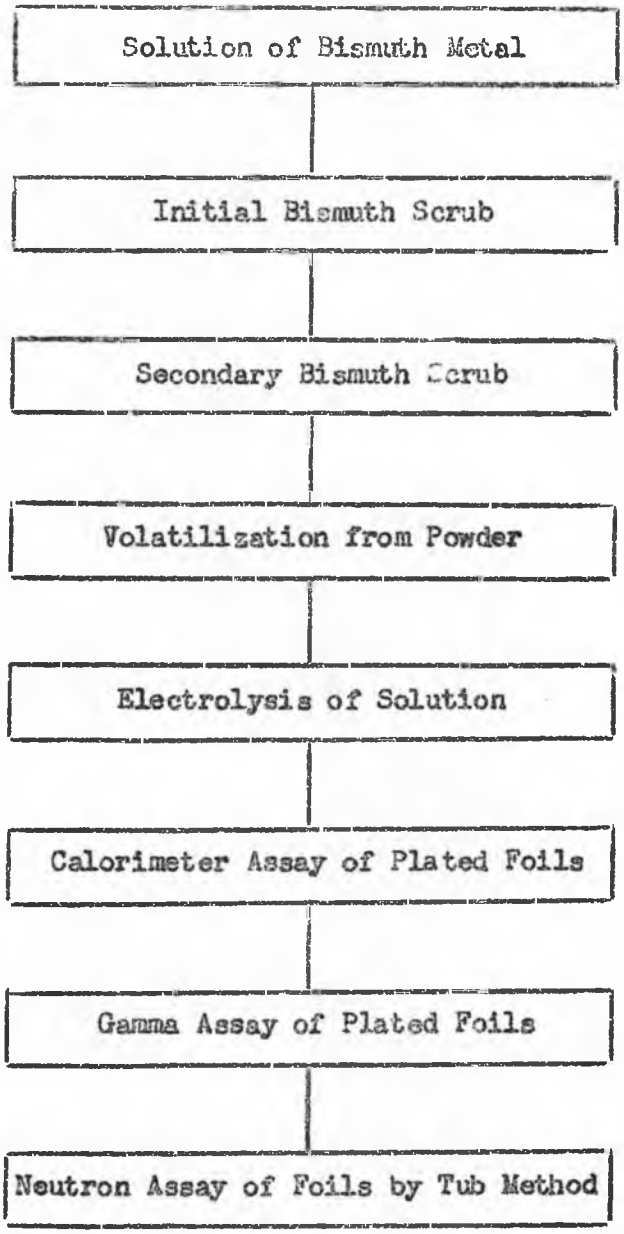
The two bismuth scrubs introduced here gave increased purification, a more suitable bismuth-polonium ratio by a factor of 100,000 and markedly decreased the stripping and replating operations. The calorimeter assay was made the official assay value for inter-site shipments. The neutron assay gave the first rough indication of the purity obtained.

c. November 1944.

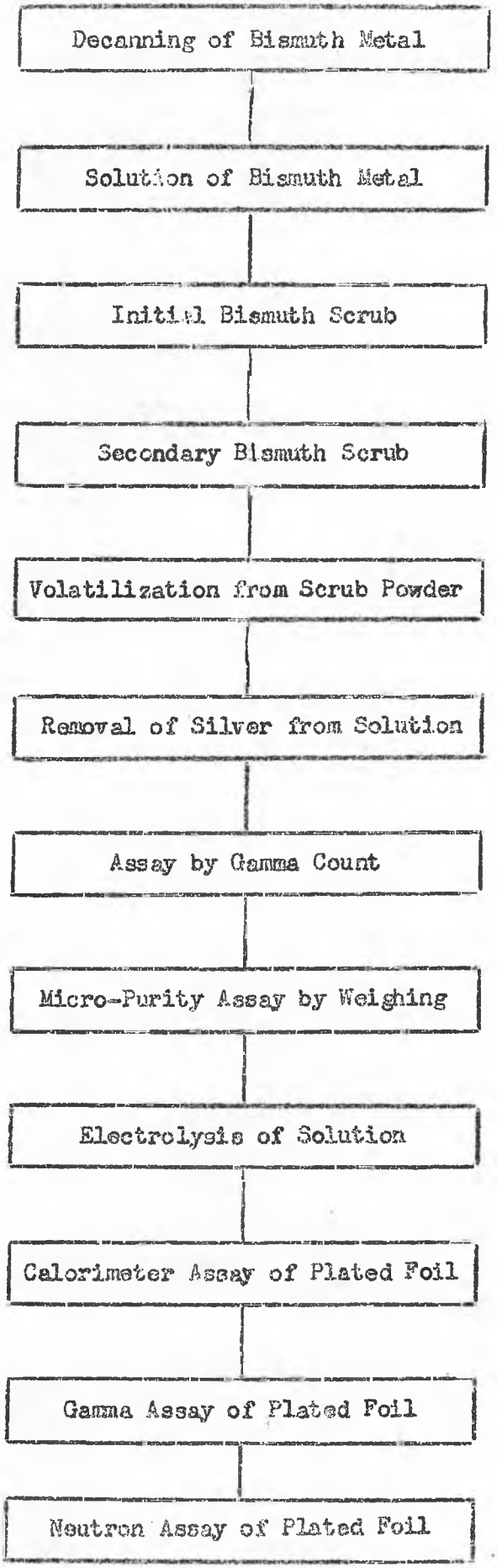


The tellurium process produced for the first time a solution for plating that was comparatively free from foreign metallic ions. Volatilization of the polonium from the foils after plating replaced the tedious acid stripping of the foils. Purity assay by use of the straggling effect were rather ineffective. Neutron assay was much more accurate.

d. March 1945.



The development of a method for the direct volatilization of polonium from bismuth powder resulted in much greater purification and lightened the load carried by the Electroplating Group to a considerable extent. The gamma assay of the plated foil, when compared to the calorimeter assay of that foil, gave a very good indication of the purity of the plated polonium.


Decanning of Bismuth Metal
Solution of Bismuth Metal
Initial Bismuth Scrub
Secondary Bismuth Scrub
Volatilization from Scrub Powder
Removal of Silver from Solution
Assay by Gamma Count
Micro-Purity Assay by Weighing
Electrolysis of Solution
Calorimeter Assay of Plated Foil
Gamma Assay of Plated Foil
Neutron Assay of Plated Foil

By this time canned irradiated bismuth was being received regularly from Hanford. This, of course, necessitated the addition of a step involving the decanning of the metal. Removal of the silver from the solution resulting from the volatilization step was followed by the assay of the solution by gamma counting. By checking this gamma value against alpha counts obtained from aliquots of the solution it was possible to test quite accurately for the completeness of silver removal. The development of the micro-purity test gave the first accurate measure of the real weight purity of the polonium preparation.

This last flow sheet gives the production procedure in use throughout the year 1946. Many refinements were made which led to more desirable operations and greater accuracies in each of the procedures outlined. Especially during 1946, the output was increased many fold and health conditions vastly improved.

5-6. References.

(1) Information Report No. 26, Possible Sources of Polonium.

(2) Final Report No. 4, The Lead Chloride Process

(3) Final Report No. 27, The Kiln Process.

(4) Final Report No. 11, Recovery of Polonium from Radioactive Lead Dioxide.

(5) Operating Directive for Processing Active Bismuth.

(6) Final Report No. 36, The Tellurium Process.

(7) Final Report No. 39, Pilot Plant Silver Process.

(8) Thermal Volatilization Progress Reports (1945).

(9) Thermal Volatilization Progress Report, April 15 - May 31 (1945).

(10) Electrolytic Production Progress Reports (1944 through 1946)

(11) Final Report No. 2, Thick Sample Method of Radiometric Analysis.

(12) Final Report No. 8, Electrometer - Linear Amplifier Circuit.

(13) Final Report No. 9, Direct Measurement of Polonium Content of Activated Bismuth Slugs.

(14) Final Report No. 22, Low Geometry Instruments for the Measurement of Strong Alpha Sources.

(15) Final Report No. 23, Measurement of Polonium by Gamma Rays.

(16) Final Report No. 18, Calorimetric Determination of Polonium.

(17) Operating Manual of Assay Group.

(18) Final Report No. 15, Light Element Contamination.

(19) Microelectrodeposition Manual.

(20) Final Report No. 42, Micro Assay Operations.

CHAPTER VI - GENERAL RESEARCH

6-1. Introduction. - The research activities of the Dayton project divided themselves early into general research and development research. In the first stages development research was greatly stressed and this work is recorded elsewhere as "Development of Production Methods". The general research program again could be divided into the major fields of Physics, Chemistry and Electronics.

6-2. Physics.

a. Physics 1944. - The entire effort of the Physics Group for the year 1944 was directed toward the development and construction of electronic equipment to measure alpha, beta, gamma, and neutron radiations. This included modification and mounting of electroscopes, constructing alpha chambers and alpha monitors (then known as integrators).(1) (2) (3) (4) With the increase in the amount of equipment in service, maintenance became a major problem and necessary test equipment had to be built. The alpha monitor was improved and a more stable AC operated design was developed. The use of a low pressure spherical chamber permitted the measurement of more active samples and the development of special chambers increased the usefulness of this instrument. Techniques for thick sample counting using a modified alpha chamber were developed and used.(5) The screen type, low-geometry chamber was tried and abandoned. Crude vacuum type, low-geometry chambers were built and found reasonably satisfactory and improvements on these were begun. Equipment for coincidence counting was constructed.(6) The building of counting equipment for production was a phase of the work. The construction of modified methane-flow, proportional counters was

essentially completed. The first instruments for Health work were constructed during this period.

b. Physics 1945. - Likewise, the major effort of the Physics Group for 1945 was counting instrumentation. The methane-flow, proportional counters were placed in service. Their usefulness was greatly expanded by the development of both short and long tube, vacuum, low-geometry attachments.(7) (8) These proved so simple to operate and so reliable that they gradually replaced the alpha monitor. The development of a three tube alpha chamber reduced difficulties with electrical interference and first tube replacements. Improvements in the linear amplifiers reduced coincidence corrections. These together with the use of more stable components and new scaling circuits resulted in alpha counting that was both reliable and consistently accurate. The production counting facilities were expanded and a service laboratory established. Central battery systems were installed. Automatic plating controls were built and a stable, sensitive vacuum-tube voltmeter for use with them was developed. Improved electronically regulated power supplies for high currents were developed and the construction of AC operated, multiple unit, automatic plating controls became possible. Thyratron and photoelectric temperature controls were developed and built for calorimetry. In addition the Physics Group carried out an extensive study of the gamma radiation of polonium.(9)

c. Physics 1946. - In 1946 the electronics function of the Physics Group was removed, forming a new group. The Physics Group devoted itself entirely to general research and began studies on the vapor pressure of sulfur, selenium, tellurium, and polonium and on the determination of the density of polonium. In addition, preliminary studies were made on the emission spectrum of polonium and on the x-ray diffrac-

tion of polonium metal and compounds. The problem of neutron counting was retained by this group for further study.

6-3. Electronics 1946. - During 1946 numerous projects, listed below, were undertaken by the newly formed Electronics Section.

1. Completely electronic, multiple unit, plating controls were developed.
2. The possibility of cracks occurring in Pfaudler kettles led to the development of an electronic alarm relay which indicated when the resistance between the solution and the jacket of the kettle was reduced.
3. A modification applying the multiplier phototube as the detecting device in a Beckman Spectrophotometer was undertaken.
4. Development work, aimed at producing a photoelectric unit to be used in determining the distribution of activity in a drop of solution, was carried on to the point where it was determined feasible. The device uses a small fluorescent screen with a multiplier phototube detector.
5. Some research work was begun on alpha chambers.
6. Considerable work was done on the development of fast trigger pairs and scaling stages. This led to the development of (1) a high-speed pulse generator which produced pulses at a rate of approximately 2.5 million pulses per second; (2) a high-rate neutron counter which counted evenly spaced pulses at a rate of 1.5 million pulses per second and (3) a four-input gamma counter, each input of which counted evenly spaced pulses recurring at a rate of 750,000 pulses per second. The work on trigger pairs led to the development of a rate meter circuit which has

essentially no pulse-height error over a pulse range of 0.2 to 75 volts.

7. A number of devices were developed for polarographic studies, one of which allowed the solution cathode potential of a cell to be increased at a predetermined rate.

8. A throttle type, thyratron heater control unit was developed for use in controlling the temperature of calorimeters. This device was so constructed that the power output to a heater was approximately proportional to light falling on a photocell.

6-4. Chemistry. - The major effort of the Chemistry Group for the year 1944 was to perfect a process for the quantity production of polonium (this phase of chemical research is covered by "Development of Production Methods"). However, the general research activities of the chemistry section began to assume definite trends at the end of this year. The major divisions which developed were general chemistry and neutron-source preparation.

a. General Chemistry.

1. Electrolysis 1944. - One of the methods of final concentration of polonium was electrolysis giving a polonium plate from polonium-rich solutions. In 1944, a program of research was started involving both the determination of fundamental electrochemical quantities as well as practical electrochemical research to make possible the preparation of polonium plates with certain specified characteristics.

2. Electrolysis 1945. - In 1945 the decomposition potentials of polonium and other elements which might be associated with polonium were determined for several acidic and basic media.(10)

Electrolytic work from a practical viewpoint in this year was begun to (1) improve the adhesion, cohesion, and uniformity, (2) eliminate "migration" losses, (3) increase the curie density, (4) increase the rate of deposition, and (5) maintain the purity requirements of electrodeposited polonium plates. The important new tool, photomicrography, was added and its use developed. The first photographs of polonium metal were made.

3. Electrolysis 1946. - In 1946 the important fundamental problem of an experimental determination of the standard electrode potential for polonium was initiated. Extensive work in polonium electroplating revealed that electrolysis from aqueous hydrofluoric acid solutions yielded polonium plates with many desirable features of adhesion, cohesion, uniformity, high curie-density, and purity.(11)

4. Chemistry 1944. - Other phases of chemical research were still in a nebulous form in late 1944. Certain isolated researches were performed on the preparation and solubility of complex coordination compounds of polonium in tracer amounts and on the establishing of the formula of polonium iodide (unsuccessful) by tracer techniques.(12) A great deal of effort was expended to determine the best preparation methods for samples of polonium to be analyzed in electronic counters.(13)

5. Chemistry 1945. - A general chemical research program was initiated at the start of 1945. At the beginning, the work scheme was to (1) decide what information about polonium should be known, (2) examine the literature to determine what information had already been reported, and (3) devise experimental procedures to obtain desired information. The first program centered around the following divisions: (1) Physical properties -- this was to be handled in conjunction with the Physics Group (see Physics). (2) Chemical behavior and typical compounds. (3) Colloidal behavior of compounds.(14) (4) Tracer work with

polonium.[15] To aid in the work of planning and executing the research program, the technical staff translated from German the treatise "Polonium" by Gmelin. In order to make and study the properties of polonium compounds it was necessary to become trained in the comparatively new techniques of ultramicro or gamma scale chemistry. A large portion of the year 1945 was devoted to the acquiring of proficiency in these techniques. An investigation was begun to determine the physical state (ionic, colloidal, or coarse dispersion) of polonium compounds in solution as a function of acidity and basicity. Using tracer amounts of polonium the following problems were investigated: (1) formula of the compound polonium iodide; (2) organic precipitants of polonium; (3) carriers for polonium; (4) solution extraction of polonium.

6. Chemistry 1946. - The newly acquired techniques of gamma scale chemistry were extensively applied to the study of metallic polonium and polonium compounds in 1946.[16] The general procedures used were: (1) Preparation of metal or compound using high vacuum equipment; (2) Analysis of product by gamma-scale analytical procedures; (3) Preparation of samples for X-ray diffraction and microscopic study. Extensive work with polonium metal, polonium chlorides, polonium oxide, and metal polonides was in progress.[17] [18] The techniques developed in studying the colloidal behavior of polonium compounds in solution were extended to a study of changes on complex ions. The tracer technique determination of the formula of polonium iodide was abandoned temporarily. A new field of endeavor was initiated in a program to determine solubilities of polonium compounds in various media. Effort was being expended to develop absorption spectroscopy as a means of investigation of ion structure in solution.

b. Neutron-source Preparation 1944. - The alpha rays from polonium are sufficiently energetic to initiate, with light element nuclei, the familiar alpha-neutron reaction. Thus, polonium in conjunction with light elements can be an effective source of neutrons.

An important problem which arose early in the polonium project work was the attempt to produce a volatile neutron source. It was proposed to prepare a volatile polonium compound which could be used alone or with another gaseous compound as such a neutron source. The objective was to obtain a neutron source which would give off few neutrons in the expanded state, but when condensed would act substantially as a thick target and emit many times as many neutrons. The most promising polonium compound suggested was polonium hexafluoride with a predicted boiling point of -40°C. The first research work in this field involved attempts to prepare this material.

c. Neutron-source Preparation 1945. - The work on the preparation of a volatile neutron source was continued in 1945 with the following breakdown of investigations and conclusions: (1) Preparation of a volatile fluoride -- All attempts to prepare a volatile fluoride of polonium were unsuccessful. This work was abandoned when it was found that selenium hexafluoride was decomposed by the action of polonium alphas. Presumably the hypothesised polonium hexafluoride would react in a similar fashion.(19) (2) Preparation of a volatile alkyl -- Likewise all attempts to prepare a volatile polonium alkyl were unsuccessful.(20) (3) Preparation of a volatile carbonyl -- A new field of endeavor was embarked upon in 1945. This was the preparation of solid neutron sources to be used for research purposes at other radioactivity research centers throughout the country. Preparation of polonium-beryllium, polonium-boron, polonium fluoborate, and polonium fluoberyllate

sources was begun in late 1945.(21)

d. Neutron-source Preparation 1946. - The main effort for 1946 in this field was to design, construct, and perfect devices to allow the preparation of strong neutron sources without endangering the personnel or the technical men handling the preparation. This proved to be a very difficult problem and required the entire effort of the technical group with a great deal of help from the machine shop. Apparatus for preparing polonium-beryllium and polonium fluoborate sources was practically complete in late 1946.(22)

6-5. References.

(1) Final Report #7 Immersion Geiger Tubes

(2) Final Report #8 Electrometer-Linear-Amplifier Circuit

(3) Final Report #9 Direct Measurement of Po Content of Activated Bi Slugs

(4) Final Report #19 Alpha Ray Camera

(5) Final Report #2 Thick Sample Method of Radiometric Analysis

(6) Final Report #21 A Measurement of Fast Neutron Energies with Proportional Counters in Coincidence

(7) Final Report #22 Low Geometry Instruments for Measurement of Strong Alpha Sources

(8) Final Report #47 Low Geometry Attachment for Methane Flow Proportional Alpha Counter

(9) Final Report #23 Measurement of Po by Gamma Rays

(10) Final Report #33 Polarographic Studies

(11) Final Report #14 Research on Electrodeposition of Po

(12) Final Report #35 The Polonium-Iodine Ratio

(13) Final Report #2 Thick Sample Method of Radiometric Analysis

(14) Final Report #23 Colloidal Properties of Po

(15) Final Report #13 The Use of Dithizone Reagent

(16) Final Report #31 Chemistry of Po

(17) Information Meeting Paper #4 Oxide of Polonium

(18) Information Meeting Paper #5 Chlorides of Polonium

(19) Final Report #44 Study of Polonium-Fluorine System

(20) Final Report #45 Study of Preparation of Polonium Alkyls

(21) Final Report #17 Preparation of Neutron Sources

(22) Final Report #34 Preparation of Neutron Sources

CHAPTER VII - HEALTH, PHYSICS AND BIOLOGICAL RESEARCH

7-1. Introduction. - Every laboratory working with radioactivity has the problem of protecting the workers against the health hazards arising from various radiations. The Dayton Project was no exception. Beside polonium alphas, betas and gammas from RaE and also from silver and iron, - which occur as impurities in bismuth, - and neutrons from Ra-Be mixtures were considered. In addition, provision was made to handle toxic lead and tellurium.

7-2. Health-Physics. - Accordingly 1 November 1943, Fernelius and Silverman visited Chicago to confer with Lt. Col. Warren and Maj. Friedell about the matter. As a result some elementary measures were instituted by 11 November 1943. These included the wearing of rubber gloves, use of a respirator when handling dry materials, wearing of special clothing, refraining from eating or smoking in a laboratory, use of a simple hand counter, blood counts, etc. However, the urgency of getting production started prevented making any health investigations until the early Spring of 1944. At the same time, a full time registered nurse was added to the staff. The services of a local physician to make physical examinations including chest X-rays, had been enlisted somewhat earlier.

It must be remembered that nothing was known at that time concerning the effects of polonium on the animal body. Means were not available to detect its presence in the human system. Even now, very little is known about the first point but the second may be considered fairly well solved. A modest research program showed that detection and estimation could be accomplished by collecting and counting the disintegrations of polonium in urine on a copper disc. On 1 June 1944, the first routine samples of urine were collected. The safe tolerance for

human beings could only be estimated by analogy. It was set at 3000 disintegrations per minute per 24 hour output of urine, although at the first it appears to have been 5000. This is 50 counts per minute per 50 ml. sample. The same researches aimed at finding methods of removing polonium from the hands if they should become contaminated. Solvents ranging from pineapple juice to aqua regia were tried. The best combination found was sodium hypochlorite followed by 3 N hydrochloric acid. In February 1945, a clinical laboratory was set up at Unit 3.

a. This situation continued without much change until April 1945 when Capt., then Lt., B. S. Wolf, was loaned to the Project to direct these health efforts. He proceeded immediately to establish much more extensive and careful survey and monitoring routines. A Health Instrument Group was organized in June, charged with the construction and maintenance of instruments and the electronic counting of survey samples of all types. The next month, a Special Problems Group was organized to handle the peculiar analytical problems encountered by the Health Division. Capt. Wolf, with two other members of the Health Division, then spent about two months with the group surveying the bomb damage at Hiroshima and Nagasaki. Despite all efforts, contamination persisted at a higher level than desired. In February 1946, Fernelius, Wolf and Burbage visited Los Alamos to study their dryboxing techniques. However, it was decided shortly thereafter that the precision of preparing and measuring the urine samples needed to be very greatly increased. Accordingly, in March 1946, a small group was established to study thoroughly the preparation of the sample for counting. One month later, a special laboratory, 3 miles from Units 3 and 4, was equipped to carry out sample preparation and actual counting. A considerable increase in precision was noted at once. However, on 1 April 1946, orders were received to lower the tolerance to 500 disintegrations per minute per 24 hour sample. The immediate result of this sent

over half of the production force to the library or uncontaminated laboratories to "cool off". For two months the output was cut in half because so much manpower was useless. However, the Design and Engineering Group had started work long before on the design and construction of an "elephant", a hood in which all operations could be carried out by remote control without ever opening the same. By working day and night it was put into operation during this dark period and immediately proved its value. Almost no workers became "hot" while using this device, even at high levels of production. Plans were therefore laid to "elephantize" all operations as time and circumstance permitted. Capt. Wolf was transferred to the Madison Square area in June 1946. In December, the method of handling samples was so much improved that very good precision was obtained even when the count fell to 5 per minute or less. This greatly increased the confidence of all in urine monitoring as a method of insuring personnel safety.

b. The Health Instrument Group had little opportunity during this period to engage in research design and development. The struggle to evaluate accurately the ever increasing number of urine samples at exceedingly low levels demanded nearly all this group could do. Personnel with time available constructed old type instruments that the Manhattan District could not supply. Nevertheless, toward the close of 1946, design and construction began on a radically modified low level alpha counter, on a greatly improved hand counter and on a continuously recording gamma monitor. All these are now in actual use.

7-3. Biological Research. - As early as January 1946 it was realized that knowledge of the effects of polonium on the human body was almost nil and that the "tolerances" under which the Project had been operating had no really valid experimental basis. Accordingly, various members of the staff began to urge the advisability of biological research on the effects

of polonium here or elsewhere. The majority felt it could best be carried on at Dayton. On 18 June 1946, Haring and R. E. Kelley, Monsanto's company physician, visited the biological research center at the University of Rochester. It was immediately apparent that only a few cases of acute poisoning had been studied and that practically nothing of real value to the Project was available. Furthermore, there was no likelihood that chronic studies at low levels, those most important to the problem, would ever be made. Accordingly, on 21 June 1946, Kelley submitted a report to Thomas in which he insisted that the Manhattan District sponsor biological research on polonium at Dayton. He also urged the necessity of additional research and development in the field of remote control and the advisability of having a health physicist on the Project staff.

a. J. L. Svirbely, a biochemist of the National Institute of Health and a specialist in industrial toxicology, was interviewed at Dayton early in July with a view to making him head of the health efforts. At that time he gave a very rough estimate of the needs for biological research to facilitate moves in that direction. Later in August he supplied a much more comprehensive study of the matter, covering equipment and animals, personnel and several proposed programs of study. These facts were transmitted to Thomas who wrote Gen. Nichols 30 August 1946 requesting approval of the program. The initial sum requested was $46,000. On 10 September 1946, Capt. Wolf wrote Dr. Kelley assuring him the Medical Committee of the Manhattan District strongly favored granting the request. On 20 September, Haring wrote Thomas to inform him that the Medical Committee felt the estimate given was much too low and that at least $125,000 should be available for the first year. Svirbely accepted employment on 1 October. On 29 October 1946, Col. Kirkpatrick wrote Thomas authorizing the Dayton Project to undertake biological research on polonium.

An expenditure of $46,000 was authorized for the first fiscal year and the effort approved in principle for later years. On 19 November, clearance was requested for R. A. Kehoe of Cincinnati, an expert on the subject of lead poisoning. Svirbely reported for work 20 November and immediately began study of the various problems of the Health Division, to plan the biological research program and to assemble personnel and equipment. A whole building was planned for the new plant but quarters were set aside in the Warehouse until that time.

SECRET

CHAPTER VIII - FOUNDATION FOR "Y" WORK

8-1. History of Urchin Production.

a. Organization. - These items, formerly made at Los Alamos, are now made in Dayton. The first written intimation that these activities might be transferred to Monsanto of Dayton occurred in a letter from J. H. Lum to W. C. Fernelius dated 19 April 1946. The possibility grew rapidly into a probability, so R. F. Meehan, C. H. Pittenger and C. B. Satterthwaite were sent to Los Alamos 9 June for a few days visit to get an idea of the magnitude of the problem. Meanwhile the Manhattan District authorized the Kewaunee Manufacturing Company to furnish copies of the plans of the dry boxes used for this work at Los Alamos. The report of the committee showed that several weeks training would be required of each man who would engage in the work. Since it now appeared almost certain that the company would be asked to undertake the manufacture of urchins, the same committee was returned to Los Alamos early in August for about six weeks. As a result these men brought back all the shop drawings, "know how", etc., necessary to plan facilities to carry on the work in Dayton. The first request for beryllium was filed with T. S. Chapman 6 September 1946, while preliminary plans with a bill of materials and estimate of required personnel were submitted by the committee 11 September 1946.

b. Transfer of Activities Indicated. - Meantime various telephone calls from Oak Ridge and Los Alamos made it clear the Manhattan District fully intended not only to transfer these activities to Dayton but to do so as soon as possible. Thus, 6 September 1946,

Col. R. J. Kasper called from Oak Ridge on behalf of W. J. Williams. They wanted an answer to each of three questions: (1) Could another building be erected on the present project site; (2) Could adequate space be rented in Dayton; (3) How long would it be before production could be started? The problem was to get into urchin production long before Unit 5 was due for completion. The first question was answered in the affirmative. To the third question a reply indicated that it would probably be late Spring of 1947 before production in Dayton would be possible. On 12 September 1946, Col. K. D. Nichols by letter to C. A. Thomas urged that Monsanto undertake urchin production in Dayton at the earliest possible moment. Thomas replied that the Company would be glad to do so, but not until the various processes had been engineered to reduce the hazard to personnel greatly below the then existing level. Accordingly, initial supplies and equipment were ordered. Designing of the dry boxing of all operations was pushed. Such work occupied the committee's attention during the balance of 1946.

c. Recruitment and Training. - Due to the urgency of certain administrative details and the desirability of having a first hand acquaintance with the operations as conducted at Los Alamos, M. M. Haring went to that site for three days beginning 7 October 1946. Conferences were held with Drs. Bradbury, Jette and Vier. One pressing question concerned personnel. Originally, it had been urged that local men be recruited for Los Alamos, these men to return to carry on the urchin work at Unit 5 when it should have been completed. However, this was untenable for several reasons - such as the urgency of getting the work under way in Dayton, the 25% extra "isolation" pay accorded chemists at Los Alamos, the desirability of indoctrinating all of the staff from the start in Monsanto policies, etc. Instead, it was agreed that the men should be

recruited at Dayton and about half of them be sent in small groups to Los Alamos for two months training. A $3 a day long term "subsistence" allowance was authorized by the District for such men. By 1 November, fourteen men had been signed up for this work, four by transfer from the existing staff and ten as new employees. On 6 November the first increment went to Los Alamos for training. The second increment left on a similar mission 30 December.

d. Search for Location. - Meantime, the search for quarters for the new work was pushed. Rented space was speedily ruled out. However, there was a possibility of securing Monsanto's former Unit 2, at the time operated by the Army Ordnance Department. It was also determined that a 40' x 100' "Transteel" Quonset Hut could be erected on Unit 3 property at a reasonable cost. Consideration of the merits of erecting a Quonset Hut versus utilization of some buildings at Unit 2 led to a unanimous report favoring the former. The report was submitted 3 December 1946 and construction was authorized next day. A room in the "C" building at Unit 3 was also set aside for "cold" work and partly equipped before the close of 1946. On 6 December 1946, W. J. Williams advised planning for an output utilizing practically all of the primary product. This required an immediate "upping of sights" in men and equipment and will be discussed in Chapter IX.

CHAPTER IX - BACKGROUND AND HISTORY OF UNIT 5

9-1. Conception. - The idea of setting up a polonium plant other than the one already in existence in Dayton, originated sometime prior to October, 1945. A report giving preliminary design data on such a plant was available 27 October 1945.

a. In a letter to W. C. Fernelius, dated 30 November 1945, Major M. J. Barnett stated that the X-10 advisory committee in session in St. Louis on 9 November 1945 had agreed that a new plant would be designed by Clinton Laboratories and built at Clinton Engineer Works. Until the following spring, the idea of locating the laboratory at C.E.W. persisted. However, there were some, at least faintly, dissenting voices. For instance, a letter from M. C. Leverett to W. F. Burggrabe dated 30 October 1945 revealed that the former thought a great deal of design and process research was in order before any firm plans were drawn for a plant in the neighborhood of Clinton Engineer Works. Also, B. S. Wolf, in a memorandum to W. C. Fernelius dated 13 December 1945, criticized, severely, the lack of essential health provisions. Nevertheless, a thorough survey was made for suitable sites in the Clinton Engineer Works, and the intention remained to build in Oak Ridge, Tennessee, as late as 1 March 1946.

b. Other factors began to shake the decision to build at Clinton Engineer Works. A quiet investigation of the Dayton personnels' opinion speedily revealed that only a very small fraction of the scientific staff and none of the non-technical people would be willing to work in Clinton Engineer Works. Furthermore, the fear of polonium contamination around a plutonium plant continued to increase. About this time, therefore, a search was made to locate suitable sites elsewhere. J.J. Burbage was sent to St. Louis for this purpose. In a letter dated 2 March 1946, he reported adversely on his

findings. Several sites in the neighborhood of Dayton were studied as revealed by a report signed by W. C. Fernelius on 3 April 1946. A letter from J. H. Lum to W. C. Fernelius dated 19 April 1946 stated that General Nichols now favored the location of the new plant at Dayton and that added responsibilities as well as a plant duplicating the new one were possibilities. The letter also hinted at an underground plant. Late in April, J. B. Wirth examined the Dayton choice of sites from the health standpoint. Complete surveys of the present facilities were made at that time and rough estimates made of the cost of a new plant. The Project request was submitted 10 May 1946 and envisioned a cost of $2,400,000. With construction starting in September 1946 it was estimated that useful occupancy would come in the Fall of 1947. On 20 May 1946 an urgent request came for an estimate covering an underground plant. A conference with E. R. Jette of Los Alamos was held to determine the additional cost for space and machines to make urchins. As a result, a supplementary appropriation request was submitted 21 May 1946 for $500,000. On the same date, an estimate was submitted indicating that it would cost about $1,500,000 to place the production plant underground. This made the original request total $4,400,000. Design work by the Dayton Monsanto group began in June and the first report was submitted 19 June 1946. Search for a site permitting readier burial of the production plant was resumed. On 19 July the report covering this search was submitted. The site on which building is now in progress was chosen as the most desirable from all standpoints. It is located about 1 mile from Miamisburg, Ohio directly in front of the famous Indian Mound donated to the State of Ohio, by Mr. Kettering. It comprises a little over 160 acres.

9-2. Design. - On 19 July 1946 a letter from Col. E. E. Kirkpatrick to C. A. Thomas authorized the design of the new plant for the chosen Dayton area. The plant was to be underground and proof against high explosive bombs. The Dayton group were to choose and recommend the site which would be procured by the War Department. They were also to recommend a suitable design and engineering firm, and to place above ground those buildings whose loss would not prevent production.

a. On 30 July another inspection party confirmed the choice of site and arranged for rights of entry, test drillings, etc. Careful surveys were made and 9 test drillings showed the subsurface structure to be suitable for the purpose. Curiosity of the Miamisburg folk about activities dates from this time. On 16 August 1946, Col. P. F. Kromer, Jr. authorized Dr. Hochwalt to proceed with the work most expeditiously. The same letter states officially that Col. R. J. Kasper would be assigned to the Project as Area Engineer. The latter's first visit occurred 19 August 1946 but he did not take residence here until September. On 23 August 1946 the firm of Giffels and Vallet in Detroit was recommended by Dr. Hochwalt as the choice for architect-engineer. This was approved in about four days. Space for the Area Engineer's office was assigned in the Project warehouse. Meantime, clearance was secured for a number of top men in the firm of G. & V. Supplement No. 7 to the contract covering the services of G. & V. was signed 29 August 1946. A favorable report on the test drillings was made 6 September and a security plan for the new plant set up 7 September 1946.

9-3. Negotiations. - A conference was held 12 September 1946 in the office of M. M. Haring to set up procedures and practices. Present were E. H. Buford, J. J. Burbage, F. G. Gronemeyer, M. M. Haring, C. A. Hochwalt,

and I. F. Phelps of Monsanto; R. F. Giffels, O. H. Pocock, W. D. Rausch and C. J. Steigleder of Giffels and Vallet; Col. R. J. Kasper and N. Varley of the Area Engineer's office and F. D. McKeon with I. A. Thorley of U.S.E.D. A schedule was agreed upon and data given on bombproofing for various alternatives. Giffels and Vallet began work on 24 September 1946. On 2 October 1946 authorization was given to plan for an underground structure proof against a 2000 lb. armorpiercing, jet assisted bomb. The plant was also to be protected against biological and chemical warfare. The physical properties of the Area Engineer's office and of Giffels and Vallet's design plant were established early in October. G. B. Boon was designated as contact man between G. & V. and the operations staff in Dayton. In a meeting held 28 October 1946 in the office of M. M. Haring, site plans were presented. The one using the isolated hill at the northerly end of the property was chosen as most suitable. On 9 October, F. G. Gronemeyer had recommended to the Manhattan District, the Maxon Construction Co., Inc., as the choice for constructor. This was approved 1 November 1946 in a letter from Col. Kirkpatrick. Contract negotiations with G. & V. began in Oak Ridge 14 November 1946 and the contract was finally signed 26 December 1946 to be effective 9 September 1946. The prime contract between the Manhattan District and Maxon Construction Co. was agreed upon and signed 24 February 1947 to become effective 22 November 1946. The overall figure was $17,900,000. On 18 December 1946, D. T. Parrish was designated by Monsanto as Project Manager for the construction of the new plant.

9-4. Activity. - The period from October through December 1946 was one of intense activity. The accumulation of data, conferring, carrying on experiments necessary for design, locating used equipment useful in the new plant, etc. received top priority attention.

CHAPTER X - NOTEWORTHY CONTRIBUTORS

10-1. Introduction. - The following epitomized eulogy of noteworthy contributors is not intended to be all inclusive. It is to be regretted that all of the faithful, loyal, cooperative employees contributing so much to the project history cannot be mentioned. They gave generously of their time and ability and made many valuable contributions.

a. However, during the organization, administration and supervision of this Project, certain individuals characterized themselves by outstanding contributions, - contributions which have in turn added refinement and artistry to the ever changing scientific age. Those listed made contributions of a type which includes them as foundation stones of the Project. Their success was made possible by the unstinted cooperation, coordination and synchronization of effort on the part of those not mentioned.

b. Elsewhere in this history basic trends were emphasized. Here these basic trends are personified.

10-2. Original Officers of the Dayton Project.

a. Project Director.

1. C. A. Thomas was at that time Director of Monsanto's Central Research Department, Deputy Chief of Division 8 of NDRC and Plutonium Coordinator for the Manhattan District. In the spring of 1945 he became a member of the executive board of Monsanto and Vice President in charge of research and development for the whole company. Simultaneously, with the acquisition of Clinton Laboratories, he became its Project Director. This necessitated his removal to St. Louis.

b. Assistant Project Director.

1. C. A. Hochwalt was, in the beginning of the Project, Associate Director of Monsanto's Central Research Department. When Thomas went to St. Louis, Hochwalt became Director of the Central Research Department and Project Director for the Dayton Project.

c. Laboratory Director.

1. J. H. Lum was formerly a Senior Group Leader at Unit 1, but appointed Laboratory Director in July 1943. He secured personnel, organized the laboratories and pushed polonium production through the war period. In June 1945, he was made Assistant Director of Central Research and in November 1945 left to become Special Assistant to Thomas in St. Louis.

2. W. C. Fernelius came to the Project on leave of absence from Purdue University where he was formerly Professor of Inorganic Chemistry. He became Assistant Laboratory Director in August 1943, Associate Laboratory Director in July 1945 and Laboratory Director in November 1945. He was responsible for the Chemical Processes which made possible the extraction and purification of polonium and for pushing pure research. He returned to Purdue in June 1946.

3. M. M. Haring was formerly Professor of Physical Chemistry in the University of Maryland. He was on leave of absence but decided to remain with the Project. He joined the Project as Senior Research Chemist in August 1944. Shortly, he became Group Leader in Fundamental Research. In July 1945, he was made Assistant Laboratory Director and became Laboratory Director in June 1946, which office he still holds. Recouping the heavy personnel losses following the war, the design and construction of Unit 5 and initiation of biological research and urchin production have been his major concerns.

d. Outstanding Figures.

1. J. J. Burbage was the second technical employee of the Project, preceded only by J. H. Lum. He joined the Project in August 1943. Familiarity with every phase of the project and ability to lead men made him responsible for production in the Fall of 1945 and

led to his subsequent appointment as Production Manager and lately Assistant Laboratory Director.

2. E. M. Larsen was an excellent research inorganic chemist, who joined the Project in September 1943 on leave from Wisconsin University. With Fernelius, he was largely responsible for the development of the processes used in winning pure polonium. He left to resume teaching at the University of Wisconsin in August 1946.

3. M. L. Nielsen came from Monsanto's Anniston Plant in October 1943. To him goes the credit for putting the electrolytic phase of the process on a reliable production scale. For a while he also served as Production Manager, transferring to Unit 1 in September 1945.

4. R. W. Moshier was a long time Monsanto employee who came from Unit 1 in October 1943. His broad research experience was invaluable in the analytical field, in electrolytic studies, and in extraction studies. He was the first to indict silver as the most annoying impurity in the process. He transferred to Unit 1 in July 1945.

5. C. L. Rollinson was an able process development chemist who came to the Project from Cleveland's DuPont in November 1943. He developed two processes, one of which was actually used and the other holds great promise. He left in August 1946 to teach at the University of Maryland.

6. M. L. Curtis joined the Project in December 1943 from Miami University. She holds a Master of Science degree in Physics and has done an excellent job in organizing and developing the electronic counting department.

7. R. A. Staniforth was an Inorganic Chemist who joined the Project on leave from General Aniline and Film Corporation in January 1944. He already had considerable knowledge of theoretical nuclear

chemistry and has engaged in more research phases of the work than any other man. As a result, he became in succession Group Leader for Fundamental Research and, subsequently, Chief of the Chemistry Research Section. His most outstanding contribution was the development of a purity assay involving the use of the Kirk-Craig balance. He has improved and applied the instrument in numerous ways.

8. F. J. Leitz, Jr. had the distinction of being the only member of the staff previously trained in the arts of Radiochemistry. He came from Leland Stanford University in January 1944 with valuable knowledge of the bismuth extraction process. He also initiated neutron counting work. He was transferred to Clinton Laboratories in February 1946.

9. H. R. Weimer was loaned to the Project by Manchester College in January 1944. More than any other person, he was responsible for the practical development of the lead dioxide process. He returned to his teaching in June 1945.

10. D. L. Scott joined the Project in December 1943 from Scioto Ordnance Plant of the United States Rubber Company. He became especially proficient in the design and application of sound production procedures.

11. J. W. Heyd was transferred to the Project from Unit 1 in January 1944. He was a research organic chemist with a hobby of electronics. His avocation has become his vocation. He has developed and organized the electronics section to the highest degree. He has several important electronic developments to his personal credit.

12. E. C. McCarthy is a chemical engineer who joined the Project from U. S. Rubber Company in January 1944. Through actual experience he became familiar with all the processes. This made him a logical candidate for Chief of the Design and Engineering Section, which

position he now holds. He has been a tower of strength in the intricate detail of Unit 5 development.

13. S. deBenedetti became Senior Research Physicist in February 1944. He had been teaching Physics at Kenyon College. His most important contribution was the development of numerous types of electronic counters necessary to the Project. He transferred to Clinton Laboratories in January 1946.

14. L. V. Coulter was a physical chemist who joined the Project in May 1944 and developed a new calorimeter for assaying the product. Recent modifications of this instrument have unusual speed, accuracy and sensitivity. He returned to teach at Boston University in October 1945, but frequently returned as general consultant thereafter.

The Army loaned two experienced officers for differing parts of the work.

15. Capt. Ralph Meints was a chemist, a major designer of Unit 4 and the first Production Manager. He came to the Project in the Spring of 1944 and left in the Fall of 1945.

16. Capt. Bernard Wolfe was an experienced radiologist, assigned to the Project in April 1945. He became Health Director, greatly strengthening the Health measures and increasing the awareness of potential hazards. He was transferred to the Madison Square Area in the Spring of 1946.

17. J. J. Spicka, a young businessman, joined the Project as Buyer in November 1943. He showed such an excellent grasp of business principles and ability to get things done that he became in succession Purchasing Agent and finally Business Manager, which office he holds today. He has been responsible for more jobs than any man associated with the Project.

18. H. E. Frost was the earliest non-technical employee.

He came to the Project in September 1943, and held several positions, chief of which were Captain of the Guards, Supervisor of Special Maintenance and Cafeteria Supervisor, all with commendation.

19. E. Sands came to the Project from Wright Field in November 1943. She was responsible for all the secretarial services and the supervision of Central Files. As confidential secretary to the Laboratory Director, she has an invaluable knowledge of the history of this Project.

20. W. G. Sampson was transferred to the Project from Unit 1 in November 1943. He was the architectural engineer who planned the remodelling of what became Unit 3, and designed much of the home made laboratory furniture. He was transferred to Monsanto's Nitro Plant September 1944.

21. C. Pittenger was Supervisor of the Machine Shop since his joining the Project in December 1943 from Wright Field. He has assembled a fine group of precision research machinists and a very valuable and varied collection of machine tools.

22. C. O. Dice joined the Project in January 1944 as a Master Carpenter and became Supervisor of Crafts. He did a splendid extensive remodelling job and was successful in building "whatever the chemists requested". Ill health forced him to resign in 1947.

23. P. P. Rhodes was hired in February 1944 as a driver but soon became Supervisor of Transportation. It is difficult to give sufficient credit to this man for his excellent work in this field. Though cars were few and mostly in bad condition, he saw to it that transportation facilities were available when needed.

24. S. J. Best joined the Project in August 1944. Due to his exceptionally wide experience in mechanical maintenance and ability to handle men, he has been invaluable in maintaining the process through several critical periods.

SECRET

CHAPTER XI - SUPPLEMENT

11-1. Production Figures.

a. Remark. - Production Figures are beyond the security classification of this historical report. Therefore, they form a special supplement that is available in the Area Manager's Office.

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