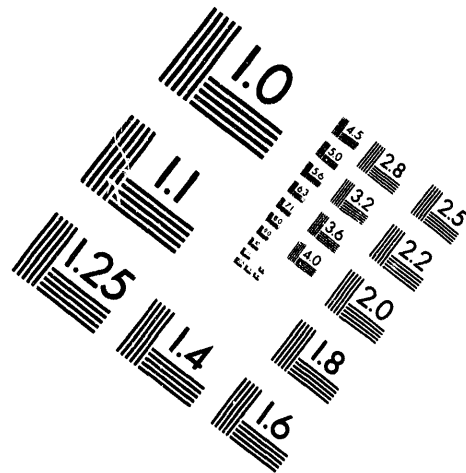
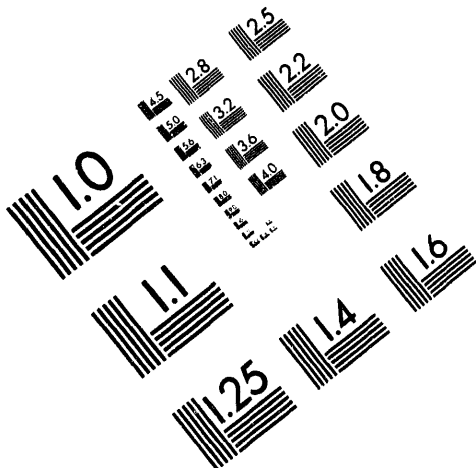




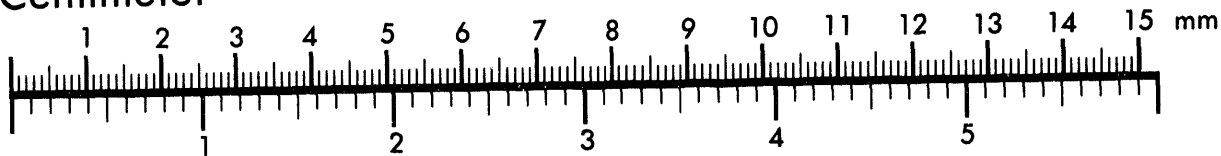
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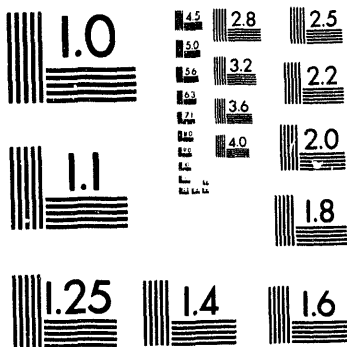
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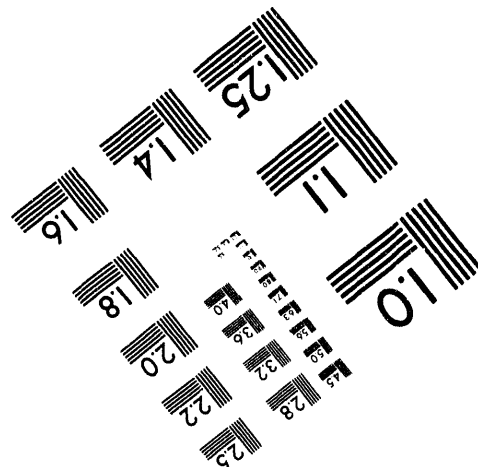
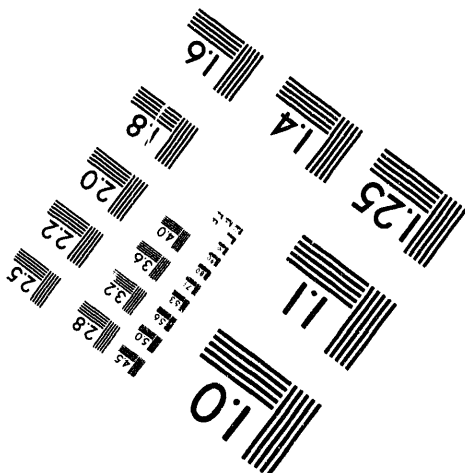
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SR/H--739

THE METAL FABRICATION PROGRAM

FOR THE
CLINTON ENGINEER WORKS
AND THE
HANFORD ENGINEER WORKS

INCLUDING
THE DUMMY SLUG PROGRAM

AND
THE UNBONDED SLUG PROGRAM - PROJECT 1553

Classification Cancelled/Changed
TO UNCLASSIFIED

By Authority of

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| 2. | <i>SWORRELL</i> | A DD | 3/29/89 |
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E. I. duPONT de NEMOURS and COMPANY, INCORPORATED
ENGINEERING DEPARTMENT - CONSTRUCTION DIVISION
WILMINGTON, DELAWARE

AUGUST, 1945

MASTER

THE METAL FABRICATION PROGRAM

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SECTION I

EXCEPTIONAL CHARACTERISTICS OF THE SLUG PROGRAM

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EXCEPTIONAL CHARACTERISTICS OF THE SLUG PROGRAM

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SECTION I

EXCEPTIONAL CHARACTERISTICS OF THE SLUG PROGRAM

INTRODUCTION

The uranium slugs, each one a small cylindrical mass of the metal enclosed within an aluminum jacket, were used as the charge into the pile for the manufacture, through nuclear processes, of minute quantities of plutonium. Acting in such a capacity, the slugs might well be considered the heart of the process: surely they represented the expenditures of vast amounts of research and developmental efforts to extrapolate on a commercial scale what until recently had been purely research data.

The employment of uranium (referred to in correspondence variously as T-metal, Tuballoy, X-metal, ~~U-10~~ du Pont Special Alloy, Chemicals NO1BN and C-105) had, prior to its inception in the present program, been confined generally to its application in small amounts, measured in grams, in the laboratory. So little was known of its commercially adaptable physical properties that it was relegated almost to the category of a laboratory curiosity. Therefore, the immediate fabrication of amounts ultimately aggregating hundreds of tons imposed an extremely difficult assignment on the du Pont Company, and necessitated the inauguration of an arduous series of experimental and developmental programs to determine not only the extrudability, machinability and other physical

characteristics of the metal, but also the influence on these of microscopic quantities of impurities present in the uranium. Because the factor of speed dominated all phases of the project, as dictated by the most urgent need for delivery of the end product at the earliest possible date, it was necessary that all developmental and experimental work be performed simultaneously with research, design, fabrication and actual construction in the Field.

The design of the Hanford Engineer Works, because of its magnitude and many unusual construction and operating characteristics, was to be determined to a very large degree upon data and information accumulated in the construction and operation of the Clinton Engineer Works. It was necessary, therefore, to assure the early completion of this plant so that essential data might be forthcoming. All efforts relating to the slug program were accordingly directed toward completion, as soon as possible, of the slug requirements for Clinton.

As incorporated in the contract, it was recognized by all interested groups that the du Pont Company had had no previous experience with the design, construction or operation of any plant even remotely similar to the Clinton Engineer Works or the Hanford Engineer Works. However, the United States Government, through its Office of Scientific Research and Development group located at the Metallurgical Laboratory of the University of Chicago, had arranged to furnish du Pont with all data relative to research, particularly in respect to nuclear physics considerations, required for the prompt

execution of design and procurement. In addition, and working under a contract placed by the OSRD, the Battelle Memorial Institute of Columbus, Ohio, was requisitioned to proceed along tangential lines to enhance and supplement any information developed at Chicago for application to the commercial production phases of research.

From time to time the services of other consultants were secured by either the Metallurgical Laboratory or du Pont as the need for their specialized knowledge became evident. Included in this group were representatives of the Massachusetts Institute of Technology, the University of Michigan, the du Pont Engineering Department Experimental Station, and the du Pont Grasselli Chemicals Department Research Laboratory.

The sole responsibility for the procurement of uranium was vested in the Corps of Engineers of the United States Army. The monetary value of this base metal was not incorporated in any of the contract negotiations, and does not appear in any cost records pertaining to either the Clinton or the Hanford Projects. Du Pont's only concern was to transform the cast billets into finished slugs.

ORGANIZATION

The procurement of uranium slugs for both Clinton and Hanford was anticipated to present a problem replete with many obstacles which would require considerable effort on the part of all interested groups before the solutions could be achieved. For this reason, the various organizations were set up so that intimate collaboration of effort and immediate

dissemination of vital information could be effected to benefit the program.

A special procurement group was organized within the War Construction Division of the Engineering Department. A carte blanche policy, in effect, was promulgated to reduce to a bare minimum any interference to the group and to permit the direction of activities in as undeviating a course as possible. This group was responsible for the determination and contracting of suitable fabricators for processing the uranium, the overall planning and scheduling of the work at the various vendors, the development of manufacturing methods, the procurement of all necessary component parts, the procurement of any special equipment required for loan to the fabricators in executing their contracts, the maintenance of accountability records, the checking and supporting of vendors' invoices, and, in short, for all matters relating in any way to the slug program.

This group worked in intimate relation with certain personnel in the TNX Division of the Explosives Department who were assigned to specific functions concerned with the slug program, and who, in the majority of cases, acted not only in a liaison capacity between the Engineering Department and the Metallurgical Laboratory of the University of Chicago but also as the interpreters of basic information with respect to operating requirements. In general, this group dictated design and quantitative requirements.

The Metallurgical Laboratory acted as the central group of all those involved in the program. This organization

carried on a considerable amount of research and experimentation, and dictated to the TNX Division the vital information derived therefrom for translation into specifications based on the requirements imposed from the standpoint of feasibility of operation. This group dictated basic design and qualitative requirements.

Responsibility for the canning, or aluminum jacketing, of active slugs was vested jointly in the special procurement group and in the Machine Development Group of the Industrial Engineering Division of the Engineering Department. This latter organization was concerned mainly with the development of manufacturing methods, whereas the War Construction Division group was interested in the procurement of component parts and the production of finished slugs concordant with requirements.

The special procurement group was assisted in its field duties by members of the Inspection Section of the Construction Division, who were assigned to cover the inspection work and the accountability records at particular plants.

At various times, when the need for additional technical personnel became necessary to conduct a study of operating conditions for determining methods of increasing the yield or for correlating billet chemical composition with extrusion performance, or for some other study, experienced men of technical training were loaned by the TNX Division to the War Construction Division for the duration of the particular work. These men remained on the TNX roll but were under

the supervision of the War Construction Division.

The Corps of Engineers was responsible for procurement and delivery to the fabricating plant of the cast uranium billets. Other of its functions were the maintenance of billet quality, conformity of billets to physical specifications, and shipment and recovery of generated scrap.

The Engineering Department was responsible for the delivery of uranium rods and the finished slugs to Clinton and to Hanford. When these were in transit this responsibility was of necessity delegated to others with the approval of the Corps of Engineers. For freight shipments the Army itself supplied guards, and for express shipments the responsibility was delegated to the express company. The fabricators themselves were accountable for the metal while in storage at each respective plant, but the cost of all guard service and protective measures necessary was reimbursable to them by the Government through du Pont.

Later in the program, when machining and canning facilities had been installed at Hanford, the TNX Division assumed responsibility for the complete fabrication of Hanford slugs from rod which had been extruded under the direction of the Engineering Department. This function included also the maintenance of accountability records for the material processed at the Project site, but did not include procurement of component parts, which still remained one of the duties of the Engineering Department until the close of the program.

As will be described later in Section X, the dummy slug program was a separate and distinct program within itself. In this endeavor the TNX Technical Division, through its operation of the experimental CMX Unit at Hanford, paralleled to a large degree the functions of the Metallurgical Laboratory. This group dictated to the TNX Division the loading patterns of the various tubes in the pile, and from this information, quantitative requirements and specifications were formulated and forwarded to the Design Division of the Engineering Department for procurement of the required dummy slugs.

Procurement of the dummy slugs was the basic responsibility of a small group in the Design Division. This group was assisted in procuring certain component parts and services, common also to the active slugs, by the War Construction Division special procurement group because of the latter's contacts and familiarity with the fabricating operations.

By the end of August, 1944, the Engineering Department had virtually completed its assignments with respect to both the active and the dummy slug programs. At this time, the TNX Division then assumed responsibility for any additional work required to satisfy procurement of operational replacement slugs, evaluations of advanced designs developed under actual operating conditions, and other work of similar nature.

The succeeding sections of this volume are devoted to a description and chronology of the part played by the Engineering Department in both the uranium and the dummy slug programs during the active life of each. Difficulties were

frequent and many, owing to the preponderance of unknowns, the paucity of information concerning the characteristics of the metal, the contaminated billets, the short tool life in machining, the development of canning methods, and many other causes. Though the need for developing fabrication methods ultimately uncovered numerous peculiarities of the uranium, these were by no means confined only to the actual physical operations of processing the metal. Others, caused by the toxicity, combustibility, or classified nature of the metal required the expenditures of considerable effort each in its own right. To understand better the succeeding sections, and to envisage more accurately the magnitude of work required in far-reaching and totally-divorced fields of endeavor, the more common of the exceptional characteristics encountered and overcome on this program are described briefly on the next few pages.

HEALTH HAZARDS

The fabrication of uranium billets into finished slugs imposed unusual conditions, heretofore not associated with commercial manufacture, which were occasioned by the radioactive and other properties of the metal itself; and thereby necessitated not only the exercising of extreme care but also the constant observance of all known precautions during all phases of handling and fabrication. These requirements, coupled with the necessity for constant adherence to protective security measures, were some of the factors that served to magnify out of all normal proportions the magnitude




8 4

of work included in the slug program.

The Engineering Department early realized the health hazards attendant to the fabrication of this metal and, on March 20, 1943, prior to the start of any actual work under this program, requested the Metallurgical Laboratory for information concerning the necessary precautions to be taken to protect the health of all individuals exposed to uranium.¹

To parallel its responsibility for the participation in the research and experimental fields associated with the slug program, the Metallurgical Laboratory assumed also the responsibility for the determination of the toxic hazards attendant to the fabricating operations. Several members of the Metallurgical Laboratory Medical Group, by this time, had been assigned to study these health problems, and as a definite part of their functions, investigated the actual fabricating operations in the vendors' plants in order to submit to the Engineering Department definite recommendations for safeguarding the health of the employees working with the metal.² The inauguration of remedial measures in line with these recommendations was the responsibility of the Engineering Department, although the Metallurgical Laboratory assisted in the follow-up at certain of the plants.³ The basic responsibility for directing the activities concerning physical examinations was vested in the du Pont Company, and all examinations and follow-up were conducted under its supervision. All medical records ultimately were to be turned over to the du Pont Medical Division.



When the program first opened, the Metallurgical Laboratory specified that, because of the possible danger of starting a chain reaction, uranium should be stored in individual stacks of specified dimensions and which aggregated not more than five tons maximum weight.⁴ This limitation imposed a distinct hardship on the fabricators⁵ and the carrier, and upon the request of the Engineering Department⁶ the Metallurgical Laboratory conducted a test which proved conclusively that no hazard from chain-reaction existed.⁷ Accordingly, all vendors were notified that these limitations were removed.⁸

The recommendations submitted by the Metallurgical Laboratory embraced two main types of precautionary measures: (1) the use of physical accessories, such as masks, respirators and gloves, for working with the metal; and (2) the determination, by means of a complete physical examination supplemented by various specimen analyses, of the physical fitness of each employee for exposure to the metal.

Because of the protective security requirements for this classified work in fabricating the uranium, all orders necessarily had to be placed before the nature and hazards of the metal could be disclosed. Although this action is contrary to normal du Pont practice, no alternate procedure could be employed under the prevailing circumstances without endangering the security of the program. For this reason, and because of the absence in literature of the toxicity of uranium, the du Pont Legal Department advanced the opinion that du Pont, acting for the Government, was legally as well as



morally responsible for safeguarding the health of all employees coming in contact with the metal.⁹ The Engineering Department informed all vendors, then or subsequently fabricating the uranium, that the cost of all protective measures - which were deemed necessary in view of the recommendations advanced by the Metallurgical Laboratory and du Pont - would be reimbursable. This included, in addition to such items as masks, respirators and gloves, the costs of all physical examinations to all employees concerned, the laboratory services attendant thereto, and the installation of adequate ventilation where necessary.¹⁰

With the fabrication program expanding to embrace machining, outgassing and straightening, canning and rolling of the metal; the Metallurgical Laboratory Medical Group visited the respective plants and made further recommendations and tests.¹¹ Among the latter was the determination of the dust count in the air near each of the operating machines, and, on the basis of these findings, a suggested tolerance limit of 150 micrograms of uranium per cubic meter of air was adopted.¹² This figure later was reduced to 120 micrograms after continued study evidenced the need for a downward revision in the tolerable limit.¹³

Many dust counts, particularly those taken at points of high local concentration, greatly exceeded the limit, and the Metallurgical Laboratory then recommended the immediate installation of adequate ventilating equipment for the areas affected or the use of respirators or masks.¹⁴ Ventilation was

provided at those shops where the benefits derived would be justified. At those few locations where the contract was of short duration, and the required time of installation would not permit any appreciable advantage, ventilation was not improved but the wearing of masks was made mandatory.¹⁵

After the first few extrusion runs had been made at Revere Copper and Brass Incorporated, in Detroit, the Metallurgical Laboratory reported that it had determined the need for the installation of ventilating equipment at this location to reduce the dust count to a safe limit.¹⁶ The Engineering Department, in confirming this recommendation, proposed that a dust collector also be installed in the system to save metal and prevent the free discharge of uranium dust to the Detroit atmosphere.¹⁷ A du Pont ventilation engineer visited the site to assist Revere with the technical aspects of the installation,¹⁸ and on the basis of this study an adequate system featuring both improved ventilation and dust collection was installed.

Entrance, periodic, and exit physical examinations were made by the plant physician, by a retained physician, or by members of the du Pont staff; as best fitted each specific case. Where an outside physician was retained, the Engineering Department issued purchase orders to cover these services and the necessary laboratory work. In the few instances where the plant medical staff performed this work, the cost of medical services was included in the fabricating order.

Upon the close of the Engineering Department's portion of work under the program, all medical records were

turned over to the Medical Division of the du Pont Company. During this period of activity a number of cases of skin irritation developed, but as these were largely confined to those employees using machining coolant in their work, the irritation was traced to properties of the coolant and not to the presence of uranium particles in the coolant. Throughout the entire program, no employee, as far as could be determined, had suffered any ill effects directly traceable to exposure to the metal.

FIRE HAZARDS

The hazards peculiar to the fabrication of uranium were by no means confined solely to those caused by the toxic or radioactive characteristics of the metal. Uranium also is readily capable of spontaneous combustion and is highly reactive under certain conditions with water. Turnings and grindings, generated during the fabrication process, thus created an extremely annoying and potentially dangerous fire hazard. Because of the pyrophoric nature of the metal when reduced to small particles, constant care during fabrication and storage of the scrap had to be observed.

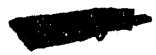
Initially it was believed that any fires due to the presence of this metal could be controlled by shutting off the supply of oxygen. Later experience, particularly during the warm weather, and subsequent tests proved that this in itself was not sufficient, and that water and proprietary extinguishers in small quantities served merely to accelerate and augment the burning. Further tests, however, proved that

large quantities of water cooled the reaction and were effective in stopping the fires. For machine turnings, this provided an adequate measure of control, but for the fine uranium powder resulting from the grinding operation some other measure had to be formulated to provide the adequate control necessary due to the high rate of activity of the fine particles with water. Storage of such grindings in small, isolated containers was possible, but shipment of this scrap to its ultimate destination could not be considered. Therefore, deliberate burning of the grindings under carefully controlled conditions was adopted to eliminate the hazard at the source, and all grindings generated were incinerated before shipment.

Considerable anxiety was felt by the various fabricators over the apparently unpredictable and spectacular hazards created by the accumulation of turnings, but by the end of August, 1943, a reasonably reliable method of controlling the hazards and extinguishing any fires that might occur was formulated. This information was then disseminated in the interests of safety to all interested parties and to the Corps of Engineers, which was responsible for the shipment and any subsequent processing or reclamation of all scrap.

METAL ACCOUNTABILITY

As might be expected of any program involving the fabrication of more than 1500 tons of a rare and expensive metal, strict and adequate controls had to be instituted and maintained to account for all uranium on hand at the various locations, whether it be in the form of cast billets, fabri-



cated pieces, finished slugs, or scrap.

Basic responsibility for the control of the metal passed to the du Pont Company at the time of transfer, from the Corps of Engineers, of the cast billets. This responsibility was delegated in part to each fabricator while the material was in his possession, with assistance being given by the du Pont representative resident at that location. The du Pont Company maintained the controls until the fabricated uranium, in one form or another, was transferred back to the Corps of Engineers, either for shipment to the Clinton or Hanford sites or after receipt at certain other Government designated destinations.

The accountability records were maintained in Wilmington by the special procurement group responsible for the fabrication of the metal. From information forwarded periodically from the Field Inspectors at each fabricating location, the operations were recorded through a double-entry bookkeeping system based on weight of the metal. Any differences in weight, due to partial or complete oxidation of the uranium, inaccurate scales, or to some other cause, were accumulated in separate accounts set up for the purpose. Statements of the accountability were prepared and submitted to the Corps of Engineers periodically and upon completion of an order.

In the fabricating operations, the uranium oxidized and became contaminated with other materials, thereby resulting in a return of scrap of a variable uranium concentration. Because of the difficulty in determining the actual concentration of this scrap, no allowance for concentration was



made in the du Pont accounting other than to identify the source and type of all scrap returned to the Government.

The greatest factors influencing the accuracy of the records were the accuracy of the scales used in weighing the metal and the assumptions which necessarily had to be made of scrap purity. Discrepancies frequently existed between the weights reported by the billet shippers and those reported by the extruding fabricators. The Corps of Engineers, in an attempt to improve this condition, authorized the purchase of suitable scales for use in weighing in the billets. The work at B. & T. Metals Company was rapidly drawing to a close, however, and a scale was not purchased for this location. Instead, the existing scale was checked and overhauled. As considerable extrusion work was planned for Revere Copper and Brass, Incorporated, this fabricator volunteered to purchase two suitable scales capable of indicating correctly to one ounce. Later in the program it also became necessary to purchase scales for inventorying the metal at certain other locations.

Facilities were provided in the 300 Area at Hanford for the fabrication of extruded rods into finished slugs. Upon arrival of the rods at the site, the Operating Department assumed the responsibility for the accountability during receiving and subsequent fabrication. The receiving weights of these shipments generally were in excellent agreement with the shipping weights from Revere.

SCRAP

All billets originally fell into one of three classes, depending upon the purity of the metal as determined by analysis of a test sample cut from the billet. The Metallurgical Laboratory, in agreement with the Corps of Engineers, advised the Engineering Department on March 29, 1943 that all solid scrap accumulated during fabrication should be segregated by class to prevent lowering the purity, and that turnings and other contaminated material should be segregated further into two other classes dependent upon the degree of contamination from outside sources such as coolant and oxygen.¹⁹ The Engineering Department then set up the scrap segregation procedure in accordance with these directions, but, as a result of a meeting with the Corps of Engineers on May 27, 1943, soon revised the procedure to specify that machine turnings would not be segregated by source, class, or billet number.²⁰ These would continue to be segregated from oxidized metal, scale or sweepings, but all would be accumulated without classification or further segregation. This general breakdown was maintained throughout the life of the program, although in certain specific cases additional segregation was made at the request of interested groups to permit experimental work in reclamation of scrap,²¹ or to prevent contamination caused by scrap from impure billets which contained relatively high percentages of iron or some other contaminant.²²

Scrap slugs were utilized whenever possible in the experimental work attendant to the program in order to release equal quantities of acceptable slugs for production purposes.²³

This was particularly true in connection with coating processes being developed both at the Metallurgical Laboratory and at the Grasselli Chemicals Department Research Laboratory. When their use was no longer required at these locations, the slugs were returned as scrap.

Du Pont's responsibility for the control ceased upon the transfer of the scrap, suitably boxed for shipment, to the Government representative at each fabricator's plant. Shipment, and any subsequent processing or reclamation, were the responsibility of the Corps of Engineers.

In the early days of the program the billet suppliers had no satisfactory means of recovering the turnings for future production. Although solid scrap was reclaimed easily by recasting, turnings were usually contaminated with coolant and were in various degrees of oxidation. The storage of these became a problem of great importance to the fabricators, owing usually to the limited storage area available, the necessity for guarding, and the ever-present possibility of a fire. The Corps of Engineers requested du Pont to arrange for the shipment of these turnings from their source to storage igloos in the Pennsylvania Ordnance Works. This was done, with the Corps of Engineers assuming the responsibility for the material during transit and subsequent storage.

Later in the program, however, suitable methods were developed for reclaiming the turnings and grindings. Every effort was made by the Engineering Department to return to the Corps of Engineers all uranium, even to the extent of

sweepings and considerable ground in the vicinity of the sludge burning furnace at one location, for recovery of the metal.

When the program drew to a close in August, 1944, strict accountability records for all scrap accordingly were required. To effect this end, accounting was taken of all sample pieces and scrap, and in addition, the ventilating and dust collecting systems installed at Revere Copper and Brass, Incorporated were cleaned to collect all possible deposits of the metal. Upon the completion of this task and of the attendant records, responsibility for the direction of any subsequent work required passed on to the TNX Division.

VALUATION

Because of the apparent high valuation placed on uranium, the Engineering Department requested from the Corps of Engineers, at the start of the program, information concerning the necessity for the various fabricators to purchase insurance to cover any possible loss while the metal was in their possession. Since the obtaining of insurance would have required disclosure of the nature of the material, the Corps of Engineers accordingly advised, on April 10, 1943, that no insurance was to be purchased on materials owned by the United States while in possession of du Pont or its subcontractors, inasmuch as it was believed that adequate protection would be afforded du Pont under the formal contract.²⁴ This information was relayed to all interested vendors and the following clause was then incorporated in each purchase order:²⁵



"The vendor shall not be required to purchase insurance against loss of or damage to the materials in his possession owned by the U. S. Government and consigned to him for fabrication, and the vendor shall not be liable for any such loss or damage".

This clause, however, in no way altered the vendor's responsibility under the United States Army protective security rules which also were incorporated in the order.

A valuation was placed on the fabricated uranium for express shipment, not for insurance protection but to assure special and unusual care, such as armed messenger service, in handling and expediting shipments. Until June 11, 1943, by Government instruction, a valuation of \$20 per pound was used, after which time a valuation of \$15 per pound was used as the basis for computing valuation.²⁶ This reduction was made in the interests of economy after du Pont advised the Corps of Engineers that the same special services would be extended by the express company for the lower figure. Truck shipments of turnings were made by the Government at nominal valuation, but with Government armed guard.

SECTION II

EXTRUSION



EXTRUSION

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SECTION II

EXTRUSION

INTRODUCTION

One of the most urgent items requiring consultant service was in the fabrication of uranium rods from cast billets. Through experiment it had been established that uranium could be extruded, and though little else was known of its physical characteristics, it was agreed that production of the slugs should start from extruded material. Working on this basis, the Engineering Department therefore initiated steps to secure the extrusion of cast billets into rods, for subsequent machining and other operations to produce the finished canned slugs.

EXTRUSION

To secure as much geographical advantage as possible, du Pont undertook to investigate various fabricating shops located in the Middle West in comparative proximity to the consultants. Accordingly, in February, 1943, an intensive survey of the facilities in this area developed the fact that the B. & T. Metals Company in Columbus, Ohio, had the equipment and manpower available to extrude uranium in production quantities. Purchase Order XPG-123-1/2 was soon placed on this vendor for the extrusion of cast billets into rods for the Clinton Engineer Works. Also, the Battelle Memorial Institute was requested to supply any and all con-

sultation services required by either the du Pont Company or the B. & T. Metals Company in connection with this work.¹ The cost of these services was, of course, to be charged to Battelle's OSRD Contract and not to the du Pont Company.

The extrusion operations practiced at B. & T. Metals Company were essentially the same as those used commercially for the production of extruded aluminum, alloys, and other non-ferrous metals. The only variations from normal practice were in the employment of higher temperatures, different pressures, the development of hard-faced dies and dummy blocks, the prevalence of oxide, the strict accountability for all amounts of the metal in all stages of fabrication, and the provision of certain protective health measures to the employees.

The first extrusion at this plant was performed on March 31, 1943, when 12 billets aggregating 1021 pounds were extruded into rod. A quantity of this rod was subsequently machined into slugs and the pieces shipped to the Metallurgical Laboratory for further experimental and research work.

Throughout the entire slug program these frequent requests were made, either through the Corps of Engineers or directly to the du Pont Company, for the delivery of quantities of uranium in various stages of fabrication to the different consultants for the determination of analytical data. It is readily discernible, therefore, that numerous changes in design and manufacturing techniques were subsequently made in accordance with information developed, thus placing a

tremendous burden on the du Pont Company and on the fabricators for the immediate changeovers required.

B. & T. Metals Company's contract stipulated that it was to convert at least eighty percent of the gross weight of billets into sound extruded rod. If its yield was below this percentage, it was not entitled to payment for extruding that particular billet. B. & T., therefore, had the privilege of examining all billets and rejecting them for extrusion if the billets were less than 9-1/2" long or if, in its opinion, the billets contained surface defects which might grade the extruded rod to less than the eighty percent of sound rod required. (This figure later was reduced to seventy percent.) However, in the interests of expediting production, if the du Pont Company felt that the billets rejected by the B. & T. Metals Company would yield as much as, say fifty percent gross billet weight of sound rod, the eighty percent of sound rod requirement could be waived.

This waiver was enforced on several occasions, principally during runs of special billets on which the Corps of Engineers had requested special reports noting the behavior of the billets during extrusion,² in order that data might be accumulated upon which its future action regarding billet quality would be governed.

To secure the most effective extrusion production consonant with requirements, it was necessary that du Pont coordinate its schedule of requirements of extruded rod from the fabricator with the billet supply. On May 19, 1943, the first schedule showing the maximum and minimum number of tons

to be extruded during each run was forwarded to the B. & T. Metals Company.³ This schedule covered the extrusion of 137.8 tons of uranium for the period extending from May 24 through July 7, 1943.

In order to provide a factor of safety in guaranteeing the continuance of extrusion in the event of mechanical failure at B. & T., as well as to develop additional facilities to handle the future requirements for Hanford, the du Pont Company, in May, 1943, investigated various plants⁴ in the Middle West and on the West Coast, with the result that Purchase Order XPG-773-1/2 was placed on Revere Copper and Brass Incorporated, Detroit, Michigan, for the extrusion of billets into sound rods to fulfill the balance of the requirements for the Clinton Engineer Works.

By June, 1943 extrusion had been demonstrated to a point where it was no longer experimental, but nevertheless was still capable of considerable improvement.⁵ However, a general review of the process was thought necessary and, from a discussion between representatives of Battelle Memorial Institute and the du Pont Company, it was the consensus that, of the many variables and unknowns still encountered in the process, certain changes in equipment (such as the development of a more reliable method of heating) and changes in operating technique (such as effective removal of oxide from the cylinder) would conceivably improve the operation. It was believed that these and other points would be determined definitely at Revere.

Other causes for retarded improvement in the process were traceable to the prevalence of defective billets,⁶ sub-standard for either physical or chemical reasons, the elimination of which was being actively pursued by the Corps of Engineers. It will be found later in this Section that these defects in the billets were the underlying causes for an "epidemic" of extrusion failures at Revere.

The first extrusion run at Revere under purchase order XPG-773-1/2 was performed on Saturday and Sunday, July 24 and 25, 1943. All runs at this location, on this and subsequent orders, were made on weekends because security limitations prevented their execution during the normal work-week. However, no difficulties were manifested in this arrangement.

The results of this first run indicated that further improvement in extrusion could be expected,⁷ and subsequent runs confirmed this belief. A contributing factor in this increase in yield was the work of the Revere technical staff, which cooperated fully in all endeavors for improvement throughout the life of the contract. In fact, the anticipation of this reception was largely responsible for Revere's being awarded the extrusion contract.

However, prior to this first extrusion run at Revere, the requirements for Hanford had crystallized sufficiently to permit the du Pont Company to secure quotations for extrusion. Accordingly, on July 16, 1943, quotations on a unit price basis were requested from both the B. & T. Metals Company and Revere Copper and Brass Incorporated for the

extrusion of a quantity of rod approximately 1.470" in diameter.

The rate of extrusion was estimated to be approximately 120 tons per month, starting in August. The minimum quantity would be 200 tons and the maximum approximately 600 tons. It was believed that this quantity would be sufficient until such time as facilities and equipment for extrusion were installed at Hanford.

Revere quoted a price of thirty-seven cents per pound of finished rod, whereas B. & T. Metals Company quoted thirty-five cents per pound on gross billet weight. According to the yield figures obtained up to this time the Revere price should be approximately one to two cents per pound cheaper than that of the B. & T. Metals Company, since the weight of rod was approximately 92% of the weight of billet.

The cost of 600 tons of finished rod at Revere Copper and Brass Incorporated would be \$444,000.00.⁶ The probable cost of a similar quantity at B. & T. Metals Company, based on past performance, would be \$456,500.00.

Immediate approval was requested and secured from the Corps of Engineers⁹ in order that purchase order RPG-704-1/2 could be placed on Revere to enable the start of extrusion of Hanford size rod on August 22, 1943.

The Battelle Memorial Institute had been working constantly on the problem of extrusion as practiced at the B. & T. Metals Company. As a result of these efforts, it was suggested since the largest potential increase in yield lay in the extrusion of smaller diameter rod, and thus reduce

the loss by machining to a minimum, that this avenue of endeavor be investigated.¹⁰

The du Pont Company had been aware of this potential improvement,¹¹ but had recognized that it could not be developed until surface imperfections had been minimized. By the end of August, 1943, however, and through the cooperation of Revere, the improvement of yield and rod surface had reached the point whereby the extruded rod diameter might be decreased. Some rods of smaller diameter had already been prepared for evaluation, and still further reduction would be made as soon as this was justified.

This possibility of reducing the extruded rod diameter paved the way for tangential endeavors aimed at developing alternate methods of production through the media of drawing, swaging or rolling. The investigation of these possibilities was undertaken and is described in Section III of this volume.

Meanwhile, purchase order XPG-123-1/2 on the B. & T. Metals Company had been completed with the extrusion run of August 3, 1943. During the life of this contract a total of 336,108.25 pounds (168.054 tons) of uranium billets were extruded into rods at a total cost of \$130,597.13, resulting in an average cost of 38.86 cents per pound of gross billet weight, or 43.00 cents per pound of gross rod weight. This total weight was composed of 300,804.50 pounds of billets extruded into Clinton-size rods, and 35,303.75 pounds into 1.445" rods required for use in the Test Pile at the University of Chicago.

Purchase order XPG-773-1/2 on Revere similarly was completed on August 29. Under this contract 170,122.50 pounds (85.061 tons) of billets were extruded to 152,845.25 pounds (76.423 tons) of rod at a total cost of \$67,579.15, resulting in an average cost of 39.72 cents per pound of gross billet weight or 44.21 cents per pound of gross rod weight.

However, in reducing these two orders to the same basis for comparison, it is found that the B. & T. order averaged approximately 48.3 cents per pound of sound rod produced against 47.6 cents for the Revere order.

Tabulations summarizing the performances of these two orders are included herein on pages 29 and 30.

From an analysis of the first few extrusions at Revere under order RPG-704-1/2 it was believed that an increase in billet size, particularly in the length, would result in a greater yield to good rod.¹² To determine the effect of this belief, 25 billets each of 5" diameter by 11" long, 4-1/4" diameter by 14" long, and 4-1/4" diameter by 20" long, were ordered from the Corps of Engineers. Subsequent extrusion confirmed the fact that improved yield could be obtained through the use of billets of a size at least equivalent to the 5" x 11",¹³ but the extent to which this size could be exceeded required further experimentation. After ensuing tests had been made the size was standardized at 4-1/4" diameter by 13-1/2" long,¹⁴ which, in the Corps of Engineers' specifications, was designated as "Form 7".¹⁵

EXTRUSIONS AT B. & T. METALS COMPANY ON XPO-123-1/2

| <u>Date</u> | <u>Rod Dia.</u> | <u>No. Billets</u> | <u>No. Rods</u> | <u>Billet Weight</u> | <u>Rod Weight</u> | <u>Average Bil. Wt.</u> | <u>Average Rod Wt.</u> | <u>Rod Yield</u> | <u>Sound Rod Yield</u> |
|--------------|-----------------|--------------------|-----------------|----------------------|-------------------|-------------------------|------------------------|------------------|------------------------|
| 3-31-43 | 1.4 | 12 | 12 | 1,021.00 | 910.00 | 85 | 76 | 89.0 | 81.2 |
| 4-3 | 1.4 | 87 | 87 | 7,956.75 | 7,254.25 | 91 | 83 | 91.0 | |
| 4-7 | 1.4 | 154 | 154 | 14,360.75 | 12,750.25 | 93 | 83 | 88.8 | |
| 4-7 | 1.2 | 4 | 4 | 331.25 | 306.75 | 83 | 77 | 92.6 | |
| 4-15 | 1.2 | 3 | 3 | 291.00 | 262.00 | 97 | 87 | 90.0 | 84.1 |
| | 1.4 | 126 | 126 | 11,965.25 | 10,457.25 | 95 | 83 | 87.5 | 77.1 |
| 4-15 | 1.2 | 3 | 3 | 239.50 | 186.75 | 80 | 62 | 78.0 | |
| 4-29 | 1.2 | 26 | 11 | 2,526.75 | 923.75 | 97 | 84 | 36.5 | 32.7 |
| 5-5 | 1.2 | 150 | 150 | 14,268.75 | 12,739.00 | 95 | 85 | 89.4 | 76.8 |
| 5-12 | 1.2 | 150 | 150 | 14,594.75 | 13,148.75 | 97 | 88 | 90.1 | 76.5 |
| 5-20 | 1.2 | 2 | 2 | 172.00 | 153.25 | 86 | 77 | 89.1 | 89.1 |
| 5-20 | 1.2 | 156 | 155 | 14,932.50 | 13,080.00 | 96 | 84 | 87.5 | 79.3 |
| 5-21 | 1.2 | 180 | 180 | 16,987.25 | 15,065.50 | 94 | 84 | 88.7 | 73.4 |
| 5-26 | 1.2 | 100 | 100 | 9,565.75 | 8,410.50 | 96 | 84 | 88.0 | 75.5 |
| 5-28 | 1.2 | 210 | 210 | 19,608.00 | 17,360.50 | 93 | 83 | 88.5 | 80.5 |
| 5-29 | 1.2 | 160 | 160 | 14,917.50 | 13,553.50 | 93 | 85 | 90.8 | 83.0 |
| 6-9 | 1.2 | 200 | 200 | 18,088.00 | 16,717.25 | 90 | 84 | 92.5 | 76.0 |
| 6-9 | 1.2 | 1 | 1 | 96.50 | 84.00 | 96 | 84 | 87.0 | 79.8 |
| 6-11 | 1.2 | 200 | 200 | 18,717.25 | 16,782.00 | 94 | 84 | 89.5 | 79.4 |
| 6-12 | 1.2 | 200 | 200 | 19,452.50 | 17,677.00 | 97 | 88 | 90.8 | 77.9 |
| 6-14 | 1.2 | 200 | 198 | 19,020.75 | 17,502.50 | 95 | 88 | 92.0 | 83.0 |
| 6-15 | 1.2 | 200 | 200 | 16,098.25 | 14,899.00 | 80 | 74 | 92.5 | 82.1 |
| 6-16 | 1.2 | 200 | 200 | 18,237.25 | 16,638.50 | 91 | 83 | 91.2 | 82.8 |
| 6-21 | 1.2 | 240 | 239 | 22,708.25 | 20,958.25 | 94 | 88 | 92.3 | 81.6 |
| 6-22 | 1.2 | 240 | 240 | 21,857.50 | 20,153.25 | 96 | 84 | 92.1 | 82.8 |
| 6-23 | 1.2 | 4 | 4 | 383.00 | 357.25 | 96 | 89 | 93.2 | 84.3 |
| 6-23 | 1.2 | 227 | 226 | 20,648.75 | 18,450.00 | 91 | 82 | 89.2 | 79.5 |
| 8-3 | 1.2 | 203 | 202 | 18,526.25 | 16,924.25 | 91 | 84 | 91.4 | 84.1 |
| Total | | <u>3638</u> | <u>3617</u> | <u>337,573.00</u> | <u>303,705.25</u> | <u>93</u> | <u>84</u> | <u>90.00</u> | <u>80.5</u> |

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EXTRUSION RUNS AT REVERE COPPER AND BRASS INCORPORATED ON XPG-773-1/2

| <u>Date</u> | <u>Rod Dia.</u> | <u>No. Billets</u> | <u>No. Rods</u> | <u>Billet Weight</u> | <u>Rod Weight</u> | <u>Average Weight</u> | | <u>Rod Yield</u> | <u>Sound Rod Yield</u> |
|--------------|-----------------|--------------------|-----------------|----------------------|-------------------|-----------------------|------------|------------------|------------------------|
| | | | | | | <u>Billet</u> | <u>Rod</u> | | |
| <u>1943</u> | | | | | | | | | |
| 7-24, 25 | 1.2 | 400 | 399 | 37,434.75 | 32,360.75 | 94 | 81 | 86.4 | 79.7 |
| 7-31, 8-1 | 1.2 | 500 | 498 | 46,219.75 | 40,930.25 | 93 | 82 | 88.5 | 83.8 |
| 8-14, 15 | 1.2 | 620 | 614 | 56,673.25 | 52,007.50 | 91 | 85 | 91.9 | 85.4 |
| 8-21, 22 | 1.2 | 309 | 309 | 29,356.25 | 27,139.00 | 97 | 88 | 92.4 | 84.6 |
| 8-29 | 1.2 | 5 | 5 | 438.50 | 407.75 | 88 | 82 | 93.0 | 76.7 |
| Total | 1.2 | 1834 | 1825 | 170,122.50 | 152,845.25 | 93 | 84 | 89.6 | 85.5 |

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LOW-TEMPERATURE EXTRUSION

On November 27, 1943, the Engineering Department learned that the Metallurgical Laboratory had reported that uranium rods had been successfully extruded from billets at low temperatures.¹⁶ The surface of the rods produced was excellent, and there was no cracking as with rods extruded at higher temperatures. The Metallurgical Laboratory also claimed that a better yield could be obtained by extrusion in the lower zones due to marked reduction in surface cracking at the end of the rods. Thus, based upon this report, the TNX Division requested the Engineering Department to make arrangements for a trial run on a number of billets at Revere for extrusion at lower temperature.¹⁷ Permission for running this test was secured from the Corps of Engineers on February 2, 1944.¹⁸

The test was performed on February 19, 1944, but due to the paucity of information previously received from the Metallurgical Laboratory on this method of operation, the results were not too encouraging.¹⁹ After the TNX Division had subsequently requested additional data from this group on temperature-phase relation, another test was attempted with no success,²⁰ as it developed that the Revere equipment was not of sufficient capacity to provide conclusive results for commercial production by this method.

In May, 1944 the Metallurgical Laboratory conducted similar tests at another location under its supervision.²¹ After subjecting the resultant machined slugs to supersonic tests and sectioning for inspection of visible internal de-

fects, it concluded that the quality was not high enough to justify further experimental work.

BILLET QUALITY

As mentioned previously, the Corps of Engineers was responsible for the procurement and delivery of the cast uranium billets to the du Pont representative at each fabricator's plant. This group was responsible too for the adherence by the suppliers to the billet specifications,²² for both the physical characteristics and the chemical composition of the billets.

However, as might be expected of any new development that literally "mushroomed" in a very short while, the suppliers at various times found it extremely difficult to conform strictly to the specifications. Many times during the course of the program their stock contained varied amounts of billets which were sub-standard in one²³ or more²⁴ respects.

Because of the many unknowns relating to the workability of the metal, the billet specifications of necessity were quite stringent. Too, the presence of a relatively high percentage of contaminants in the uranium was thought to be deleterious to its ultimate activity in the pile. These factors all contributed to the accumulation of sub-standard billets. In an endeavor to utilize as many of these as possible, and to make deliveries in accordance with extrusion or rolling requirements; as well as to test the behavior of these particular billets under actual fabricating operations with the objective of relaxing the specifications where possible,

the Corps of Engineers often requested the du Pont Company to accept, for special observation, these billets for extrusion and subsequent fabrication.

The metal procurement program by the Corps of Engineers resolved itself basically into several factors, the first and foremost of which was to supply billets to the du Pont representative at each fabricator's plant in sufficient quantities to meet production requirements. Although the acceptable limits of impurities in the billets were unknown at the start of the program, it was believed that, while the prevalence of these impurities in relatively small amounts would perhaps alter the physical characteristics of the uranium to the point where its subsequent fabrication into slugs would be rendered difficult,²⁵ the primary purpose had been achieved in the act of delivering the metal for fabrication. It was recognized, too, that the programs inaugurated at the various suppliers' plants in establishing facilities for the earliest possible refining of the metal were of such paramount importance that various advancements in operating technique had not yet been developed to the extent that impurities could be kept to the desirable minimum. Various consultants, working under contracts placed by the Government, were busily engaged in research and developmental work to improve billet quality and to determine the effects of impurities with respect to the end use of the slugs.

It subsequently developed that the presence of contaminants was quite objectionable from a physical standpoint.

with high manganese content perhaps might cause disintegration in the furnace, or failure at some later step in fabrication.³² Combinations of these impurities were similarly reported by heat number by the Corps of Engineers. Still later reports by this group placed a maximum iron content of 300 ppm for the billet composition.³³

In addition to these reports mentioning the downward trend in the maximum allowable iron content, the Corps of Engineers at various times informed the du Pont Company of other indications relative to behavior caused by certain physical characteristics or chemical impurities in the billets. In many cases these interpretations of the data were made independently of the du Pont Company;³⁴ at other times they were released only after joint discussion between representatives of the two groups.³⁵

On February 28, 1944 the Corps of Engineers advised that approximately 1%-2% of all billets shipped for extrusion failed to give satisfactory rods, either because of burning in the preheating furnace or because of severe cracking or disintegration after extrusion. Results to this time had shown that a large portion of these extrusion failures were closely related to the presence of relatively large amounts of iron in the billets.

On March 17, 1944 it further advised that its study of a considerable amount of data had shown that more than 75% of all billets having an iron content of greater than 300 ppm failed during the extrusion operation.³⁶

The Corps of Engineers recognized and appreciated the fact that, throughout the life of the Engineering Department's interest in the extrusion program, the du Pont Company had assigned various of its technical personnel to observe, study, and correlate the behavior of billets to physical and chemical characteristics.³⁷ The resultant interpretations of these accumulated data assisted in no small way the allied work being performed by the Corps of Engineers.³⁸ This collaboration of effort was dominant throughout the entire program, but became most pronounced during the intensified study made from January to May, 1944; the period during which extreme difficulties were experienced in extruding good rod.³⁹ This study is recounted more fully later in this section, under the heading "Extrusion Improvement Program".

BILLET SIZE

The original billet size for extrusion under this program was designated as "Form 5", which was basically of cylindrical shape, 4-1/4" plus or minus 1/8" in diameter by 10" plus or minus 1/2" in length, with a small-diameter projection, or "egg", cast on the bottom end for sampling purposes. These dimensions were specified in order to conform to the size which could be used in the equipment at the B. & T. Metals Company.⁴⁰ Subsequent developments necessitated first reducing the length to 10-1/4"⁴¹, later increasing it to 11-1/4" maximum.⁴² The length was ultimately stabilized at 13-1/2" maximum.⁴³

The Engineering Department on several occasions

requested quantities of oversize,⁴⁴ double-length,⁴⁵ or square billets for developmental work on extrusion and rolling. These sizes were never recognized in the billet specifications as their subsequent performances on the equipment used did not justify acceptance. This, however, did not preclude the future consideration of larger billets for Hanford, which could be determined only by additional experimental runs by the TNX Division after the equipment was installed on the project site.

EXTRUDED ROD DIAMETER

The extruded rod diameters remained fairly constant throughout the program, the few changes that were made in the Hanford size rod having been done at the request of the TNX Division as a result of interpretations of accumulated data from developmental and research work.

On March 30, 1943 the du Pont Company confirmed prior verbal advice to the B. & T. Metals Company that, until further notice, all extrusions would be made to produce rod of either 1.445" diameter or of 1.260" diameter.⁴⁶ However, only four runs, totalling 379 rods and aggregating 31,371.25 pounds of extruded rod weight, were made to the larger diameter for use in the Test Pile at the University of Chicago. The balance of the order, amounting to 3238 rods of 272,333.50 pounds extruded rod weight, was made to the smaller diameter for Clinton.

The five extrusion runs at Revere Copper and Brass Incorporated on purchase order XPG-773-1/2 were all made at

1.23" rod diameter. During these runs a total of 1825 rods were extruded, aggregating 152,845.25 pounds of extruded rod weight.

When Revere started extrusion on August 21, 1943 on purchase order RPG-704-1/2 the diameter of extruded rod produced was 1.45 inches. On September 27, after 2511 rods totalling 206,241.50 pounds had been extruded, the TNX Division advised that, starting with the run on October 2 and continuing until further notice, the rod should be extruded to a diameter of 1.49 inches.⁴⁷ This diameter continued in effect until the run of January 22, 1944, for which the TNX Division had further revised the specifications to a rod diameter of 1.46 inches.⁴⁸ During the period from October 2, 1943 to January 22, 1944, 6231 rods totalling 581,658.14 pounds had been extruded to the 1.49" diameter.

From January 22, 1944 to the last extrusion run on this order, on August 20, 1944, the diameter remained unchanged at 1.46 inches. During this time 13,114 rods totalling 1,443,235.29 pounds were extruded.

On a few occasions small quantities of rods were extruded to smaller diameters for experimental or other work. These requests were taken care of during the normal extrusion periods and amounted to:

1. 260 rods of 1.19" diameter totalling 24,427.66 pounds
2. 41 rods of 0.89" diameter totalling 3,789.25 pounds
3. 20 rods of 1.20" diameter totalling 1,896.30 pounds

EXTRUSION IMPROVEMENT PROGRAM

After the initial extrusion problems at B. & T.

Metals Company and at Revere Copper and Brass Incorporated had been solved, the yield from billet to good rod showed a steady improvement up to the end of December, 1943. However, it was discovered that a substantial portion of the rod extruded for subsequent machining and canning at Hanford Engineer Works contained at least potentially serious defects in the form of cracks, holes, porosities, and inclusions of scale.⁴⁹ To combat this problem, the Engineering Department, later assisted by the Corps of Engineers,⁵⁰ Metallurgical Laboratory,⁵¹ Battelle Memorial Institute⁵² and the TNX Division, undertook an extensive program to determine the causes therefor.

As soon as this condition was discovered, the Engineering Department undertook machining tests on samples of representative extruded rods to determine the extent of the defects.⁵³ At the same time the Hanford Engineer Works was instructed by the TNX Division to perform similar tests on samples of rod it had received.⁵⁴

To follow this program actively to a satisfactory completion, the Engineering Department requested and secured from the TNX Division the loan of a technical specialist, to be resident full-time at Revere, for the accumulation and correlation of data from which the unknowns could be determined.⁵⁵ A part-time representative of the Industrial Engineering Division, who in the past had been assisting in the development of extrusion, was also assigned to this problem. These men were under the direct supervision of the Engineering Department for the duration of the study, and one or both of them covered virtually every extrusion run at Revere from

January, 1944 to the close of the contract in August, 1944.

From the start of this study it was believed that a contributing factor in causing the defects known to be present in the metal, as evidenced by inspection after the cutting and sectioning of the extruded rod, was due to imperfections in the cast billet itself.⁵⁶ From previous indications advanced by the Corps of Engineers it was also believed quite probable that the presence of chemical impurities in the billet was a definite contributing factor.⁵⁷

On the basis of these indications, the Corps of Engineers, inasmuch as it was its direct responsibility to maintain high quality billets for extrusion, together with representatives of the Clinton Laboratories, the du Pont Company, and the Battelle Memorial Institute, held a meeting at the Revere plant on February 4, during which it was agreed that the runs of February 5-6 and February 12-13 would be devoted to experimental extrusions. However, no conclusive data were secured from these runs.

The Corps of Engineers later reported that approximately 1% to 2% of all billets shipped for extrusion failed to give satisfactory rods, either because of burning in the preheating furnace or because of severe cracks or disintegration after extrusion.⁵⁸ Results had shown that a large portion of these extrusion failures were closely related to the presence of relatively large amounts of iron in the billets. It also stated that the cause of imperfections of the type prevalent at Hanford; namely, stratification, fine cracks, and the like, in the interior of the rods, was unknown.

Since these internal imperfections could not be detected by inspection of the surfaces of the extruded rods, study of their cause and nature required careful examination of machined sections of the rods.

It was the consensus that the du Pont Company should continue its sectioning of rods at the Revere plant and to attempt a further correlation of billet behavior during extrusion with chemical composition, as data had shown that approximately 75% of all high-iron billets either burned in the preheating furnace, failed during extrusion, or the rods failed during straightening; and also that analyses of the runs of January 22-23 and February 19-20 indicated that the severe cracking of the rod was related to billet composition.⁵⁹

Later it was definitely established that burned billets, extrusion failures, and cracked rods could be coordinated reasonably well with chemical composition and other characteristics of the original billets.⁶⁰ This had been established to the extent that failure of certain billets could be predicted under normal extrusion conditions. Specifically, a difference of a few parts per million of certain impurities in the metal, such as iron, manganese and nickel in the analysis of the composition, made a very considerable difference in the behavior of the billets during extrusion.

It was also believed that porosity, intense cracks and spongy metal were due, in part, to the characteristics of the billet material; but on the other hand were also re-

lated to extrusion conditions. It was felt that even if the physical operation of extruding was improved, solid metal could not be obtained in an extruded piece unless the billet itself was sound.

These indications provided a firm basis upon which to coordinate the activities of the various groups involved in the program. The Corps of Engineers became actively engaged in improving billet quality, both with respect to the improvement of physical characteristics and the reduction of chemical impurities. Its representatives visited the fabricators' shops⁶¹ and the Hanford Engineer Works⁶² to establish direct contact with the problems under consideration and to obtain basic information by which its efforts could be better directed to secure an early solution. As an initial step, it placed a maximum iron content of 300 ppm in acceptable billets.⁶³

While the Corps of Engineers was pursuing these avenues of responsibility, the du Pont Company continued along various paths which ultimately would lead to improvement in the physical operation of extrusion. Many possibilities were explored, some resulting in few or no definite conclusions upon which to base any correlation, whereas others produced gratifying results. In addition, many tangential attacks either were made or planned on the elemental breakdowns of each operation⁶⁴ as the study became more involved, in order to investigate further any possible factors contributing to the prevailing conditions.

During a meeting in Wilmington on March 17, 1944

it was reported that since the middle of December, the yields had shown less uniformity and the level had dropped slightly.⁶⁵ The weighted average of the three best yields during this period was 88.7 percent.

These figures showed that a 2.2 percent difference existed between the average yield since January 1, 1944 and the average of the three best yields. This 2.2 percent loss amounted to over 9,000 pounds of metal having a rework value of the order of \$90,000. The incentive for additional work therefore was clearly indicated, particularly since it might be possible to develop a method of satisfactorily extruding billets of poorer quality, and since the higher yield anticipated from the larger average billet size had not been realized.

Continued experiments at Revere, under du Pont supervision and direction, soon established the fact that very few failures occurred during runs in which the iron content in the billets was limited to 300 ppm maximum, and that these failures were found to be assignable to other known difficulties.⁶⁶ Other conclusive data also were determined, an analysis of which indicated that a very influential factor in extrusion was temperature control, both in the furnace and in the press.⁶⁷

By May, 1944 the inspection of cut slugs from forty-five rods machined at Baker Brothers, Incorporated showed emphatic progress in the reduction of internal flaws, cracks, and other imperfections.⁶⁸ Extrusion failures were

very few and croppings had been reduced materially. There was reason to believe that rods, made with improved practice, later would tend to improve quality even further.

However, no sooner had the extrusion difficulties been reasonably well eliminated, or at least analyzed, than new difficulties arose due to the re-appearance of "red-ban" (high-iron content) billets in the shipments to Revere.⁶⁹ There was also a preponderance of billets containing surface imperfections. It was found, also, that the quality of billets differed with respect to the various suppliers.

These conditions persisted during virtually every billet delivery to Revere for several weeks,⁷⁰ and on June 13, 1944 the Corps of Engineers was formally requested by the Engineering Department to make every effort to hold billet physical quality to the highest possible standard⁷¹ since, as had been proved during this extensive study, further progress in rod quality and yield improvement would be largely dependent upon improvement in the physical quality of the billet. By this time, however, the major difficulties had been overcome.

As the time approached for the transfer of the responsibility for fabrication of uranium from the Engineering Department to the TNX Division, the practice of extrusion had become reasonably well standardized and, upon the completion of order RPG-704-1/2 at Revere in August, 1944, the TNX Division was ready to carry on with the program. Altogether, 2,525,082.40 pounds of billets had been extruded into 2,261,248.27 pounds of rod on this contract at a total cost

of \$750,020.72. This resulted in an average cost of 34.49 cents per pound of extruded rod weight or approximately 35.6 cents per pound when based on the yield of sound rod produced. Tables included herein on the following two pages list the performances on this order.

CONCLUSION

In conclusion, therefore, it is well to emphasize certain points peculiar to this program which deviated from normal practice because of the paucity of information attendant thereto, and to review briefly the performance of the program together with the recommendations proposed for the continuation of the work.

The Engineering Department in sixteen months had processed through subcontractors some 1500 tons of uranium billets into rods¹² for subsequent machining into slugs. During the last twelve months of the program some 1200 tons had been extruded into rod for Hanford Engineer Works at Revere Copper and Brass Incorporated at Detroit. After the Engineering Department order on Revere was completed the TNX Division then placed an order on this same fabricator for future requirements.

In the Fall of 1943, extrusion was considered to be a demonstrated process with only yield improvement and unit equipment capacity increase as further goals. Some progress was made on both, but early in 1944 extruded rod quality and yield fell off considerably. An intensive study of extrusion was immediately organized with the assistance of TNX Division

EXTRUSION RUNS AT REVERE COPPER AND BRASS INCORPORATED ON RPG-704-1/2

| <u>Date</u> | <u>Rod Dia.</u> | <u>No. Billets</u> | <u>No. Rods</u> | <u>Billet Weight</u> | <u>Rod Weight</u> | <u>Average Weight Billet</u> | <u>Weight Rod</u> | <u>Yield Rod</u> | <u>Yield Rod</u> |
|---------------|-----------------|--------------------|-----------------|----------------------|-------------------|------------------------------|-------------------|------------------|------------------|
| 1943 | | | | | | | | | |
| 8-21, 22 | 1.45 | 205 | 205 | 19,864.75 | 18,611.75 | 97 | 91 | 93.7 | 87.3 |
| 8-28, 29 | 1.45 | 590 | 589 | 51,587.00 | 44,166.50 | 87 | 75 | 85.6 | 81.0 |
| 9-4, 5 | 1.45 | 600 | 596 | 53,061.50 | 47,034.00 | 88 | 79 | 88.6 | 85.3 |
| 9-11, 12 | 1.45 | 550 | 543 | 50,628.00 | 44,963.50 | 92 | 83 | 88.8 | 85.5 |
| 9-18, 19 | 1.45 | 580 | 578 | 56,974.00 | 51,465.75 | 98 | 89 | 90.3 | 87.8 |
| 10-2, 3 | 1.49 | 416 | 410 | 41,098.75 | 36,464.00 | 99 | 89 | 88.5 | 85.3 |
| 10-9, 10 | 1.49 | 550 | 549 | 52,838.50 | 47,294.75 | 96 | 86 | 89.2 | 86.2 |
| 10-16, 17 | 1.49 | 590 | 588 | 60,280.25 | 53,760.00 | 102 | 91 | 89.5 | 86.2 |
| 10-23, 24 | 1.49 | 500 | 498 | 50,932.00 | 45,904.62 | 102 | 92 | 90.3 | 87.3 |
| 11-6, 7 | 1.49 | 570 | 567 | 57,690.63 | 51,545.63 | 101 | 91 | 89.5 | 86.4 |
| 11-13, 14 | 1.49 | 630 | 513 | 53,355.00 | 47,138.00 | 101 | 92 | 88.5 | 85.6 |
| | 1.19 | | 100 | 10,489.88 | 9,157.28 | | 92 | 87.5 | 84.6 |
| 11-19, 20, 21 | .89 | 1032 | 41 | 4,216.00 | 3,789.25 | 102 | 92 | 89.8 | 87.0 |
| | 1.19 | | 160 | 16,738.00 | 15,270.38 | | 95 | 91.1 | 88.3 |
| | 1.49 | | 821 | 84,599.63 | 76,392.00 | | 93 | 90.2 | 87.2 |
| 12-4, 5 | 1.49 | 462 | 453 | 46,909.86 | 41,766.20 | 102 | 92 | 89.3 | 86.3 |
| 12-10, 11 | 1.49 | 710 | 701 | 74,510.19 | 67,932.72 | 105 | 97 | 91.2 | 88.3 |
| 12-18, 19 | 1.49 | 630 | 605 | 65,167.68 | 56,484.58 | 103 | 93 | 86.7 | 83.9 |
| | | | | | | | | | |
| 1944 | | | | | | | | | |
| 1-8, 9 | 1.49 | 535 | 526 | 63,321.87 | 56,975.64 | 118 | 108 | 89.8 | 87.8 |
| 1-22, 23 | 1.46 | 679 | 625 | 78,697.13 | 66,493.23 | 116 | 106 | 84.6 | 82.5 |
| 2-5, 6 | 1.46 | 333 | 332 | 35,985.95 | 33,137.84 | 108 | 100 | 92.1 | 89.5 |
| | 1.20 | 20 | 20 | 2,138.38 | 1,896.30 | 107 | 95 | 88.8 | 86.0 |
| 2-12, 13 | 1.46 | 570 | 557 | 82,417.03 | 72,321.14 | 144 | 130 | 87.8 | 86.0 |
| 2-19, 20 | 1.46 | 381 | 349 | 44,840.60 | 37,410.20 | 118 | 107 | 84.9 | 81.7 |
| 3-4, 5 | 1.46 | 612 | 607 | 73,976.91 | 67,212.13 | 121 | 111 | 90.8 | 88.5 |

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EXTRUSION RUNS AT REVERE COPPER AND BRASS INCORPORATED ON RPG-704-1/2 (Continued)

| <u>Date</u> | <u>Rod Dia.</u> | <u>No. Billets</u> | <u>No. Rods</u> | <u>Billet Weight</u> | <u>Rod Weight</u> | <u>Average Weight Billet</u> | <u>Rod</u> | <u>Rod Yield</u> | <u>Sound Rod Yield</u> |
|--------------|-----------------|--------------------|-----------------|----------------------|---------------------|------------------------------|------------|------------------|------------------------|
| 3-11, 12 | 1.46 | 306 | 306 | 36,729.19 | 33,116.44 | 120 | 108 | 90.3 | 87.8 |
| 3-24, 25 | 1.46 | 607 | 605 | 73,358.13 | 65,396.03 | 121 | 108 | 88.8 | 86.3 |
| 3-31, 4-1 | 1.46 | 616 | 613 | 78,867.89 | 70,147.01 | 128 | 114 | 88.5 | 86.9 |
| 4-14, 15 | 1.46 | 554 | 553 | 66,202.46 | 58,416.07 | 119 | 106 | 88.4 | 85.3 |
| 4-29 | 1.46 | 330 | 329 | 39,055.57 | 34,121.71 | 118 | 104 | 89.3 | 86.8 |
| 5-6, 7 | 1.46 | 596 | 596 | 70,479.90 | 63,063.02 | 118 | 106 | 89.2 | 86.9 |
| 5-13 | 1.46 | 324 | 324 | 39,298.69 | 34,969.30 | 121 | 108 | 88.3 | 86.8 |
| 5-19, 20, 21 | 1.46 | 962 | 962 | 118,942.14 | 107,884.82 | 124 | 112 | 91.2 | 88.2 |
| 6-2, 3, 4 | 1.46 | 939 | 938 | 112,989.99 | 102,999.04 | 120 | 110 | 90.2 | 86.7 |
| 6-9, 10 | 1.46 | 648 | 648 | 76,729.56 | 69,432.52 | 118 | 107 | 90.5 | 88.0 |
| 6-17, 18 | 1.46 | 600 | 591 | 71,698.03 | 62,187.32 | 120 | 105 | 86.7 | 84.7 |
| 6-23, 24, 25 | 1.46 | 940 | 938 | 113,626.80 | 103,058.23 | 121 | 110 | 90.8 | 88.0 |
| 6-30, 7-1 | 1.46 | 640 | 639 | 77,804.53 | 71,578.22 | 122 | 112 | 92.0 | 90.7 |
| 7-15, 16 | 1.46 | 657 | 656 | 78,199.63 | 72,015.42 | 119 | - | 92.1 | 89.5 |
| 7-29, 30 | 1.46 | 654 | 653 | 79,459.26 | 72,432.49 | 121 | 111 | 91.2 | 88.6 |
| 8-12, 13 | 1.46 | 620 | 620 | 74,963.21 | 68,060.78 | 121 | 110 | 90.8 | 88.7 |
| 8-19, 20 | 1.46 | 676 | 676 | 84,357.89 | 77,782.33 | 125 | 115 | 92.0 | 89.6 |
| Total | | 22,414 | 22,180 | 2,525,082.40 | 2,261,248.27 | 113 | 102 | 89.6 | 86.8 |

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personnel temporarily assigned to the Engineering Department, with the result that the principal variables were brought under control, internal rod structure was considerably improved, and the relationship of metal analysis and extrusion performance considerably clarified. The limit of extrusion performance had not been reached, but the point of diminishing returns at Revere undoubtedly was at hand.

In placing metal fabrication orders, the du Pont Company had been unable to use the normal incentive basis whereby the vendor profits from yield improvement, guarantees quality, and takes all losses incident to not meeting specifications. The lack of firm product specifications, the limited supply of metal, and the high cost of any reworking of scrap made it necessary to retain the responsibility for seeing that quality and yield were maintained, and to provide only to a minor degree financial incentive to the fabricators. It was believed that this situation would continue to persist, and further improvement would be obtained only through active and continuous du Pont participation in the fabricator's work. It was entirely possible that the limit of improvement in extrusion by outside fabricators was near, and it was believed almost certain that any substantial further gain would be made only by du Pont performance of the fabrication. Therefore, if improvement in extruded rod quality or yield from billet were necessary, it was recommended that the extrusion operation be adequately staffed and done at Hanford.

Regardless of the possibility of extruding at

Hanford, it was thought that extrusion should be continued at Revere for at least some months. Continuance of the present performance levels would probably, and improvement of these levels would certainly, require continuance of existing supervisory, engineering, and inspection activities at this location. Therefore, it was recommended that the metal fabrication program of the TNX Division in the East be placed in charge of a supervisor with sufficient resident staff to see that existing standards were maintained and improved.

The uranium accountability records, which the Engineering Department had maintained, were in a condition that they could readily be transferred to Hanford without difficulty.

As the fabrication of uranium rod from billet passed from the Engineering Department to the TNX Division, it was emphasized that this fabrication could not be handled on the basis of normal procurement of operating supplies. Quality specifications were still largely uncertain, yields were not at a maximum, and, possibly more important than either, continuance of existing standards of quality and yield was by no means assured without considerable supervision and follow up.

SUMMARY

To summarize briefly, the extrusion program involved the placement of four orders for the actual development and production of extruded uranium rod, as follows:

For Clinton Engineer Works

Purchase Order XPG-123-1/2 on the B. & T. Metals Company, Columbus, Ohio, for the extrusion of 303,705.25 pounds of extruded rod at a total cost of \$130,597.13.

Purchase Order XPG-773-1/2 on Revere Copper and Brass Incorporated, Detroit, Michigan, for the extrusion of 152,845.25 pounds of extruded rod at a total cost of \$67,579.15.

For Hanford Engineer Works

Purchase Order RPG-704-1/2 on Revere Copper and Brass Incorporated, Detroit, Michigan, for the extrusion of 2,261,248.27 pounds of extruded rod at a total cost of \$780,020.72.

Purchase Order RPG-4033-1/2 on Revere Copper and Brass Incorporated for additional developmental work in connection with, but over and above that, covered on RPG-704-1/2, at a total cost of \$7,000.00.

From the foregoing figures, it can be seen that the actual cost of extruding billets to produce 2,717,798.77 pounds of extruded rod amounted to \$985,197.00, or at an average unit price of 36.25 cents per pound.

SECTION III

DRAWING, SWAGING AND ROLLING

DRAWING, SWAGING AND ROLLINGCONTENTS

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SECTION III

DRAWING, SWAGING AND ROLLING

INTRODUCTION

Extrusion was considered to be the most commercially-adaptable method for the fabrication of uranium rod from cast billets, but, after the program had progressed to the degree that the largest potential increase in yield was believed to be effected by reducing the diameter of the extruded rod (in order to lessen the amount of machining required), other methods of fabrication, such as drawing, swaging, and rolling, were proposed as possible alternates.

These all are squeezing operations wherein the metal is reduced in cross-sectional area by the application of one or more external forces, either with or without the accompaniment of external heat. Drawing is that operation in which a rod is pulled under tension through a slightly smaller orifice to induce a circumferential compressive stress capable of decreasing the diameter of the rod; swaging reduces the diameter by a series of intermittent hammer-like blows acting through split dies of the proper profile; and rolling reduces the diameter in a continuous operation by squeezing the rod through rollers in which a configuration of the proper profile has been machined. In this program, only the rolling operation was performed with the uranium at an elevated temperature.

DRAWING

Early in August, 1943, the Battelle Memorial Institute reported that a large part of the benefit of extrusion of common metals and alloys lay in the fact that extruded material was made commercially very close to the finished size, so that the removal of only a small amount of material was required by machining.¹ For simple shapes this enabled extrusion to compete with rolling, which was a much simpler operation.

However, in the present practice, this advantage was not being obtained, as approximately twenty-two percent of the rod was being removed to provide a slug machined to the proper diameter and length. This turning loss, when compared to the weight of the original billet, further reduced the yield to approximately 62.5% of finish-machined slug to billet weight. If, however, the rod size could be reduced, the recovery would be increased by as much as eighteen percent.

This possibility created a need for a general review of the problem, and, in a meeting, consideration was given to the possibility of drawing the rod to a size somewhat closer to the finished dimension than might be possible in plain extrusion. Revere was receptive, and immediately undertook preliminary developmental work in line with this proposal, such work being considered a part of purchase order RPG-704-1/2 and no additional charge therefore was to be made.

Within a short while Revere had drawn short lengths

of rods in its laboratory, but considerable "chatter" had occurred and the resulting surface was not satisfactory.² Consequently, its laboratory equipment was not considered desirable for further work along these lines. Similarly, subsequent work did not prove encouraging to the adoption of this method as an alternate, as Revere's current experiments with swaging as another consideration indicated this method would be far superior to drawing.³

However, in January, 1944, the Metallurgical Laboratory undertook a series of experiments at the Joslyn Manufacturing & Supply Company, Fort Wayne, Indiana, to determine the ductility of the uranium. Since embrittlement was found to a marked degree in the drawn rods, thus necessitating annealing before further fabrication, it was concluded that drawing was not commercially feasible. Therefore, no further work was performed on the development of this method, either by the Metallurgical Laboratory or by the Engineering Department.

SWAGING

In order to expedite the developmental work relating to the other alternate considerations for the fabrication of rod, the Engineering Department planned to conduct experiments on swaging concurrently with those on drawing.

It is to be emphasized that the primary purpose for the evaluation of this method was to attempt to reclaim 6231 extruded rods which had become oversize because of a revision in the specifications. The swaging of this quantity of uran-

ium, if feasible, was known to represent a considerable potential saving in time, money and metal loss, and with the developmental work thus justified, the Engineering Department accordingly requested Revere to determine experimentally the practicability of resizing by this method. In addition, the information accumulated would enhance the overall knowledge of the characteristics of the metal; information which perhaps might prove valuable at some future date.

Revere, in carrying out this assignment, made arrangements to have the rods swaged at the Wolverine Tube Company as its equipment was not suitable for this purpose.⁴

Subsequent analysis of the data from the swaging test indicated that the dimensions could not be held to a sufficiently close tolerance.⁵ Furthermore, whereas the surface was satisfactory, the rod was out-of-round, which was undoubtedly due to the poor condition of the Wolverine machine. Despite this difficulty, however, Revere was firmly convinced of the practicability of swaging⁶ and, because of its superiority over drawing, Revere consequently was stopping all work connected with the development of a drawing process.

Since an elongation in the rod of eleven percent had been obtained by swaging, thus effecting an equal reduction in the amount of metal to be removed and thereby greatly increasing the ultimate yield of finished rod to billet charge, it was believed that the results looked sufficiently promising to do some further work if a satisfactory machine

could be found, or if the Wolverine machine could be put in first-class condition.

The Engineering Department then investigated other fabricators and learned that the American Chain & Cable Company, Incorporated, in Bridgeport, Connecticut, had facilities for, and were willing to make, this test on several representative rods.⁷ When the trial swaging was attempted, however, it was found that the swaging machine in use was not large enough to conduct a satisfactory test, so it was then decided that the larger machine located at this fabricator's Wilkes Barre Plant should be tried. Accordingly, the rods were shipped to this location and the test was again attempted. However, the correct size dies were not available and only one rod was swaged.

To test the operation more conclusively, the Engineering Department then placed purchase order RPG-3199-1/2 on this fabricator for altering the dies and swaging eight additional rods from 1.46" down to 1.39" in diameter. These resultant swaged rods were shipped to the Metallurgical Laboratory for evaluation,⁸ but it was soon reported that the operation would not be suitable for the end use to which these slugs would be put, as the cold-working of the metal was so drastic that the metal structure around the outside surface was considerably impaired. In view of this statement, reclamation of the oversize rods by this method was abandoned.

By this time the Engineering Department was

urgently engaged in investigating the possibilities of rolling, which, it was believed, would prove far superior to either the drawing or swaging operations heretofore undertaken; therefore, no further experimental work on swaging was performed.

ROLLING

In June, 1943 the du Pont Company learned that the Metallurgical Laboratory had under way an active program to develop rolling as an alternative to extrusion.⁹ This group had placed an order on the Joslyn Manufacturing & Supply Company for the development of a rolling technique, and several runs on small quantities of billets were subsequently performed.

The first of these rollings was made on June 29, 1943. After the Engineering Department had performed certain machining tests on these rolled rods, it later advised the Metallurgical Laboratory that in view of du Pont's past experience in machining extruded rods, and from the experience gained on these rolled rods, present indications were that efforts to secure a minimum diameter with this method would result in the same problems as similar efforts on extruded rod.¹⁰

Following additional examination and testing of these slugs, the development of rolling remained comparatively dormant until March, 1944, when the Metallurgical Laboratory, stimulated by the prevalence of defects then being encountered in the extruded rods, again became in-

terested in the problem and undertook to conduct additional rollings."

This reopening of the rolling program coincided with du Pont's entrance in the same field of endeavor, for at this time the Metallurgical Laboratory recommended, and the TNX Division requested,¹² that the Engineering Department arrange for a larger test rolling in order to establish more definitely the position of this method of fabrication in comparison with extrusion. The Engineering Department, therefore, placed purchase order RPG-3779-1/2 on the Joslyn Manufacturing & Supply Company to roll thirty tons of 200-pound billets into rods.¹³ Although this was to be strictly a production order, as all developmental work by this fabricator had been covered on its order from the Metallurgical Laboratory, it was evident from examination of samples after the first run that additional experimentation was required. This accordingly was attempted on the balance of the order, but progress was considered very slow. Therefore, only three rolling runs were performed at this location, the first of which was made on May 9-10-11 when 231 billets totalling 60,122.35 pounds were rolled into 462 rods aggregating 57,203.48 pounds, for an actual rod yield of 95.1 percent.¹⁴ The second run, on June 2, resulted in the rolling of twenty-three billets into forty-six rods with billet and rod weights of 5899.80 and 5150.18 pounds respectively, for a yield of 87.3 percent.¹⁵ In the last run, on June 22-23-24, 252 billets totalling 64,725.21 pounds were rolled into

496 rods aggregating 61,622.86 pounds, to produce a yield of 95.3 percent.¹⁶

From an analysis of the rolling operation after these three runs it appeared that this process in its present state of development was not as attractive commercially as extrusion,¹⁷ but was believed to indicate that rolling could be developed as an acceptable method of fabrication.¹⁸

Altogether, the progress made at Joslyn was questionable to the extent that the du Pont Company believed this work might better be transferred to another fabricator, for, despite the fact that Joslyn had ostensibly developed this process for the Metallurgical Laboratory, the results of its three runs for du Pont proved that its knowledge of the conditions under which the billets should be rolled was inadequate. However, one more run was planned for July 20, 21 and 22, but after an examination of representative rods by the Metallurgical Laboratory disclosed the presence of many defects, the Engineering Department advised Joslyn that the order was to be terminated without further work.

Because the quality of the rolling was definitely inferior, owing to Joslyn's lack of sound technical knowledge of the process with respect to the rolling of uranium, the du Pont Company immediately investigated other fabricators for the purpose of appraising the ability of each to develop the rolling technique which to date had been lacking. Two stainless steel and two non-ferrous rolling mills were inspected¹⁹ and, in consideration of its adequate technical

staff and ability to perform developmental work, together with the fact that the rolling of uranium was believed to be quite similar to that of stainless steel, the Engineering Department placed purchase order RPG-4671-1/2 on the Carpenter Steel Company, Reading, Pennsylvania, for the development of this rolling process.²⁰ To execute this order, a total of six round double-length billets and six square billets were to be rolled, as it was believed this quantity would provide sufficient data for the development of the process and the direction of subsequent action. Two of these billets were rolled on August 27, and the remaining ten on September 3, 1944.

After an examination of representative samples from these runs, the Metallurgical Laboratory reported that the quality of these rods, in general, also was found to be inferior,²¹ and from the results obtained, it was thought that rolling was not a suitable alternative to supplant the extrusion operation at this time.

With the completion of this order on the Carpenter Steel Company in September, 1944, the responsibility of the Engineering Department with respect to the development of rolling was fulfilled. Such production rolling as had been performed at Joslyn, and the developmental work at Carpenter, had been made at the request of the TNX Division. Analyses of data had shown that rolling was a feasible method for the hot fabrication of uranium, provided that the inherent defects in the rods, which could not be eliminated by variations in the rolling operations, could be tolerated, as these

imperfections were caused by some deficiency in the billet casting method.²² It was believed also that from 1/10" to 1/16" machining allowance would probably be required for acceptable clean-up to finished diameter; allowances that would not permit of any reduction in the machining loss.

It was concluded, therefore, that this operation would not prove favorable in comparison with extrusion.

CONCLUSION

Thus, upon the completion of the Carpenter Steel Company order the responsibility for the metal fabrication program passed from the Engineering Department to the TNX Division. The data accumulated to date were forwarded to this latter organization for future guidance, and the development of any additional information relating to conditions or operations yet undetermined would be made by, and at the discretion of, this group. The TNX Division also was to place any subsequent orders required.

The interest of the Engineering Department throughout its participation in the rolling program, though active, might be considered as secondary for the reason that its primary responsibility lay in the delivery of fabricated rod in sufficient quantities to satisfy the requirements for Hanford Engineer Works. This had been achieved through the development of extrusion and in the application of data accumulated during intensive study to correlate billet behavior with respect to extrusion technique, billet chemical composi-

tion, and billet physical characteristics. It logically followed, therefore, that any divergence in any appreciable magnitude from this central objective would have been deleterious to the program as a whole. The fact that this goal had been achieved, and in addition had permitted the alternate considerations of drawing, swaging and rolling to be investigated, was indicative of the unified effort put forth by the Engineering Department in attacking the various elements of the many possibilities afforded in this program for the essential production of rod.

SUMMARY

In brief summation, the investigation of the alternate methods of drawing, swaging and rolling covered the placement of three orders, as follows:

Drawing

The work in connection with drawing was included in the charges for extrusion developmental work under purchase order RPG-704-1/2, placed on Revere Copper and Brass Incorporated, and was not invoiced separately. This same order also covered Revere's portion of the work in the development of swaging.

Swaging

Purchase order RPG-3199-1/2 on the American Chain and Cable Company for the swaging of eight rods and necessary revisions to existing dies, at a total cost of \$135.00.

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Rolling

Purchase order RPG-3779-1/2 on the Joslyn Manufacturing & Supply Company for the production rolling of 163,664 pounds of billets at a total cost of \$36,110.87.

Purchase order RPG-4671-1/2 on the Carpenter Steel Company for the development of a rolling technique at a total cost of \$13,000.00.

OUTGASSING AND STRAIGHTENINGCONTENTS

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SECTION IV

OUTGASSING AND STRAIGHTENING

INTRODUCTION

In normal extrusion of the common non-ferrous metals and alloys, it is the customary practice to straighten the rod manually after it has been quenched. This operation was performed at B. & T. Metals Company on order XPG-123-1/2, and in addition, a primary straightening operation was performed, also manually, before the rod was quenched.¹ However, though these two straightening operations were observed on all rods extruded at this location, the degree of straightness produced was not acceptable to the machining fabricators as the rods caused considerable difficulty in their turret lathes due to the presence of slight bows resulting in unbalance and "whip".

EXTRUDED ROD

When this condition became known, the Engineering Department immediately contacted the Joslyn Manufacturing & Supply Company, for the purpose of placing an order for the mechanical straightening of the rods, as a demonstration at this location on four rods proved this method to be satisfactory. In negotiating for a quotation, however, it was learned that a plant addition would be required in order to fulfill the protective security requirements, and this firm was consequently not considered for the work.

Another survey by du Pont disclosed that the Copperweld Steel Company, in Warren, Ohio, was able to perform the operation satisfactorily² and, in addition, could provide the required protection. Accordingly, purchase order XPG-492-1/2 was immediately placed on this firm for the straightening of an estimated 3000 rods of the diameter required for Clinton Engineer Works.

At this same time the Metallurgical Laboratory, after an analysis of representative extruded rods, advised that approximately fifty percent of the total metal would require outgassing, or removal of the gases entrapped in the rod.³ In accordance with this, the Engineering Department then negotiated with Copperweld for the inclusion of this operation as a part of its order for straightening, as it was believed the two operations could be performed at the one plant.⁴ Copperweld was receptive and with the assistance of Battelle Memorial Institute it immediately set up facilities for this purpose. After the first outgassing it was found that the complete cycle could be performed in not more than twenty-four hours on 25,000 pounds of metal, and the capacity could therefore be maintained concordant with requirements.⁵

To determine the relative efficiency of this operation, samples were prepared from each of five representative rods from the first run at Copperweld and were sent to the Battelle Memorial Institute for analysis. Results proved the operation to be satisfactory.

Virtually all of the rods that required outgassing

and straightening for the Clinton Engineer Works were processed at Copperweld Steel Company on this order. The total quantity comprised 5016 rods which were straightened, of which 3485 were outgassed in addition, at a total cost including experimental work, guarding and shipping of \$49,192.79. These figures indicate that of the 5063 rods extruded to the Clinton size at B. & T. and at Revere on orders XPG-123-1/2 and XPG-773-1/2, respectively, approximately ninety-nine percent were straightened and sixty-nine percent were outgassed at Copperweld. The few remaining rods had been manually straightened only at B. & T. Metals Company.

Shortly before Revere was to start extrusion of the Hanford size rods, the Engineering Department was requested to supply a small quantity of outgassed and straightened metal for some experimental tests.⁶ In compliance therewith, it was planned to furnish a quantity of rods from the first extrusion run at the Hanford size, and to have these rods subsequently outgassed and straightened at Copperweld, as this was the only vendor set up for immediate performance of this work. Purchase order RPG-705-1/2 was placed accordingly on Copperweld to cover the processing of 205 rods at a total cost, including guarding and shipping, of \$1306.22.

However, prior to this date, the Engineering Department, in setting up the tentative production schedule to meet the requirements for the Hanford Engineer Works, believed that if the outgassing and straightening operations could be performed by the vendor who was awarded the extrusion

contract, the delivery of processed rods to the machining fabricators would not only be expedited but also would effect a pronounced saving to the Government by eliminating both the additional shipment to a third party and the attendant charges for protective security measures. Accordingly, negotiations were initiated with Revere Copper and Brass Incorporated for including these operations in with extrusion.⁷ Revere was agreeable to the suggestion and immediately undertook to set up its equipment under the guidance of the Battelle Memorial Institute, using the same method as that previously employed at the Copperweld Steel Company. Revere expected to start outgassing Hanford size rods during the run of September 11 and 12.⁸

Although Revere owned a small Medart Straightener, it preferred to straighten the rod with a twelve-roll machine of larger capacity. This was satisfactory with the Engineering Department, and most of the subsequent rods were processed in this manner. However, after part of Revere's later production had been shipped to various outside fabricators for machining into Hanford slugs on Project 1553, it was learned that the extreme ends of the rods were slightly bowed in emerging from the twelve-roll machine, and eventually caused difficulty during high-speed machining operations. To eliminate this condition, Revere straightened on the Medart machine all remaining rods intended for fabrication on Project 1553. The rods for Project 9536 were processed as usual through the twelve-roll straightener, as Hanford Engineer

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Works had expressed no objection to the presence of the slight bow.

The Battelle Memorial Institute performed a check analysis on some samples from the first outgassing, and subsequently revised the specifications to stipulate an increase in the soaking period from six hours to nine hours in order to provide for the larger diameter rods being outgassed. This revision was inaugurated in the next run on October 2, and remained in effect for the duration of the contract.

Up to this time all gas analyses had been made at Battelle Memorial Institute for Revere. In an effort to centralize all phases of the work relative to outgassing, the Engineering Department requested Revere to undertake in its laboratory, under the initial guidance of Battelle, the determination of gas content in the metal. This request was acceptable to Revere, but it was not until several weeks later that it was fully set up to perform the tests in its laboratory.

The technical staff of Revere Copper and Brass Incorporated had been actively interested in the outgassing operation since its inauguration, and, during the course of the initial runs, it frequently contacted representatives of the Battelle Memorial Institute for specialized technical advice. During one of these visits it was agreed that argon be used instead of natural gas in the muffle furnace when heating the billets for extrusion, in an attempt to reduce

both the amount of oxide formed on, and the amount of hydrogen absorbed by, the billet.

The Engineering Department approved the running of one test using this method.¹⁰ It was du Pont's feeling, however, that the relative scarcity of argon might have a tendency to result in less complete blanketing and, in spite of the limitations of natural gas, a good natural gas blanket was preferable to an incomplete argon blanket.

This test was tried but the results indicated that the use of argon would not eliminate the need for outgassing.¹¹ Accordingly, Revere used a natural gas atmosphere in its furnace for the balance of the contract.

From the end of November, 1943 to August, 1944 the outgassing procedure was standardized to the degree that little or no difficulty was experienced. Revere had set up its laboratory for determination of gas content and had been making these analyses on samples removed from the front end and from the back end of each rod. Later it was agreed that only the back end sample be analyzed in order to reduce the burden on the laboratory facilities.¹² The front end sample was to be run as a check only if necessary.

In the meantime the Metallurgical Laboratory had been conducting tests on heat treatment of the rods in an attempt to improve dimensional stability. The procedure used was reported to the TNX Division, which requested that the Engineering Department adopt it at Revere if the equipment so permitted. However, Revere stated that the proposal

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appeared to be very impracticable for its furnace and equipment, as approximately twenty-four hours would be required to cool the rods after each heat treatment.¹³ In view of these difficulties, the Engineering Department advised the TNX Division that no change in the outgassing procedure would be made.¹⁴

The process, therefore, remained stabilized until the close of the work in August, 1944.

ROLLED ROD

Because it has been found necessary to outgas and straighten the extruded rod, it was believed necessary also to perform these same operations on the rolled rod. Hence, purchase order RPG-4034-1/2 was placed on Revere Copper and Brass Incorporated for the outgassing and straightening of approximately 150 tons of rod which was to be rolled at the Joslyn Manufacturing & Supply Company on order RPG-3779-1/2.

Samples were taken from the first production rolling at Joslyn and were sent to Battelle Memorial Institute for determination of hydrogen content. Subsequent analysis indicated that outgassing of rolled rod would not be required for metal of this quality.¹⁵

This indication was further strengthened after analysis of samples from the second run showed less than 2 ppm of hydrogen. In view of these results, the TNX Division advised that no outgassing was required for the rods rolled on the second run.¹⁶ However, in the interests of expediting fabrication, these rods had already been processed at Revere.

It was believed, though, that this was not work performed unnecessarily, as the outgassing operation was so inexpensive in comparison to the remaining operations required for completion of the finished slugs that the factor of safety thus obtained was justified.

During the course of these analyses on rolled rod, it developed that the gas content in the metal varied considerably between the different suppliers. This trend was definitely established after the second run, so that of the 496 rods produced on the last run, only ten required outgassing.

The processing of the rods from the first two runs, and of these ten from the third run, constituted the entire performance of work by Revere on order RPG-4034-1/2.

Upon the completion of this work on the rolled rods, and of that included in order RPG-704-1/2 on the processing of extruded rods, the outgassing and straightening portion of the metal program was concluded.

SUMMARY

The Engineering Department's participation in the work of outgassing and straightening comprised the placement of four orders, as follows:

For Clinton Engineer Works

Purchase order XPG-492-1/2 on the Copperweld Steel Company, Warren, Ohio, for outgassing 3485, and straightening 5016, extruded rods, at a total cost including experimental work, guarding and shipping, of \$49,192.79.

For Hanford Engineer Works

Purchase order RPG-705-1/2 on the Copperweld Steel Company, Warren, Ohio, for outgassing and straightening 205 extruded rods, at a total cost including guarding and shipping, of \$1306.22.

Purchase order RPG-4034-1/2 on Revere Copper and Brass Incorporated, Detroit, Michigan, for the outgassing and straightening of 487 rolled rods, totalling 62,446.14 pounds, at a total cost of \$3122.31.

The balance of the outgassing and straightening was performed on extruded rods and was included in purchase order RPG-704-1/2, placed on Revere Copper and Brass Incorporated, for developmental work, extrusion, and outgassing and straightening. The charges for this particular portion of the work were not segregated.

SECTION V

PROJECT 1030

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SECTION V

PROJECT 1030

INTRODUCTION

In December, 1943, the Clinton Laboratories initiated arrangements for the procurement of an additional sixty tons of finished slugs over and above that quantity originally supplied them.¹ Though these sixty tons would require the extrusion of approximately ninety tons of billets reserved for Hanford, the TNX Division had stated that it would be satisfactory to divert this quantity of material for this specific purpose. Moreover, the assistance of the Engineering Department was requested and obtained, by the Clinton Laboratories, for the procurement and fabrication of these slugs.

The du Pont Company would not be intimately involved with this undertaking as it was the responsibility of the Clinton Laboratories to place the orders and to keep all accountability records. Du Pont would, however, be concerned with it in the respect that its personnel would be assigned to cover the inspection of material at the fabricators' plants; and also, because the required fabrication would conflict to some degree with delivery schedules to Hanford, since the expediency of the work necessitated placement of orders on fabricators then processing material for Hanford.

On January 17, 1944, Clinton Laboratories advised that its purchase order CL-3224 was being written to cover the services outlined in the quotation, despite the fact that formal Governmental approval of the order had not yet been received but was assured.⁴ On the basis of this information, the du Pont Company opened Project 1030 to record the charges incurred against this order.⁵

The Clinton Laboratories later advised the Engineering Department that additional services would be required to cover the inspection of its order on Paul & Beekman, Philadelphia, Pennsylvania, for the manufacture of aluminum cans. These services were included as an alteration to order CL-3224 at an estimated increase of \$600.00.⁶

Taking into consideration the scope of work outlined in the original order plus this alteration, the du Pont Company was to furnish inspection services at four locations, namely:

| | |
|--------------------------------------|---------------------------------|
| Revere Copper and Brass Incorporated | Detroit, Michigan |
| Baker Brothers, Incorporated | Toledo, Ohio |
| Aluminum Company of America | New Kensington, Pennsylvania |
| Paul & Beekman | Philadelphia, Pennsylvania |

These services were furnished for the duration of Clinton Laboratories' orders on these vendors, or until the du Pont Company was advised that its services were no longer required.

The Clinton Laboratories made one later request of the Engineering Department to the effect that all invoices

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covering salaries and expenses in connection with work under its purchase order CL-3224 (Project 1030) should be certified by the Corps of Engineers auditors before being submitted for payment.⁷ This procedure accordingly was adopted on April 27, 1944.

No subsequent changes were made for the balance of the work covered by this project.

The total costs charged against Project 1030 amounted to approximately \$20,500.00.

SECTION VI

MACHINING, GRINDING AND GROOVING

MACHINING, GRINDING AND GROOVINGCONTENTS

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SECTION VI

MACHINING, GRINDING AND GROOVING

INTRODUCTION

The sequence of major operations in the fabrication of slugs comprised extrusion (or rolling), outgassing, straightening, machining and canning. Extrusion, together with the alternate method of rolling and supplemental considerations of drawing and swaging, as well as the operations of outgassing and straightening, have all been described in previous sections. This section will be devoted to the problems encountered relative to the machining operations.

At the start of the slug program the machining characteristics of uranium were virtually unknown, and it was therefore necessary that the Engineering Department arrange for the prosecution of considerable work of a developmental nature in order that sufficient information might be accumulated with which to direct future activities to produce the fabricated slugs concordant with requirements.

The slug length and diameter for Clinton Engineer Works were more-or-less fixed at 4.000" and 1.100" respectively. However, the end contours were open to considerable revision as they were dependent upon the type of closure which ultimately would be developed in the canning process. This condition necessarily accentuated the initial difficulties attendant to the machining program.

MACHINING

In order to prosecute the work in the most expeditious manner, the Engineering Department investigated numerous machine shops in the general vicinity of the B. & T. Metals Company for the purpose of securing the geographical advantage of proximity to the extruding fabricator. Altogether, some twenty-five shops were investigated in the Columbus-Cincinnati area, and it was found that the Herring-Hall-Marvin Safe Company in Hamilton, Ohio was able to provide the necessary machines and operators for this work; and in addition, was able to segregate the machines into one area of its shop to satisfy the protective security requirements.¹ The other shops contacted either did not have the proper equipment or else were unable to consider an order as their facilities were taken up with other war orders. This survey, therefore resulted in the placement of purchase order XPG-174-1/2 on the Herring-Hall-Marvin Safe Company for furnishing labor and equipment to machine an estimated quantity of approximately 4000 slugs, 1.280" diameter by 6.000" long, and approximately 50,000 slugs, 1.100" diameter by 4.000" long.²

Because so little was known of the machining characteristics of the metal, the fabricator had no firm basis on which to quote. Coupled with this condition was the anticipation of numerous design changes and the necessity for considerable developmental work in the determination of proper cutting speeds, applications of various cutting oils, and standardization of cutting tools. For these reasons, the

Engineering Department was logically unable to exact a quotation on a unit price basis whereby the vendor would assume the loss in the event any machined slugs failed to pass inspection. Since this normal incentive was lacking, this first machining order, and several subsequent ones, were placed on a machine-hour basis. It is well to note, however, that after the machining characteristics of the uranium had become known, and the specifications "frozen", the remaining orders under this program were placed on a unit price basis.

In order to satisfy the security requirements and to prosecute the work in the most effective manner, it was necessary to enclose one portion of Herring-Hall-Marvin's shop and to rearrange and relocate certain equipment. Later, it also became necessary to install a rebuilt turret lathe which had been purchased by du Pont on order XPG-117-1/2.³ The machine-hour price on this particular lathe reflected this ownership and was, of course, less than on each of the several shop-owned lathes also used for the prosecution of the work.⁴

This order, while placed for production quantities, nevertheless was virtually experimental in nature. It was recognized from the start that the work being performed concurrently at the Metallurgical Laboratory, Grasselli Chemicals Department Research Laboratory, Aluminum Company of America and Battelle Memorial Institute would require the machining of quantities of slugs to different dimensions and contours at numerous times during the life of the contract. These

requests, and they were frequent in number, were accordingly filled either at this fabricator's shop or at other shops which later were covered by subsequent purchase orders.

The immediate problems to be undertaken at Herring-Hall-Marvin centered in the determination of the machining characteristics of the uranium, and soon it was found that the metal work-hardened rapidly, the outer surface was very abrasive and difficult to machine, and tool life was very short.⁵ Too, the adherence to close tolerances presented a problem extremely difficult to master in view of these conditions, as it developed that equipment that performed satisfactorily when machining steel would produce a pronounced taper and out-of-round condition when turning uranium. As a result, the machining problems encountered in the performance of all orders under this program required the thorough overhauling and rebuilding of virtually all used equipment in order to produce machined slugs capable of meeting the specifications.

While Herring-Hall-Marvin was endeavoring to perfect the operation, the Engineering Department was conducting another investigation of other shops in this general area for the purpose of securing additional machining facilities so that the fabrication of one hundred tons of Clinton slugs could be completed by September 1, 1943. It was anticipated that at least four more turret lathes would be required for exclusive use on this work during June and the major portion of July in order to complete this phase of the work in the allotted time.⁶

Approximately forty shops were contacted, but of these only Baker Brothers, Incorporated, in Toledo, Ohio, appeared to be capable of handling the work to satisfy the developmental, production and security requirements. Purchase order XPG-582-1/2 was placed on this fabricator on May 29, 1943 for a portion of the total machining required.

By this time certain revisions in the finished dimensions were required in order to adapt the contour of the slugs to the caps being used in the canning operation at Aluminum Company.⁷ These revisions were applicable also to the new order just placed on Baker Brothers⁸ and to the order soon to be placed on the B. & T. Metals Company.⁹

Shortly thereafter, it was evident that the two fabricators then machining the metal would be unable to maintain production as scheduled, and the development of additional facilities again became necessary.¹⁰ This was accomplished readily by the placement of order XPG-753-1/2 on the B. & T. Metals Company, of Columbus, Ohio, as this fabricator, since the previous investigation, had secured sufficient items of used equipment to handle this additional work. Also, as B. & T. had performed a portion of the extrusion for this project, on order XPG-123-1/2, the protective security requirements were already satisfied and a minimum of from two to four weeks saved thereby over the placement of an order on a fabricator not cleared. This lag in clearing a firm placed every incentive on the Engineering Department to profit expeditiously by not changing from vendors who had been cleared, and through-

out the entire program this procedure was followed whenever possible.

It subsequently developed, however, that field conditions on the project site were such that the requirement for early delivery of finished slugs could be relaxed somewhat. This protraction was immediately reflected in the lessened amount of machining work that was allotted to B. & T., as it had developed that its equipment was not sufficiently accurate to hold the required tolerances without extreme difficulty. In order to use these facilities to the best advantage, the Engineering Department then diverted some slugs, which had been used by the Grasselli Research Laboratory in its experiments, to the B. & T. Metals Company for reclaiming by machining. This quantity was small, however, and after completion of the reclaiming work the order was closed out. Altogether, only 110 slugs were machined on this order at a total cost including guarding, boxing and shipping, of \$2123.83.

Up to this time the developmental work had shown that the optimum peripheral speed in machining appeared to be approximately one hundred forty feet per minute["] when using a dilute solution of Hydromite as a cutting oil. This liquid was tried after numerous tests had indicated that other solutions produced an inferior surface. The Corps of Engineers also requested that it be used at all fabricators, after it had been discovered that a higher recovery of turnings was obtainable when Hydromite was used in the machining. While

its cost was greater than that of the usual lubricants, it was therefore specified over the objections of the fabricators after the Metallurgical Laboratory had approved its use.¹²

Numerous tests were being conducted also in determining the most satisfactory cutting tool to be used. Because of the abrasive surface of the metal the usual tool tips could not be used for machining to diameter. After experimenting with various alloys and with Carboloy tips, it was agreed, and later standardized, that tungsten-carbide tools be used.

By the latter part of June, 1943, the Engineering Department was faced with the problem of scrapping a quantity of machined slugs which did not pass inspection because of oversize or undersize dimensions. While every effort had been made at the fabricators to conform to the specifications, it was inevitable that some slugs would be produced which were sub-standard in one or more respects. To utilize as many of these as possible, the Engineering Department submitted to the Metallurgical Laboratory a procedure¹³ (which later was approved)¹⁴ whereby those slugs falling within certain dimensional ranges could be re-machined for acceptance. The original tolerances were still retained after the procedure was inaugurated, but, in the interests of expediting fabrication and in attaining a minimum loss of slugs to scrap, the causes for rejection were considered slightly more flexible within certain approved limits.

The metal requirements for Clinton were well along toward completion when, in early September, 1943, the Engi-

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neering Department was advised that an additional thirty tons of rod, which to this time had been held in reserve, was to be machined to the standard Clinton specifications.¹⁵ The Engineering Department accordingly included this work in that being performed on orders XPG-174-1/2 and XPG-582-1/2 at Herring-Hall-Marvin and Baker Brothers, respectively.

The work at Herring-Hall-Marvin was completed in October. No undue difficulty had been experienced in machining the rods after the essential information relating to the optimum method had been determined. In all, 3100 rods had been machined into 63,985 slugs, at a total cost including guarding, medical services, boxing, shipping, express charges, necessary repairs to machines and similar allowable expenses, of \$119,712.82.

The work at Baker Brothers, Incorporated on order XPG-582-1/2 also came to a close about this same time, after machining 2107 rods into 41,133 slugs and reclaiming 4267 other slugs, at a total cost including all incidentals allowed in the contract of \$63,113.47. However, prior to this completion, order RPG-800-1/2 had been placed on this same fabricator for approximately 500 hours of machining work in connection with the slug development program for Hanford Engineer Works, and included also the reclamation of used experimental slugs for the Grasselli Research Laboratory.¹⁶ Baker was selected because of its heavier machines and the inherent ability of these to maintain closer tolerances.¹⁷

The Engineering Department, in placing this order,

anticipated the early installation of machining facilities at Hanford Engineer Works to handle the production work for that project. These facilities were put into operation in December, 1943 and, except for certain amounts of material described later in this chapter, machined all subsequent slugs required at the site.

The status of machining at the close of 1943 resolved itself into the following:

1. All uranium which had been allocated to Clinton Engineer Works had been extruded and machined by the end of September.¹⁸
2. Experimental slugs for the canning development program were being machined at Baker Brothers, together with what reclaiming of used slugs was required for Grasselli Research Laboratory.
3. The facilities in the 300 Area at Hanford were in operation in machining slugs.
4. Defects in extruded rod had just become quite prevalent at Revere Copper and Brass Incorporated, and machining tests were to be made at Baker Brothers to determine the extent of the imperfections.¹⁹

At the start of 1944, therefore, with the production machining of slugs well under way at Hanford, the interest of the Engineering Department in the machining program lay primarily in the fulfillment of various requests for experimental

slugs. The actual production machining for Hanford had been absorbed by the Explosives Department, and the Engineering Department's portion of this phase of the slug program was drawing to a close.

MACHINING - PROJECT 1553

However, the program was reactivated in May, 1944 when Project 1553 was opened to record the charges on a special order from the Explosives Department for the fabrication of 48,000 unbonded slugs for Hanford Engineer Works.²⁰ The work covered by this project comprised essentially machining and canning, as the procurement of rod was already covered by orders RPG-704-1/2 on Revere and RPG-3779-1/2 on Joslyn, and required merely the diversion of a portion of the total production. As much as possible of the rolled rod, however, was to be used for these unbonded slugs.²¹

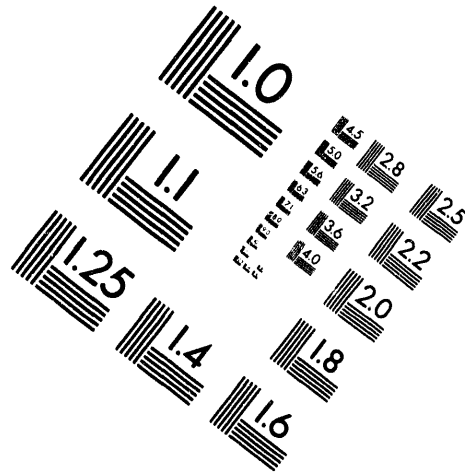
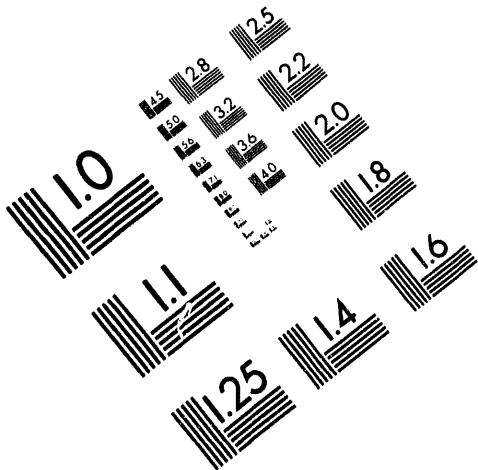
The need for these finished slugs was so critical²² that the Engineering Department planned to distribute the machining work among several fabricators. An investigation of various firms was undertaken immediately for the purpose of placing orders on a unit price per piece basis, as the machining characteristics of the metal had been well established by this time. As a result, orders were placed in rapid succession on three machining fabricators: RPG-4014-1/2 on Baker Brothers, Incorporated, Toledo, Ohio; RPG-4018-1/2 on C. H. Schnorr & Company, Springdale, Pennsylvania; and RPG-4021-1/2 on McKinney Tool & Manufacturing Company, Cleveland, Ohio. These orders were all to be performed on a 24-hour per day basis to expedite delivery.



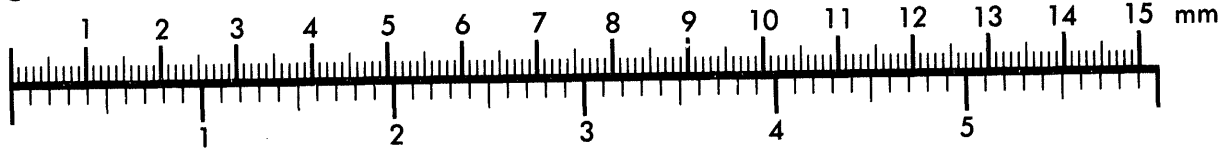
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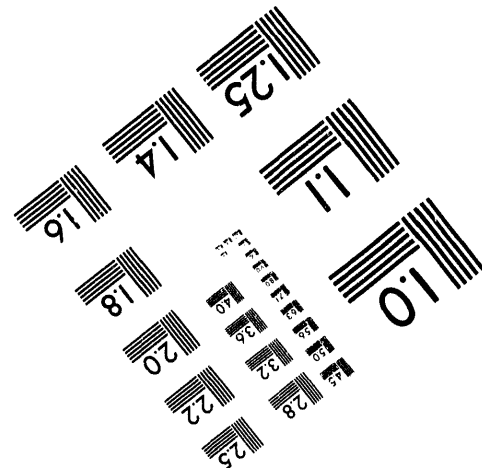
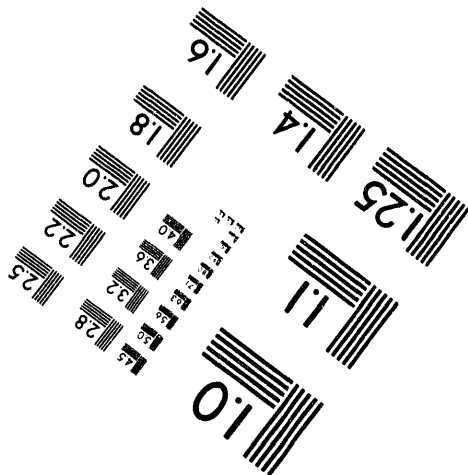
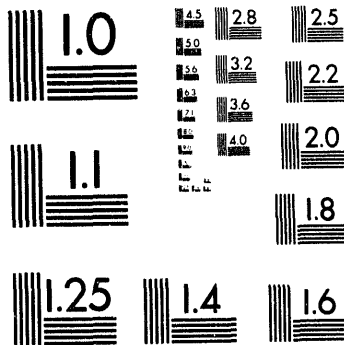
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The unit prices quoted by these firms varied considerably. Baker was lowest at \$2.75 each, and Schnorr was highest with a variable price ranging from \$11.97 to \$9.13 each, depending upon the final quantity machined.

The reasons for these wide differentials in price could be traced to the unfamiliarity with working the metal, the comparative ages of the equipment with respect to the ability to hold the tolerances, and the costs for segregating the work behind enclosures. However, these slugs were required for startup of Building 105-B at Hanford, and in compliance with procedures dictated by the Corps of Engineers for use during emergencies, cost became secondary to delivery.²³

The scope of work of these orders originally contemplated machining the slugs to finished diameter and length. Soon after the work had started, however, Baker Brothers suggested that production could be increased if rough-turned slugs were ground to finished diameter, as this was the best-known high-production method to produce work to close tolerances. Accordingly, this firm arranged to purchase and install a centerless grinder for production by this method.

The Engineering Department immediately acted upon this suggestion and purchased, on order RPG-4042-1/2, a centerless grinder for ultimate use in the 300 Area but for immediate use at McKinney in the performance of order RPG-4021-1/2. Schnorr already had equipment to center-grind and conversion was made immediately to this operation.

By this time, however, it was learned that Baker

could not secure its grinder in time to meet the stringent delivery requirements on the slugs, so the Engineering Department then was forced to place order RPG-4291-1/2 on the Wm. E. Pratt Manufacturing Company of Joliet, Illinois, for the centerless grinding, at a unit price of \$1.20 each, of rough-turned slugs. This company had been performing certain work for the Metallurgical Laboratory and thus was cleared for the immediate execution of this order. The scope of the order on Baker was then altered to include only the work preparatory to the grinding operation.²⁴ Because of this change, Baker was able to increase greatly its production by using equipment which was suitable to the wider range of tolerances acceptable for rough-turning. This increased output necessarily was accomplished at increased cost due to the use of additional personnel on overtime shifts, greater consumption of Hydromite, and various other factors not previously contemplated. For these reasons, no adjustment was made in the unit price for the elimination of the finishing operation as the increased costs closely approximated the original cost of the finishing operation.

No unusual difficulties were experienced in the performance of this work other than with the previously-mentioned prevalence of bows in the ends of the rod. After this condition was corrected, however, the operations assumed the aspects of normal commercial production.

GRINDING

From the start of the machining program, the Engi-

neering Department had been interested in the development of a method which would produce a superior finish on the surface of the slugs to facilitate the application of the anticipated bonded coating which must follow for the Hanford Engineer Works. Because a method of securing higher production rates to closer tolerances was also being sought, and, because the end use to which these slugs would be put was believed to require as perfect a surface as possible for the efficient operation of the pile, finishing by centerless grinding was thought to be a solution to both problems.

In May, 1943 the Engineering Department shipped ten Clinton size unfinished slugs to the Carborundum Company in Niagara Falls, New York, for the purpose of experimentally grinding to determine the type of abrasive wheel to use and the optimum speeds to maintain during a production grinding job.²⁵ These findings were reported soon thereafter, but were not put to use until the Metallurgical Laboratory conducted centerless grinding tests at the Joslyn Manufacturing & Supply Company in Fort Wayne, Indiana.²⁶ The results of these first tests proved that the operation was feasible, although further developmental work was required.²⁷ Subsequent tests by the Metallurgical Laboratory confirmed these findings and enabled the development of a suitable technique for fabrication by this method.²⁸ From this time on the Metallurgical Laboratory used centerless grinding quite extensively for the preparation of samples.²⁹

However, all slugs for Clinton Engineer Works had

been fabricated, and the facilities for Hanford had been purchased, installed and were in operation before the grinding technique had been developed. This method therefore was not used for the fabrication of the slugs in the 300 Area at Hanford until much later in the program, after receipt of the grinder which had been loaned to McKinney Tool & Manufacturing Company for use on order RPG-4021-1/2.³⁰ However, with the inception of Project 1553 for the fabrication of 48,000 unbonded slugs, grinding was early considered as an essential operation and thus was incorporated in the necessary scope of work. As mentioned previously, orders were placed on a total of three firms able to grind the slugs to finished diameter.

The only difficulties experienced in the fulfillment of these contracts were attributed to the pyrophoric character of the metal when reduced to grindings, and with its tendency to react with water. So hazardous were these conditions that it was necessary to incinerate all grindings in order to accumulate and ship safely the scrap generated from the operation. Other than this, though, the operation was standard and was performed without difficulty.

GROOVING

In September of 1943 it became evident that in order to perform a satisfactory test on the unbonded slugs, revisions to testing methods and slug design would be necessary. The Engineering Department had suggested that a longitudinal groove be milled on the machined surface for the full length of the slug to accomplish this result. Later, after it had

made certain tests, the Metallurgical Laboratory accepted this idea and worked out the mechanics of the deflection test. Accordingly, it was planned to mill the groove in all Clinton slugs then uncanned.

The machining order XPG-174-1/2 on Herring-Hall-Marvin was nearing completion at this time, so, in order to expedite the grooving operation by utilizing available facilities, the Engineering Department awarded this portion of the work on a machine-hour basis as an alteration to the order. In the same manner Baker was requested to groove those slugs then in its possession on an alteration to order XPG-582-1/2.

Similarly, this operation was included in order RPG-800-1/2, also on Baker, for the grooving of slugs, as directed, for any unbonded canning development.

As this operation involved merely the milling or shaping of a 60° V-groove approximately 0.010" wide at the top, no difficulty was experienced in the performance of any of the orders.

The Clinton Laboratories advised soon after this that it was in process of stripping the cans from a quantity of fifteen tons of rejected slugs.^{3/} As these slugs constituted a portion of the original requirements for this project, it was thus the responsibility of the Engineering Department to arrange for grooving, refacing the ends, and recanning. Since Baker was the only fabricator then performing any machining of uranium for the Engineering Department, it was thought advisable to place the grooving and refacing work on this

firm also, on order XPG-1795-1/2, and thereby effect a saving by eliminating the need for additional guard service, which was already provided on order RPG-800-1/2.

With the completion of order XPG-1795-1/2 in April, 1944, the machining and grooving phases for Clinton Engineer Works came to a close.

The program under Project 1553 for Hanford Engineer Works originally included the grooving of all slugs, which was to be performed as a part of the canning order RPG-4040-1/2 on the Quality Hardware & Machine Corporation in Chicago.³² Only a few slugs had been grooved at this location when another can-testing method was developed, thereby eliminating the need for this operation.³³ No subsequent grooving was performed on any slugs.³⁴

CONCLUSION

With the completion of the machining work for Project 1553 being performed at Baker Brothers, Schnorr, McKinney and Pratt, the responsibility of the Engineering Department in connection with the machining of uranium slugs was fulfilled. The program embraced the initial determination of the machining characteristics of the metal, and required the analyses of much experimental effort to establish the optimum machining speed, the type of cutting lubricant, and the class and contour of cutting tips to be used for successful production. In addition, the practice of centerless grinding was investigated and later adopted after it was proved a feasible method of finishing to diameter.

Altogether, the program required the production machining of more than one hundred thirty tons of slugs for the Clinton Engineering Works and of approximately 51,000 Hanford size slugs for Project 1553, as well as the reclamation of used slugs and the experimental machining of slugs for the various consultants working on the development of canning. Quantities of uranium were processed also for other special tests, and for use in the exponential test pile at the Metallurgical Laboratory.

SUMMARY

The program required the placement of ten purchase orders for the performance of the work as listed below. All incidental costs, such as for guarding, express, medical services and the like, insofar as are contained in the final alterations, are included in the cost figures for each order.

For Clinton Engineer Works

Purchase order XPG-174-1/2 on the Herring-Hall-Marvin Safe Company, Hamilton, Ohio, for the development of methods and production of 63,985 slugs at a total cost of \$119,712.82.

Purchase order XPG-582-1/2 on Baker Brothers, Incorporated, Toledo, Ohio, for the development and production of 41,133 slugs and the reclamation of 4267 others, at a total cost of \$63,113.47.

Purchase order XPG-753-1/2 on the B. & T. Metals Company, Columbus, Ohio, for the production of 71 slugs and

the reclamation of 39 others at a total cost of \$2,123.83.

Purchase order XPG-1795-1/2 on Baker Brothers, Incorporated, Toledo, Ohio, for the grooving and refacing of ends on 12,435 slugs at a total cost of \$4,262.34.

For Hanford Engineer Works - Project 9536

Purchase order RPG-800-1/2 on Baker Brothers, Incorporated, Toledo, Ohio, for the machining, grooving and reclamation of slugs as required in connection with the slug development program, at a total cost of \$19,888.48.

For Hanford Engineer Works - Project 1533

Purchase order RPG-4014-1/2 on Baker Brothers, Incorporated, Toledo, Ohio, for the rough-machining and facing to length of 16,899 slugs, 7004 of which were finish-machined in addition, at a total cost of \$51,270.91.

Purchase order RPG-4018-1/2 on C. H. Schnorr & Company, Springdale, Pennsylvania, for the rough-machining, facing and grinding of 16,308 slugs at a total cost of \$163,815.74.

Purchase order RPG-4021-1/2 on McKinney Tool & Manufacturing Company, Cleveland, Ohio, for the rough-machining, facing and grinding of 17,746 slugs at a total cost of \$81,924.08.

Purchase order RPG-4040-1/2 on Quality Hardware & Machine Corporation, Chicago, Illinois, for the unbonded canning of slugs. The charges for grooving the few slugs prior to the elimination of this operation were included in

the unit price for canning and were not segregated.

Purchase order RPG-4291-1/2 on William E. Pratt Manufacturing Company, Joliet, Illinois for the centerless grinding of 10,007 slugs at a total cost of \$12,250.00.

SECTION VII

DEVELOPMENT OF CANNING METHODS

DEVELOPMENT OF CANNING METHODS

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SECTION VII

DEVELOPMENT OF CANNING METHODS

INTRODUCTION

From the start of du Pont participation in the design and construction of Hanford Engineer Works, it was recognized by all interested parties that the great majority of the design information covering certain phases of the project must be secured through the medium of the Metallurgical Laboratory of the University of Chicago. The necessity for this information with respect to the metal fabrication program was particularly urgent. Because of the very nature of the project, the du Pont Company was initially unable to perform the design work on this program until certain necessary information was supplied by the various consultants. The metal fabrication program required, therefore, that adequate information and specifications be provided by the Metallurgical Laboratory, through the TNX Division of the Explosives Department, to the Engineering Department; in order that procurement of the finished slugs might be effected at the earliest commensurate date.

Owing to the peculiar properties of uranium, and to the absolute necessity that its performance in the pile conform to certain requirements, it was essential that the exterior surface of the slugs be protected in some manner which would prevent its reaction with the water in the pile. The

earliest consideration proposed as a means of protecting these surfaces visualized the application of a metallic coating to the machined slug, either by electroplating or by a hot-dip process. The Office of Scientific Research and Development placed a separate contract with the Grasselli Chemicals Department Research Laboratory, located in Cleveland, Ohio, for the development of a satisfactory coating process utilizing this conception. Despite considerable research work and experimentation by this latter group, the electroplating process subsequently proved unfeasible for commercial production, and ultimately was abandoned in favor of a hot-dip process that also was being evaluated, and which, it was believed, would satisfy more fully the requirements.

Past research had determined that the most suitable covering for the protection of the uranium slug and for its efficient operation in the pile was aluminum. Therefore, with but few exceptions, virtually all investigations and developmental work incurred in the protective coating of slugs employed aluminum in one form or another.

Whereas the responsibility for the development of the canning methods was vested in the Metallurgical Laboratory, the Engineering Department was responsible for the quantity production of the finished slugs and for the procurement of all special equipment — whether to be used at the fabricators or at the Hanford Engineer Works — which was required for this production.¹ Since the fabrication of any of the component parts making up the finished slug assembly neces-

sarily required experimental work to varying degrees, it was but a short step for the Engineering Department to absorb the attendant responsibilities therefor in the prosecution of its duties to provide adequate production. The actual developmental work, however, was subcontracted to firms familiar with that particular type of fabrication. Furthermore, to effect the start of production, or to maintain it, necessitated that the Engineering Department on several occasions accept the present method as satisfactory, rather than to jeopardize the program by waiting for more-advanced information or subsequent revisions to the process.²

CLINTON SLUGS

On March 3, 1943 it was agreed between representatives of the Clinton Laboratories and the du Pont Company that the coating of uranium slugs by a hot-dip process could best be carried out at Clinton Engineer Works, and that the Engineering Department would arrange, in cooperation with the Grasselli Laboratory, to see that the necessary equipment facilities for housing it were installed in time to carry through the coating operation on the 100-ton initial quantity of slugs.³

It was recognized, however, that there was a distinct possibility that the hot-dip coating would not be satisfactory for the Clinton slugs, and in this event some other coating technique must be found. Grasselli Laboratory was still working on the electroplated coating as a possible alternative, and the Metallurgical Laboratory was studying

the possibility of fabricating aluminum jackets on the metal slugs.

No suitable coating method had been demonstrated by the latter part of March.⁴ While electroplating or hot-dip coating conceivably might still be developed for Clinton, it remained entirely possible that canning in aluminum, which was anticipated for Hanford, might have to be extended to Clinton. However, no commitments for work on canning were undertaken by the Engineering Department at this time.

The Grasselli Laboratory soon advised the Engineering Department that there was little possibility of a decision being reached regarding the construction of the coating plant at Clinton, to use either the electroplating or hot-dipping method, until such time as further information had been developed covering an alternative procedure then being investigated by the Metallurgical Laboratory.⁵

In view of the original schedule which called for the completion by June 1, 1943 of the coating of the total number of slugs required for Clinton, Grasselli had proceeded with the preliminary work of laying out coating plants for both the hot-dipping and electroplating processes, locating suppliers for required equipment, and securing estimates of delivery dates. These plans for a commercial coating plant were tentative only, and no commitments were made. It was apparent, moreover, if large-scale coating by either of these processes was to be started by May 1, that construction of the coating plant must be started at once. There was serious

doubt, even then, that the construction of a plant would be accomplished in the allowable time.

Representatives of the Metallurgical Laboratory and the Grasselli Laboratory then agreed that sufficient evidence to justify the construction of an electroplating or hot-dip coating plant was not then available, and the Grasselli Laboratory discontinued any further activity in connection with the design or recommendation for construction of any such plant. This left the possibility of applying an aluminum jacket, or can, around the slug as the only feasible method.

The Engineering Department immediately investigated two avenues of endeavor to develop a satisfactory canning method. Developmental work was initiated at the Aluminum Company of America in New Kensington, Pennsylvania, and at the Wolverine Tube Division of the Calumet & Hecla Consolidated Copper Company in Detroit, Michigan. Alcoa basically was requested to develop a method for sealing the slug in the can by the insertion of a cap over the open end of the slug, and then to braze or weld the can to the cap. An alternate endeavor by Alcoa was directed toward closing the can by spinning it over the end of the slug, followed by brazing or welding over the resultant small opening.⁶ Wolverine's activities were occupied only with this alternate method.⁷

From the start, Alcoa contributed invaluable assistance in the development of its method. Preliminary tests made on a few experimental canned slugs proved that brazing,

as attempted, was unsuitable; and that unless this method could be considerably improved, canning by this means must be considered as impracticable and without justification for further development along these lines.

In order to prevent any deleterious effects on the process in the pile, it was recognized that no impurities or particles of foreign matter should be contained within the sealed can. This requirement therefore excluded the use of any welding flux, and imposed upon all groups an assignment that already was extremely difficult to conquer. Fluxless welding of thin aluminum sheets was virtually an uncharted field, and, though commercial equipment had been developed to weld heavier-gauge sheets, the attendant burning of the sheets and running of the weld with extremely light-gauge stock ultimately proved to be the major obstacle to the canning program.

This exigency accordingly prompted the investigation of seam welding and spot welding, and, although no experimental work had been performed on the former, it was believed that this method would quite probably be more adaptable than spot welding. However, both spot- and seam-welding experiments were to be carried on concurrently so that the respective merits of each could be determined and evaluated.

During April, 1943, many time-consuming attempts were made by Alcoa to obtain a sound type of fluxless spot weld on a riveted end. When welding was attempted with uranium slugs instead of with the steel slugs previously used, the results were uniformly disappointing. However, with the

cooperation of the Taylor-Winfield Company, Alcoa later obtained some very promising examples of seam welding with this manufacturer's machines. These specimens were recorded as being sufficiently successful to warrant the installation at Alcoa of a Taylor-Winfield seam welder, with the thought that the New Kensington Plant be set up for production experiments.

By the end of April, 1943, Alcoa had progressed with canning to the point where samples of both seam-welded and spot-welded cans were ready for inspection by representatives of the Engineering Department. These samples were displayed for comparison, and a test made on the tightness of the cans proved conclusively that seam welding was the more satisfactory method.⁸ However, this type of closure required approval from the standpoint of heat transfer, necessity for evacuation, importance of individual air content, hot hydrogen test and final methods of inspection for plant use.

At a meeting held subsequently to discuss the status of the work at both Alcoa and Wolverine, it was decided that the du Pont Company would purchase a special welding machine from the Taylor-Winfield Company for use in a seam-welding the canned slugs at Alcoa, as it was the consensus that the canning method as adopted by Alcoa would be satisfactory.

By the early part of May, 1943, Alcoa had become sufficiently familiar with the problems involved to submit a firm quotation to cover the developmental work in connection with, and the production of, 90,000 canned Clinton size slugs. Purchase Order XPG-423-1/2 was accordingly issued

to cover this work.

It was decided also that order XPG-427-1/2 would be placed on the Wolverine Company for the developmental work and canning of 500 slugs to be produced by an alternate method. This procedure was believed desirable in view of the remote possibilities of the ultimate failure of the welded casings which then appeared so satisfactory.

Although the representatives of the Metallurgical Laboratory had expressed the thought that there would probably be some further improvements in canning technique,⁹ it was nevertheless agreed between Alcoa and du Pont that in order to meet the expected start-up of production on June 1, 1943, the method as proposed would be considered satisfactory until proved otherwise. From this date on, experiments with seam welding continued to improve and progress was rapid.

The sequence of operations as performed at Alcoa comprised: insertion of slug and cap in can, polishing the can, seam-welding the can and cap, trimming off the excess can to length, testing of control cans, and crimping the up-standing edge of the can to force it flat against the face of the cap.¹⁰

As a part of the developmental work included in order XPG-423-1/2, Alcoa was requested on numerous occasions to fulfill various requests by the Metallurgical Laboratory or Grasselli Laboratory for specimen¹¹ or special¹² canned slugs. These were used for additional research or for development of testing methods, corrosion studies, or bonding techniques,

and were not made available for later use at Clinton.¹³

By the middle of July, 1943, the Engineering Department had been advised that the requirements for Clinton Engineer Works would be 100 tons of canned slugs and, in addition, thirty tons which would be machined only.¹⁴ Inasmuch as the type of coating had a direct bearing on the diameter of the machined slug, the Engineering Department immediately requested the Metallurgical Laboratory for advice concerning the anticipated method of coating to be used on these additional thirty tons. The Metallurgical Laboratory stated that the hot-dip coating, which was still being evaluated, cracked at the edges during the canning operation and it was very unlikely that this method would be available in time to affect the canning operation on any part of the 100 tons originally ordered for Clinton.¹⁵ Experimental work was proceeding in an effort to improve the hot-dip process but, pending receipt of this information, the Engineering Department was to proceed on the assumption that all of the slugs ordered for Clinton should be machined to the standard 1.100" diameter. Subsequent developments in the hot-dip process did not justify its use in the Clinton program.

Early in August, Wolverine reported that progress was improving in the canning of the 500 experimental slugs.¹⁶ When du Pont explained that complete evaluation of these would be necessary before further steps could be taken for the procurement of additional quantities, Wolverine emphasized the fact that there was some doubt as to its ability to continue

the development of new closures required for Hanford Engineer Works, in view of new fabricating business which it was then scheduling in its shops. This decision left Alcoa the only remaining source of canning for either the Clinton or the Hanford slugs, until canning facilities could be set up in the 300 Area at Hanford.

Wolverine endeavored to fulfill the requirements of order XPG-427-1/2, however, and ultimately completed a total of 487 canned slugs of the 500 requisitioned. The great majority of these were not acceptable¹⁷ and all developmental work against this order was stopped.¹⁸ The order was later closed out without additional work having been performed.

By September, 1943 the welding operations at Alcoa had become somewhat standardized and performance was fairly predictable. Several different cleaning solutions had been tried with varying degrees of success. However, the Engineering Department believed that the welding procedure could be improved to the extent that fewer rejects would be produced. In an endeavor to further the development of welding and to uncover any possible alternate methods, representatives of the Engineering Department visited the General Electric Company in Schenectady, New York, to investigate methods under development.¹⁹ Here it was learned that thin aluminum sheets could be welded satisfactorily by means of an alternating current tungsten arc working in an atmosphere of argon. Arrangements were made for metallographic examination of welded samples at the Engineering Department Experimental

Station and, on order RPG-1384-1/2, for the welding of additional samples at the General Electric Laboratories. After additional testing this method was specified for the canning of Hanford slugs.

In the meantime, purchase order XPG-1628-1/2 had been placed on Alcoa for the canning of 60,000 Clinton slugs, to be sealed by resistance welding. Only 12,768 slugs had been canned when this welding method was considered unsatisfactory for higher-temperature pile operation. Although the fusion welding method had not then been fully developed, it was known to be superior to resistance welding under the proposed conditions, and order XPG-1628-1/2 was accordingly cancelled.

All canned slugs from Alcoa were tested by the hydrogen and the hot-air methods after their receipt at Clinton Engineer Works. Both methods loosened the mechanical bond between the slug and the can because of the annealing characteristics of the test, and this loosened condition made possible the testing of slugs by the later-developed deflection test, which, by November, 1943 indicated that a quantity of approximately fifteen tons leaked and would require re-canning. Inasmuch as the Engineering Department was yet to supply thirty tons of Clinton slugs which were to be machined only, the Clinton Laboratories stripped the cans from these leakers and applied these slugs against the thirty tons. The Engineering Department then placed order XPG-1750-1/2 to cover the developmental work and canning, employing the fusion

welding method developed by General Electric Company, of slugs to replace the leakers. This order, unlike the two previous orders placed on Alcoa, was awarded on the basis of du Pont's supplying all component parts required in the assembly, as well as furnishing the special arc welding machine for Alcoa's use.

Ultimately, the process was developed under du Pont direction and a total of 17,456 slugs was canned on this order. This completed the requirements for the Clinton Engineer Works with respect to the Engineering Department's participation in the program.

HANFORD SLUGS

The development of canning methods for Clinton was necessarily extensive because of the paucity of information on any form of coating or welding process, and the lack of any firm specifications based on performance characteristics of the slug in the pile.

This situation was somewhat different with the Hanford slugs, as the information gained from the preliminary developments in canning the Clinton slugs was considered applicable to the larger slugs for Hanford. In addition, the machining and canning facilities to be installed in the 300 Area were expected to produce all the slugs required for Buildings 105-B, 105-D and 105-F. The developmental work required in the Hanford program, however, surpassed in magnitude that required for Clinton, owing to the need for a bonded type of slug for efficient use in the water-cooled piles.

Up to June, 1943, virtually all of the information on the Hanford slugs was very tentative and subject to continued revision by the Metallurgical Laboratory. On June 5, however, slug size was crystallized to the extent that the Engineering Department could undertake preliminary work in the development of certain phases of the canning program.²⁰ It was then the intention that practically the same welding methods for sealing the slug in an aluminum can would be followed for Hanford as for Clinton.

Purchase order RPG-277-1/2 was placed immediately on Alcoa to cover the developmental work, procurement of required tools, machines, and other necessary equipment to enclose satisfactorily the Hanford size slugs as directed by the Engineering Department. This work would include also the furnishing of 3000 experimental canned slugs of three different types.

In the developmental work attendant to the canning of these slugs, Alcoa had been attempting, in conjunction with the Metallurgical Laboratory, to perfect a method for bonding the cans to the slugs.²¹ This procedure involved, in brief, pickling the slugs in a warm nitric acid solution, and dipping first in molten zinc and then in a 92% tin-8% zinc bath. The slug was then inserted into the can and the assembly was forced through a hot die to effect a metallic bond between the can and the slug.

Alcoa expressed willingness to attempt the incorporation of bonding technique into its production of slugs,

and the Metallurgical Laboratory agreed to provide the Engineering Department with an outline of the method as it was then understood.

In September, 1943, representatives of the Metallurgical Laboratory and du Pont decided that orders would be placed for the equipment necessary to can the Hanford slugs in accordance with three methods:²²

1. An exact duplicate of the method then used for Clinton slugs.
2. An electroplating applied to the slug and the can the same as the Clinton method.
3. A hot-dipped slug bonded to the can with a tin-zinc solder.

The Metallurgical Laboratory later proposed double-canning the slugs, and it was the opinion of the Alcoa group that more would be gained by using a thicker can than by the use of two separate cans encasing the slugs. However, the TNX Division had lined up a program with Alcoa for the improvement of the welded closure which included, among other considerations, the use of the double cans and also the alternate use of a double cap, each cap being welded or brazed in place.²³

Meanwhile, it was the consensus of various Divisions in the Engineering Department that efforts to produce a perfect weld should be continued while the alternate closure designs were being investigated.²⁴ Then, in order to eliminate any possible interference with this work from other essential war orders at Alcoa, the Engineering Department requested,

and received, the support of General L. R. Groves, who instructed Alcoa that this work be given preference over any other work on its production schedule.²⁵

The immediate program of developmental work to be undertaken at Alcoa by the end of September, 1943, resolved itself into the following:²⁶

- a. Two hundred Hanford-size slugs would be canned with the double-welded seams, one directly above the other.
- b. Alcoa would determine the minimum thickness of aluminum that could be used on a design employing two caps. The Engineering Department would then decide whether further work on this plan was worth while.
- c. Ten Hanford-size slugs would be canned, using two cans, one assembled over the other and with the caps seam-welded at opposite ends.

On October 15, 1943 the TNX Division advised the Design Division that the development of canning should proceed along the following lines:²⁷

1. The outside diameter of the canned slug, encased in a double can with alloy bonds at all inner surfaces in the assembly, would be 1.440 inches. The bare slug diameter would be determined by the thickness of the aluminum cans, which should be kept to a minimum consistent with the assembly and welding requirements. The aluminum end caps which provide for an air space at each end of the assembly should be designed to withstand 200 pounds per square inch

operating pressure without collapse or excessive deflection.

2. In developing a method of assembly it should be the objective to incorporate a sufficient degree of flexibility to permit elimination of the inner can and assembly and to provide for an enlarged-diameter slug within the single can.

By the latter part of October, 1943, the Engineering Department believed that the developmental work for the various canning methods had progressed sufficiently to permit a firm decision as to the ultimate method to be adopted. As a consequence, therefore, representatives of the University of Chicago and the TNX, Design and Construction Divisions agreed generally on the following:²⁸

1. A bonded can with air-gap insulated ends would be intensively developed. Double-canning, employing tin-zinc solder, was favored. Air-gap insulation must be provided by a tight-fitting aluminum end cap in order to insure that no solder would penetrate into the cap space where reaction with the hot base metal could result in loss of insulating value.
2. The Metallurgical Laboratory should be responsible for the development of a satisfactory bonded aluminum can and the methods for testing the qualities of the finished slugs. The responsibility for developing manufacturing methods should lie with the du Pont Company.

3. The real responsibility for the manufacturing developmental work would have to lie within the du Pont Company, and it would be necessary for the members of the Engineering and Explosives Departments to come to some agreement between themselves as to the best location for the prosecution of this work.

In order to provide production facilities for Hanford, du Pont recommended that a production unit be developed and set up complete, insofar as time would permit, and perform on a limited production basis the necessary steps to manufacture canned slugs for Hanford.²⁹ The development of this unit was necessary not only to save time but to permit development of equipment for this process, such equipment not existing at that time, and to demonstrate that the equipment so developed would function satisfactorily at Hanford. The locations suggested for this unit were the University of Chicago, Hanford Engineer Works, and the Wilmington Shops.

From an analysis of the facilities at these locations, it appeared that Wilmington Shops would best serve the purpose. It had available space, complete mechanical facilities located within a short distance of the source of cans, the use of both the chemical and metallurgical facilities of the du Pont Experimental Station, and could be under complete supervision of the Development Engineers, the Design Division, and the technical and operating personnel of TNX.

Before this experimental canning line could be set up, however, certain developmental work would be required which possibly would necessitate additional effort in the development of equipment or practices not then considered. The inauguration of the work would require the immediate development of:

1. Perfectly straight side wall aluminum cans with tolerances of plus or minus .001 inch. Cans had never been manufactured commercially to these specifications.
2. A production method for tinning the surface of the cans and procurement of the necessary equipment.
3. The time sequence for the various elements of the operation, and the design and procurement of the special fixtures and handling devices to prevent damage to the slugs.
4. An end closure of minimum thickness, and
5. Automatic operation of the selected type of welding machine.

The magnitude of this work required close coordination of effort between Divisions and Departments of the du Pont Company. Meetings were held at frequent intervals to plan and schedule the work to be performed at the Shops. Whenever possible, equipment intended for ultimate use in the 300 Area at Hanford was diverted for this experimental line. Portions of orders on fabricators of the various component parts making up the assembly were delivered to the Shops. When modifications to existing equipment or fabrication of

new equipment became necessary, the facilities of the Shops were utilized for the purpose.

On November 1, 1943 the TNX Division advised the Engineering Department of the design that would be utilized as a basis for developing a canned slug suitable for use at Hanford.³⁰ Though it was recognized that this design, even as modified by development of the Shops program, might not represent ultimate perfection; the object of the program nevertheless was to arrive at a method of canning which would yield usable slugs.

The experimental canning program thus was divided into three parts:

1. Research, to be the responsibility of the Metallurgical Laboratory.
2. Procurement and Design, by the Engineering Department.
3. Production Process Refinement, by the Explosives Department.

The initial efforts by the Engineering Department were to be directed toward specifying simple and easily-obtainable equipment which might be adequate for the purpose, but not necessarily either efficient or mechanized.

As a part of the program, the Engineering Department placed orders for equipment required for the experimental canning line at the Shops. After the Corps of Engineers had secured General Electric Company's approval for omission of the patent clause, order RPG-1439-1/2 was also issued for four argon-shielded fusion welding machines. One of these was shipped to the Shops, one to Alcoa, and the

remaining two to Hanford. All equipment was charged to the 300 Area and ultimately was reshipped to this destination.

Meanwhile, developmental work had been progressing at Alcoa in an effort to improve the seam welding method. Alcoa was still experimenting with various cleaning solutions and had discovered a vapor degreasing and immersion method that gave excellent results.³¹ This procedure was later approved by the Metallurgical Laboratory.³²

Early in January, 1944, the Metallurgical Laboratory, in summing up the status of Hanford coating methods to date, advised that from the corrosion point of view aluminum-silicon bonding was capable of providing a perfect coating for Hanford slugs, as can undercutting and swelling troubles were practically non-existent.³³ However, the present uncertainties involved in this particular type of bonding process were:

1. How soon and how completely could the process problems be solved, and,
2. How much trouble might result from the brittleness of the bonds?

Aside from these, the two main process problems that remained to be solved were concerned with the aluminum insulating caps and the equipment used for the actual canning operation.

On January 8, 1944 the TNX Division advised the Design Division that from the accumulated evidence on corrosion testing at the Metallurgical Laboratory, it would be advisable to abandon the tin-zinc bonded double-canned slug assembly.³⁴ Therefore, further work on double canning, includ-

ing that at the Wilmington Shops, should be limited to only that which was necessary to complete unfinished testing of equipment and which might contribute to the development of an alternate method of assembly.

The most promising alternate method at this time comprised an aluminum can of 0.035" wall thickness, bonded with aluminum-silicon on a base coat of copper-tin applied directly to the slug by hot-dipping. The work at Wilmington Shops, at the Metallurgical Laboratory, and at Grasselli Laboratory was to be concentrated on the further development of this assembly system. At the latter two locations, equipment was then being fabricated for the assembly of slugs by this method. Meanwhile, the activity at these two sites would be in the nature of preparation, but would include also some experimental production of single-canned slugs bonded with tin-zinc alone. Neither of these methods, however, would be permitted to interfere with anything that could be done at any time on the aluminum-silicon method.

Equipment necessary for producing assembled slugs with the aluminum-silicon method of bonding was to be installed at the Wilmington Shops as quickly as possible. While awaiting completion of this equipment, however, testing was to continue of tools, fixtures, and other equipment which could be used on the aluminum-silicon method and which was then on hand at the Shops. This would include insulator cap testing, production of different types of insulator caps, and development of equipment for applying the cap to the slug.

As each piece of equipment for the aluminum-silicon bonded single-can system was developed to the point where it could be used, even though on a limited scale, at Hanford for production assembly of canned slugs, it was to be installed as quickly as possible in the 300 Area as well as at the Shops.

By the close of January, 1944, the TNX Division had advised the Design Division of various recent developments at the Metallurgical Laboratory and at the Grasselli Laboratory which might affect the design and equipment testing at Wilmington Shops.³⁵ These developments disclosed the fact that:

1. The most promising electroplated base coat now appeared to be chromium,
2. The bronze-tin aluminum-silicon hot-dip coating method was favored on the basis of test performance, and
3. It might be necessary to use aluminum cans with an aluminum-silicon veneer on the inside.

At this time the developmental work at Metallurgical Laboratory and at Grasselli had crystallized to the extent that a tentative method of canning the aluminum-zinc-silicon single can assembly could be reported.³⁶ This method ultimately developed into that used at Hanford, but a considerable amount of work remained at this time in order to perfect the process to a degree suitable for production.

One of the most persistent faults encountered in the developmental work at the various locations was the damage to the can while in the heated die. Both the Wilmington Shops

and the Metallurgical Laboratory were attempting to overcome this difficulty and also, as a part of the same problem, to prevent fouling of the die with molten aluminum-silicon. After a variety of discussions and tests, it was agreed that the most promising method would employ an expendable steel sleeve, in the form of a can, in which the slug and aluminum can would be encased temporarily during the assembly operation.³⁷ The steel can would then be removed during the quenching operation. This method was adopted in principle and was to be evaluated in practice. The Grasselli Laboratory was to secure steel and brass sleeves for trial,³⁸ and the Engineering Department was to develop a source for the steel cans.

Results from experimental work at all locations during February, 1944, were encouraging.³⁹ Considerable progress had been made at Grasselli in assembling slugs in 0.035" wall aluminum cans, using the aluminum-silicon bonding method. Samples of canned slugs were prepared by using a thin steel sleeve in the hot die, with satisfying results. Further work was done at the Metallurgical Laboratory on the tin-zinc solder bond method, which it was felt was now completely developed as an alternative in the event that aluminum-silicon could not be used for some unforeseen reason.

Welding continued to be the chief problem of the slug assembly. Various experiments were made to reduce the tungsten electrode diameter but the resultant quality and yield were very poor. Slugs being welded on a production scale at Alcoa, under the supervision of du Pont and Metal-

lurgical Laboratory, showed an acceptable yield of about sixty-five percent. The work on welding at the Wilmington Shops was directed toward developing fixtures for holding the slugs, adjusting the electrodes, and removing heat from the welding zone.

It was found that an objection to the aluminum-silicon method was in the formation of a brittle alloy layer, but further study at Grasselli, and also at Massachusetts Institute of Technology, revealed that this brittleness was limited only to certain conditions. Also, the electroplated chromium base coat used in this method was not satisfactory.

Despite the vast amount of experimental work which had been performed on all phases of the canning operations, it was believed that additional improvement could be made in the cleaning of the aluminum cans. To pursue this matter farther, members of the Engineering Department visited Rensselaer Polytechnic Institute early in March, 1944, to witness tests and obtain information on the cleaning method which had been developed there for the National Advisory Committee on Aeronautics.⁴⁰ This method was subsequently evaluated at the Metallurgical Laboratory, Wilmington Shops, Grasselli and Hanford,⁴¹ and while it produced an excellent surface, was not as rapid as the caustic process and thus was not used.

By the middle of April, 1944, tests on aluminum-silicon bonded slugs proved that less than 20% of the slugs were acceptable.⁴² The Metallurgical Laboratory then recommended that Hanford take steps to set up as soon as possible a cann-

ing line for the production of zinc-bonded slugs. However, the main obstacle to complete acceptance of this process at this time was the lack of a complete solution to the welding problem, but recent improvements in this operation looked so promising that there was little doubt of its feasibility.

By the latter part of April, the status of the slug program for Hanford was interpreted as follows:⁴³

1. Three methods of canning were currently receiving consideration: aluminum-silicon bonded, zinc-bonded and unbonded.
2. The aluminum-silicon method had passed through Laboratory and Semi-Works development. The zinc process had passed through Laboratory development only. The unbonded slugs of the Hanford size had passed through Laboratory development only, but more than 100,000 slugs of this type had been manufactured for Clinton.
3. Equipment was in operation at Hanford and additional equipment was to be delivered there shortly for the aluminum-silicon process. No equipment for the zinc or unbonded processes as such had been procured but both methods could use portions of the aluminum-silicon equipment with little change.
4. Cans in quantity were available for either the aluminum-silicon or the zinc process but not for the unbonded. Caps in quantity would be available in the near future for the aluminum-silicon process but not for the zinc or unbonded.

5. Finished slugs were tested for bond penetration and welding. Testing methods were probably adequate. Standards of acceptability necessarily were based almost entirely on theory and calculation and might be significantly in error.
6. The aluminum-silicon process was currently producing approximately 25% acceptable slugs under present standards. Corresponding figures for the zinc and unbonded processing were not available but most recent data on Clinton unbonded slugs indicated approximately 85% acceptance.
7. The quality of aluminum-silicon bonded slugs could not be expected to improve substantially by operating technique alone.
8. Defective slugs from the unbonded process could be reclaimed immediately. Possibility of reclaiming from the aluminum-silicon and zinc processes was being studied actively with encouraging results. Plant installation of such recovery equipment was probably at least two months off. Reclamation of defective slugs was absolutely necessary to conserve metal.
9. No method of fabrication would produce 50,000 slugs by July 1 without lowering the standards of acceptance.
10. By lowering the standards of acceptance, the aluminum-silicon process could produce 50,000 slugs for the first pile by July 1.

11. Zinc-bonded slugs could be produced for the second pile by September 1.
12. Unbonded slugs could be produced for the second pile by September 1, or for a portion of the first pile if it were unable to go into operation until August.

On August 18, 1944 the Engineering Department confirmed instructions given it by the TNX Division that additional facilities, as listed below, would be provided for canning of slugs by means other than those installed at present at Hanford Engineer Works.⁴⁴

1. Equipment similar to that in use for canning unbonded slugs on Project 1553 would be procured. Modifications in this equipment, as indicated by the experience of the members of the Engineering Department or TNX Division, would be made for more efficient operation of this process in a production line set-up. The essential pieces of equipment would be provided, recognizing that such things as tools for this equipment, dies, etc. would be dependent upon further information to be developed by the Operating Department at Hanford.
2. Equipment similar to that used at the Metallurgical Laboratory for canning of slugs with a zinc bond between the slug and the can would be procured. Designs for this equipment were available from the Metallurgical Laboratory and would be used without revision.

3. No developmental work in connection with any of the equipment or processes involved was to be conducted by the Engineering Department at this time.

PROJECT 1553

By May 2, 1944, the aluminum-silicon process appeared so discouraging, from the viewpoint of immediate production of acceptable slugs, that the TNX Division requested the Engineering Department to arrange for the immediate fabrication of 48,000 unbonded Hanford slugs.⁴⁵ These slugs would be used for charging the first pile in the event that the bonded method could not be evolved satisfactorily in time to meet requirements.^{46, 47}

This program, charged to Project 1553 for convenience in segregating the costs, was primarily one which utilized known procedures of operation, and thus did not embody to any great extent the development of extensively modified or untried methods. It was recognized, too, during the subsequent fabrication of these slugs, that the urgency of the program would necessitate upon occasion the relaxation of specifications and acceptance of quantities of finished slugs or component parts which would be dimensionally outside the tolerable limits originally imposed.^{48, 49}

Since the Operating Department at Hanford meanwhile had been undertaking the development of production methods for the aluminum-silicon process, it was requested that the manufacture of the 48,000 unbonded slugs be performed at various commercial fabricators' plants in order that the work

might not be delayed or be caused any interference. This accordingly was done and the work at Hanford benefited thereby.

During the life of the unbonded slug procurement on Project 1553, developmental work at the various locations continued without interruption. The work at the Wilmington Shops drew to a close in May. That at Hanford was concentrated on perfecting the various operations developed by all the consultants in an endeavor to meet the stringent requirements for startup, not only of Building 105-B, but also of 105-D and 105-F.

By the latter part of July the major difficulties in the aluminum-silicon method had been surmounted at Hanford. Production of acceptable slugs was increasing and the urgent need for unbonded slugs diminished to the extent that the two orders for canning were terminated after completion of approximately 37,000 of the specified 48,000 unbonded slugs.⁵⁰

ADDITIONAL DEVELOPMENTAL WORK - PROJECT 9536

Despite the fact that procurement of finished slugs appeared to be assured for startup of the piles, developmental work continued with the ever-present thought of improving the canning process and, indirectly, the operating characteristics of the slugs in the pile — through the media of more effective heat transfer and greater resistance to leaking at the weld.

One such anticipated improvement, requested by the TNX Division, was the development of a slug assembly which

would be characterized by a double-weld closure.⁵¹ The Design Division, in undertaking this assignment, arranged for the work to be carried out at Alcoa on order RPG-5342-1/2; which covered the development and production of fifty samples to du Pont design, assembled by means of drawing a thick-wall aluminum can on a sample steel slug in such a way that the desired thickness be produced at the top of the can in a single drawing operation.^{52,53} The Metallurgical Laboratory was to furnish seventy-five heavy-wall cans suitable for this work.⁵⁴

Alcoa proceeded with this work and by the end of 1944 had sent samples of canned, but unbrazed, slugs to Hanford.⁵⁵ Additional samples, brazed at Alcoa's Research Laboratory, later were submitted for the approval of the Operating Department. This completed the work on this order and, while it was an unusual process, Alcoa had developed methods which gave results of excellent quality and which were entirely practicable for high quality production.

Upon completion of this order, the Engineering Department's responsibility for developing the manufacturing methods for canning slugs drew to a close. It was expected that any additional developmental work required would be worked out by the Operating Department either with, or without, the coordinated efforts of the various consultants.

SECTION VIII

PRODUCTION OF CANNED SLUGS

PRODUCTION OF CANNED SLUGSCONTENTS

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SECTION VIII

PRODUCTION OF CANNED SLUGS

INTRODUCTION

The production of canned slugs was performed, to an appreciable extent, concurrently with the developmental work associated with the various operations of the process. As soon as a workable method was devised, production by this method was intensified until later developments justified changes in the process. This recycling effect was anticipated and, despite its disadvantages from the viewpoint of the fabricator, represented perhaps the most expedient means of securing delivery of slugs concordant with requirements.

The manufacture of slugs under these conditions imposed an abundance of work on all involved, whether it be the Metallurgical Laboratory or the Grasselli Laboratory in developing the various laboratory methods, the du Pont Company in extrapolating and applying these methods to a quantity production scale, or the fabricators in making immediate revisions to operations or equipment to permit production by the latest-known methods.

A production program of this magnitude, with respect to both the quantities of slugs ultimately to be produced and to the ever-present probability of immediate changes in methods and techniques, required the procurement of a vast amount of fabricated component parts to make up the finished assembly.

As might be expected from such a kaleidoscopic undertaking, stability of design, tolerances, and even the composition or the need of the basic part itself, were momentary.

CLINTON SLUGS

The Engineering Department, faced with the responsibility for procuring these slugs in startup quantities for Clinton, and for the manufacturing developmental work for both the Clinton and Hanford slugs, immediately undertook the placement of orders on two fabricators for the development of a canning process. It was realized that only with the prompt utilization of fabricators experienced in working non-ferrous metals could the program hope to succeed within the allotted time. Coordination of effort, invaluable assistance, and sound technical experience were thus acquired immediately and served in no small way to advance the program.

As described previously in Section VII, the Aluminum Company of America and the Wolverine Tube Division undertook, under the direction of the Engineering Department, the preliminary manufacturing developmental work on purchase orders XPG-423-1/2 and XPG-427-1/2 respectively. Whereas the latter order ultimately was terminated without any appreciable contribution to the process having been made, the order on Alcoa produced tangible results and soon was altered to cover not only the development of the process but also the canning of 90,000 Clinton slugs — considerably more than were required for startup. This order included also the furnishing of both extruded and drawn types of aluminum cans, aluminum caps, the

sealing of the slugs in the cans, and the testing (by a method to be developed by Alcoa and du Pont) of the finished slugs.

The original schedule of deliveries as set up by the Engineering Department called for 56,000 canned slugs at Clinton by June 30, 1943, 17,000 by July 31, and the balance of 17,000 by August 31, 1943. This schedule proved to be too difficult to hold, however, in view of the essential developmental work influencing the extrusion, machining and canning production, and it thus was not until June 14, 1943 that canning actually got under way. Slugs had been canned prior to this date, but only for experimental purposes to improve the operations.

The operations performed in the canning process comprised: cleaning, drying, assembling, sizing, welding, trimming, crimping, testing the control slugs and inspecting the uranium slugs.

Cleaning, the first operation in the process, caused considerable difficulty throughout the program. It was specified that no foreign matter such as grease, oil or dirt be encased within the can for obvious operational reasons, and also that the weld area be devoid of any contaminants which conceivably might cause the formation of a defective weld. Extensive study and experimentation were made by the various groups and, though satisfactory cleaning methods were devised and incorporated in the process, each method used was characterized by one or more disadvantages.

The most obstinate operation was that of welding without flux the can and cap to seal the slug inside the can.

Through developmental work it had been determined that a Taylor-Winfield seam welding machine, modified in accordance with suggestions by du Pont and Alcoa, would produce a more satisfactory weld than would the use of spot-welding equipment. Alcoa accordingly used this type of seam-welder for production of the unbonded Clinton slugs.

Small quantities of machined slugs began arriving at Alcoa early in June and were canned. The daily production rate on one-shift operation at first was extremely low, but was sufficient for working out the process and for accumulating a supply of uncanned slugs preparatory to the inception of a second shift in early July. Production was dropped back to a single shift in the latter part of August, however, as this was able to handle the canning of all incoming machined slugs.

By this same time, it was determined that slugs up to approximately 1/4" under the specified 4" length might be used for subsequent processing. This decision released a sizable quantity of slugs which were segregated and later canned at Alcoa. This segregation was necessary because the extent of the adjustments to be made on the equipment — to accommodate the shorter slugs — justified processing only in large groups.

For the first month of production on XPG-423-1/2, Alcoa averaged approximately 865 canned slugs per day. Successive monthly periods averaged approximately 1260, 830, 450 and 290 per day for the months of August, September, October and November, respectively.

During the life of the order numerous requests were fulfilled for shipment of slugs, in various stages of completion, to various groups for experimental or research purposes. These requests amounted to approximately 1900 slugs, or more than two percent of the total quantity of 90,000 requisitioned. The total cost of the order amounted to \$93,511.68, which included the cost of canning 1000 slugs of special material (not contained in the foregoing figures) for the Metallurgical Laboratory.

When this order was placed, the overall procurement plans called for the canning of one hundred tons of 1.100" x 4.000" slugs and the machining, but not the canning, of an additional thirty tons. Quantities in excess of these figures ultimately were prepared to allow for the shrinkage during testing.

When the finished slugs were tested by the hydrogen and hot-air methods at Clinton Laboratories, the mechanical bond between the slug and the can was loosened sufficiently to permit additional testing by the later-developed deflection test, by which it was learned that more than forty percent of the slugs were unacceptable. The Engineering Department immediately had the thirty-ton lot grooved (to permit application of this deflection test before shipment to Clinton) and sent to Alcoa for canning against order XPG-1628-1/2, which in the meantime had been awarded on a unit price basis for the canning of 60,000 Clinton slugs. It was the intention that this order would include also the recanning of approximately

twenty tons of unacceptable slugs which were then being stripped at Clinton Laboratories, and which were left in excess after the Clinton Laboratories had withheld twenty-five tons of unacceptable slugs for a special experiment.

The absence of a clear-cut specification as to what was required of the slug under process conditions was believed to be responsible to no small extent for the status of the welding operation up to October, 1943. Alcoa believed for some time that approximately ninety-seven percent of the closures made were tight, and, according to the testing procedure at that time, this was substantiated. Later, the testing was made more severe and the leakers were found to be not three percent but approximately fifty percent, but in the meantime the welding process had been considered under control and developmental work on the welding technique was discontinued.

It was not known, also owing to the lack of definite specifications, whether the resistance welding method used at Alcoa was going to be satisfactory. This method had been improved, but by the middle of October it was uncertain if it could be refined any further. In view of these conditions, the Engineering Department believed it advisable to continue the investigation of the new fusion-welding method then under development at the General Electric Company in Schenectady, New York.

This new method was developed rapidly in the ensuing weeks. Tests indicated that the closure produced, when using thick-wall cans, was excellent. In view of this, the Clinton

Laboratories, on November 24, decided that all future Clinton slugs should be encased in a thick-wall can sealed by fusion welding. They agreed, however, that the remainder of the thirty tons being canned at Alcoa on order XPG-1628-1/2 should be seam-welded in thin-wall cans until such time as the fusion welding equipment was set up and more thoroughly proven. They also hoped that the quantity of stripped slugs at Clinton, in excess of their requirements for the special experiment, could be canned by this new method, even though the original intention had been to process these in the same manner as the thirty tons.

In compliance with these decisions, the Engineering Department immediately negotiated with Alcoa for the developmental work and canning of 45,000 slugs by the fusion-welding process. It was stated that, should this method be developed successfully, this new order would reduce the quantity of work covered by order XPG-1628-1/2.

Purchase order XPG-1750-1/2 was soon awarded to cover this scope of work. Unlike those previously placed, it provided that du Pont was to furnish all cans, caps and slugs, as well as to lend to Alcoa a fusion-welding machine for the prosecution of the order.

Because of the extensive developmental work being performed on this method of welding, results were very encouraging. It was subsequently determined that order XPG-1628-1/2 could be terminated in favor of order XPG-1750-1/2, after 12,768 slugs had been canned by the now-obsolete seam-

welding method. The termination of this work required subsequent cancellation charges because a quantity of 47,232 pieces had been in process at that time. Altogether, these charges amounted to \$3779.99, and thus brought the total cost of the order to \$14,513.82.

By the latter part of February, 1944 it appeared that a total of approximately 15,500 slugs would be available for canning on order XPG-1750-1/2. Production by the fusion-welding method was started on February 24 and completed on April 12, 1944, with the canning of 17,456 slugs — a quantity much less than that originally estimated, but which represented the total number of re-usable stripped slugs supplied by Clinton Laboratories — at a total cost, including the developmental work and incidentals, of \$16,224.62.

This work completed the responsibility of the Engineering Department with respect to the Clinton program. In all, a total of 120,224 unbonded uranium slugs had been canned at Alcoa on the three orders at a total cost, as shown by the final alterations to the orders, of \$124,250.12.

Component Parts for Clinton Slugs

The manufacture of these finished slugs required the placement of several purchase orders for the fabrication of the component parts comprising the finished assembly.

The cans and caps required for orders XPG-423-1/2 and XPG-1628-1/2 were furnished by Alcoa as a necessary part of each order. However, du Pont furnished this material for the fusion-welded slugs on XPG-1750-1/2. Deep-drawn aluminum

cans were purchased on XPG-1703-1/2 from Paul & Beekman, Philadelphia, Pa., the same supplier previously used by Alcoa for cans of this type. These cans were fabricated with the same drawing dies that had been used on Alcoa's orders, and were modified, with Alcoa's permission, to compensate for the heavier-wall can. The cost of this tooling charge was \$775.00 which, added to the unit price of \$97.00 per thousand cans, made the total price of the order \$6595.00 for the production of the 60,000 cans ordered.

Numerous difficulties were experienced in the manufacture of these cans until the process was perfected. By the end of January, 1944 it was estimated roughly that approximately seventy-five percent of the fabricated cans were acceptable. The production rate was such that, even with this percentage of rejections, it was well ahead of canning requirements.

The 60,000 coined caps, the only other component part necessary for this assembly, were purchased from James H. Matthews Company, Pittsburgh, Pa., on order XPG-1726-1/2. Before quantity production of these could begin, however, one hundred caps were sent to Alcoa for approval. An additional one thousand were shipped a few weeks later, but production of the balance was held up pending possible design changes.

Within the next few weeks the design had been altered because of the developmental work being undertaken at Alcoa on XPG-1750-1/2, and in March a revised quotation for furnishing 15,000 caps of this new design was secured.

Production of these was started immediately and shipment was made to Alcoa in accordance with requirements.

The General Electric fusion welder furnished to Alcoa, for the execution of the work on XPG-1750-1/2, was purchased on order RPG-1439-1/2. After this equipment was no longer required at Alcoa, it subsequently was shipped to Hanford for use in the 300 Area.

HANFORD BONDED SLUGS - PROJECT 9536

The program for the fabrication of Hanford slugs was resolved basically into: procurement of component parts required in the assembly, development and procurement of necessary equipment, and development of all manufacturing methods in the vendors' plants — all the responsibility of the Engineering Department; and, the supplementary development of manufacturing methods at Hanford and the fabrication of the canned slugs — all the responsibility of the Explosives Department.

Probably the largest part played by the Engineering Department in this particular portion of the overall program lay in the development of manufacturing methods in the vendors' plants and in the development of necessary equipment — all of which has been discussed in Section VII. This section, therefore, will be devoted only to the participation by the Engineering Department in the procurement of all necessary component parts.

Early in June, 1943 the TNX Division advised the Engineering Department that the size of the Hanford slug

could then be specified as 1.340" plus or minus .002" in diameter by 8.000" plus or minus .010" in length, and any deviation from this size should be only that required to aid in the canning. This was to be determined by the Engineering Department's development of manufacturing methods subject to approval from the process viewpoint. Moreover, it was then the intention to use practically the same welding methods as were being followed for Clinton for sealing the slug in an aluminum can.

Procurement of Aluminum Cans - Project 9536

With this basic information at hand, the Engineering Department placed order RPG-277-1/2 on the Aluminum Company for the development of a canning process and the procurement of required tools, machines, and other necessary equipment — all as directed by the Engineering Department. No quantity production was to be performed on this order as the information developed was to be applied to the design of the component parts and necessary equipment required in the final assembly.

Later, after additional information had been developed, order RPG-1077-1/2 was placed on Paul & Beekman for the development and production of a small quantity of drawn cans of various sizes and grades of aluminum. Various quantities of each type were shipped to the Metallurgical Laboratory, Grasselli Laboratory, Alcoa, and the Wilmington Shops for furtherance of the developmental work on bonding and end closures which was being undertaken. Additional orders

RPG-1264-1/2 and RPG-2887-1/2 were placed also on Paul & Beekman for supplementary developmental work to perfect the drawing operations, but, due to the complexity of the work and the frequent revisions in the types of cans, all three orders later were cancelled and were replaced on order RPG-3880-1/2 to clarify the requirements. No appreciable quantity of cans was made on this composite order as all cans for production purposes were manufactured on other orders as mentioned below.

The first production order for cans was awarded to Paul & Beekman on order RPG-2291-1/2, and covered the manufacture of 25,000 cans of 2S aluminum of 0.035" wall x 1.370" I.D. x 8-3/4" long, at a unit price of \$0.30 each. However, in order to proceed with this work, it was necessary that du Pont lend Paul & Beekman a rebuilt press and trimmer which had been purchased on order RPG-2157-1/2. After installation of this equipment, manufacture of the cans proceeded without undue difficulty. Of the total quantity of 25,000 cans which had been manufactured and shipped by June 5, 1944, one thousand each were delivered to the Wilmington Shops, Grasselli Laboratory and Metallurgical Laboratory for experimental purposes; and the balance of 22,000 to Hanford for assembly of slugs and canning operations in the 300 Area.

In November, 1944, Paul & Beekman submitted an offer for the press and trimmer, with the understanding that, if accepted, any subsequent du Pont orders for cans would have first preference on these machines regardless of any other job the vendor might have scheduled for production. This

offer was accepted by the Corps of Engineers on January 1, 1945 and order RPG-2291-1/2 was credited accordingly.

Meanwhile, order RPG-3335-1/2 had been awarded to Paul & Beekman for the manufacture of 100,000 28 aluminum cans of the same size as those manufactured on RPG-2291-1/2. These cans, however, were to be clad on the inside with 5 to 10% of 7-1/2% silicon alloy in order to permit a better surface for bonding the slug to the can. Before fabrication started, the specifications were changed to increase the length of the can from 8-3/4" to a maximum of 9-1/2" overall. Production of cans to this length was started in June, 1944, but it later was learned in the actual canning operation that the silicon cladding separated from the aluminum wall of the can. This condition necessitated the cancellation of the balance of the order.

The du Pont Company, in utilizing this vendor as a source of cans, attempted also to develop other suppliers to secure a factor of safety in the event of some unforeseen production stoppage at Paul & Beekman. Early in January, 1944, order RPG-2274-1/2 was placed on McCauley Metal Products, Incorporated, of Buffalo, New York, for the development and manufacture of 500 experimental 280 aluminum cans of 0.035" wall x 1.370" I.D. x 8-3/4" long. A third supplier, the Worcester Pressed Steel Company, of Worcester, Massachusetts, was also developed concurrently under order RPG-3839-1/2, which covered the developmental work and fabrication of 500 experimental 28 aluminum cans of 0.035" wall x 1.370" I.D. x

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was made to the revised thickness. In all, 104,967 cans were manufactured at a total price of \$17,497.57.

Order RPG-3407-1/2, placed on Paul & Beekman at this same time, covered the manufacture of 100,000 thin-bottom 28 aluminum cans of 0.035" wall x 1.370" I.D. x 8-3/4" long. The specifications for the length of the can were increased, however, to 9-1/2" prior to the start of production. This revision caused considerable difficulty in production, and by the end of May, the length was decreased to 9-5/16" overall. Production to this length was maintained until approximately 65,000 cans had been shipped to Hanford, when the balance of the order was cancelled.

With four sources of supply developed, the Engineering Department proceeded to utilize these facilities. Order RPG-3570-1/2 was placed on McCauley Metal Products for the manufacture of 10,000 cans of 1.370" I.D. x 0.350" bottom thickness x 9-1/2" inside length; 5000 each of which were to have a wall thickness of 0.035" and 0.030" respectively. The order later was altered to provide for the cancellation of the 0.030" wall cans and for increasing the quantity of the 0.035" wall cans to 10,000.

Many difficulties were experienced in production. Cans were out-of-round, bottoms contained gouges; and experimental work, with the assistance of the Parker Rust Proof Company, was necessary to develop a bonderite free from boron for use in the drawing operations. These difficulties were eliminated gradually and, in all, 11,003 acceptable cans were produced on this order at a total price of \$12,763.48.

Despite the fact that several orders for cans were in various stages of activity — all concurrently, in order to meet delivery requirements to the field — and that numerous improvements had been made in the quality of the cans, it was believed that the finish could be bettered to produce a can superior to those being manufactured. In an endeavor to accomplish this, the Engineering Department placed order RPG-4358-1/2 on Paul & Beekman for the manufacture of 100,000 cans of 2B aluminum, made from sheets with alumilite-finish — the highest grade finish in the industry. These cans were to be the thin-bottom type, with 0.035" wall, 1.370" I.D. and 9-1/2" long. Owing to the difficulty in securing the alumilite-finished material, however, and to evaluate better the cans produced from differently-finished materials, the order was soon altered to cover the fabrication of 50,000 cans to the original dimensions, but with the length reduced to 9-5/16"; and manufactured in equal lots of 25,000 each in alumilite-finish and in mill-finish (a finish not quite so highly processed).

Material was secured in August and production of the alumilite cans got under way. After a six-weeks' stoppage to permit completion of other canning orders, production was resumed in October and proceeded without difficulty until the stock on hand at the vendor's was exhausted in the manufacture of 20,860 alumilite-finish cans and 16,760 mill-finish cans. The order was reduced accordingly and was closed out at a total price of \$13,167.00.

With the placement of order RPG-5112-1/2 on Alcoa for the development of a special extruded can of 99.6% aluminum of 1.368" I.D. x 8.305" overall length and with a thick, tapered wall ranging from 1.439" O.D. at the closed end to 1.568" O.D. at the open end; the Engineering Department's responsibility for this portion of the program became fulfilled. Any future work, whether it be for procurement of fabricated materials or for development of manufacturing methods, was to be under the placement, direction and supervision of the Explosives Department.

Procurement of Aluminum Caps - Project 9536

Preliminary developments established the fact that the assembled slug could best be sealed by the insertion of an aluminum cap over the open end of the slug. Welding the cap to the can wall and subsequent machining to dress up the end would then complete the canning operation.

Because the production of caps in any sizable quantities necessarily required their fabrication by coining methods — for uniformity of tolerances and speed and economy of production — it was necessary that coining dies be manufactured for each type of cap. Moreover, the development of the canning operation was subject to considerable revision, to the extent that cap design could not be stabilized until methods and techniques had been evaluated and definitely established.

In the early stages of the Hanford canning program it was not known which of the tin, zinc, or aluminum-silicon

bonded methods would be adopted; or, in lieu of these, whether or not double-canning or some other form of bond could be developed capable of supplanting the unbonded type of slug held in favor as a last line of defense. Therefore, each method was attacked individually and concurrently, with the result that each one was found to require caps of a different design; though in some cases the design was maintained but dimensions and tolerances revised, which, nevertheless, necessitated the manufacture of additional dies.

The Engineering Department, at the request of the Explosives Department, assumed the responsibility for the manufacture of these dies. Because the urgency of the overall program necessitated the exercising of all possible precautions to eliminate any form of delay, it thus was necessary that arrangements be made for the immediate manufacture of coining dies for all types of caps under consideration. Though it also was recognized that the majority of these dies might not be used — because of design changes — the procurement of caps of the designs finally accepted would be greatly expedited. These caps, in production quantities, originally were to be procured by the Engineering Department, but before the development had progressed to the degree that production to stabilized design could be effected, the Explosives Department had assumed the responsibility for the procurement of all components required.

Early in January, 1944, purchase order RPG-2233-1/2 was placed on the James H. Matthews Company of Pittsburgh, Pennsylvania, for the manufacture of dies and the fabrication

of 5000 experimental caps to a design which, at that time, was felt to be suitable. However, it was necessary almost immediately to revise the design, and the order was altered accordingly to provide for the dies and 500 caps of this later type.

Shortly thereafter, order RPG-2882-1/2 was placed on the same vendor for the dies and fabrication of 500 caps each of two additional designs. However, it soon became apparent that the status of the developmental work on bonding would require, for the expediency of the program, the incorporation of all work relating to die manufacture into one order. Order RPG-2882-1/2 was then cancelled without charge and the work covered by it accordingly included under RPG-2233-1/2, which then became a developmental order for the manufacture of all dies and the fabrication of experimental caps of different designs — all as directed by the Engineering Department.

Considerable work was performed in the development of a suitable cap. The first conception of the bonded assembly visualized a cap containing an insulating air space between it and the end of the slug, and so designed that the high temperature produced along the longitudinal axis of the slug could be insulated from the end of the finished assembly. Upon further investigation and after many trial assemblies, however, it was learned that the molten bond would penetrate to, and fill up, this space. The design was therefore abolished in favor of a solid cap of sufficient thickness to per-

mit the dissipation of heat, by conduction, to the periphery of the cap where it would be carried away by the cooling water.

The solid conductor cap also paved the way for the design of the thick-bottom can. By the adoption of this type of can in the assembly of the slug, the need for conductor caps was eliminated except when the urgency of the program necessitated the supplemental use of thin-bottom cans to satisfy field delivery requirements.

Manufacture of the cap coining dies was attended, in some instances, with resultant difficulties during the trial runs in producing samples. Because of the high pressures required to produce fluidity in the aluminum, many of the dies were broken before the vendors were able to determine the best type of construction able to withstand the applied forces.

In conformity with du Pont's established practice to develop additional sources of supply whenever practicable, the Engineering Department also placed order RPG-2234-1/2 on the Scovill Manufacturing Company of Waterbury, Connecticut, for the manufacture of dies and the fabrication of a total of 15,000 caps of two designs. This quantity was soon reduced to 1000 but when advancements in the developmental work rendered obsolete these two designs, the order was cancelled prior to the start of production.

Later in the program additional orders were placed for the manufacture of dies or the fabrication of small quantities of experimental caps. These orders: RPG-4013-1/2 on Scovill, and RPG-4378-1/2, 4918-1/2 and 5045-1/2 on

Matthews; were all cancelled, however, before any appreciable quantities had been made. With this action, the participation by the Engineering Department drew to a close, after a total of twenty coining dies of different designs had been manufactured for the subsequent use of the Explosives Department in procuring production quantities of caps of the designs finally selected.

Procurement of Steel Cans - Project 9536

Steel cans, though not an integral part of the assembled slug, were necessarily required as an expendable item to prevent damage to the aluminum can while in the heated die. As such, it was the responsibility of the Engineering Department to develop manufacturing methods and to procure these cans in amounts as required by the Explosives Department for use in the 300 Area operations at Hanford.

Early in February, 1944, purchase order RPG-2720-1/2 was placed on McCauley Metal Products for the development of methods to fabricate steel cans of 1.450" I.D. x 0.035" wall x 8-3/4" inside length. By the end of the month McCauley had finished manufacture of the dies and had produced a few experimental cans. Additional quantities were fabricated in March for shipment to the various locations engaged in the development of the bonding method. All samples were acceptable except for a minor condition which soon was corrected.

In April the order was altered to provide for the fabrication of 5000 cans to a revised length of 9-1/2".

Production began immediately and, because of the extremely critical status of developmental work, all shipments were made to Hanford by air express. This urgent need for all steel cans existed throughout the life of this and similar contracts, and resulted in the shipment of virtually all cans either by rail or air express.

Additional developmental work to produce cans with a 0.070" wall and with a 3/16" hole centered in the bottom was authorized the latter part of April, followed by authorization in June for developing a reclamation process for used cans and for an interior polishing process. These methods were subsequently developed and the order was closed out at a total cost of \$38,381.61.

Meanwhile, order RPG-3542-1/2 was placed in March on this same vendor for the production of 25,000 cans of 1.450" I.D. x 0.035" wall x 9-1/2" inside length, with a 3/16" hole centered in the bottom. Fabrication began late in April after production difficulties on RPG-2720-1/2 had been overcome. By the end of May, approximately 17,000 cans had been manufactured, with rejections of less than one percent. Production was completed on June 10, 1944 and the order was closed out at a total cost of \$20,250.00.

Order RPG-3900-1/2, placed on McCauley in April, covered the production of 70,000 cans of the same design as those furnished on RPG-3542-1/2, and 70,000 to the same inside dimensions but with 0.070" wall thickness. Production of the thin-wall cans started immediately upon the

completion of RPG-3542-1/2 and was continued until 156,419 cans, at a total cost of \$89,421.61, had been fabricated and shipped. Owing to the successful operation at Hanford with the 0.035" wall can, the order was later altered to cancel the production of the 70,000 cans of the thick-wall type.

In accordance with established practice, du Pont attempted to develop a second source of supply to prevent loss of production in the event of some unforeseen occurrence. Early in May, order RPG-4017-1/2 was placed on the Worcester Pressed Steel Company, of Worcester, Massachusetts, for the development and production of 500 each of the thin-wall and the thick-wall cans. The resultant cans were satisfactory, but because of the limited production capacity and the abundance of other war orders in the plant, this vendor was not considered as an active source of supply.

Meanwhile, developmental work with steel cans had indicated that a steel tube, flanged inside on the lower end, could be used instead of a deep-drawn steel can. The Engineering Department immediately investigated this possibility and, in May, 1944, placed experimental order RPG-4309-1/2 on the Brown Fence & Wire Company, of Adrian, Michigan, for 1000 pieces of steel tubing 1.450" I.D. x 0.035" wall x 10" long. However, the vendor did not have the necessary equipment capable of manufacturing the tubing to the plus or minus 0.001" diametrical tolerances required, and the order thus was cancelled without charge.

It soon developed, however, that this vendor was able to furnish and fabricate the tubing to an intermediate stage, which would enable the final drawing and flanging to be accomplished at another vendor's plant. Accordingly, order RPG-4541-1/2 was placed for 30,000 pieces of tubing of 1.525" I.D. x 0.039" wall x 20" long. Production to these dimensions occasioned no undue difficulty and, in all, 31,821 pieces of tubing were produced and shipped at a total cost of \$14,630.00.

This tubing was drawn and inside-flanged under order RPG-4540-1/2 at H. N. White Company, Cleveland, Ohio. Considerable difficulty was experienced with an out-of-round condition and from oxidized tubes during production, and, though tolerances were relaxed for 2000 pieces, the finished product was usable but not too acceptable. Continued fabrication of additional pieces improved this condition to a small degree, but when developmental work on canning rendered this design obsolete, production was stopped after 7314 sleeves had been fabricated. Approval was secured from the Corps of Engineers for the sale of the excess tubing as scrap (after investigation at Hanford disclosed that it could not be used there for any purpose) and the order was cancelled.

The participation by the Engineering Department in the procurement of steel cans came to an end with the termination of this order. Any future orders were to be placed by the Explosives Department.

HANFORD UNBONDED SLUGS - PROJECT 1553

Project 1553 was written to record the charges against a special request from the TNX Division to the Engineering Department for the procurement of 48,000 unbonded slugs. These slugs, similar to those fabricated for Clinton except for their larger size, were required with the utmost dispatch for charging the first Hanford pile at startup, in the event the aluminum-silicon bonding operations were not developed to an acceptable degree within sufficient time to satisfy requirements.

This project comprised the procurement of all component parts, necessary equipment, machining of the slugs, canning and testing of the finished slug assemblies. Only the work associated with canning production will be described herein as the remainder is covered in other sections of this volume.

In order that procurement of these finished slugs would not affect adversely the existing canning facilities at Hanford, then entirely occupied in the development of the aluminum-silicon process, it was imperative that the Engineering Department develop new facilities for performing the highly-specialized canning operations. An intensive investigation of forty-seven firms was made, and of those considered, the Quality Hardware and Machine Corporation, of Chicago, Illinois, was the only one which had the necessary equipment, personnel and capacity for the undertaking. Purchase order RPG-4040-1/2 was promptly placed on this vendor

for canning the entire quantity of 48,000 slugs.

To prosecute this work, it was necessary that du Pont furnish to Quality, for the duration of the contract, numerous items of special equipment which either were purchased specifically for this order or were diverted from some other source. After completion of the work all items subsequently were shipped to various destinations as directed by du Pont.

In addition to the installation of this loaned equipment, it was necessary to build two temporary extensions to an existing building to handle adequately the equipment and to maintain the strict security requirements. The cost of erecting and dismantling these additions was included in Quality's unit price, and both extensions later were to be removed upon completion of the order. Before erection of these could be started, however, it was necessary that signatures of the adjoining property owners be secured to waive temporarily the recently-altered zoning regulations that prohibited industrial expansion in that neighborhood.

Experimental canning of steel slugs to perfect the operations was begun on May 30 — less than one month after the project was first conceived. Difficulties were experienced with some phases of the work, but within a few days limited production of acceptable uranium slugs was started. However, by the end of June only 980 slugs had been canned, of which 878, or 89.6%, were acceptable. Production during July did not reflect the progress made in perfecting the

process, as only 8325 slugs were canned at an acceptance rate of 92.8 percent. By August, however, the operational difficulties had been overcome and of the 20,472 slugs canned, 20,322, or 99.2%, were acceptable.

By the middle of June it was apparent that Quality alone could not meet production requirements. The Aluminum Company was the logical vendor remaining to contact in this emergency as it previously had canned all of the unbonded Clinton slugs and was familiar with the process, but its facilities were in use for the production of canned slugs on a Clinton Laboratories order and were not available. Permission was immediately secured from the latter group, however, to divert these facilities for a period of six weeks. Order RPG-4492-1/2 was placed immediately, and after making the necessary alterations and adjustments to accommodate the larger pieces, Alcoa canned a total of 8166 slugs.

By the latter part of July the aluminum-silicon process at Hanford had been perfected to a satisfactory degree, and, with continued production by this method assured, the work under Project 1553 no longer assumed its original importance, though satisfactory unbonded slugs were being produced. Order RPG-4040-1/2 on Quality was closed out upon the completion of 28,913 acceptable slugs, and RPG-4492-1/2 on Alcoa after canning 8166 slugs. In all, 37,079 unbonded slugs were canned on this project.

Procurement of Aluminum Cans - Project 1553

With the inception of this project the Engineering

Department was faced with the immediate procurement of cans necessary for the earliest practicable fabrication of the specified 48,000 unbonded slugs. Therefore, order RPG-4022-1/2 was placed immediately on Paul & Beekman — the most satisfactory supplier developed for the fabrication of the thin-bottom cans required for unbonded slugs — for 100,000 cans of 28 aluminum.

These cans differed in size from those for bonded slugs because no allowance was necessary for thickness of bond between the slug and the can. This condition required that Paul & Beekman make alterations to existing dies in order to produce cans of the specified diameters.

No appreciable difficulties were experienced in the production of the cans. The first shipment on the order was made on May 29, 1944, when 504 cans were shipped by Air Express — because of the urgency of the program — to Quality to permit experimental work on canning operations to begin.

Early in June order RPG-4276-1/2 was placed also on Paul & Beekman for the fabrication of an additional 100,000 cans from sheet for aluminite finish. Prior to the start of production, however, estimates were revised and, due to the much lower-than-anticipated mortality rate of the cans during the welding operation, the order was cancelled in its entirety without charge. Order RPG-4022-1/2 therefore remained the only order placed for the necessary unbonded cans.

Procurement of Aluminum Caps - Project 1553

The speed with which procurement of the unbonded

slugs must be effected was manifested also in the procurement of the required aluminum caps. Early in May, 1944, when the Engineering Department accepted this assignment, design of the caps was crystallized and believed to be stabilized. Unlike the main Hanford slug program, Project 1553 required that the Engineering Department procure all component parts in addition to arranging for any supplementary developmental work necessary. To start production at the earliest date, therefore, developmental order RPG-4254-1/2 for the manufacture of coining dies was placed on the H. P. Snyder Manufacturing Company, Incorporated, of Little Falls, New York. This was followed in quick succession by placement of RPG-4258-1/2 on the Joyce Machine Company, Philadelphia, Pennsylvania, for the fabrication (by an automatic lathe operation instead of by coining) of 10,000 caps each of two details; RPG-4285-1/2 on James H. Matthews Company, Pittsburgh, Pennsylvania, for the coining of 5000 caps each of the same two details; RPG-4484-1/2 on Snyder for manufacturing dies to a slightly-revised design; RPG-4490-1/2 also on Snyder for manufacturing dies and the fabrication of 10,000 caps of another slightly-revised design; and RPG-4664-1/2 on Matthews for 5000 caps each of two new designs.

Order RPG-4285-1/2 soon was increased to provide for the fabrication of additional caps; and ultimately, a total of 140,335 caps of the two designs were coined. Order RPG-4490-1/2 also was increased to cover the 21,377 caps ultimately fabricated. RPG-4258-1/2 was reduced to provide for

a total of 14,048 caps of the two designs, which were machined from all the available material on hand. Order RPG-4664-1/2 was subsequently cancelled with charge prior to start of production.

To secure the most advantageous delivery concordant with requirements, the du Pont Company used its facilities to procure all the aluminum stock required in the fabrication. Owing to design changes, certain of this material proved to be too thick to meet the specifications of the finished caps, thereby necessitating du Pont's placement of orders on other fabricators for rerolling the aluminum to the specified thickness. To prevent any delay resulting from this action, however, thickness tolerances in the caps were relaxed for certain small quantities in order to supply the canning fabricators with parts necessary to progress with subsequent assembly operations.

With the close or cancellation of the existing orders on Project 1553, and of those few still outstanding on Project 9536, the participation by the Engineering Department in the canning phases of the slug program came to an end. All subsequent work in this connection would be undertaken by the Explosives Department.

SECTION IX

METHODS OF TESTING CANNED SLUGS

METHODS OF TESTING CANNED SLUGSCONTENTS

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SECTION IX

METHODS OF TESTING CANNED SLUGS

INTRODUCTION

When it first became apparent that slugs were to be encased within aluminum cans, the question arose as to how the finished assembly could be tested. It was recognized that a positive method was necessary in order to segregate the "leakers", which obviously would fail in service, from the acceptable slugs.

Owing to the fact that firm specifications for testing the canned slugs were lacking, ultimately for an extended period of the program,¹ some form of procedure was therefore required to determine the acceptability of the slug, particularly in the area of the welded closure. This need prompted the Engineering Department, in conjunction with the Aluminum Company, to devise a method which, though not the best, was believed to indicate those slugs which should be rejected. Later developments proved this method inaccurate, but it nevertheless served to get under way a program which would permit no delay in production pending the development of more satisfactory testing methods.

TESTING CLINTON SLUGS

The original testing procedure practiced at Alcoa on order XPG-423-1/2 comprised the canning of two steel

control slugs with the canning of every ten uranium slugs.² One of these control slugs was stripped immediately after it had been welded, and, the can closure was then tested with eighty pounds air pressure under oil. If it did not leak, the remaining eleven slugs all were welded and crimped. The second control slug was then stripped and tested in a similar manner, and if it tested satisfactorily, the ten uranium slugs it represented were accepted as satisfactory. Conversely, if it leaked, the ten slugs were all stripped and recanned, also with two control slugs, in the same manner as before.

Results of tests by this method, taken during the first two weeks of Alcoa's production, indicated that 3.7% of the slugs were unacceptable after the second control test.

Meanwhile, the Metallurgical Laboratory had been developing the hydrogen test. In its original state of development it comprised: heating the canned slugs to 325°C. in a hydrogen atmosphere, cooling in air, and inspecting for flaws, which showed up as a visible black hydride spot or bulge in the can.³ Safety precautions would be observed by flushing the chamber with nitrogen between stages.

The conduction of this test required the purchase, on order XPG-587-1/2, of a vertical retort electric furnace, which it was planned to install at Alcoa for testing the slugs canned on XPG-423-1/2.⁴ However, Alcoa refused this installation because of the fire and explosion hazards attendant with the operation,⁵ and this action therefore necessitated

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the immediate installation of the equipment at Clinton.⁶

The installation was ready for service at Clinton by the end of June, 1943, and for the next few weeks considerable experimental work was performed there, with the assistance of the Metallurgical Laboratory, in evaluating the hydrogen test under various conditions.⁷ A few minor modifications were made in the procedure and all slugs were then inspected, any which showed visible flaws being rejected. It was the consensus of Metallurgical Laboratory, Clinton and du Pont that this method would suffice for testing the initial charge for the pile as long as the power output of the pile was to be kept down. Should a higher power output be contemplated, however, it was believed that additional protection to the slug, in the form of a supplementary hot-dip coat, would be essential. This thought later culminated in the development of a bonded type of slug for Hanford.

By the end of July the Metallurgical Laboratory had further revised the procedure to provide for heating the slugs in air to 300°C., pulling a 29" vacuum for thirty minutes, and then breaking the vacuum with hydrogen at 300°C. for a soaking period of ten hours, followed by flushing with nitrogen and then inspection.⁸

Meanwhile, other methods of testing also had been under development. The Engineering Department designed and built a hydraulic tester which appeared to afford a quick method of testing the closures.⁹ With this method, however, it was necessary that a small longitudinal groove be milled

previously on the surface of the bare slug in order to provide a hydraulic channel within the can. The Metallurgical Laboratory objected to this design on the basis that any leak in the can would permit the seepage of oil under pressure into the slug, thus contaminating the uranium. The idea was abandoned but subsequent changes in the design paved the way for the development of other types of testers.

The Metallurgical Laboratory believed that a method more positive than the hydrogen test should be devised. Accordingly, it tested several slugs, which appeared to have sound closures by the hydrogen test, in an atmosphere of hydrogen under fifty pounds pressure followed by plunging the slugs under water.¹⁰ All slugs appeared to leak. The Metallurgical Laboratory believed this test was too severe, as it did not correspond to working conditions and, therefore, was not conclusive. The experiment indicated, however, that the hydrogen test was not the solution to the testing problem.

Pending the development of an improved method of testing, Clinton continued the inspection of slugs with the hydrogen test. This method was used for testing the 442 slugs which had been canned by Wolverine on order XPG-427-1/2, and of these, 213 were defective.^{11,12} Those from Alcoa tested much better, as only 2.9 percent were found to be unacceptable up to the end of August, 1943.

By the early part of September it was believed that the hydrogen test was not reliable, as it appeared quite

definite that acceptance by this test still permitted leakage around the weld.¹³ Also, personal judgment on the part of the inspector influenced too greatly the results obtained. The test therefore was discontinued at Clinton on September 9 in favor of improved methods then under development and which were to be inaugurated in the very near future.¹⁴

It soon developed, in a meeting at Clinton with representatives of the Metallurgical Laboratory, Clinton Laboratories and du Pont, that two types of tests were to be made,¹⁵ the deflection test and the nitrogen-kerosene test, basically as follows:

1. The deflection test would be performed with five machines to be furnished by the Metallurgical Laboratory, designed to test the leakage of nitrogen under pressure through the weld closure by measuring the deformation of the bottom of the can away from the slug. This test was to be applied to the approximately 55,000 slugs which had previously been given the hydrogen test.
2. The nitrogen-kerosene test would use three machines to be furnished from the Wilmington Shops. Nitrogen under pressure would be admitted to a sealed chamber containing the slug, and the slug would then be immersed in kerosene to detect bubble leaks. Approximately 25,000 slugs which had not previously been tested with hydrogen were to be given this test.

The Clinton Laboratories were to have the full responsibility

for the test methods employed and the final results obtained.

The temperatures attained in the original testing procedure at Clinton produced an annealing effect in the stressed aluminum can, which resulted in a loosening of the mechanical bond between the can and the slug. For the anticipated low-power output of the pile this condition not only was not objectionable but, moreover, it also permitted the application of the deflection test on all slugs previously tested at Clinton.

By the end of September, approximately 4500 slugs had been given this test, from which it was learned that thirty-nine percent showed unmistakable evidence of bad leaks, and an additional nineteen percent, of intermediate degrees of leaks.¹⁶ To permit application of the deflection test to a slug not previously heated, the Metallurgical Laboratory stated that all future slugs to be canned should have a longitudinal groove down the side to provide a pressure channel within the can.

A total of 61,739 slugs had been deflection-tested at Clinton by October 8, 1943. Of these, fifty-three percent showed zero deflection and the balance a deflection of 0.001" or more.¹⁷

At this time the Metallurgical Laboratory loaned three deflection testers to Alcoa for use in testing the grooved slugs canned on order XPG-423-1/2.¹⁸ The specifications for this test, released by the Metallurgical Laboratory also at this time, stated that "... the canned slug is subjected to a pressure of not less than 150 lbs. per square

inch, for a time of not less than one minute. Slugs that show any deflection whatsoever are to be designated as rejects, and should, therefore, not be shipped to Clinton".

Because of the strong probability that the method of sealing the welded end of the slug in the deflection tester produced a doubt as to the veracity of the test, Alcoa, at the direction of the Engineering Department, agreed to test for acceptance all grooved slugs, canned on order XPG-1628-1/2, by a side-seal, rather than by the end-seal, deflection method.^{19,20} This test otherwise was performed under virtually the same conditions as previously specified by the Metallurgical Laboratory, and became known as the Type "M" deflection test. The specifications differed, however, in the respect that this test recognized the presence of a minute deflection caused by sealing the slug in the apparatus, and rejected only those slugs that showed a progressively-greater deflection while under test.

With the improvement in the welding technique the percentage of leakers soon decreased. By the latter part of November only about seven percent of the slugs failed to pass inspection.²¹ These were then stripped, recanned and retested at Alcoa before being shipped to Clinton.

Though it was believed that deflection testing probably was as reliable as any simple test method that could be devised, additional evaluation of this method nevertheless was made. A group of doubtful leakers, which had been deflection-tested at Alcoa, was further tested at the du Pont Exper-

imental Station by sealing within a closed chamber filled with water under pressure.²² Results confirmed the accuracy of the deflection method.²³

One additional order, XPG-1750-1/2, was placed by the Engineering Department on Alcoa before the Clinton portion of the program came to a close. This order provided for the canning of unbonded slugs, sealed by the new fusion-welding process, and included the testing of all closures by the Type "M" deflection test.

With the completion of this order, all responsibilities of the Engineering Department with respect to the procurement of Clinton slugs were fulfilled. No modifications or improvements had been made to the testing procedure, as it was believed that the Type "M" deflection test was entirely satisfactory as developed.

TESTING HANFORD SLUGS - PROJECT 9536

The Hanford slugs, unlike those for Clinton, were to be bonded to the can to form an integral assembly, with the ends sealed by the fusion-welding process. Because of this type of manufacture the deflection method of testing necessarily would not be applicable. Other methods, therefore, were required.

Inasmuch as all Hanford slugs — except a small number required for experimental work at the Metallurgical Laboratory and Grasselli Laboratory — were to be canned under the direction of the Explosives Department in the 300 Area at the project site, the Engineering Department did not

assume too prominent a role in the development of testing methods for bonded slugs. The greater portion of this work was accomplished at the Metallurgical Laboratory,²⁴ with contributing assistance from the Massachusetts Institute of Technology and Grasselli Laboratory, and supplemented with work performed by the Explosives Department at Hanford in perfecting the process for full-scale production in the 300 Area.

TESTING HANFORD SLUGS - PROJECT 1553

With the inception of Project 1553, which covered the procurement and complete fabrication of 48,000 unbonded Hanford size slugs, the Engineering Department again entered actively into the program. The testing procedures for unbonded slugs had been well established in the Clinton program, and it was intended that the acceptability of slugs would again be determined by means of the Type "M" deflection test; for, in the intervening months since the Engineering Department had fulfilled the Clinton requirements, the Clinton Laboratories had continued the use of this method for testing the additional slugs they had ordered for maintaining the operation.²⁵

In the meantime, however, the Metallurgical Laboratory had developed a "vacuum bubble" test which enabled the detection of leaks by the formation of bubbles in a liquid bath maintained at a pressure lower than that inside the slug.²⁶ So promising was this method that the TNX Division requested the Engineering Department that it be used in testing the unbonded slugs at the Quality Hardware and Machine

Corporation, Chicago — the firm which was awarded the contract for canning the slugs.²⁷

By the middle of May, 1944, the TNX Division also advised the Engineering Department that some provision would be required for detecting any improper placement of the aluminum caps in the can after the component parts had been assembled.²⁸ It was further stated that perhaps the most positive method of detection would employ a fluoroscopic examination of the assembled slugs and, if preliminary experiments of other methods to be tried at Wilmington Shops and at Quality Hardware proved inadequate, the fluoroscopic equipment could probably be borrowed from the Metallurgical Laboratory. Subsequent results confirmed these assumptions, and the necessary equipment was obtained from the Metallurgical Laboratory and installed at Quality Hardware.²⁹

By early June, equipment was nearing completion at Quality for a double-vacuum test and a hot-air test.³⁰ However, it then appeared that the latter test probably would not be used, as it resulted in the destruction of much of the mechanical bond between the can and slug caused by the annealing of the stressed aluminum can. The Metallurgical Laboratory endeavored to prevent this condition but was unsuccessful.

It soon became apparent that Quality could not meet the urgent production schedule necessary to satisfy field requirements. The Engineering Department then placed purchase order RPG-4492-1/2 on Alcoa, for canning a supplemental quantity of slugs, immediately after Clinton Laboratories agreed to release Alcoa (for a period of approximately six weeks)

from production on their order for unbonded Clinton slugs. Testing under this new order was to be made with three vacuum bubble testers loaned by the Metallurgical Laboratory.³¹ Training of personnel in the use of this equipment also was to be conducted by the Metallurgical Laboratory.

The vacuum bubble testing apparatus used at Quality was developed by du Pont and was of a design different from that of the Metallurgical Laboratory tester. Though insufficient vacuum pump capacity and the prevalence of leaks in the vacuum lines prevented it, at the start, from functioning properly,³² elimination of these conditions soon proved the apparatus to be superior in some respects to the Metallurgical Laboratory tester.^{33,34} From this point on, no trouble was experienced and tests were performed satisfactorily on all the slugs canned.

On July 15, 1944 the fluoroscopic test to detect misplaced insulators was discontinued at Quality³⁵ so that the apparatus could be shipped to Hanford for inspection of the aluminum-silicon bonded assembly, to ascertain the thickness of the top end piece after machining in preparation for welding.³⁶ However, since this test had rejected as much as five percent of the daily production at Quality, all future unbonded slugs canned at Quality were to be fluoroscopically-examined upon their receipt at Hanford. In fact, all canned slugs on Project 1553 were re-tested at Hanford to eliminate without question any which might not be suitable for charging into the pile.

No further changes were made in the testing procedure for the balance of the work covered under Project 1553. The need for unbonded slugs had been fulfilled, and the Engineering Department's portion of the program came to a close. The Explosives Department continued its work in fabricating and canning the bonded slugs in the 300 Area, and retained the responsibility for all testing operations and results at Hanford. Some modifications to existing test methods, and development of new tests, were subsequently made, either individually or in collaboration with the consultants; but these are not discussed herein as the Engineering Department was not involved.

SECTION X

THE DUMMY SLUG PROGRAM

THE DUMMY SLUG PROGRAMCONTENTS

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SECTION X**THE DUMMY SLUG PROGRAM****INTRODUCTION**

The extremely high power output of the Hanford-type pile necessitated the employment of a shielding agent, in the physical form of a slug, to reduce to a safe level the radio-activity in the ends of the tubes. This requirement was the basis for promoting an extensive program to embrace the design, procurement and evaluation of the various agents, or dummy slugs, ultimately fabricated in order to determine the suitability of each under the conditions imposed by the process.

This program, like that for the fabrication of the uranium slugs, involved the Metallurgical Laboratory in the capacity of a consulting agency; the Explosives Department, in a design and engineering capacity; and the Engineering Department, to handle the procurement and the development of manufacturing methods. As before, Engineering functioned in accordance with the requests of the Explosives Department, and, as the situation demanded, contributed engineering assistance. Beyond this functional breakdown, however, the departure between the two different slug programs was pronounced. The TNX Technical Division entered actively into the design and, with its operation of the CMX Unit at Hanford, the testing of the various types of dummies. Results of

these tests under simulated operating conditions influenced, more than any other single factor, the designs and the required quantities of the various types of dummy slugs ultimately procured. Like many other individual phases of the Hanford project, design, testing and fabrication of the dummies progressed concurrently; to expedite delivery to the field of those dummies which at that time were believed to be of the best designs for the purpose. In some instances, drastic revisions to these designs resulted in the virtual overnight change in complexion of portions of the program, and occasioned the immediate endeavors of the Engineering Department to arrange for further development of manufacturing methods in the fabricating shops.

Ultimately, the Engineering Department's portion of the program embraced the procurement of two basic functional types of dummies:

1. "Poison" slugs, of 90% lead and 10% cadmium, used to improve the power output by modifying the heat distribution in the pile; and
2. Aluminum, lead, stainless steel and steel slugs, to reduce the escape of radiation through the ends of the tubes.

DUMMY SLUG DESIGN

In May, 1943, the earliest design visualized a dummy slug made of a graphite rod, clad with aluminum tubing on its circumferential surface, but left open at the ends.¹ Aluminum coverings, or cans, were specified from the start,

in order to protect the interior of the ribbed tubing from electrolytic action;² and the ends were to be left open because the graphite was believed to evolve gas under the conditions in the pile. In such circumstances, there would be a graphite-aluminum couple which might cause corrosion in the tubes, and because of the possible deleterious effects resulting from this design, this type of dummy never progressed beyond the design stage.

By the middle of June, the aluminum-clad graphite design had not entirely been discarded, but other types of dummies were proposed for consideration as alternates. At this time, and continuing in ever-increasing importance throughout the life of the program, considerable thought was given, and extensive theoretical calculations were made, to arrive at a design of dummy which would produce a minimum pressure drop in the cooling water flowing past the dummy in the tube. This requirement was one of the two ultimate determining factors by which the dummies were evaluated for acceptability in the pile.

Three alternate designs were under consideration by the TNX Technical Division, and each was characterized by its low resistance to water flow. These types were:

1. The tubular dummy, made of open-ended lengths of aluminum tubing, with holes or notches at the ends. These slugs were to be used simply as spacers, and only if the water flow was adequate, in the shield and reflector regions of the tube.

2. The modified twist drill, or long-pitch auger, made of almost any solid material, but probably coated with aluminum. These were developed for placement in the shield portions to satisfy the supposed requirements advanced by the Metallurgical Laboratory that any straight line parallel to the axis must pass through 50% metal and 50% water. Ship augers satisfied this requirement, but no way had yet been found to avoid the necessity of careful orientation of successive augers without introducing significant end-to-end friction losses. In a preliminary test made of these two possibilities, the ship auger spun at the expected water velocity, whereas the twist drills did not. To combat this tendency, the design of a slug on the auger principle would employ a reverse twist for half the slug length.

3. The "egg-and-doughnut" slugs, made of almost any solid material, but probably must be coated with aluminum. This type consisted of successive elongated eggs and doughnuts, and was developed as an alternate to the auger-twist design in an attempt to produce a shape which could not spin, could be cast, and, if necessary, could be sheathed in a piece of tubing.

The Metallurgical Laboratory at this time recommended that aluminum slugs of the twisted or egg-and-doughnut type be used in the active portion of the pile;³ that aluminum slugs also be used in the thermal shield and inner parts of the biological shield; and that the tubes in the outer thirty inches of the biological shield should contain aluminum-

coated iron, copper, lead, bismuth, or stainless steel slugs, with the prospect that such slugs could be reused.

By the end of July, 1943, the twisted dummy was believed to be the most suitable for the process conditions. The need for sample specimens and limited production quantities now brought the Engineering Department into the program, which, prior to this time, had involved only the Explosives Department and the Metallurgical Laboratory. Procurement was started immediately, and purchase orders RPG-662-1/2 and 766-1/2 were placed on the Wolverine Tube Division of the Calumet & Hecla Consolidated Copper Company for experimental quantities of twisted dummies, made of lead and encased in an aluminum jacket.

In August, the TNX Division was planning to use only one type of dummy,⁴ with the exception that another, of a bullet design, might be placed just ahead of the uranium slugs; and a third, placed in the inlet and exit fittings in order to improve the flow.

In addition to the design problems relative to pressure drop across the slugs, the TNX group was concerned with the possibility of handling the dummy for reuse. It was believed, however, that a lead slug would be damaged sufficiently during discharge to prohibit its reuse, and subsequent findings confirmed this assumption. The Engineering Department was concerned, too, lest the helices of the twisted dummies would prove unable to withstand the end thrust during the slug discharging operation.⁵ To

resist this thrust, it was considered at one time practicable to increase the compressive strength of the twisted dummies by the incorporation of an aluminum or dural rod along the longitudinal axis of the slug. This possibility was never evaluated in practice, however, as other developments were later introduced that obviated consideration of this detail.

Although initial efforts had been directed toward the development of the twisted dummy, active consideration was nevertheless being given also to the development of other types of dummies to fulfill certain conditions in the pile. The first definitely-crystallized outgrowth of these endeavors was the design for two types of stainless steel dummies, each 1.440" in diameter, one eight inches long and the other four inches long, for use in the water fittings to improve the flow.⁶ The cylindrical shape too, was preferred at this location because the twisted dummy would permit too great a leakage when the water fitting closures were removed. On November 15, 1943, the TNX Division requested the Engineering Department to procure these dummies, of 12%-14% chromium steel, in the production quantities of 14,000 of the four-inch length and 7000 of the eight-inch length. Purchase orders RPG-1638-1/2 and 2198-1/2 were placed to cover the material and the fabrication, respectively, of this number of dummies.

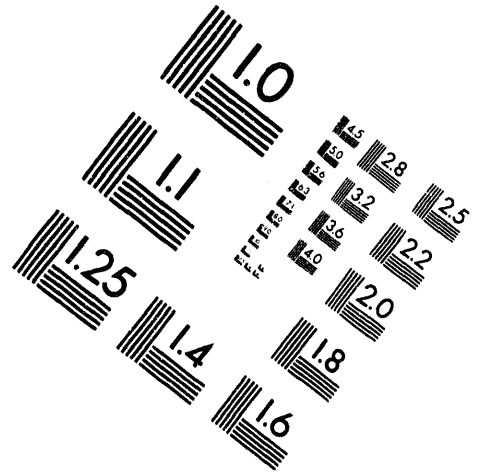
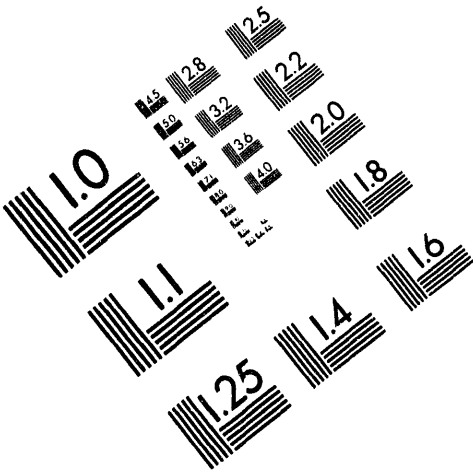
This request was soon followed by another from the TNX Division, when, on November 29, 1943, the Engineering Department was advised that 30,000 aluminum-jacketed lead slugs, 1.440" overall diameter by 8.000" long, would be required to act as fillers for those water-cooling tubes, out-



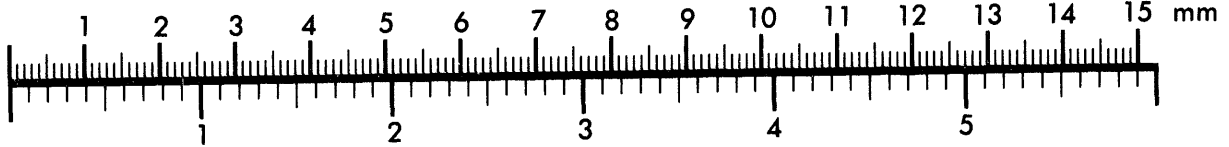
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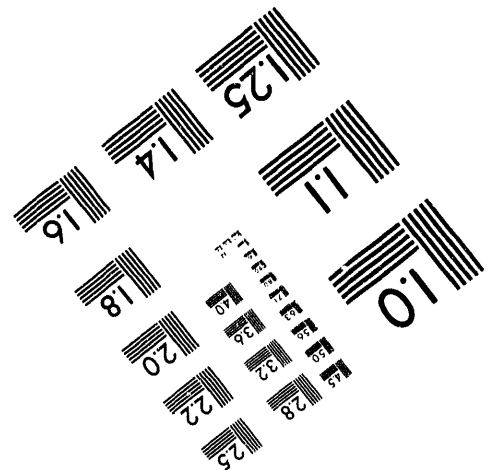
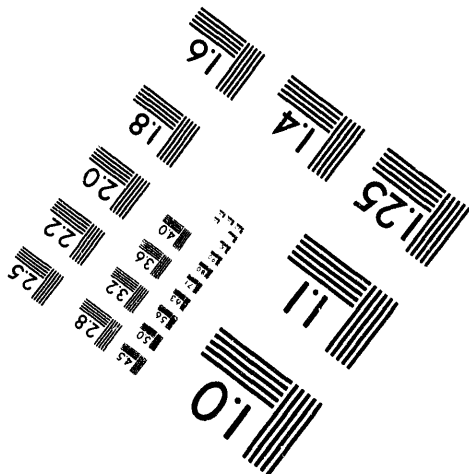
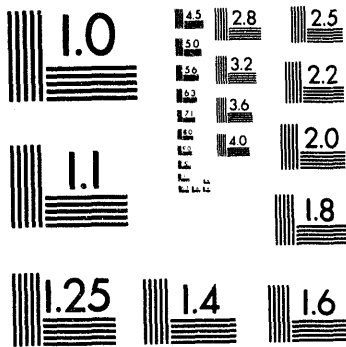
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Centimeter



Inches



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3 of 4

side the sphere of activity in the pile, which would not be charged with uranium slugs.⁷

By the end of 1943, development of dummy slug design was believed to be fairly well established for those dummies which were to be placed in the active tubes and in the water-cooling inactive tubes. It was recognized, however, that some form of dummy would be required in the air-filled inactive tubes on the fringe of the pile, to prevent the escape of radiation and of air containing activated argon. The design evolved for this condition visualized a steel plug, of a diameter slightly less than the inside diameter of the tube, and grooved to an accurate profile to clear the ribs of the tube. On January 12, 1944 the TNX Division advised the Engineering Department that nine of these plugs would be required in each end of the air-filled tubes, and, on the basis of 450 tubes per pile, 25,000 grooved steel plugs would be required for the three piles.⁸

Meanwhile, considerable difficulty had been experienced in the fabrication of the twisted dummies, the principal obstacle being the development of a satisfactory welded closure.⁹ The Metallurgical Laboratory had reported that this type of closure was necessary for process conditions, but in view of the attendant problems, the TNX Division believed that the spun and coined closure proposed by Wolverine would give satisfactory results. By February, 1944, all production work on the twisted slugs had been stopped, awaiting either the Metallurgical Laboratory's approval of the Wolverine closure or its development of a suitable welding technique.

Several attempts were made in the latter direction, but trouble had been encountered because the twisted assembly was not a precision job,⁹ and hence could not be rotated suitably on its center to form a satisfactory weld; the aluminum wall was undesirably thin and not particularly uniform; and the coating of lead on the aluminum interfered with the welding operation. Though developmental work continued, suitable welding performance was not achieved.

A quantity of the twisted slugs had been tested in the ribbed tubing at the Metallurgical Laboratory to determine the amount of force required to load and discharge the tube. These tests indicated the presence of two objectional characteristics of the twisted slugs,¹¹ which were: tilting and rocking of the slug, caused by the flow of water at anticipated operating velocities; and wearing of the tube ribs, which was accelerated by the configuration of the slug sides.

On February 24, 1944 the Metallurgical Laboratory advised that the situation at that time with respect to the twisted dummies was unsatisfactory, not only because of these two characteristics but also because of the small contact area at the slug ends, a condition which would be unsuitable in view of the apparent high loading force required as indicated in the experiments conducted.¹² As a possible alternative, the Metallurgical Laboratory stated that a sufficiently low pressure loss could be obtained by the use of cylindrical slugs only.

The Explosives Department endeavored to explore

this possibility, and, as a possible forerunner in determining a suitable substitute for the twisted dummy, stated that if the water-cooling tubes outside the sphere of activity were filled with solid aluminum slugs rather than with the aluminum-jacketed lead slugs, the change in effect on pile operation would be practically negligible.¹³ This possibility would permit diversion of the canned lead slugs for use in shielding the ends of the active tubes.

Other developments were being manifested at this same time. Continued research in the theory of pile operation disclosed that the presence of a "poisoning" agent, placed at strategic locations within the pile, would improve the power output by modifying the heat distribution. These poison slugs might consist of a standard-size aluminum can filled with a lead-bismuth-calcium alloy, containing not less than 10% calcium by weight, or alternatively:

1. Of an aluminum-boron alloy containing not less than 11% of boron by weight,
2. Of an aluminum-calcium alloy containing not less than 23% of calcium by weight, or
3. Of an aluminum can inside which is placed a rolled sheet of 0.020" cadmium.

By the end of February, however, design of the poison dummy was specified as an alloy slug, of 90% lead and 10% cadmium, sealed in a cylindrical aluminum can.¹⁴ A total of 11,000 of these slugs would be required for the three piles. Other revisions in the dummy requirements at this time increased the quantity of grooved steel plugs from

25,000 to 35,000; and specified the procurement of 25,000 solid aluminum slugs, each 6" long by 1.440" in diameter, for use in the water-cooling inactive tubes.

On March 11, 1944, the TNX Division advised the Engineering Department that it had been decided to use perforated aluminum tubes in place of the twisted dummies, and that any orders which had been placed for the latter should be cancelled.¹⁵ Instead, orders were to be placed as soon as possible for 120,000 of the perforated design.

This design had been worked up not only because of the inherent difficulties in the fabrication of the twisted dummies, but also because of the mechanical tendencies of the latter to rock within the tube and thereby score the tube ribs.¹⁶ Before the twisted dummy design was abandoned, however, the TNX Division had received approval from the Metallurgical Laboratory for the proposed replacement.¹⁷ Procurement of the perforated dummies was instituted immediately by the Engineering Department.

On March 16, however, the TNX Division again advised the Engineering Department that certain revisions in the type and quantity of dummy slugs would be required.¹⁸ These changes decreased the diameter of the aluminum-jacketed lead slugs from 1.440" to 1.360" (to permit a 6.5% increase in the flow rate¹⁹ through the tube for a given overall pressure drop), and increased the required quantity of perforated aluminum tubular dummies from 120,000 to 200,000.

At this time the TNX Division advised the Operating

Department of the status of the dummy slug program.²⁰ It was planned to charge three canned lead dummies of 1.360" diameter near the outer face of the shield section of each end of each tube. These under-size slugs will permit approximately the same water flow at the same pressure drop as originally planned, but will introduce a larger clearance which could be compensated for by charging the space between the lead slugs and the active slugs, and between the lead slugs and the stainless steel slugs at the ends of the tubes, with the perforated aluminum tubular dummies. The small-diameter lead slugs were to be located as far as possible from the active slugs so that normal flow might be re-established by the time the water reached the active slugs.

In establishing the quantitative requirements for dummies it was assumed that the second pile would start operation two months after the first pile, and that the third pile would be ready six months after the initial pile. It was assumed also that no replacements would be required during the first month's operation and that normal replacements would be required thereafter. The Operating Department was to procure any dummy slugs required in excess of those to be furnished by the Engineering Department. The requirements of dummies at this time are included in the tabulation on the following page.

On March 20, 1944, the TNX Division advised the Engineering Department that some slugs received at the CMX Unit had shown evidence of damage in transit, and accordingly,

DUMMY SLUG REQUIREMENTS AS OF MARCH 17, 1944

| Slug Description | Quantity Required For | | | | | | To be Ordered by Eng. Dept. |
|---|-----------------------|------------------------------------|--------|--------------------|------------------------------------|---------|--------------------------------|
| | 1 Pile | | | 3 Piles | | | |
| | Initial Loading | Replacement Aug. 1 to Feb. 1 | Total | Initial Loading | Replacement Aug. 1 to Feb. 1 | Total | |
| Lead Cylindrical - .030" Al covered 6" x 1.360" ± .003" | 12,024 | 7,200 | 19,224 | 36,072 | 11,520 | 47,592 | 30,000 |
| 12-14% Chrome 8" x 1.440" | 4,008 | 2,400 | 6,408 | 12,024 | 3,840 | 15,864 | 7,000 |
| 4" x 1.440" | 2,004 | 1,200 | 3,204 | 6,012 | 1,920 | 7,934 | 14,000 |
| Perforated Al Tubes 8" x 1.440" ± 0.001" O.D. x 1.080" ± .003" ID (0.18 wall) | 48,096 | 28,800 | 76,896 | 144,288 | 46,080 | 190,368 | 200,000 |
| Solid Aluminum 6.144" x 1.440" ± .001" | 8,400 | None | 8,400 | 25,200 | None | 25,200 | 25,000 |
| Grooved Steel 8" x 1.582" + 0.000" - .002" | 10,176 | None | 10,176 | 30,528 | None | 30,528 | 35,000 |
| Poison 10% Cadmium-90% Lead 6.144" ± .020" x 1.440" ± .001" | 4,600 | None | 4,600 | 13,800 | None | 13,800 | 11,000 |

108
201

the Engineering Department was requested to prepare designs for special shipping containers.²¹ This was done, and, in an effort to expedite and safeguard the program, procurement of packing boxes and corrugated liners was also undertaken by the Engineering Department.

By early April, 1944, the TNX Technical Division had tentatively fixed the loading pattern for the active tubes.²² Each tube contained: two 8" stainless steel slugs, two 4" stainless steel slugs, twenty-three 8" perforated tubular aluminum slugs, six 1.360" diameter lead slugs, and thirty-two uranium slugs; so arranged that the lead dummies were entirely within the limits of the biological shield.

This pattern was soon revised, however, to provide for only one 4" stainless steel dummy, and to increase the number of perforated aluminum slugs from twenty-three to twenty-four, per tube.²³ It was specified also that eighty-four solid aluminum slugs, and two 8" and one 4" stainless steel slugs, would be used in each of the approximately one hundred water-cooling tubes on the fringe of the pile; twenty-four grooved steel plugs in the air-filled tubes on the periphery of the pile; and forty-six poison slugs, in addition to a complement of stainless steel, lead, and perforated slugs, in each of the thirty-five tubes to be loaded with this charge.

The pile charging pattern was not yet entirely stabilized. The concensus was that this would have to be evolved in actual operation, though tentative considerations

could be proposed. The Engineering Department was advised that, since the number of tubes that would be loaded with uranium had not definitely been decided upon, it should provide adequate quantities of the various types of dummies in the event of a 1500-tube charging of uranium. Conversely, it should also provide for sufficient slugs of all types in the event all 2004 tubes were charged with the active slugs.

By May, the TNX Division had determined that additional solid aluminum slugs, and a quantity of aluminum spacers, would be required. The Engineering Department therefore was requested to procure 16,000 additional slugs and 84,000 spacers.²⁴ The latter were to be used in those tubes that contained an 8" and a 4" stainless steel slug in each end fitting, and two lead dummies in the shield section, at each end of the tube; and could be fabricated from aluminum tubes, rods, or any other shape that would insure positive spacing and would withstand the required pushing force.²⁵ These spacers were to be approximately 8" in length, and if cylindrical, of 1.40" - 1.44" outside diameter.

This request was followed shortly by another for an additional 16,000 stainless steel slugs, required for the initial loading of the second and third piles.²⁶ The design of these was revised, from those originally procured, to change the lengths from 8" and 4" to a standard 6.144" length.

Meanwhile, the CMX Unit had been conducting numerous tests on the flow characteristics of the various loading

patterns under consideration, and it was learned that the perforated aluminum tubular dummies vibrated in the tubes and severely marked the tube ribs.²⁷ The TNX Division was attempting to determine a way in which these perforated dummies could be used, as a large quantity of these slugs had already been fabricated. If necessary, it was proposed to use the 1.360" diameter canned lead slugs as a substitute throughout the pile, except for a short distance in the shields where the 1.440" diameter canned lead slugs would be used. This alternate loading charge was evaluated at the CMX Unit, and it was determined that the resultant pressure drop was unobjectionable.²⁸

By the latter part of June, 1944, the TNX Division advised that the perforated dummies apparently would not prove satisfactory, and the Engineering Department accordingly was to procure 153,500 additional 1.360" diameter and 34,500 additional 1.440" diameter canned lead slugs.²⁹ Production of the perforated dummies was to cease upon the completion of 75,000 pieces, as this quantity would take care of the requirements for the first pile. Because of the impossibility of procuring replacements in time for initial startup, the substitute lead dummies were to be used in the second and third piles only, until sufficient quantities had been received to charge also into the first pile as operating replacements.³⁰ These replacement slugs were included in the total quantities mentioned above, which were based on an initial charging of 1600 tubes per pile.

Early in August, the TNX Division advised that the 1.360" diameter lead slugs would be eliminated, because of the attendant vibration and chattering due to water flow in the tube, in favor of a standard 1.440" diameter dummy.³¹ These under-size slugs could be brought up to proper diameter by inserting the complete assembly within a can of the appropriate size, and would apply to the approximately 60,000 of the smaller slugs which had been fabricated to that time. The Engineering Department arranged for an experimental test of the double-canning operation and soon proved it to be practicable.³²

Continued experiments at CMX with various loading arrangements in the tubes disclosed the fact that the stainless steel slugs at the end of the inlet nozzles were forced downstream against the main column of the slugs.³³ This condition caused accelerated wear on the tube ribs and produced pressure fluctuations. It was learned, however, that these tendencies could be eliminated by decreasing the diameter of the upstream end of the slug to one inch for a distance of 1-1/2" along the slug.

On the basis of these findings, a change in the loading arrangement for the initial charge into the active tubes was again under consideration, this time to specify six lead, twenty-one perforated, and thirty-two active slugs; in addition to one 8" shouldered stainless steel slug and one new-design stainless steel slug 5.125" long by 1.440" in diameter. This arrangement was favored over that in which

all the perforated dummies would be replaced by 1.440" lead dummies, because it permits a 15% greater water flow for a given pressure drop. Regardless of which plan was adopted, however, the TNX Division had provided sufficient dummies for the complete loading, as it had arranged for the fabrication, at Hanford, of 5000 of the 8" shouldered slugs and 2000 of the 5-1/8" cylindrical slugs from the 7000 eight-inch stainless steel slugs previously ordered.³⁴ The Engineering Department, upon advice from TNX, stopped immediately the production of the 6.144" long stainless steel slugs. The first 3000 of these received at Hanford were to be refabricated there into 5-1/8" dummies to complete the initial requirements.

The Engineering Department was requested to evaluate these proposed changes in design of the stainless steel slugs, and found that both the 8" shouldered type and the short 5.125" type affected the mechanical operation of the new drum sorting mechanism.³⁵ Engineering suggested that a plain cylindrical dummy 6.144" long and a shouldered dummy 7" long, counter-bored at the end opposite the shoulder with a 1" hole, possibly would work in the sorter, and would accomplish the same end. These types then were evaluated in the field and were found to operate satisfactorily in the sorter.³⁶ Machining of the obsolete 8" cylindrical slugs to the 7" shouldered slug was immediately started, in lieu of fabricating the 8" shouldered and 5-1/8" cylindrical slugs.

With the establishing of this design for the stainless steel slugs, the Engineering Department's portion of the

dummy slug program came virtually to a close. Certain orders were still open, and ultimately, two more were to be placed,^{37,38} but prior to their completion, the Explosives Department assumed full responsibility for all further design and the procurement of necessary operating replacements.

DUMMY SLUG PROCUREMENT

The Engineering Department was responsible for the procurement and the development of manufacturing methods required for the production of the various types of dummy slugs ultimately evaluated and fabricated under this program.

Twisted Dummies

The first approach to this problem, like all succeeding activities in this connection, was made at the request of the TNX Division, and concerned the procurement of two experimental aluminum-jacketed twisted lead dummies. Purchase order RPG-662-1/2 was placed on August 30, 1943, on the Wolverine Tube Division of the Calumet & Hecla Consolidated Copper Company for the fabrication of these samples. At the same time, order RPG-766-1/2 was placed, also on this vendor, for the production of 500 twisted dummies. Later, this order was altered to include the necessary work for the development of manufacturing methods for anticipated high-production runs of twisted dummies; and ultimately included the fabrication of 408 samples of 1.380" diameter and 367 samples of 1.440" diameter twisted slugs, for testing and evaluating at the Metallurgical Laboratory, Clinton Engineer

Works, Wilmington Shops, Experimental Station, and the CMX Unit.

To expedite the procurement of production quantities of twisted dummies, the Engineering Department soon placed order RPG-1556-1/2 on Wolverine for the fabrication of 150,000 of these slugs. Work on this order was to start after acceptance of the 500 samples fabricated on RPG-766-1/2, and was to proceed at the rate of 20,000 slugs per month starting in January, 1944. This schedule was the best possible under the conditions imposed and was accepted in lieu of the original requirements stipulating completion of the 150,000 slugs by the end of March.

Due to the difficulties encountered in developing a satisfactory welded closure, start of production necessarily was delayed. In March, 1944, before any twisted dummies had been fabricated on this order, the design was revised completely to specify a perforated tubular aluminum type of slug. Order RPG-1556-1/2 was accordingly altered to cancel the 150,000 twisted slugs and to provide instead 200,000 of the tubular type.

Perforated Tubular Aluminum Dummies

Production to this design was rather slow at first, due to the lack of proper equipment; but after multiple-spindle drill presses had been received at Wolverine the daily output increased rapidly. Certain tolerances and specifications were relaxed somewhat by the Design Division to permit increased production. By June 27 approximately 59,000 tubular dummies had been fabricated. At this time, however, Wolverine

was advised that the perforated tubular dummy was to be discontinued, and that production should stop upon the completion of 75,000 acceptable pieces (required for charging the first pile). In all, 75,925 acceptable slugs were fabricated on this order.

Stainless Steel Dummies

Stainless steel dummies were required for use in the water fittings, in all water-filled tubes, to decrease the leakage when the tube was uncapped for charging or discharging. On November 15, 1943 the TNX Division requested the Engineering Department to procure 7000 of these 8" long and 14,000 4" long, all to be 1.440" in diameter and of 12%-14% chromium steel.

To effect the fabrication of these slugs in the most expeditious manner, the du Pont Company believed it best to utilize its purchasing contacts to secure material from recognized sources for subsequent fabrication into slugs at another vendor's shop. This procedure was adopted not only in procuring the stainless steel slugs, but also in getting under way the early production of canned lead slugs, solid aluminum slugs, poison slugs, and grooved steel plugs; all of which are discussed later in this section.

On November 26, 1943 order RPG-1638-1/2 was placed on G. O. Carlson, Inc. for stainless steel bar stock with partial deliveries to be made in December, January and February. With the material located, the Engineering Department shortly placed order RPG-2198-1/2 on the Koppers Company

for the subsequent fabrication, which progressed without difficulty. The order was completed on March 29, 1944, upon the acceptance of a total of 7104 eight-inch slugs and 14,104 four-inch slugs.

Early in June, 1944, the TNX Division requested the Engineering Department to procure 16,000 stainless steel slugs for the initial loading of the second and third piles. These slugs were to be 6.144" in length, as suggested by the Engineering Department, in order to standardize on the length of dummies and to permit more efficient operation in the drum sorting mechanism. A portion of the necessary bar stock was utilized from that left in excess after completion of order RPG-2198-1/2, and the balance of the material was purchased by du Pont on RPG-4502-1/2; all for use by the Stearns-Roger Manufacturing Company in fabricating the dummies on RPG-4602-1/2.

By the early part of August, the continued experimental work at the CMX Unit had indicated a revision in the design of these slugs. The new design embodied two types: an 8" shouldered slug with a reduced diameter at one end, and a plain cylindrical slug 5-1/8" in length. The slugs purchased on RPG-2198-1/2 were to be machined at Hanford to these designs, and RPG-4602-1/2 was to be cancelled immediately, since the 6.144" dummies would not be used. This order accordingly was terminated upon the acceptance of the 8212 slugs fabricated to that time.

Almost immediately, however, the design was again revised in accordance with the suggestion by the Engineering

Department that a 7" shouldered dummy counterbored on the opposite end be used in conjunction with a plain cylindrical dummy 6.144" in length. Machining the obsolete 8" cylindrical slugs to the 7" shouldered slug was started immediately at Hanford.

In November, 1944, the Operating Department requested the Engineering Department to purchase 5000 of the 7" shouldered slugs to complete its requirements for this type. These were subsequently fabricated from a portion of the excess bar stock, on hand from RPG-4602-1/2, at Stearns-Roger under order RPG-5336-1/2. The unused balance of the material was to be shipped to Hanford for the future use of the Operating Department.

Canned Lead Slugs

On November 29, 1943 the TNX Division requested the Engineering Department to procure 30,000 aluminum-jacketed lead slugs, for use as fillers in those water-cooling tubes outside the sphere of activity in the pile, which would not be charged with uranium slugs.

Because these slugs were to be canned in aluminum, the Engineering Department believed it advisable to utilize developed sources for procurement of the various component parts. The first approach to the problem, however, was to develop a source of bare lead slugs. Purchase orders RPG-2812-1/2 and 2813-1/2 were placed on American Smelting and Refining Company and on Eagle-Picher Sales Company, respectively, for experimental quantities of sample slugs 8.000"

long by 1.380" in diameter. These samples were shipped to the Aluminum Company for use on order RPG-3383-1/2 in developing methods for canning the dummies. Impact-extruded caps were furnished as a necessary part of this order, and the small quantity of aluminum cans required was diverted, from those which were on hand for another order, at Alcoa.

By the middle of March, 1944, the TNX Division changed the specifications to call for dummies 6" long by 1.360" in diameter. On this basis the Engineering Department placed orders for the procurement of the 30,000 canned lead slugs. Deep-drawn aluminum cans were supplied by Paul & Beekman on RPG-3018-1/2; the bare lead slugs by Eagle-Picher and the National Lead Company on RPG-3883-1/2 and 4094-1/2, respectively; and the caps and complete assembly of components by Alcoa on RPG-4420-1/2.

Some degree of difficulty was experienced in the production canning of these dummies. Because of the soft slug material, mortality was higher than anticipated, despite the exercising of extreme care. Special wooden shipping boxes and corrugated liners and pads were purchased on RPG-4074-1/2 and 4079-1/2, respectively. Orders for component parts were altered to increase the initial quantities. On one occasion, Alcoa exhausted its supply of component parts, but the production facilities immediately were utilized in fabricating a quantity of poison slugs on another order, so that the overall program was not delayed.

By the latter part of June, the TNX Division stated that the perforated tubular aluminum dummies were to be

replaced by two sizes of canned lead slugs, each 6" in length, one of 1.360" diameter and the other of 1.440" diameter.

Initial requirements of these were estimated to be 150,000 of the 1.360" size and 34,500 of the 1.440" size. Shipment was required in the quantities and on the dates as tabulated below:

| <u>To be shipped by</u> | <u>1.360" diameter</u> | <u>1.440" diameter</u> |
|-------------------------|------------------------|------------------------|
| September 1, 1944 | 41,000 | 10,000 |
| October 1, 1944 | 12,500 | 24,500 |
| November 1, 1944 | 50,000 | - - |
| December 1, 1944 | 50,000 | - - |
| | <u>153,000</u> | <u>34,500</u> |

If these dates could be met, the production of perforated tubular aluminum dummies at Wolverine on RPG-1556-1/2 could be stopped upon completion of the 75,000 pieces required for the first pile. The canned lead dummies could then be used for the second and third piles and for replacements in the first pile.

Procurement was started immediately, and was based on quantities sufficient to allow for an anticipated production mortality of 25% during the canning operation. A total quantity of 191,875 aluminum cans for the 1.360" dummies, and 43,025 for the 1.440" dummies, was ordered from Paul & Beekman on RPG-4628-1/2; 60,000 small and 47,000 large bare lead slugs from National Lead Company on RPG-4629-1/2; and 150,000 of the small slugs from Eagle-Picher on RPG-4630-1/2. Assembly and canning, as well as the furnishing of caps, were by Alcoa on RPG-4742-1/2; and order RPG-4648-1/2 was placed for

of single-canned 1.440" slugs from 150,000 to 96,000, and thereby effected not only a considerable savings in time but also in cost.

Quantities of the larger-size slugs were required in the field on the following dates:

10,000 by September 1, 1944

47,500 by October 1, 1944

57,500 by November 1, 1944

35,000 by December 1, 1944

Because of the reclamation of the smaller slugs by double-canning, this schedule was met and bettered. Approximately 3000 small slugs were double-canned in the 300 Area at Hanford to help expedite the program.

The abrupt change in the canned lead dummy program necessarily required the immediate cancellation of certain orders, and alterations to others, to conform to the new requirements. Fabrication of the small bare lead slugs on RPG-4629-1/2 was terminated upon the completion of 26,700 pieces. Work on RPG-4630-1/2 was stopped after 13,368 pieces had been made, and the order was altered to provide for the fabrication of 81,000 large slugs. A portion of RPG-4628-1/2 was terminated upon completion of 35,597 small cans, and the quantity of large cans on the same order was increased from 43,025 to 117,000. Alcoa revised its order for caps in accordance with these developments. Immediate change-overs to the larger size were made in the vendors' shops.

It was subsequently determined that a higher-than-anticipated percentage of acceptable slugs was being produced at both Alcoa and Quality. Order RPG-4628-1/2 was accordingly terminated upon the completion of 105,168 large-size cans, and RPG-5049-1/2 after a quantity of 58,503 cans had been fabricated. These quantities were sufficient to complete the balance of the work at Alcoa and Quality, respectively.

The procurement of canned lead slugs came to a close by the end of November, 1944. In all, 54,413 of the 1.360" diameter dummies (of the 57,883 which had been canned at Alcoa on orders RPG-4420-1/2 and 4742-1/2) were double-canned at Quality Hardware and Machine Corporation. Approximately 3000 of the balance were double-canned in the field, and the remainder were used for experimental purposes. In addition, Alcoa single-canned 100,373 dummies of the 1.440" diameter size. The total effective number of this size therefore fulfilled the requirements as requested by the TNX Division.

Grooved Steel Plugs

Grooved steel plugs were required for insertion in the ends of the air-filled inactive tubes around the fringe of the pile, to prevent the escape of radiation and of air containing radioactive argon. On January 12, 1944, the TNX Division requested the Engineering Department to procure 25,000 of these plugs; a figure based on charging nine plugs in each end of 450 tubes in each of the three piles.

In conformity with the usual procedure, the Engi-

neering Department placed separate orders for material and fabrication: RPG-2809-1/2 on the Cumberland Steel Company, and RPG-2808-1/2 on the Herring-Hall-Marvin Safe Company, respectively. The latter order was soon altered to increase the quantity to be fabricated from 25,000 to a total of 35,000 plugs, in accordance with the revised estimate by the TNX Division.

No unusual difficulties were experienced in the fabrication of these plugs. In order to meet the delivery schedule for initial requirements of the first pile, some overtime work was necessary, but throughout the entire program this practice was not uncommon.

By the middle of July the need for additional material prompted the placement of RPG-4865-1/2 on Cumberland Steel Company. However, this order was cancelled and was replaced by RPG-4916-1/2 on Jones & Laughlin Steel Corporation in order to secure earlier delivery. After this material was received at Herring-Hall-Marvin, fabrication proceeded to completion of the order. In all, 36,207 grooved steel plugs were fabricated and shipped.

Poison Slugs

The procurement of poison slugs containing 10% cadmium and 90% lead was initiated by the Engineering Department upon the request of the TNX Division. Order RPG-3324-1/2 was placed early in March, 1944, on the American Smelting and Refining Company for a small quantity of experimental poison slugs. Samples of these were shipped to the

Wilmington Shops and to the Aluminum Company for experimental canning operations. Soon thereafter, order RPG-3882-1/2 was placed on the National Lead Company for production quantities of these slugs, but when it developed that deliveries could not be made concordant with requirements, the order was cancelled and was replaced by RPG-4227-1/2 on the American Smelting and Refining Company. Cans were ordered from Paul & Beekman on RPG-3705-1/2; and the caps, together with the assembly of all components and the canning, from Alcoa on RPG-4077-1/2. A supplemental order, RPG-4537-1/2, was later placed on the National Lead Company for an additional quantity of slugs required to offset the anticipated loss by rejection after the canning operation.

The most important single factor in the fabrication of the poison slugs was the absolute necessity for their physical segregation from the plain canned lead dummies. This condition prompted the adherence to extremely close controls over the complete range of fabricating operations in the suppliers' shops.

No unusual difficulties were encountered during the fabrication of these slugs. Order RPG-4227-1/2 was terminated upon the completion of 9638 bare lead poison slugs; RPG-4537-1/2 was completed with the acceptance of 5004 bare slugs; 18,722 cans were fabricated on RPG-3705-1/2; and 11,461 dummies were canned by Alcoa on RPG-4077-1/2.

Solid Aluminum Slugs and Spacers

On February 25, 1944, the TNX Technical Division

reported that if solid aluminum slugs, rather than the aluminum-jacketed lead slugs, were used in the water-cooling inactive tubes outside the sphere of activity in the pile, the change in effect on pile operation would be practically negligible. This disclosure was followed immediately by a request from the TNX Division that the Engineering Department procure a quantity of 25,000 of these aluminum slugs, each 6" long by 1.440" in diameter.

Order RPG-3706-1/2 was soon placed on Extruded Metals, Incorporated for the total quantity, but when it shortly developed that this vendor would be unable to meet the dimensional specifications, the order was cancelled without charge. Order RPG-3922-1/2 was placed immediately on Alcoa for the furnishing of the aluminum rod, and RPG-3924-1/2 on the Weatherhead Company for the fabrication of the required 25,000 solid aluminum slugs. Some difficulty was experienced in the fabrication of these due to the exterior surface of the rod being damaged in shipment, but certain specifications were relaxed to permit use of this material.

On May 9, 1944 the TNX Division requested the Engineering Department to procure an additional quantity of 16,000 of these slugs, to meet the new total requirements of 41,000 slugs for the three piles. Also, a quantity of 84,000 solid aluminum spacers — to be inserted in those tubes that contained an 8" and a 4" stainless steel slug in each end fitting and two lead dummies in the shield section — would be required. These spacers were to be virtually the same as the solid alu-

perimental dummy design or of a base material easily fabricated which, after canning, could be used as a simulated uranium slug for the purpose of the test, were procured by the Engineering Department. Most of the latter type were fabricated from steel shafting at Baker Bros, Incorporated, on RPG-800-1/2, and were subsequently canned at Alcoa under RPG-277-1/2 and 1263-1/2. It is well to emphasize that these canned steel slugs were never considered as dummies, inasmuch as their use was confined only to serving as a substitute for the uranium slugs in developing a satisfactory welding method, or in determining data relative to corrosion behavior or other essential phases of the work.

Fabrication of some of the experimental dummy types was performed at Wilmington Shops. Seventy-two perforated tubular stainless steel dummies were made on RPG-3543-1/2 for testing at SMX; and two tool-made samples of a die-cast perforated tubular aluminum dummy design were made, on RPG-5281-1/2, and were tested to destruction in comparison with the machined and drilled type furnished on RPG-1556-1/2.

Orders were also placed on outside vendors in order to develop fabrication methods or to provide a developmental group with needed dummies. Seventy bare slugs of two percent antimony lead were procured on RPG-3384-1/2 for use in experimental canning operations at Alcoa and at Wilmington Shops; 500 "B" dummies were canned by Alcoa on RPG-4779-1/2; and orders XPG-1071-1/2 and 1133-1/2 were placed for the fabrication of a total of 2200 zinc-coated steel dummies required for the SMX Unit.

TESTING CANNED DUMMY SLUGS

Because the dimensional limitations of the slugs were enforced concordant with commercial high-scale production, inspection of the dummy slugs was necessarily held to close tolerances in order to satisfy the requirements imposed by the process. A few thousandths of an inch difference in slug diameter was shown by tests performed at CMX to influence greatly the water flow characteristics and pressure drop within the loaded tube. Tolerances on slug length also had to be held, as far as commercially possible, in order to eliminate an accumulative error in a chain of dummies which tended to form a small unfilled space between two adjoining slugs; a condition which affects not only the water flow characteristics but also the rate of heat transfer within the tube.

All uncanned dummies, such as the perforated tubular aluminum, stainless steel, steel plugs, and solid aluminum types, were inspected in the vendors' shops by representatives of the Engineering Department. Acceptable slugs only were shipped, except in a few cases where small quantities of rejected slugs would serve the purpose equally as well for the execution of a particular test.

In similarity with the uranium slugs, all canned lead and poison dummies required testing to determine the acceptability of the welded closure. With the dummy slugs, however, the testing procedure was less difficult, since all canned dummies were unbonded and the deflection test method developed for the unbonded Clinton size uranium slugs could

be employed. To facilitate the test, and to make the results more conclusive, a groove was formed on the surface of the bare lead slug during fabrication, similar to the groove specified for a large number of the Clinton slugs. All canned lead and poison dummies were tested by the deflection method, which is described in detail in Section IX - Methods of Testing Canned Slugs.

Appendix

| <u>Exhibit</u> | <u>Title</u> |
|----------------|---|
| A | Footnotes |
| B | Tabulation of Clinton Slug Program |
| C | Tabulation of Hanford Bonded Slug Program |
| D | Tabulation of Hanford Unbonded Slug Program |
| E | Tabulation of Hanford Dummy Slug Program |
| F | Numerical List of Clinton Orders |
| G | Numerical List of Hanford Orders - Project 9536 |
| H | Numerical List of Hanford Orders - Project 1553 |
| I | Index to Files Relating to Slug Programs |
| J | Drawings Relating to Slug Design |

Appendix A

FOOTNOTES - SECTION I

EXCEPTIONAL CHARACTERISTICS OF THE SLUG PROGRAM

| No. | Correspondence | Dated | File |
|-----|---|--------------------|------|
| 1 | C. E. Daniels' letter to J. B. Miles | March 20, 1943 | D-10 |
| 2 | Dr. J. J. Nickson's letter to C. E. Daniels | April 3, 1943 | D-17 |
| 3 | J. B. Miles' letter to C. E. Daniels | April 20, 1943 | D-17 |
| 4 | C. E. Daniels' letter to C. H. Greenewalt | June 28, 1943 | D-3 |
| 5 | Baker Bros, Inc. letter to C. F. Lange | July 3, 1943 | D-23 |
| 6 | W. R. Huey's letter to C. E. Daniels | July 15, 1943 | D-3 |
| 7 | W. R. Huey's letter to C. E. Daniels | August 31, 1943 | D-66 |
| 8 | C. E. Daniels' letter to Herring-Hall-Marvin Safe Co. | September 1, 1943 | D-19 |
| 9 | C. F. Lange's memorandum to File | - - | D-4 |
| 10 | C. E. Daniels' letter to B. & T. Metals Co. | April 10, 1943 | D-17 |
| 11 | Dr. W. D. Norwood's letter to Dr. G. H. Gehrman | May 26, 1943 | D-10 |
| 12 | Dr. J. J. Nickson's memorandum to J. B. Miles | May 27, 1943 | D-10 |
| 13 | Dr. J. J. Nickson's memorandum to A. B. Greninger | April 13, 1944 | D-56 |
| 14 | Dr. J. J. Nickson's memorandum to Messrs. Todt et al | July 29, 1943 | D-22 |
| 15 | C. E. Daniels' letter to J. B. Miles | June 4, 1943 | D-10 |
| 16 | Dr. W. D. Norwood's letter to Revere C. & B. Inc. | September 3, 1943 | D-49 |
| 17 | C. E. Daniels' letter to Revere C. & B. Inc. | September 27, 1943 | D-49 |
| 18 | M. G. Kershaw's memorandum to C. E. Daniels | October 9, 1943 | D-66 |
| 19 | J. B. Miles' letter to C. E. Daniels | March 29, 1943 | D-1 |
| 20 | C. E. Daniels' letter to J. B. Miles | June 1, 1943 | D-1 |
| 21 | C. F. Lange's letter to Herring-Hall-Marvin Safe Co. | July 8, 1943 | D-19 |
| 22 | Capt. R. D. Morse's letter to C. E. Daniels | March 21, 1944 | D-49 |
| 23 | C. E. Daniels' letter to P. E. Spahn | September 23, 1943 | D-19 |
| 24 | Major W. L. Sapper's letter to C. E. Daniels | June 15, 1943 | D-29 |
| 25 | C. E. Daniels' letter to Herring-Hall-Marvin Safe Co. | June 30, 1943 | D-29 |
| 26 | Major W. L. Sapper's letter to C. E. Daniels | August 2, 1943 | D-3 |

Appendix A

FOOTNOTES - SECTION II

EXTRUSION

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|--|--------------------|-------------|
| 1 | C. E. Daniels' letter to Battelle Memorial Institute | March 30, 1943 | D-17 |
| 2 | Lt. Col. Ruhoff's letter to F. A. Shinn | June 16, 1943 | D-3 |
| 3 | P. L. Spruance's letter to B. & T. Metals Company | May 19, 1943 | D-28 |
| 4 | F. M. Hart's letter to C. E. Daniels | June 7, 1943 | D-44 |
| 5 | W. E. Kirst's memorandum to File | June 28, 1943 | D-6 |
| 6 | R. A. Kinckiner's letter to C. E. Daniels | July 1, 1943 | D-6 |
| 7 | C. E. Daniels' letter to Revere Copper & Brass Inc. | August 2, 1943 | D-22 |
| 8 | C. E. Daniels' memorandum to File | August 30, 1943 | D-50 |
| 9 | C. F. Lange's letter to Major Sapper | August 21, 1943 | D-50 |
| 10 | Battelle's letter to C. E. Daniels | August 7, 1943 | D-6 |
| 11 | C. E. Daniels' letter to Battelle M. I. | August 24, 1943 | D-6 |
| 12 | R. A. Kinckiner's letter to C. E. Daniels | October 8, 1943 | D-6 |
| 13 | C. E. Daniels' letter to Major Sapper | November 6, 1943 | D-49 |
| 14 | C. E. Daniels' letter to Major Sapper | November 22, 1943 | D-49 |
| 15 | Maj. Hadlock's letter to Mallinckrodt Chemical Works | November 27, 1943 | D-66 |
| 16 | W. R. Huey's letter to C. E. Daniels | November 27, 1943 | D-49 |
| 17 | Revere's letter to C. E. Daniels | December 27, 1943 | D-49 |
| 18 | C. E. Daniels' letter to Major Sapper | February 2, 1944 | D-49 |
| 19 | Revere's letter to C. E. Daniels | February 29, 1944 | D-49 |
| 20 | R. P. King's letter to C. E. Daniels | April 11, 1944 | D-6 |
| 21 | Franke Foote's memorandum to A. B. Greninger | August 12, 1944 | D-67A |
| 22 | Major Hadlock's letter to C. E. Daniels | September 14, 1943 | D-96 |
| 23 | Major Hadlock's letter to C. E. Daniels | August 6, 1943 | D-22 |
| 24 | Major Hadlock's letter to J. F. Simon | July 27, 1943 | D-22 |

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FOOTNOTES - SECTION II

EXTRUSION

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|--|--------------------|-------------|
| 25 | Major Hadlock's letter to C. E. Daniels | September 14, 1943 | D-96 |
| 26 | Capt. Bassett's letter to C. E. Daniels | February 4, 1944 | D-96 |
| 27 | Lt. Col. Ruhoff's letter to C. E. Daniels | June 23, 1943 | D-3 |
| 28 | Lt. Col. Ruhoff's letter to C. E. Daniels | June 22, 1943 | D-3 |
| 29 | Major Hadlock's letter to C. E. Daniels | August 6, 1943 | D-22 |
| 30 | Major Hadlock's letter to C. E. Daniels | August 7, 1943 | D-22 |
| 31 | Major Hadlock's letter to C. E. Daniels | September 14, 1943 | D-96 |
| 32 | Capt. Bassett's letter to C. E. Daniels | February 4, 1944 | D-96 |
| 33 | Capt. Sturges' letter to C. E. Daniels | March 29, 1944 | D-6 |
| 34 | Lt. Stanford's letter to Major Sapper | May 18, 1944 | D-67 |
| 35 | Major Hadlock's letter to Major Sapper | February 28, 1944 | D-6 |
| 36 | Capt. Sturges' letter to C. E. Daniels | March 29, 1944 | D-6 |
| 37 | R. P. King's letter to C. E. Daniels | March 18, 1944 | D-6 |
| 38 | Capt. Bassett's letter to C. E. Daniels | February 4, 1944 | D-96 |
| 39 | R. A. Kinckiner's letter to C. E. Daniels | April 3, 1944 | D-6 |
| 40 | C. E. Daniels' letter to Major Sapper | July 16, 1943 | D-13 |
| 41 | C. E. Daniels' letter to J. B. Miles | April 10, 1943 | D-13 |
| 42 | Major Hadlock's letter to C. E. Daniels | July 27, 1943 | D-3 |
| 43 | Maj. Hadlock's letter to Mallinckrodt Chemical Works | November 27, 1943 | D-66 |
| 44 | C. E. Daniels' letter to Major Hadlock | August 16, 1943 | D-3 |
| 45 | C. E. Daniels' letter to Major Hadlock | August 21, 1943 | D-66 |
| 46 | P. L. Spruance's letter to B. & T. Metals Company | March 30, 1943 | D-28 |
| 47 | C. E. Daniels' letter to J. N. Tilley | September 27, 1943 | D-49 |
| 48 | C. E. Daniels' letter to J. N. Tilley | January 19, 1944 | D-49 |

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FOOTNOTES - SECTION II

EXTRUSION

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|-------------------|-------------|
| 49 | R. A. Kinckiner's letter to C. E. Daniels | April 3, 1944 | D-6 |
| 50 | Major Hadlock's letter to Major Sapper | February 28, 1944 | D-6 |
| 51 | A. B. Greninger's letter to C. E. Daniels | January 11, 1944 | D-6 |
| 52 | Battelle's letter to C. E. Daniels | February 14, 1944 | D-6 |
| 53 | C. E. Daniels' letter to R. P. Putman | January 12, 1944 | D-49 |
| 54 | Tilley's teletype to Swensson-Sanford | January 15, 1944 | D-6 |
| 55 | R. P. King's letter to C. E. Daniels | March 18, 1944 | D-6 |
| 56 | R. P. Putman's memorandum to C. E. Daniels | January 20, 1944 | D-6 |
| 57 | Major Hadlock's letter to Major Sapper | February 28, 1944 | D-6 |
| 58 | Major Hadlock's letter to Major Sapper | February 28, 1944 | D-6 |
| 59 | R. A. Kinckiner's letter to C. E. Daniels | March 3, 1944 | D-6 |
| 60 | R. P. King's letter to C. E. Daniels | February 29, 1944 | D-6 |
| 61 | R. P. King's letter to C. E. Daniels | March 13, 1944 | D-6 |
| 62 | Lt. Stanford's letter to Major Sapper | May 18, 1944 | D-67 |
| 63 | Capt. Sturges' letter to C. E. Daniels | March 29, 1944 | D-6 |
| 64 | R. P. King's letter to C. E. Daniels | March 14, 1944 | D-6 |
| 65 | R. A. Kinckiner's memorandum to C. E. Daniels | March 17, 1944 | D-6 |
| 66 | R. P. King's letter to C. E. Daniels | April 11, 1944 | D-6 |
| 67 | R. P. King's memorandum to C. E. Daniels | April 24, 1944 | D-6 |
| 68 | R. P. King's letter to C. E. Daniels | May 8, 1944 | D-6 |
| 69 | R. P. King's note to C. E. Daniels | May 19, 1944 | D-67 |
| 70 | R. P. King's letter to C. E. Daniels | May 31, 1944 | D-67 |
| 71 | C. E. Daniels' letter to Major Sapper | June 13, 1944 | D-67 |
| 72 | C. E. Daniels' memorandum to M. F. Wood | August 7, 1944 | D-67A |

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FOOTNOTES - SECTION III

DRAWING, SWAGING AND ROLLING

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|--|---------------------|-------------|
| 1 | Battelle's letter to C. E. Daniels | August 6, 1943 | D-6 |
| 2 | R. A. Kinckiner's letter to C. E. Daniels | October 8, 1943 | D-6 |
| 3 | Revere's letter to C. E. Daniels | December 27, 1943 | D-66 |
| 4 | Revere's letter to C. E. Daniels | November 11, 1943 | D-49 |
| 5 | R. A. Kinckiner's letter to C. E. Daniels | January 14, 1944 | D-6 |
| 6 | Revere's letter to C. E. Daniels | December 27, 1943 | D-66 |
| 7 | C. E. Daniels' letter to Major W. L. Sapper | February 5, 1944 | D-67 |
| 8 | Frank Foote's memorandum to A. B. Greninger | July 28, 1944 | D-67A |
| 9 | W. E. Kirst's memorandum to File | June 28, 1943 | D-6 |
| 10 | C. E. Daniels' letter to J. B. Miles | July 21, 1943 | D-66 |
| 11 | A. B. Greninger's letter to C. E. Daniels | March 23, 1944 | D-6 |
| 12 | H. M. Sawyer's letter to C. E. Daniels | March 25, 1944 | D-56 |
| 13 | C. E. Daniels' letter to Major W. L. Sapper | March 31, 1944 | D-56 |
| 14 | Furnace and Extrusion Log | May 9-10-11, 1944 | RPG-3779† |
| 15 | Furnace and Extrusion Log | June 2, 1944 | RPG-3779† |
| 16 | Furnace and Extrusion Log | June 22-23-24, 1944 | RPG-3779† |
| 17 | R. P. King's memorandum to C. E. Daniels et al | July 7, 1944 | D-67A |
| 18 | R. P. King's memorandum to C. E. Daniels et al | July 7, 1944 | D-67A |
| 19 | W. R. Huey's memorandum to R. F. Peterson | July 14, 1944 | D-67A |
| 20 | C. E. Daniels' letter to Major W. L. Sapper | August 1, 1944 | D-80 |
| 21 | A. B. Greninger's letter to W. R. Huey and C. E. Daniels | September 21, 1944 | D-80 |
| 22 | C. E. Daniels' letter to W. R. Huey | September 26, 1944 | D-80 |

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FOOTNOTES - SECTION IV

OUTGASSING AND STRAIGHTENING

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|--|-------------------|-----------------------|
| 1 | W. E. Kirst's memorandum to File | June 28, 1943 | D-6 |
| 2 | Copperweld's letter to P. L. Spruance | May 24, 1943 | XPG-492 $\frac{1}{2}$ |
| 3 | C. E. Daniels' letter to J. B. Miles | June 1, 1943 | D-13 |
| 4 | C. E. Daniels' letter to J. B. Miles | June 16, 1943 | D-20 |
| 5 | W. E. Kirst's memorandum to File | June 28, 1943 | D-6 |
| 6 | C. F. Lange's letter to Major W. L. Sapper | August 21, 1943 | D-81 |
| 7 | C. E. Daniels' letter to F. M. Hart | July 16, 1943 | D-68 |
| 8 | C. E. Daniels' letter to Battelle Memorial Institute | September 4, 1943 | D-49 |
| 9 | Revere's letter to C. E. Daniels | November 1, 1943 | D-49 |
| 10 | C. E. Daniels' letter to Revere Copper & Brass Inc. | November 5, 1943 | D-49 |
| 11 | C. E. Daniels' letter to Revere Copper & Brass Inc. | November 5, 1943 | D-49 |
| 12 | C. E. Daniels' letter to Revere Copper & Brass Inc. | May 3, 1944 | D-49 |
| 13 | Revere's letter to C. E. Daniels | July 14, 1944 | D-49 |
| 14 | C. E. Daniels' letter to W. R. Huey | August 2, 1944 | D-49 |
| 15 | A. B. Greninger's memorandum to Cooper-Chipman | June 8, 1944 | D-56 |
| 16 | R. P. King's memorandum to C. E. Daniels | June 19, 1944 | D-56 |

Appendix A

FOOTNOTES - SECTION V

PROJECT 1030

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|-------------------|-------------|
| 1 | C. E. Daniels' letter to M. F. Wood | January 3, 1944 | D-95 |
| 2 | C. E. Daniels' letter to Revere Copper & Brass Inc. | December 29, 1943 | D-95 |
| 3 | E. G. Ackart's letter to Clinton Laboratories | January 4, 1944 | D-95 |
| 4 | W. C. Kay's teletype to R. H. Wadhams | January 17, 1944 | R-3 |
| 5 | W. J. May's letter to G. S. Long et al | January 22, 1944 | R-3 |
| 6 | S. Heyward's letter to Clinton Laboratories | March 20, 1944 | D-94 |
| 7 | W. J. May's letter to J. R. Medford | April 27, 1944 | R-3 |

Appendix A

FOOTNOTES - SECTION VI

MACHINING, GRINDING AND GROOVING

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|--------------------|-----------------------|
| 1 | C. J. Veith's memorandum to J. H. Shaw | April 3, 1943 | D-29 |
| 2 | P. L. Spruance's letter to Herring-Hall-Marvin Safe Co. | April 5, 1943 | D-29 |
| 3 | P. L. Spruance's letter to Herring-Hall-Marvin Safe Co. | April 15, 1943 | D-29 |
| 4 | Herring-Hall-Marvin Safe Co's letter to P. H. Spruance | May 18, 1943 | D-29 |
| 5 | C. F. Lange's letter to Lt. Col. J. R. Ruhoff | June 25, 1943 | D-3 |
| 6 | C. F. Lange's memorandum to C. E. Daniels | June 9, 1943 | D-33 |
| 7 | C. E. Daniels' letter to Herring-Hall-Marvin Safe Co. | May 29, 1943 | D-19 |
| 8 | C. E. Daniels' letter to Baker Brothers, Inc. | June 1, 1943 | D-33 |
| 9 | C. E. Daniels' letter to B. & T. Metals Co. | June 17, 1943 | D-31 |
| 10 | Reason Sheet with purchase order XPG-753 $\frac{1}{2}$ | July 2, 1943 | XPG-753 $\frac{1}{2}$ |
| 11 | Baker Brothers, Inc. letter to C. E. Daniels | September 2, 1943 | D-48 |
| 12 | J. B. Miles' letter to C. E. Daniels | July 26, 1943 | D-3 |
| 13 | C. E. Daniels' letter to J. B. Miles | June 21, 1943 | D-13 |
| 14 | J. B. Miles' letter to C. E. Daniels | June 26, 1943 | D-13 |
| 15 | J. B. Miles' letter to C. E. Daniels | September 2, 1943 | D-13 |
| 16 | C. E. Daniels' letter to Major W. L. Sapper | September 23, 1943 | D-47 |
| 17 | C. E. Daniels' letter to P. L. Spruance | August 23, 1943 | D-48 |
| 18 | H. H. Kerslake's letter to Major W. L. Sapper | September 28, 1943 | D-19 |
| 19 | C. E. Daniels' letter to Baker Brothers, Inc. | January 12, 1944 | D-47 |
| 20 | J. M. Aarons' letter to C. C. Maddux et al | May 8, 1944 | D-71 |

Appendix A

FOOTNOTES - SECTION VI

MACHINING, GRINDING AND GROOVING

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|-------------------|-------------|
| 21 | J. N. Tilley's letter to M. F. Wood | May 18, 1944 | D-67 |
| 22 | J. N. Tilley's letter to M. F. Wood | May 2, 1944 | D-74 |
| 23 | Design Procedure - Project 9536 | October 29, 1942 | D-68 |
| 24 | J. C. Geuther's letter to Baker Brothers, Inc. | June 15, 1944 | D-59 |
| 25 | C. F. Lange's letter to Carborundum Company | May 28, 1943 | D-3 |
| 26 | Carborundum Co.'s letter to C. F. Lange | July 2, 1943 | D-48 |
| 27 | J. M. Simmons' memorandum to A. B. Greninger | December 31, 1943 | D-66 |
| 28 | J. M. Simmons' memorandum to A. B. Greninger | January 26, 1944 | D-67 |
| 29 | J. M. Simmons' memorandum to A. B. Greninger | July 5, 1944 | D-56 |
| 30 | W. R. Huey's letter to C. E. Daniels | June 17, 1944 | D-63 |
| 31 | Clinton Laboratories' letter to C. E. Daniels | December 21, 1943 | D-95 |
| 32 | C. E. Daniels' letter to Quality Hdw. & Mach. Corp. | June 29, 1944 | D-65 |
| 33 | W. R. Huey's letter to C. E. Daniels | July 11, 1944 | D-74 |
| 34 | E. H. Judkins' letter to Quality Hdw. & Mach. Corp. | July 11, 1944 | D-65 |

Appendix A

FOOTNOTES - SECTION VII

DEVELOPMENT OF CANNING METHODS

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|--|--------------------|----------------------|
| 1 | C. M. Cooper's memorandum to File | October 22, 1943 | D-7 |
| 2 | S. A. Chantland's memorandum to C. R. Johnson | June 26, 1943 | D-60B |
| 3 | C. H. Greenewalt's memorandum to M. D. Whittaker | March 3, 1943 | D-13 |
| 4 | C. E. Daniels' memorandum to File | March 20, 1943 | D-13 |
| 5 | A. S. Weygandt's letter to C. E. Daniels | March 25, 1943 | D-3 |
| 6 | S. A. Chantland's memorandum to C. R. Johnson | April 8, 1943 | P-44 |
| 7 | S. A. Chantland's memorandum to C. R. Johnson | April 28, 1943 | P-60A |
| 8 | J. A. Burns' memorandum to H. T. Daniels | May 3, 1943 | D-2 |
| 9 | S. A. Chantland's memorandum to C. R. Johnson | June 26, 1943 | P-60B |
| 10 | M. Matsen's memorandum to L. H. Haupt | July 2, 1943 | P-60B |
| 11 | J. B. Miles' letter to C. E. Daniels | June 28, 1943 | D-21 |
| 12 | J. B. Miles' letter to C. E. Daniels | June 23, 1943 | D-21 |
| 13 | J. B. Miles' letter to C. E. Daniels | September 2, 1943 | D-13 |
| 14 | C. E. Daniels' letter to J. B. Miles | July 21, 1943 | D-13 |
| 15 | J. B. Miles' letter to C. E. Daniels | July 26, 1943 | D-13 |
| 16 | J. A. Burns' memorandum to H. T. Daniels | August 6, 1943 | D-27 |
| 17 | Wolverine's letter to F. M. Hart | September 8, 1943 | XPG-427 ¹ |
| 18 | Wolverine's letter to F. M. Hart | October 22, 1943 | XPG-427 ¹ |
| 19 | C. E. Daniels' memorandum to File | September 28, 1943 | D-97 |
| 20 | W. R. Huey's letter to H. T. Daniels | June 5, 1943 | P-60B |
| 21 | J. P. Howe's memorandum to File | August 10, 1943 | P-13B |
| 22 | C. R. Johnson's memorandum to H. T. Daniels | September 7, 1943 | P-60C |
| 23 | J. P. Howe's memorandum to J. Chipman | September 20, 1943 | P-13C |
| 24 | C. E. Daniels' memorandum to H. T. Daniels | September 21, 1943 | D-7 |
| 25 | R. W. Fulling's letter to T. C. Gary | September 22, 1943 | P-13C |
| 26 | C. R. Johnson's letter to Alcoa | September 30, 1943 | D-7 |
| 27 | W. R. Huey's letter to H. T. Daniels | October 15, 1943 | D-7 |

Appendix A

FOOTNOTES - SECTION VII

DEVELOPMENT OF CANNING METHODS

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|-------------------|-------------|
| 28 | C. M. Cooper's memorandum to File | October 22, 1943 | D-7 |
| 29 | C. R. Johnson's memorandum to F. W. Pardee | October 26, 1943 | D-66 |
| 30 | J. N. Tilley's memorandum to R. Williams | November 1, 1943 | D-54 |
| 31 | Alcoa's letter to C. R. Johnson | November 4, 1943 | D-39 |
| 32 | J. B. Miles' teletype to C. E. Daniels | December 10, 1943 | D-39 |
| 33 | A. B. Greninger's memorandum to C. M. Cooper | January 3, 1944 | D-67 |
| 34 | W. R. Huey's letter to H. T. Daniels | January 8, 1944 | P-60I |
| 35 | W. R. Huey's letter to H. T. Daniels | January 26, 1944 | D-67 |
| 36 | W. R. Huey's letter to H. T. Daniels | January 27, 1944 | D-67 |
| 37 | C. E. Daniels' memorandum to C. R. Johnson | February 10, 1944 | D-15 |
| 38 | C. E. Daniels' memorandum to C. R. Johnson | January 28, 1944 | D-15 |
| 39 | W. R. Huey's letter to E. E. Swensson | February 8, 1944 | P-133A |
| 40 | W. R. Myers' letter to C. E. Daniels | March 6, 1944 | D-70 |
| 41 | W. R. Huey's letter to E. E. Swensson | March 18, 1944 | D-67 |
| 42 | A. B. Greninger's memorandum to C. M. Cooper | April 15, 1944 | D-67 |
| 43 | C. E. Daniels' memorandum to G. M. Read | April 24, 1944 | D-67 |
| 44 | F. W. Pardee's letter to R. M. Evans | August 18, 1944 | D-133C |
| 45 | J. N. Tilley's letter to M. F. Wood | May 2, 1944 | D-74 |
| 46 | M. F. Wood's memorandum to File | May 1, 1944 | R-1 |
| 47 | C. E. Daniels' memorandum to M. F. Wood | May 3, 1944 | R-1 |
| 48 | W. R. Huey's letter to C. E. Daniels | June 19, 1944 | D-74 |
| 49 | E. H. Judkins' letter to Quality Hdw. & Mach. Corp. | July 5, 1944 | D-65 |
| 50 | Roger Williams' letter to M. F. Wood | July 27, 1944 | D-74 |
| 51 | W. R. Huey's letter to F. W. Pardee | August 24, 1944 | P-60U |
| 52 | W. R. Huey's letter to F. W. Pardee | October 2, 1944 | P-60X |
| 53 | S. A. Chantland's memorandum to Alcoa | October 4, 1944 | P-133C |
| 54 | S. A. Chantland's memorandum to C. R. Johnson | October 2, 1944 | P-60X |
| 55 | Alcoa's letter to C. R. Johnson | January 2, 1945 | RPG-53424 |

Appendix A

FOOTNOTES - SECTION IX
METHODS OF TESTING CANNED SLUGS

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|--------------------|-------------|
| 1 | W. R. Myers' letter to H. T. Daniels | October 13, 1943 | D-97 |
| 2 | P. E. Collins memorandum to C. J. Veith | July 6, 1943 | D-30 |
| 3 | C. E. Daniels' letter to J. B. Miles | June 16, 1943 | D-5 |
| 4 | C. E. Daniels' letter to Alcoa | May 28, 1943 | D-30 |
| 5 | Alcoa's letter to C. E. Daniels | June 5, 1943 | D-30 |
| 6 | C. E. Daniels' letter to J. B. Miles | June 16, 1943 | D-5 |
| 7 | K. G. Jones' memorandum to File | July 12, 1943 | D-5 |
| 8 | J. B. Miles' letter to C. E. Daniels | July 26, 1943 | D-5 |
| 9 | R. R. Nydegger's memorandum to J. A. Burns | May 27, 1943 | P-60A |
| 10 | S. A. Chantland's memorandum to C. R. Johnson | May 9, 1943 | P-44 |
| 11 | P. E. Collins' memorandum to C. E. Daniels | August 28, 1943 | D-5 |
| 12 | P. E. Collins' memorandum to C. E. Daniels | September 2, 1943 | D-5 |
| 13 | C. E. Daniels' memorandum to H. T. Daniels | September 21, 1943 | D-7 |
| 14 | C. E. Daniels' letter to J. D. Wilson | September 10, 1943 | D-5 |
| 15 | J. D. Wilson's memorandum to Central File | September 25, 1943 | D-5 |
| 16 | J. P. Howe's memorandum to File | October 1, 1943 | D-7 |
| 17 | W. R. Myers' letter to H. T. Daniels | October 13, 1943 | D-97 |
| 18 | J. B. Miles' letter to C. E. Daniels | October 12, 1943 | D-25 |
| 19 | S. A. Chantland's letter to Alcoa | October 16, 1943 | D-97 |
| 20 | C. E. Daniels' letter to W. H. McKinney | October 16, 1943 | D-25 |
| 21 | W. C. Kay's memorandum to M. D. Whitaker | November 29, 1943 | D-3 |
| 22 | W. R. Myers' letter to C. E. Daniels | November 17, 1943 | D-21 |

Appendix A

FOOTNOTES - SECTION IX

METHODS OF TESTING CANNED SLUGS

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|------------------|-------------|
| 23 | W. H. McKinney's memorandum to C. J. Veith | December 3, 1943 | D-21 |
| 24 | A. B. Greninger's memorandum to C. M. Cooper | January 3, 1944 | D-67 |
| 25 | W. Grinus Jr's. memorandum to R. F. Peterson | May 10, 1944 | D-26 |
| 26 | W. R. Huey's letter to C. E. Daniels | June 27, 1944 | D-74 |
| 27 | C. E. Daniels' memorandum to M. F. Wood | May 16, 1944 | D-74 |
| 28 | W. R. Huey's letter to C. E. Daniels | May 18, 1944 | D-74 |
| 29 | W. R. Huey's letter to Major W. L. Sapper | July 14, 1944 | D-65 |
| 30 | C. E. Daniels' memorandum to M. F. Wood | June 10, 1944 | D-74 |
| 31 | A. B. Greninger's letter to Alcoa | June 23, 1944 | D-77 |
| 32 | A. B. Greninger's memorandum to C. E. Daniels | June 21, 1944 | D-65 |
| 33 | C. E. Daniels' letter to Quality Hardware & Mach. Corp. | June 29, 1944 | D-65 |
| 34 | A. B. Greninger's memorandum to C. E. Daniels | July 3, 1944 | D-65 |
| 35 | E. H. Judkins' letter to Quality Hardware & Mach. Corp. | July 17, 1944 | D-65 |
| 36 | W. R. Huey's letter to Major W. L. Sapper | July 14, 1944 | D-65 |

Appendix A

FOOTNOTES - SECTION X

THE DUMMY SLUG PROGRAM

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|-------------------|-------------|
| 1 | T. B. Drew's memorandum to Hood Worthington | May 19, 1943 | TNX-1 |
| 2 | T. B. Drew's memorandum to Hood Worthington | June 12, 1943 | TNX-1 |
| 3 | S. K. Allison's letter to C. H. Greenewalt | June 19, 1943 | TNX-1 |
| 4 | M. H. Smith's memorandum to G. D. Graves | August 25, 1943 | TNX-1 |
| 5 | Hood Worthington's memorandum to G. D. Graves | September 1, 1943 | TNX-1 |
| 6 | W. R. Huey's letter to H. T. Daniels | November 15, 1943 | TNX-1 |
| 7 | M. H. Smith's letter to H. T. Daniels | November 29, 1943 | TNX-1 |
| 8 | M. H. Wahl's letter to H. T. Daniels | January 12, 1944 | TNX-2 |
| 9 | J. N. Tilley's teletype to S. K. Allison | February 4, 1944 | TNX-2 |
| 10 | J. P. Howe's memorandum to C. M. Cooper | February 7, 1944 | TNX-2 |
| 11 | W. R. Huey's letter to H. T. Daniels | February 9, 1944 | TNX-2 |
| 12 | C. M. Cooper's memorandum to S. K. Allison | February 24, 1944 | TNX-2 |
| 13 | Wheeler's memorandum to D. F. Babcock | February 25, 1944 | TNX-2 |
| 14 | W. R. Huey's letter to H. T. Daniels | February 26, 1944 | TNX-2 |
| 15 | W. R. Huey's letter to H. T. Daniels | March 11, 1944 | TNX-2 |
| 16 | W. K. Wood's memorandum to J. N. Tilley | March 13, 1944 | TNX-2 |
| 17 | S. K. Allison's teletype to C. H. Greenewalt | March 6, 1944 | TNX-2 |
| 18 | W. R. Huey's letter to H. T. Daniels | March 16, 1944 | TNX-2 |
| 19 | W. K. Wood's memorandum to J. N. Tilley | March 13, 1944 | TNX-2 |
| 20 | M. H. Wahl's letter to E. E. Swensson | March 17, 1944 | TNX-2 |
| 21 | W. R. Huey's letter to H. T. Daniels | March 20, 1944 | TNX-2 |
| 22 | Hood Worthington's letter to J. N. Tilley | April 8, 1944 | TNX-8 |

Appendix A

FOOTNOTES - SECTION X

THE DUMMY SLUG PROGRAM

| <u>No.</u> | <u>Correspondence</u> | <u>Dated</u> | <u>File</u> |
|------------|---|-------------------|-------------|
| 23 | GE. McMillan's letter to H. T. Daniels | April 18, 1944 | TNX-3 |
| 24 | W. R. Huey's letter to H. T. Daniels | May 9, 1944 | TNX-3 |
| 25 | M. H. Wahl's letter to H. T. Daniels | May 18, 1944 | TNX-3 |
| 26 | W. R. Huey's letter to H. T. Daniels | June 5, 1944 | TNX-3 |
| 27 | Hood Worthington's memorandum to C. H. Greenewalt | June 9, 1944 | TNX-3 |
| 28 | T. B. Drew's memorandum to J. N. Tilley | June 15, 1944 | TNX-3 |
| 29 | F. McLellan's memorandum to J. A. Burns | June 24, 1944 | TNX-3 |
| 30 | H. M. Sawyer's letter to H. T. Daniels | June 26, 1944 | TNX-3 |
| 31 | W. R. Huey's letter to F. W. Pardee, Jr. | August 7, 1944 | TNX-3 |
| 32 | C. E. Daniels' memorandum to W. N. Wherrett | August 15, 1944 | TNX-3 |
| 33 | M. H. Wahl's letter to S. K. Allison | August 9, 1944 | TNX-4 |
| 34 | J. A. Burns' teletype to W. N. Wherrett | August 9, 1944 | RPG-2198½ |
| 35 | R. R. Nydegger's letter to M. H. Smith | August 14, 1944 | TNX-3 |
| 36 | R. R. Nydegger's teletype to O. S. Petrescu | August 19, 1944 | P-60U |
| 37 | H. M. Sawyer's letter to W. O. Simon | October 24, 1944 | TNX-4 |
| 38 | R. C. Stanton's teletype to H. W. Jones | November 14, 1944 | RPG-2198½ |

CLINTON ENGINEER WORKS SLUG PROGRAM

PROJECTS 9733 AND 58

TABULATION OF ORDERS BY TYPES OF WORK

| XPG NO. | VENDOR | FOR XPG- | MATERIAL | COSTS MEDICAL | FABRICATION | TOTAL COST |
|---|------------------------------|----------|-----------------|------------------|---------------------|---------------------|
| <u>Development and Production of Extruded Rods</u> | | | | | | |
| 1234 | B. & T. Metals Co. | | | | 136,369.67 | |
| 7734 | Revere Copper & Brass Inc. | | | | 67,579.15 | |
| 16674 | Central Laboratories | 7734 | | 285.00 | | |
| 17884 | Dr. D L. Mahanna | 1234 | | 96.00 | | |
| | | | | <u>\$381.00</u> | <u>\$203,948.82</u> | <u>\$204,329.82</u> |
| <u>Outgassing and Straightening</u> | | | | | | |
| 4924 | Copperweld Steel Co. | | | | \$49,192.79 | \$49,192.79 |
| <u>Machining</u> | | | | | | |
| 1744 | Herring-Hall-Marvin Safe Co. | | | | 119,712.82 | |
| 5824 | Baker Bros. Inc. | | | | 20,230.00 | |
| 7534 | B. & T. Metals Co. | | | | 2,123.83 | |
| 17854 | Dr. E. C. Leyrer | 1744 | | 130.00 | | |
| 17864 | Baker Bros. Inc. | 5824 | | 74.00 | | |
| 17954 | Baker Bros. Inc. | | | | 4,262.34 | |
| | | | | <u>\$204.00</u> | <u>\$146,328.99</u> | <u>\$146,532.99</u> |
| <u>Development and Production of Canned Slugs</u> | | | | | | |
| 4274 | Aluminum Company | | | | 93,511.68 | |
| 4274 | Wolverine Tube Division | | | | 9,997.43 | |
| 16254 | Aluminum Company | | | | 14,513.82 | |
| 17504 | Aluminum Company | | | | 16,224.62 | |
| | | | | | <u>\$134,247.55</u> | <u>\$134,247.55</u> |
| <u>Development and Production of Aluminum Cans</u> | | | | | | |
| 4964 | Paul & Beekman | 4274 | | | 96.10 | |
| 1704 | Paul & Beekman | 17504 | | | 6,595.00 | |
| | | | | | <u>\$ 6,691.10</u> | <u>\$ 6,691.10</u> |
| <u>Production of Aluminum Caps</u> | | | | | | |
| 17264 | James H. Matthews Co. | 17504 | | | \$ 1,074.70 | \$ 1,074.70 |
| <u>Production of Dummy Slugs for Project 58 - SNX</u> | | | | | | |
| 10694 | Addison Ciarke & Bro. | 10714 | 219.52 | | | |
| 10714 | Modern Bond Co. | | | | 957.00 | |
| 11334 | Modern Bond Co. | | | | 990.00 | |
| 11344 | Addison Ciarke & Bro. | 11334 | | 234.59 | | |
| | | | | <u>\$454.11</u> | <u>\$ 1,947.00</u> | <u>\$ 2,401.11</u> |
| <u>Total Costs</u> | | | <u>\$454.11</u> | <u>\$585.00</u> | <u>\$543,470.95</u> | <u>\$544,470.06</u> |

*Costs are as shown in Purchase Order Files

EXHIBIT B

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TABULATION OF PURCHASE ORDERS
INCLUDED IN THE
CLINTON ENGINEER WORKS SLUG PROGRAM
PROJECT 9733

| <u>XPG NO.</u> | <u>VENDOR</u> | <u>FOR</u> |
|-------------------------|------------------------------|--------------------------------------|
| 1231 | B. & T. Metals Co. | Extrusion - Development & Production |
| 1741 | Herring-Hall-Marvin Safe Co. | Machining - Development & Production |
| 4231 | Aluminum Company | Canning Development & Production |
| 4271 | Wolverine Tube Division | Canning Development |
| 4921 | Copperweld Steel Company | Outgassing & Straightening |
| 4961 | Paul & Beekman | Aluminum Cans - Development |
| 5821 | Baker Bros., Inc. | Machining - Development & Production |
| 7531 | B. & T. Metals Co. | Machining - Development |
| 7731 | Revere Copper & Brass Inc. | Extrusion - Development & Production |
| 1546 | Paul & Beekman | Aluminum Cans |
| 1628 | Aluminum Company | Canning |
| 1667 | Central Laboratories | Medical Laboratory Services |
| 1703 | Paul & Beekman | Aluminum Cans |
| 1726 | James H. Matthews Co. | Aluminum Caps |
| 1750 | Aluminum Company | Canning - Development & Production |
| 1785 | Dr. E. C. Leyrer | Medical Services |
| 1786 | Baker Bros., Inc. | Medical Services |
| 1788 | Dr. D. L. Mahanna | Medical Services |
| 1795 | Baker Bros., Inc. | Machining |
| <u>SMX - Project 58</u> | | |
| 10691 | Addison Clarke & Bro. | Steel Rod for Dummies |
| 10711 | Modern Bond Co. | Machining Steel Dummies |
| 11331 | Modern Bond Co. | Machining Steel Dummies |
| 11341 | Addison Clarke & Bro. | Steel Rod for Dummies |

Exhibit F

TABULATION OF PURCHASE ORDERS
INCLUDED IN THE
HANFORD ENGINEER WORKS SLUG PROGRAM
PROJECT 9536

| RPG NO. | VENDOR | FOR |
|---------|----------------------------|-----------------------------------|
| 114 | Wilmington Shops | Steel Slugs |
| 277 | Aluminum Company | Canning Development |
| 662 | Wolverine Tube Division | Develop Twisted Dummies |
| 704 | Revere Copper & Brass Inc. | Extrusion |
| 705 | Copperweld Steel Co. | Outgassing and Straightening |
| 766 | Wolverine Tube Division | Dummy Slugs |
| 800 | Baker Bros., Inc. | Machining |
| 1077 | Paul & Beekman | Develop Aluminum Cans |
| 1263 | Aluminum Company | Canning Development |
| 1264 | Paul & Beekman | Develop Aluminum Cans |
| 1265 | Aluminum Company | Aluminum Caps |
| 1336 | Central Laboratories | Medical Laboratory Services |
| 1384 | General Electric Co. | Experimental Welding of Aluminum |
| 1396 | Drs. Kenning & Harris | X-Ray Services |
| 1556 | Wolverine Tube Division | Tubular Aluminum Dummies |
| 1638 | G. O. Carlson | Stainless Steel Rod for Dummies |
| 1669 | Wilmington Shops | Canning Development |
| 1877 | Dr. R. J. Hall | Medical Services |
| 1907 | Baker Bros., Inc. | Medical Services |
| 1908 | Central Laboratories | Medical Laboratory Services |
| 1909 | Dr. Kenning | X-Ray Services |
| 2198 | Koppers Company | Machining Stainless Steel Dummies |

Exhibit G

| RFG NO. | VENDOR | FOR |
|---------|----------------------------------|------------------------------------|
| 2233 | James H. Matthews Co. | Develop Aluminum Caps |
| 2234 | Scovill Manufacturing Co. | Develop Aluminum Caps |
| 2252 | Addison Clarke & Bro. | Steel Shafting |
| 2274 | McCauley Metal Prod. Co. | Develop Aluminum |
| 2291 | Paul & Beekman | Aluminum Cans |
| 2720 | McCauley Metal Products Co. | Develop Steel Cans |
| 2808 | Herring-Hall-Marvin Safe Co. | Machining Steel Plugs |
| 2809 | Cumberland Steel Co. | Steel Shafting |
| 2812 | American Smelting & Refining Co. | Lead Dummy Slugs |
| 2813 | Eagle - Picher Sales Co. | Lead Dummy Slugs |
| 2882 | James H. Matthews Co. | Develop Aluminum Caps |
| 2887 | Paul & Beekman | Develop Silicon Clad Cans |
| 3018 | Paul & Beekman | Aluminum Cans for Dummies |
| 3199 | American Chain & Cable Co. | Test Swaging |
| 3324 | American Smelting & Refining Co. | Lead Dummy Slugs |
| 3335 | Paul & Beekman | Aluminum Cans |
| 3383 | Aluminum Company | Lead Slug Canning Development |
| 3384 | American Smelting & Refining Co. | Antimony Slugs |
| 3407 | Paul & Beekman | Aluminum Cans |
| 3446 | Aluminum Company | Aluminum Cans |
| 3447 | Edgcomb Steel Co. | Stainless Steel Tubing for Dummies |
| 3542 | McCauley Metal Products Co. | Steel Cans |

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Exhibit G

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| RPG NO. | VENDOR | FOR |
|---------|-----------------------------|--------------------------------------|
| 3543 | Wilmington Shops | Experimental Stainless Steel Dummies |
| 3570 | McCauley Metal Products Co. | Aluminum Cans |
| 3705 | Paul & Beekman | Aluminum Cans for Dummies |
| 3706 | Extruded Metals Co. | Solid Aluminum Dummy Slugs |
| 3779 | Josylvn Mfg. & Supply Co. | Rolling Uranium |
| 3839 | Worcester Pressed Steel Co. | Development of Aluminum Cans |
| 3850 | Addison Clarke & Bro. | Steel Rod |
| 3880 | Paul & Beekman | Develop Aluminum Cans |
| 3882 | Eagle - Picher Sales Co. | Poison Dummies |
| 3883 | Eagle - Picher Sales Co. | Lead Dummies |
| 3886 | Aluminum Company | Aluminum Sheet and Plate for Caps |
| 3900 | McCauley Metal Products Co. | Steel Cans |
| 3922 | Aluminum Company | Aluminum Rod for Dummies |
| 3924 | Weatherhead Company | Machining Aluminum Dummies |
| 4013 | Scovill Manufacturing Co. | Develop Aluminum Caps |
| 4017 | Worcester Pressed Steel Co. | Develop Steel Cans |
| 4033 | Revere Copper & Brass Inc. | Development of Extrusion |
| 4034 | Revere Copper & Brass Inc. | Outgassing and Straightening |
| 4074 | Streater Lumber Company | Shipping Containers for Dummies |
| 4077 | Aluminum Company | Canning Poison Slugs |
| 4079 | Astabula Corrugated Box Co. | Pads and Liners for Shipping Dummies |
| 4094 | National Lead Co. | Lead Dummy Slugs |

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Exhibit G

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| RFG NO. | VENDOR | FOR |
|---------|--------------------------------|---------------------------------|
| 43091 | Brown Fence & Iron Co. | Tubing for Steel Cans |
| 4348 | Aluminum Company | Aluminum Rod for Dummies |
| 4358 | Paul & Beekman | Aluminum Cans |
| 4360 | Aluminum Company | Aluminum Rod for Dummies |
| 4378 | James H. Matthews Co. | Aluminum Caps |
| 4393 | Thompson Aircraft Products Co. | Solid Aluminum Spacers |
| 4420 | Aluminum Company | Canning Lead Dummies |
| 4430 | Read Machinery Co. | Solid Aluminum Spacers |
| 4431 | Franklin Rubber Co. | Solid Aluminum Spacers |
| 4502 | G. O. Carlson | Stainless Steel Rod for Dummies |
| 4537 | National Lead Co. | Poison Dummies |
| 4540 | H. N. White Co. | Flanging Steel Tubing |
| 4541 | Brown Fence & Iron Co. | Steel Tubing |
| 4562 | Streater Lumber Co. | Birch "Pusher" Slugs |
| 4580 | Hays Manufacturing Co. | Solid Aluminum Spacers |
| 4602 | Stearns - Roger Mfg. Co. | Stainless Steel Dummies |
| 4628 | Paul & Beekman | Aluminum Cans for Dummies |
| 4629 | National Lead Co. | Lead Dummies |
| 4630 | Eagle Picher Lead Co. | Lead Dummies |
| 4648 | Streater Lumber Co. | Shipping Containers for Dummies |
| 4655 | Dr. Paul A. Davis | Medical Services |
| 4671 | Carpenter Steel Co. | Development of Rolling |
| 4742 | Aluminum Company | Canning Lead Dummies |

Exhibit G

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| RFG NO. | VENDOR | FOR |
|---------|----------------------------------|--------------------------------------|
| 4779½ | Aluminum Company | Develop and Can Special Slugs |
| 4799½ | Aluminum Company | Aluminum Rod for Dummies |
| 4865½ | Cumberland Steel Co. | Rod for Steel Plugs |
| 4916½ | Jones & Laughlin Steel Co. | Rod for Steel Plugs |
| 4918½ | James H. Matthews Co. | Aluminum Caps |
| 4957½ | Aluminum Company | Aluminum Plate for Caps |
| 5017½ | Quality Hardware & Machine Corp. | Double-Canning Lead Dummies |
| 5045½ | James H. Matthews Co. | Aluminum Caps |
| 5049½ | Paul & Beekman | Aluminum Cans for Dummies |
| 5050½ | James H. Matthews Co. | Aluminum Caps for Dummies |
| 5112½ | Aluminum Company | Develop Special Extruded Cans |
| 5281½ | Wilmington Shops | Testing Aluminum Dummies |
| 5336½ | Stearns - Roger Mfg. Co. | Stainless Steel Dummies |
| 5342½ | Aluminum Company | Develop Double-Welded Dummy Assembly |
| 5379½ | Dr. R. J. Hall | Medical Services |

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Exhibit G

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TABULATION OF PURCHASE ORDERS
INCLUDED IN THE
HANFORD ENGINEER WORKS UNBONDED SLUG PROGRAM
PROJECT 1553

| <u>RPG NO.</u> | <u>VENDOR</u> | <u>FOR</u> |
|----------------|------------------------------------|--------------------------|
| 4014 | Baker Bros. Inc. | Machining Unbonded Slugs |
| 4018 | C. H. Schnorr & Co. | Machining Unbonded Slugs |
| 4021 | McKinney Tool & Mfg. Co. | Machining Unbonded Slugs |
| 4022 | Paul & Beekman | Aluminum Cans |
| 4039 | Whitehead Metal Products Co. | Aluminum Rod for Caps |
| 4040 | Quality Hardware & Machine Corp. | Canning Unbonded Slugs |
| 4253 | Whitehead Metal Products Co. | Aluminum Rod for Caps |
| 4254 | H. P. Snyder Mfg. Co. | Develop Aluminum Caps |
| 4258 | Joyce Machine Co. | Aluminum Caps |
| 4276 | Paul & Beekman | Aluminum Cans |
| 4285 | James H. Matthews Co. | Aluminum Caps |
| 4291 | Wm. E. Pratt Mfg. Co. | Grinding Unbonded Slugs |
| 4293 | White Metal Rolling & Stamping Co. | Re-sizing Plate for Caps |
| 4297 | Whitehead Metal Products Co. | Aluminum for Caps |
| 4480 | Dr. R. C. Johnston | Medical Services |
| 4484 | H. P. Snyder Mfg. Co. | Aluminum Caps |
| 4490 | H. P. Snyder Mfg. Co. | Aluminum Caps |
| 4492 | Aluminum Company | Canning Unbonded Slugs |
| 4664 | James H. Matthews Co. | Aluminum Caps |
| 4668 | Rome Strip Steel Co. | Re-size Plate for Caps |

Exhibit H

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INDEX TO FILES RELATING TO SLUG PROGRAMS

C. E. Daniels File

| <u>File No.</u> | <u>Title of File</u> |
|-----------------|---|
| D-1 | - Procedure General |
| D-2 | - Minutes of Meetings - Project 9733 |
| D-3 | - Project 9793 |
| D-4 | - Metal History |
| D-5 | - C.E.W. Test |
| D-6 | - Extrusion Development |
| D-7 | - Design Division Correspondence |
| D-8 | - Fire Hazard |
| D-9 | - C.E.W. Test |
| D-10 | - Health - General |
| D-11 | - Chronological Telegrams |
| D-12 | - Progress Reports - Proj. 1553 - TNX Supervisors |
| D-13 | - Specifications and Schedules |
| D-14 | - Statement of T-Metal Accounts 1553, 9733 and 9536 |
| D-15 | - Wilmington Shops Minutes |
| D-16 | - Wilmington Shops Progress Report |
| D-17 | - XPG-123½ - B. & T. Metals Co. |
| D-18 | - XPG-753½ - B. & T. Metals Co. |
| D-19 | - XPG-174½ - HHM Safe Co. |
| D-20 | - XPG-492½ - Copperweld |
| D-21 | - XPG-423½ - Alcoa |
| D-22 | - XPG-773½ - Revere |
| D-23 | - XPG-582½ - Baker Bros. |

| <u>File No.</u> | <u>Title of File</u> |
|-----------------|---------------------------------------|
| D-24 | - XPG-1795½ - Baker Bros. |
| D-24A | - XPG-1795½ - Baker Bros. |
| D-25 | - XPG-1628½ - Alcoa |
| D-26 | - XPG-1750½ - Alcoa |
| D-27 | - XPG-427½ - Wolverine |
| D-28 | - XPG-123½ - B. & T. Metals Co. |
| D-29 | - XPG-174½ - HHM Safe Co. |
| D-30 | - XPG-423½ - Alcoa |
| D-31 | - XPG-753½ - B. & T. Metals Co. |
| D-32 | - XPG-427½ - Wolverine |
| D-33 | - XPG-582½ - Baker Bros. |
| D-34 | - XPG-492½ - Copperweld |
| D-35 | - XPG-547½ - Norton Co. |
| D-36 | - XPG-587½ - Hevi Duty Electrical Co. |
| D-37 | - XPG-666½ - Carbaloy Co. |
| D-38 | - XPG-773½ - Revere |
| D-39 | - XPG-1628½ - Alcoa |
| D-40 | - XPG-1667½ - Central Laboratory |
| D-41 | - XPG-1703½ - Paul & Beekman |
| D-42 | - XPG-1726½ - Jas. H. Matthews Co. |
| D-43 | - XPG-1750½ - Alcoa |
| D-44 | - Project 9733 - (Miscellaneous) |
| D-45 | - RPG-277½ - Alcoa |
| D-46 | - RPG-277½ - Alcoa |
| D-47 | - RPG-800½ - Baker Bros. |
| D-48 | - RPG-800½ - Baker Bros. |
| D-49 | - RPG-704½ - Revere |

| <u>File No.</u> | <u>Title of File</u> |
|-----------------|--|
| D-50 | - RPG-704½ - Revere |
| D-51 | - RPG-897½ - Hevi-Duty Electrical Co. |
| D-52 | - RPG-1263½ - Alcoa |
| D-53 | - RPG-1263½ - Alcoa |
| D-54 | - RPG-1669½ - Wilmington Shops |
| D-55 | - RPG-1669½ - Wilmington Shops |
| D-56 | - RPG-3779½ - Joslyn Mfg. & Sup. Co. |
| D-57 | - RPG-3779½ - Joslyn Mfg. & Sup. Co. |
| D-58 | - RPG-4014½ - Baker Bros. |
| D-59 | - RPG-4014½ - Baker Bros. |
| D-60 | - RPG-4018½ - C. H. Schnorr Co. |
| D-61 | - RPG-4018½ - C. H. Schnorr Co. |
| D-62 | - RPG-4021½ - McKinney Tool & Mfg. Co. |
| D-63 | - RPG-4021½ - McKinney Tool & Mfg. Co. |
| D-64 | - RPG-4040½ - Quality Hardware |
| D-65 | - RPG-4040½ - Quality Hardware |
| D-66 | - Project 9536 - July, 1943 to January, 1944 |
| D-67 | - Project 9536 - January, 1944 - June 30, 1944 |
| D-67A | - Project 9536 - July 1, 1944 |
| D-68 | - Project 9536 - To January 1, 1944 |
| D-69 | - Project 9536 - January 1, 1944 |
| D-70 | - Project 9536 - June 1, 1944 |
| D-70A | - Project 9536 - August 1, 1944 |
| D-71 | - Project 1553 |
| D-72 | - Paul & Beekman - Cans |
| D-73 | - Scoville Mfg. Co. - Caps |
| D-74 | - Project 1553 |
| D-75 | - J. H. Matthews Co. - Caps |

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| <u>File No.</u> | <u>Title of File</u> |
|-----------------|--|
| D-76 | - RPG-4671½ - Carpenter Steel Co. |
| D-77 | - RPG-4492½ - Alcoa |
| D-78 | - McCauley Metal Products - Steel Cans |
| D-79 | - Worcester Pressed Steel Co. - Steel Cans |
| D-80 | - RPG-4671½ - Carpenter Steel Co. |
| D-81 | - RPG-705½ - Copperweld Steel Co. |
| D-82 | - RPG-766½ - Wolverine |
| D-83 | - RPG-1556½ - Wolverine |
| D-84 | - RPG-1265½ - Alcoa |
| D-85 | - RPG-4492½ - Alcoa |
| D-86 | - RPG-4034½ - Revere |
| D-87 | - RPG-4034½ - Revere |
| D-88 | - RPG-3446½ - Alcoa |
| D-89 | - RPG-1336½ - Central Laboratory |
| D-90 | - RPG-1887½ - Dr. R. J. Hall |
| D-91 | - RPG-1907½ - Baker Bros. Medical |
| D-92 | - RPG-1396½ - Drs. Kenning & Harris |
| D-93 | - RPG-705½ - Copperweld Steel Co. |
| D-94 | - Project 1030 - Clinton Lab. Special Work |
| D-95 | - Project 1030 - Clinton Lab. Special Work |
| D-96 | - Performance of Special Billets |
| D-97 | - Design Division - Correspondence |
| D-98 | - RPG-4033½ - Revere - Development |
| D-99 | - Heat Classification |

F. W. Pardee, Jr. File

| <u>File No.</u> | <u>Title of File</u> |
|-----------------|--|
| P-13B | Project 9536 General - July 1, 1943 to Aug. 31, 1943 |
| P-13C | Project 9536 General - Sept. 1, 1943 to Sept. 30, 1943 |
| P-44 | Project 9536 - Progress Reports |
| P-60A | Bldg. 105 - December, 1942 to May 30, 1943 |
| P-60B | Bldg. 105 - June 2, 1943 to July 31, 1943 |
| P-60C | Bldg. 105 - August 2, 1943 to Sept. 30, 1943 |
| P-60I | Bldg. 105 - January 1, 1944 to January 15, 1944 |
| P-60U | Bldg. 105 - August 16, 1944 to August 31, 1944 |
| P-60X | Bldg. 105 - October 1, 1944 to October 15, 1944 |
| P-133A | 300 Area General - Start to May 31, 1944 |
| P-133C | 300 Area |

Control Division Record File

| | |
|-----|---|
| R-1 | Project 9536 - Correspondence - Operating |
| R-2 | Project 1553 - H.E.W. |
| R-3 | Project 1030 - Clinton Laboratories |

TNX Files

| <u>File No.</u> | <u>Title of File</u> |
|-----------------|--|
| TNX-1 | File - Dummy Slugs - 1943 |
| TNX-2 | File - Dummy Slugs - January, February, March, 1944 |
| TNX-3 | File - Dummy Slugs - April, May, June, 1944 |
| TNX-4 | File - Dummy Slugs - July, August, 1944 |
| TNX-5 | Corrosion Test Unit - Slugs |
| TNX-6 | Corrosion Test Unit (CMX)-April-October, 1943 |
| TNX-7 | Corrosion Test Unit (CMX)-November, 1943 |
| TNX-8 | Corrosion Test Unit (CMX)-March 1, 1944-April 30, 1944 |
| TNX-9 | Corrosion Test Unit (CMX)-May 1, 1944-June 26, 1944 |
| TNX-10 | Corrosion Test Unit (CMX)-July 1, 1944 |

Drawings Relating to Slug Design

| <u>Drawing Number</u> | <u>Title of Drawing</u> |
|-----------------------|--------------------------------|
| S-114912 | Bonded W Slug |
| S-116433 | Bonded W Slug |
| S-116868 | Bonded W Slug |
| S-156668 | Spiral Dummy |
| S-156952 | W Can |
| S-157176 | Double Can Bonded W Slug |
| S-157288 | W Caps |
| S-157470 | W Caps |
| S-157635 | X Caps |
| S-157636 | X Can |
| S-157642 | W Caps |
| S-157643 | X Slug |
| S-157654 | Steel Slug - 1.380" Diameter |
| S-157655 | Unbonded W Slug |
| S-157656 | Grasselli Caps |
| S-157814 | W Caps |
| S-157818 | Dummy Slug |
| W-73996 | Cylindrical Lead Dummy |
| D-61880 | Steel Slug - 1.340" Diameter |
| D-6370 | Grooved Steel Plug |
| D-63710 | Solid Aluminum Dummy |
| D-63711 | "P" Dummy |
| D-63734 | Cylindrical Lead Grooved Dummy |

| <u>Drawing Numbers</u> | <u>Title of Drawing</u> |
|------------------------|---------------------------------------|
| D-63735 | "P" Cylindrical Lead Dummy |
| D-63765 | Tubular Aluminum Dummy |
| D-63794 | Aluminum Can Insert - Sheet #1 |
| D-63795 | Aluminum Can Insert - Sheet #2 |
| D-63796 | Aluminum Can Insert - Sheet #3 |
| D-63797 | Aluminum Can Insert - Sheet #4 |
| D-63921 | Aluminum Can Inserts - Sheet #5 |
| D-63922 | Aluminum Can Inserts - Sheet #6 |
| D-63995 | Aluminum Can (Heavy Bottom) |
| D-63996 | Steel Can |
| D-64291 | Aluminum Can Inserts - Sheet #7 |
| D-64299 | Aluminum Can Assembly (Unbonded Slug) |
| D-64836 | Aluminum Can Inserts - Sheet #8 |
| D-64878 | Aluminum Can Inserts - Sheet #9 |

Correspondence Related to the Metal Fabrication Program
Included in C. E. Daniels' Files

| <u>Date</u> | <u>Subject</u> | <u>Letter Memorandum Teletype</u> | <u>File No.</u> | <u>To: From:</u> |
|-------------|----------------|---|-----------------|----------------------|
|-------------|----------------|---|-----------------|----------------------|

| | | | | |
|----------|--------------|---|-----|--------------------------------|
| *3-17-43 | Organization | L | D-1 | Col. Marshall A. H. Compton |
|----------|--------------|---|-----|--------------------------------|

Project 9733
Responsibility for procurement of metal and graphite outlined
(for experimental quantities only).

| | | | | |
|----------|--------------|---|-----|-----------------------------|
| *3-17-43 | Organization | M | D-1 | R. L. Dean A. H. Compton |
|----------|--------------|---|-----|-----------------------------|

Project 9733
Doan appointed Director of Primary Metals for the Metallurgical
Laboratory.

1. To serve as Metallurgical Laboratory's representative in all matters concerning metal production and fabrication for the Laboratory.
2. C. E. Daniels to arrange for and supervise contracts relating to procurement of fabricated metal. He will receive his instructions thru Miles of TNX.
3. Doan responsible for graphite allocations, purity specifications and new methods of production for Metallurgical Laboratory.

| | | | | |
|----------|-------|---|-----|------------------------------|
| *3-29-43 | Scrap | L | D-1 | C. E. Daniels J. B. Miles |
|----------|-------|---|-----|------------------------------|

Outlines procedure for scrap metal segregation into 5 classes.

| | | | | |
|---------|----------------|---|-----|------------------------------|
| *4-3-43 | Billet Quality | L | D-1 | C. E. Daniels J. B. Miles |
|---------|----------------|---|-----|------------------------------|

Mentions possible future segregation of metal into fourth grade of purity.

| | | | | |
|---------|-----------|---|-----|------------------------------|
| 4-30-43 | Extrusion | L | D-1 | C. E. Daniels J. B. Miles |
|---------|-----------|---|-----|------------------------------|

Allows the extrusion and fabrication of metal to proceed without holding for analytical results. Billets to be identified. Scrap need not be classified.

*6-1-43 Scrap L D-1 J.B. Miles
C.E. Daniels

Outlines simplified procedure for segregation of scrap into three classes, as per meeting with Manhattan District representative on May 27, 1943.

6-4-43 Scrap L D-1 C.E. Daniels
J.B. Miles

Approves simplified procedure for segregation of scrap into three classes.

6-7-43 Procedure L D-1 J.D. Wilson
D. Woleben

Outlines purchasing procedure on special orders by C. E. Daniels' group.

6-16-43 Testing L D-1 J.B. Miles
C.E. Daniels

1. Ship all finished jacketed slugs from Aluminum Company to CEW for test in hot hydrogen.
2. Some tested or untested slugs may be required at Chicago for functional tests.

12-15-43 Organization L D-1 N. Hillberry
J.B. Miles

Simplifies procedure for requesting fabricated metal by Metallurgical Laboratory from du Pont by having Metallurgical Laboratory contact C. E. Daniels, direct instead of taking request thru J. B. Miles.

*3-3-43 Extrusion M D-2 M.D. Whitaker
C.H. Greenewalt

1. Outlines preliminary arrangements for extrusion of metal at B. & T. Metals Company and coating by hot dip process.
2. Dr. Chipman exploring possibilities of aluminum jackets on slugs.

*3-20-43 Canning M D-2 Minutes

Outlines preliminary considerations concerning fabrication of metal, including coating. Mentions possibility of canning for HEW and possibility for CEW if other methods fail.

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3-20-43 Scrap L D-3 J.B. Miles
C.E. Daniels

Lists sources of scrap and usable metal. Requests shipping instructions of same.

*3-25-43 Canning L D-3 Dr. J. Chipman
A.S. Weygandt

1. Mentions developmental work on alternate method other than the electroplating or hot-dipping being investigated at Pittsburgh.
2. Insufficient information available to justify construction of coating plant.
3. Grasselli is discontinuing design for coating plant.

No date Extrusion L D-3 C.E. Daniels
J.B. Miles

1. When will extrusion and machining start at B. & T.?
2. Dr. Nickson to advise vendors of hazards in working the metal.

4-15-43 Hazards L D-3 C.E. Daniels
J.B. Miles

Precautions to prevent contamination of metal - don't use borax soap.

4-23-43 Scrap L D-3 C.E. Daniels
Major Ruhoff

Lists procedure for shipping metal turnings from the source.

5-28-43 Grinding L D-3 Carborundum Co.
C.F. Lange

Sending 10 unmachined slugs for test to determine best grinding wheel.

*6-10-43 Shipping L D-3 Major Sapper
C.F. Lange

Express Charges - lists in detail transportation procedure.

*6-23-43 Billet Quality L D-3 C.E. Daniels
Major Ruhoff

Procedure for exchange of information pertinent to abnormal behavior or potentially abnormal behavior of metal during extrusion and machining.

6-25-43 Machining L D-3 Major Ruhoff
Lange

Unusual machining characteristics. Lists difficulties experienced with various billets.

*6-28-43 Hazards L D-3 Greenewalt
C.E. Daniels

Maximum Metal Storage Quantity
Requests upward revision of the five-ton limit for ease of transportation and storage difficulties. (See also letters of 7-20-43, 7-15-43, 7-21-43, and 9-10-43).

6-29-43 Extrusion L D-3 Col. Crenshaw
C.E. Daniels

Billet Preheating - Request for testing high-frequency induction furnace at Dye Works for billet preheating before extrusion.

6-13-43 Extrusion L D-3 Major Ruhoff
Lange

Extrusion Characteristics -lists density of rods from various billets.

7-16-43 Machining L D-3 C.E. Daniels
J.B. Miles

Machining and Canning of Slugs -
6 rolled rods to be machined at Herring-Hall-Marvin to determine machinability of rolled rods.

6-22-43 Billet Quality L D-3 C.E. Daniels
Ruhoff

Low densities of billets after extruding owing to impurities. Mentions brush process.

*7-19-43 Outgassing L D-3 Miles Lange

Procedure for Outgassing of Rods (prepared by Copperweld Steel Co.).

7-26-43 Machining L D-3 C.E. Daniels Miles

OK to use Hydromite as coolant for machining slugs.

7-27-43 Extrusion L D-3 C.E. Daniels Maj. Hadlock

Segregation of special billets from each vendor for test extrusion.

*8-2-43 Valuation L D-3 C.E. Daniels Maj. Sapper

Reduction in value from \$20 to \$15 per pound for insurance of metal in transit.

*8-16-43 Billet Size L D-3 Maj. Hadlock C.E. Daniels

Instructions to increase size of billet to 5" OD x 11" long for greater extrusion efficiency.

10-15-43 Dummy Slugs M D-3 H.T. Daniels C.E. Daniels

Requesting Design to modify arrangements with Wolverine to provide for two sizes of dummies because of Hanford size slugs for test at Clinton.

10-23-43 Testing L D-3 C.R. Johnson Greninger

Requesting transfer of 2 Kerosene Testers from Clinton to Metallurgical Laboratory.

*11-3-43 General L D-3 W.E. Kirst H.T. Daniels

1. Slugs - summarizing present information on slug situation.
2. Canning closure not settled yet.

9-7-43 Hazards L D-5 C.E. Daniels
R.B. Smith

Metal Handling - use leaded leather gloves if possible.

9-10-43 Testing L D-5 C.R. Johnson
C.E. Daniels

Results of Hydrogen Test - XPG-427½ on 159 Wolverine slugs.

*9-25-43 Testing L D-5 File
J.D. Wilson

Testing of canned slugs and responsibility for conducting
of tests - two new tests to be made at Clinton.

*6-28-43 General M D-6 File
W.E. Kirst

Visits to B. & T. Metals Company, Battelle Institute and
Copperweld Steel Corporation.
Describes in detail procedures used in billet preheating,
extrusion, degassing, and straightening.

*6-2-43 Extrusion L D-6 Greenewalt
C.E. Daniels

Extrusion of T-Metal. Includes report by Kinckiner supple-
menting Kirst's report of June 28, 1943 on extrusion.

*7-7-43 Extrusion L D-6 C.E. Daniels
Kinckiner

Extrusion of T-Metal. Results of meeting held on July 3, 1943,
giving recommendations for extruding to be done at Revere.

*8-2-43 Extrusion L D-6 Greenewalt
C.E. Daniels

Extrusion of T-Metal. Includes report by Kinckiner of
Revere's first extrusion performance on July 24 and July 25.

*8-24-43 Extrusion L D-6 H.W. Russell
C.E. Daniels

Extrusion of T-Metal - Includes recommendations by Battelle
for increasing yield of extruded rod.

*2-28-44 Extrusion L D-6 Area Engr.
Maj. Hadlock

Defective Extruded Rods - outlines additional testing to be done by Revere.

*3-3-44 Extrusion L D-6 C.E. Daniels
Kinckiner

Extrusion - discusses effect of quenching, cooling of billet and position of billet in press. Requests additional tests to determine results of above effects.

*3-13-44 Billet Quality L D-6 C.E. Daniels
R.P. King

Metal Billets - outlines meeting with Army. Army to prevent shipment of billets outside tolerable limits of composition to combat defects.

*3-14-44 Extrusion L D-6 C.E. Daniels
R.P. King

Metal Fabrication - Defects. Covers all information to date on causes of defects, summarizes steps taken and gives recommendations.

*3-16-44 Extrusion M D-6 - -
- -

Extrusion Study - itemizes suggestions for further study and test. To be submitted to Revere on March 17 for comment.

3-18-44 Organization L D-6 C.E. Daniels
R.P. King

King to supervise and coordinate problem to eliminate defects in extrusion.

*3-18-44 Billet Quality L D-6 C.E. Daniels
R.P. King

Metal Defects - lists program for determining metal quality in rods and slugs.

4-11-44 Extrusion L D-6 C.E. Daniels
R.P. King

Metal Extrusion - covers status and immediate prospects of the extrusion improvement work being done at Revere.

*4-24-44 Extrusion L D-6 J.N. Tilley
C.E. Daniels

Extrusion - minutes of Wilmington meeting of March 17, 1944 concerning defective rods. Includes also exhibits on:

- A - Resume of Extrusion Yields
- B - Metal Porosity
- C - Metal Defects
- D - Causes of Defective Rods

*4-24-44 Extrusion M D-6 C.E. Daniels
R.P. King

Metal Extrusion - Status of April 22, 1944.

1. Main stress at present is being put on temperature control.
2. Billet heating furnace partially rebuilt at Revere.

5-8-44 Extrusion L D-6 C.E. Daniels
R.P. King

Extrusion - Progress. Experiments being conducted at Revere show improved rod.

5-18-44 Rolling L D-6 C.E. Daniels
Voytilla

Alpha Rolling Temperatures - Results of some temperature readings of heated billets at Joslyn Mfg. & Supply Co., Fort Wayne, Indiana.

9-21-43 Canning M D-7 H.T. Daniels
C.E. Daniels

Jacketing of Slugs -

1. Dr. Maxwell to test the welds on three cans to combat hydrogen leakage.
2. Efforts to produce 100% weld should be continued at Alcoa while alternate closure designs were being investigated.

5-11-43 Hazards L D-10 Met. Lab. Gehrman

Suggests procedure for payment of doctor's bills in examining du Pont employees.

6-4-43 Hazards L D-10 Miles C.E. Daniels

Health Precautions (includes copies of doctors' visits to B. & T. and H.H.M.) Monthly check-up examinations being made at du Pont expense. Du Pont contemplates no other action unless further requested.

6-17-43 Hazards L D-10 Greenewalt Dr. Allison

Biological effect of Handling Heavy Metal -
1. Maximum of 2 hours per day handling with bare hands.
2. Five hours per day with horsehide gloves.
3. Other tests to be made.

6-19-43 Hazards L D-10 Gehrman Dr. Norwood

1. Desires list of du Pont men inspecting metal.
2. Desires ventilation installation for Revere C. & B. Co.

6-26-43 Hazards L D-10 Gehrman C.E. Daniels

Precautions in Fabricating Metal. Mentions outgassing being performed at Copperweld and requests follow-up by Dr. Norwood.

7-24-43 Hazards L D-10 Dr. Messick Wadhams

Medican Examinations of Inspectors exposed to T-Metal -
1. Inspectors previously advised of possible health hazards.
2. Medical records of all inspectors to be reviewed (later were approved).
3. Check-up every three weeks.

9-22-43 Hazards L D-10 R.S. Stone C.E. Daniels

Information regarding payment of medical services at fabricators' plants.

3-20-44 Hazards L D-10 Col. Warren
Dr. Norwood

Health Conditions in Industries - supplying metal to du Pont.
Lists the work done at various vendors to satisfy exposure
requirements and results.

5-30-44 Hazards L D-10 Gehrman
Dr. Stone

- At Joslyn Mfg. & Supply Company -
1. Laboratory tests and X-ray examinations will have to be done separately.
 2. Suggests that Dr. Cantril (Clinton Laboratory) be empowered to make any necessary arrangements.

5-29-43 Slugs M D-11 Litton
Lange

Daily Telegram - set up procedure for giving complete status
of flow of metal at all fabricators by means of daily telegram
from each inspector.

3-5-43 Extrusion L D-13 Greenwalt
Col. Ruhoff

Estimated delivery schedule of T-Metal billets to B. & T.
(112.3 tons by June 12, 1943).

3-5-43 Organization L D-13 Col. Ruhoff
Greenwalt

C. E. Daniels to handle metal procurement.

3-15-43 General L D-13 C.E. Daniels
Miles

Fabricated Metal for Chicago Experimental Pile
Preliminary specifications on slug sizes - Chicago to require
10 tons (April 30, 1943 require only 8 tons).

3-23-43 General L D-13 C.E. Daniels
Miles

- Size and Shape of Metal Billets
1. $4\frac{1}{2}$ " \pm 1/8" dia. x 10" \pm 1/2" long with cylindrical test casting on end.
 2. B. & T. ready for 2 or 3 tons for extruding.
 3. Safety precaution data being worked on.
 4. Disposition of scrap data being prepared.

7-16-43 Billet Size L D-13 Col. Ruhoff
C.E. Daniels

Requested that billet specifications be revised to accept lengths from 9 1/2" to 11 1/2" to reduce amount of cropping necessary.

7-26-43 Canning L D-13 C.E. Daniels
Miles

Slug Specifications

1. Hot dip coating is brittle and cracks at edges while canning.
2. Experimental work is proceeding.
3. Proceed on basis that all slugs for CEW be machined to present standard dimensions.

8-17-43 Inspection L D-13 Veith
C.E. Daniels

Slug Machining Tolerances

Slugs 1/4" under length are acceptable for canning.

9-2-43 Machining L D-13 C.E. Daniels
Miles

Metal Requirements for Clinton

1. Machine 30 tons of slugs for CEW to dimensions used for Alcoa method of canning.
2. Slugs are not to be jacketed.

9-2-43 General L D-13 C.E. Daniels
Miles

Disposition of Clinton sized jacketed slugs. All slugs received at Metallurgical Laboratory to date will be used in experimental work and none will be available for CEW.

7-15-43 Accountability L D-14 Maj. Sapper
C.E. Daniels

T-Metal Statements

1. Operations recorded through a double entry bookkeeping system based on weight of metal.
2. Differences in weights are accumulated in accounts set up for the purpose.
3. 15 billets overheated and oxidized.

12-6-43 Accountability L D-14 Maj. Sapper
C.E. Daniels

T-Metal Statement - CEW
Summarizes metal accountability at -
1. B. & T. XPG-123½ and 753½.
2. Revere XPG-773½.
3. Copperweld XPG-492½.
4. Baker Bros. XPG-582½.

3-6-44 Accountability L D-14 Maj. Sapper
Thackery

T-Metal Statement - CEW
Summarizes metal accountability at H-H-M Safe Co. - XPG-174½.

3-30-43 Security L D-17 B. & T.
C.E. Daniels

XPG-123½ - Confirming instructions that nature and analysis
of T-Metal is secret - disclosure constitutes criminal liability.

*3-30-43 Extrusion L D-17 Battelle Mem. Inst.
C.E. Daniels

XPG-123½
1. B. & T. to extrude T-Metal for 45¢ to 30¢ per pound gross
billet weight of metal plus actual cost of dies, cylinder
liners and dummy blocks.
2. Contract also proposed with B. & T. for a portion of the
machinery - other machining by H-H-M Safe Company.
3. Requests Battelle Memorial Institute to supply consultation
services in B. & T. Cost to be charged to their OSRD
contract and not to du Pont.

*4-6-43 Extrusion L D-17 Maj. Sapper
C.E. Daniels

Proposed Procedure for Handling Metal at B. & T. Metals Co. -
XPG-123½
Outlines proposed procedure and requests Sapper's approval,
which was received.

*4-9-43 Inspection M D-17 - -
- -

Inspection Procedure - XPG-123½. Describes in detail all steps
to be taken by du Pont inspector at B. & T.

6-12-43 Scrap L D-19 H-H-M Safe Co.
C.E. Daniels

XPG-174½

- 1. Ship 500 pounds of clean turnings to Westinghouse E. & M. Co., Bloomfield, N.J., for further experimental work in connection with recovery of turnings.

6-30-43 Slugs and Hazards L D-19 H-H-M Safe Co.
Lange

XPG-174½

- 1. Limitations to size of stacks and distances between stacks of stored metal. (All limitations removed by C. E. Daniels' letter of Sept. 1, 1943 to H-H-M Safe Co.)

7-8-43 Scrap L D-19 H-H-M Safe Co.
Lange

XPG-174½

- Segregate 500 pounds of turnings which have been machined with Hydromite and ship to WEMCO, Bloomfield, as per Col. Ruhoff's letter of July 3, 1943.

7-17-43 Hazards M D-19 Veith
Litton

XPG-174½

- Report of Fire at H-H-M Safe Co. on July 16 caused by spark falling in metal barrel of scrap.

7-20-43 Machining L D-19 C.E. Daniels
Litton

XPG-174½

- 1. Slugs now being turned to 4-3/32" lengths.

7-29-43 Machining L D-19 H-H-M Safe Co.
Lange

XPG-174½

- 1. Machine 2 heats of slugs to 1.092" O.D.
- 2. Machine at least 40 slugs to 1.090" O.D.
- 3. Ship all of above to Grasselli, Cleveland (for hot dipping experiments).

7-29-43 Hazards L D-19 C.E. Daniels
Met. Lab.

H-H-M Safe Company - Health Conditions (XPG-174½)

1. Dust counts OK.
2. Men in good condition but their anxiety probably influences their imagination concerning headaches, etc.

7-30-43 Canning L D-19 H-H-M Safe Co.
Lange

XPG-174½

Ship 20 slugs machined from rolled rods to Alcoa (for testing of coating). Metallurgical Laboratory requests canceling their order for 50 slugs per week, starting August 2, 1943.

8-17-43 Machining L D-19 H-H-M Safe Co.
C.E. Daniels

XPG-174½

1. All rejected slugs to be reclaimed and shipped by Sept. 1, 1943 in accordance with letter - Lange to Veith, dated July 1, 1943 and C. E. Daniels' to Veith Aug. 17, 1943.
2. September rejects to be segregated from those above.

8-19-43 Hazards L D-19 C.E. Daniels
H-H-M Safe Co.

XPG-174½

Two separate fires in drums full of turnings this week. Slight damage.

8-24-43 Accountability L D-19 H-H-M Safe Co.
C.E. Daniels

XPG-174½

Requests physical inventory as of Sept. 4, 1943 of T-Metal in various stages of fabrication and scrap.

9-23-43 Scrap L D-19 H-H-M Safe Co.
C.E. Daniels

XPG-174½

Dry and package the wet oxides and fines H-H-M Safe Co. has on hand, as directed by F. A. Shinn.

9-23-43 Scrap L D-19 Spahn
C.E. Daniels

XPG-174 $\frac{1}{2}$

Disposal of Scrap Slugs

1. Ship up to 300 scrap slugs to Grasselli-Cleveland, and up to 150 to Metallurgical Laboratory.

9-28-43 Machining L D-19 Sapper
Kerslake

XPG-174 $\frac{1}{2}$ - Disposition of Government-Owned Lathe

1. Purchased lathe on XPG-117 $\frac{1}{2}$ for use at H-H-M Safe Company.
2. OK to ship now to CEW? (approved by Maj. Stowers on October 4, 1943).

10-2-43 Grooving L D-19 H-H-M Safe Co.
C.E. Daniels

XPG-174 $\frac{1}{2}$

1. Immediately groove all unshipped 1.1" x 4" slugs and ship to Alcoa.
2. Purchasing Department to request quotation for grooving.

10-15-43 Scrap L D-19 Spahn
C.E. Daniels

XPG-174 $\frac{1}{2}$ - Disposal of Scrap Slugs. Ship additional 156 scrap slugs to Grasselli - Cleveland.

6-16-43 Outgassing L D-20 Miles
C.E. Daniels

XPG-492 $\frac{1}{2}$

Outgassing - Brief description of procedure.

8-9-43 Hazards L D-20 Copperweld
Dr. Norwood

XPG-492 $\frac{1}{2}$

Medical symptoms of excessive exposure to T-Metal.

8-19-43 Hazards L D-20 Copperweld
Dr. Norwood

XPG-492 $\frac{1}{2}$

1. Results of metal dust counts at Copperweld.
2. All counts are above maximum tolerable limit.
3. Recommends respirators and ventilation.

275

8-23-43 Scrap L D-21 McKinney
C.E. Daniels

XPG-423 $\frac{1}{2}$ - Alcoa

1. Segregate and hold any machined slugs with pits of sufficient size to make them unsuitable for jacketing.
2. If no use develops for these we will return them to Government as solid scrap.

8-11-43 Canning L D-21 Alcoa
Lange

XPG-423 $\frac{1}{2}$

1. Lot 3064-RH, which was specially canned, to be shipped to CEW for special test.
2. Inspectors are segregating off-size material so that special runs can be made to can these slugs properly.

10-2-43 Grooving L D-21 C.E. Daniels
Alcoa

Special Grooved Slugs

1. Suggests that du Pont inspector examine all grooves before canning.

10-27-43 Scrap L D-21 Maj. Sapper
C.E. Daniels

XPG-423 $\frac{1}{2}$ - Scrap Shipment

Requests Government representative to visit Alcoa to receive and ship a quantity of solid scrap.

10-30-43 Canning L D-21 Fletcher
C.E. Daniels

XPG-423 $\frac{1}{2}$

Ship 5 heats of slugs complete except for welding to Metallurgical Laboratory for experimental work on welding.

10-30-43 Scrap L D-21 Fletcher
C.E. Daniels

XPG-423 $\frac{1}{2}$

Ship rejected slugs to Metal Hydrides at Beverly, Massachusetts, as solid scrap.

*11-10-43 Testing M D-21 C.E. Daniels
McKinney

Deflection Test X Slug Cases
Describes test for deflection of slug cases.

11-10-43 Testing L D-21 McKinney
C.E. Daniels

XPG-423 $\frac{1}{2}$ - Retest slugs rejected by deflection test and
send 100 doubtful leakers to Experimental Station.

11-17-43 Testing L D-21 C.E. Daniels
Myers

XPG-423 $\frac{1}{2}$ - Doubtful leakers tested OK at Experimental
Station as described.

12-3-43 Testing L D-21 Veith
McKinney

Efficiency of "M" Deflection Test. Results prove this method
is accurate in determining leakers.

6-14-43 Hazards L D-22 Met. Lab.
Gehrmann

It is believed that Revere Medical Department can take care
of employees' examinations for working on T-Metal.

7-15-43 Accountability L D-22 Revere
C.E. Daniels

XPG-773 $\frac{1}{2}$
Requesting Revere to get its scales checked before receiving
billets.

7-27-43 Extrusion L D-22 Putman
Lange

XPG-773 $\frac{1}{2}$
Requesting Putman to take particular notice of how two BX
Billets behave during extrusion.

7-29-43 Hazards M D-22 Revere
Dr. Nickson

Dust hazards at Revere and suggestion for improvement.

7-30-43 Extrusion L D-22 Putman Lange

XPG-773 $\frac{1}{2}$

Take special note of extrusion of 25 billets (five each from five suppliers) and submit special report, to determine if cropping specifications can be modified.

7-30-43 Hazards L D-22 C.E. Daniels Met. Lab.

Revere C. & B. Co. (XPG-773 $\frac{1}{2}$)

1. Dr. Norwood examined 49 men at Revere - rejected nine.
2. Du Pont to make monthly check-up examinations.

8-11-43 Billet Quality L D-22 Putman Lange

XPG-773 $\frac{1}{2}$

Take special note on behavior of some W Billets containing more than 250 ppm aluminum.

8-7-43 Billet Quality L D-22 C.E. Daniels Maj. Hadlock

Government to notify du Pont in the future of numbers of all billets which contain more than 1000 ppm iron.

8-17-43 Billet Quality L D-22 Putman Lange

XPG-773 $\frac{1}{2}$

Requesting special report on peculiarities of high iron content billets.

8-13-43 Extrusion L D-22 Revere Lange

XPG-773 $\frac{1}{2}$

Prepare 2 dies to extrude rod to 1.205" and 1.190".

8-18-43 Extrusion M D-22 J.H. Shaw Putman

1. General performance by Revere in extruding 1500 T-Metal billets.
2. Description of extrusion equipment.
3. Description of extrusion process including preheating.

7-3-43 Hazards M D-23 C.E. Daniels
Aaron

XPG-582½
Enclosing report on fire at Baker on June 10, 1943.

7-3-43 Hazards L D-23 Met. Lab.
C.E. Daniels

XPG-582½
Action undertaken at Baker together with report on conditions there.

7-26-43 Fire Hazards M D-23 Shaw
Dunn

XPG-582½
1. Report of fire at Baker on July 25, 1943.
2. Baker Bros. refuses to accept any more rods until something definite is done about fire hazard of T-Metal.

8-24-43 Accountability L D-23 Baker Bros.
C.E. Daniels

XPG-582½
Requesting metal inventory of all stages of fabrication as of Sept. 4, 1943.

8-24-43 Machining L D-23 R.T. Dunn
Lange

XPG-582½
1. Machine 25 bars in normal manner but submit separate report on machining characteristics.
2. This is one of steps taken in trying to improve the overall yield of the T-Metal.

8-28-43 Hazards L D-23 C.E. Daniels
Dr. Norwood

XPG-582½
1. Monthly check-up of Baker's employees.
2. Suggests having inspectors use tongs instead of using their hands for lifting and holding metal for gauging, etc.

10-2-43 Grooving L D-23 Baker Bros.
C.E. Daniels

XPG-582 $\frac{1}{2}$

1. Immediately groove all unshipped CEW slugs and ship to Alcoa.

11-1-43 Grooving L D-23 Baker Bros.
C.E. Daniels

XPG-582 $\frac{1}{2}$

Groove 390 machined slugs being shipped from Alcoa and return to Alcoa.

11-9-43 Grooving L D-23 Baker Bros.
C.E. Daniels

XPG-582 $\frac{1}{2}$

1. Groove and touch up approximately 20 tons of slugs from which jackets have been removed. Perform this machine work on XPG-582 $\frac{1}{2}$.

2. Ship slugs to Alcoa after grooving and touching up.

1-22-44 Grooving L D-24 Spahn
C.E. Daniels

Ship as soon as possible 200 grooved CEW slugs to Area Engineer - Chicago.

1-22-44 Grooving L D-24 Maj. Sapper
C.E. Daniels

Requesting approval to place order on Baker Bros. for grooving approximately 12000 slugs to permit application of the deflection test at Alcoa. (Approved by Maj. Stowers Jan. 22, 1944).

10-12-43 Testing L D-25 C.E. Daniels
Miles

Canned Slug Tests at Alcoa

1. Three deflection type testers were delivered to Alcoa on October 5 and will be used for production testing of all future CEW slugs.

*11-9-43 Canning L D-25 Whitaker
C.E. Daniels

XPG-1628 $\frac{1}{2}$ - Canning of Slugs

1. CEW to strip cans from 20 tons of defective slugs and ship to Baker Bros.

2. Baker to groove and touch up and ship to Alcoa.

3. 30 tons to be canned.

4. Later 20 tons to be canned.

5-19-43 Extrusion L D-28 B. & T. Spruance

XPG-123½
Submitting tentative schedule of tonnage expected from May 24 to work of July 7 inclusive.

5-29-43 Extrusion L D-28 Shaw C.E. Daniels

XPG-123½ - Furnace
Advising that tile for rebuilding the furnace has been ordered on XPG-547½.

7-3-43 Machining L D-28 B. & T. C.E. Daniels

Verbal order XPG-753½ issued for machining and guarding incidental to machining.

*4-3-43 Machining M D-29 Shaw Veith

Investigation for Machining Facilities - List of shops investigated near Columbus, Ohio for machining slugs.

4-29-43 Machining TT D-29 Wilson C.E. Daniels

XPG-117½
J. L. Lathe was loaned to H-H-M Safe Company. Will be shipped to CEW after completion of work.

4-29-43 Hazards L D-29 H-H-M Safe Co. C.E. Daniels

XPG-174½
We are supplying H-H-M Safe Co. with Government-owned Claridge fans for ventilating the lathes.

5-28-43 Machining L D-29 H-H-M Safe Co. Lange

XPG-174½
Submitting tentative schedule for machining extruded rods.

5-28-43 Grinding M D-29 Shaw Lange

1. Ship 10 pieces to Carborundum Company.
2. Ship 1 piece to Alcoa Research Department.

5-29-43 Scrap L D-29 H-H-M Safe Co. C.E. Daniels

- XPG-174½
1. Ship 500 pounds of turnings.
 2. Pack in vented (4 - 1/16" holes in cover) 5 gallon metal containers.
 3. 25 pounds maximum in any container.

6-16-43 Scrap L D-29 H-H-M Safe Co. Lange

XPG-174½
Requesting purchase of 75 drums for storage shipment of turnings. Specifications of drums given.

*6-30-43 Valuation L D-29 H-H-M Safe Co. C.E. Daniels

XPG-174½
Vendor not liable for any loss or damage to Government-owned materials in his possession.

7-2-43 Machining L D-29 H-H-M Safe Co. Lange

XPG-174½
Requesting advice concerning power requirements in machining T-Metal. (Apparently data for purchasing equipment for HEW).

7-3-43 Crating L D-29 H-H-M Safe Co. Lange

XPG-174½
Requesting them to ship slugs in boxes constructed as per attached sketch.

7-17-43 Hazards L D-29 C.E. Daniels H-H-M Safe Co.

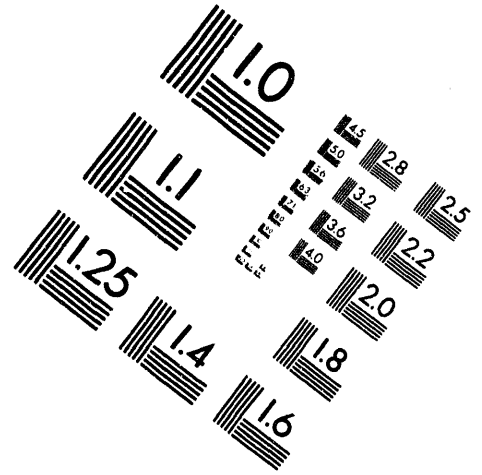
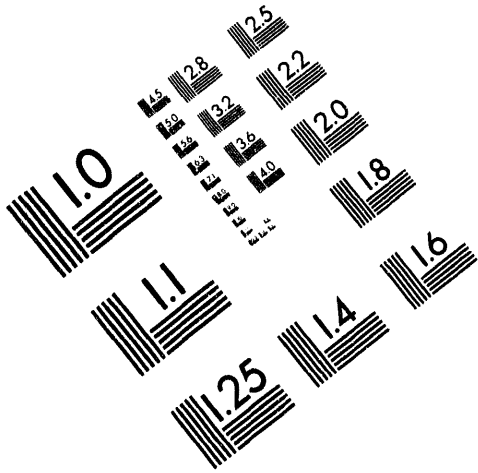
- XPG-174½
1. 30,000 pounds turnings on hand at H-H-M Safe Company.
 2. Additional guards necessary.
 3. Please expedite removal of scrap.



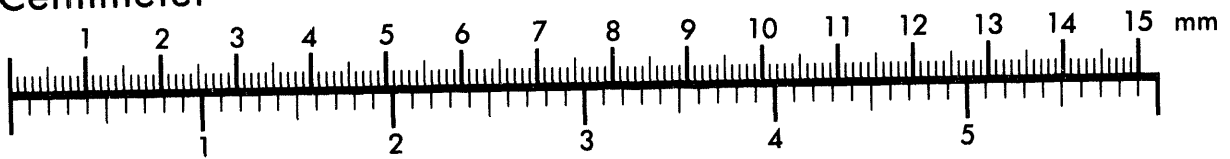
AIM

Association for Information and Image Management

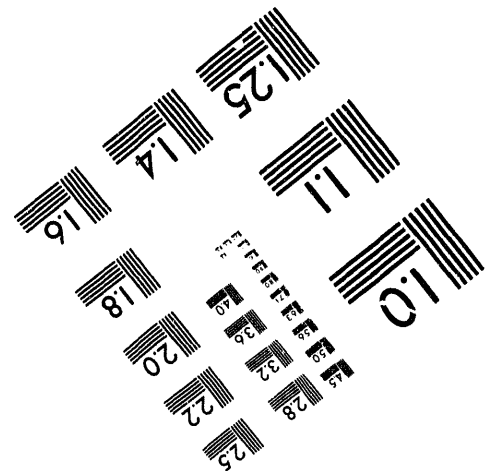
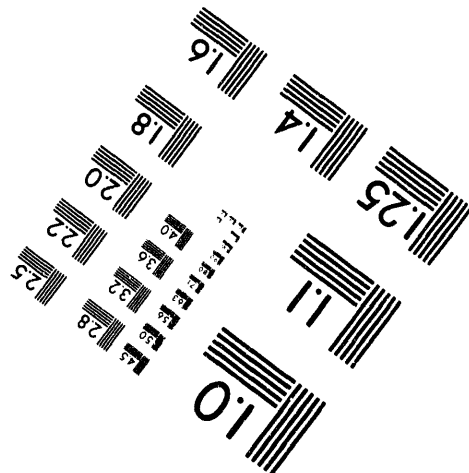
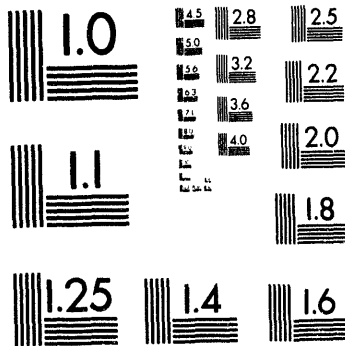
1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202



Centimeter



Inches



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BY APPLIED IMAGE, INC.

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9-25-43 Hazards L D-29 P.L. Spruance
H-H-M Safe Co.

XPG-174 $\frac{1}{2}$
H-H-M Safe Co. has dismantled crated and shipped attached list of ventilating equipment loaned to them.

10-6-43 Extrusion L D-29 Spahn
C.E. Daniels

XPG-174 $\frac{1}{2}$
Ship 1/2 of rod (front half as extruded) to Department of Commerce, Bureau of Standards, Washington.

10-6-43 Grooving L D-29 Spruance
H-H-M Safe Co.

Quoted \$2.75/hr. for uncrating, grooving, filing, and re-crating approximately 18,000 slugs.

10-19-43 Hazards L D-29 Maj. Sapper
Kerlake

Disposition of Government owned Fan, Motor and Piping.
Requesting disposition of listed material since the H-H-M Safe Co. has finished work on XPG-174 $\frac{1}{2}$.

10-22-43 Hazards L D-29 Kerlake
Maj. Stowers

XPG-174 $\frac{1}{2}$
Ship equipment in letter of Oct. 29 to CEW (from H-H-M Safe Co.).

10-30-43 Security L D-29 Maj. Sapper
Kerlake

XPG-174 $\frac{1}{2}$
Requesting approval for giving title of screened enclosure to H-H-M Safe Co. to eliminate cost of dismantling.

11-2-43 Security L D-29 C.E. Daniels
Maj. Sapper

XPG-174 $\frac{1}{2}$
1. Maj. Sapper is unauthorized to give title of enclosure to H-H-M Safe Company.
2. Du Pont may secure quotes from other sources for cost of dismantling.

1-12-44 Security L D-29 C.E. Daniels
Maj. Stowers

XPG-174 $\frac{1}{2}$

1. OK to transfer title on enclosure to H-H-M Safe Company.
2. Request H-H-M Safe Co. for quote for this material.

1-17-44 Security L D-29 Du Pont Co.
H-H-M Safe Co.

XPG-174 $\frac{1}{2}$

Bidding \$2.00 for material comprising the enclosure.

1-22-44 Security L D-29 Kerslake
Maj. Stowers

XPG-174 $\frac{1}{2}$

Approving \$2.00 bid for enclosure by H-H-M Safe Company.

12-2-43 Canning M D-30 Veith
McKinney

XPG-423 $\frac{1}{2}$

Attached corrected invoice dated Aug. 17, 1943 for delivery of canned slugs as listed therein.

11-2-43 Canning L D-30 Alcoa
C.E. Daniels

XPG-423 $\frac{1}{2}$

1. Send 500 small cans without caps to Cleveland Laboratory, 3092 Broadway, Cleveland.
2. Reject cans are suitable.

7-23-43 Testing L D-30 P.E. Collins
Lange

XPG-423 $\frac{1}{2}$

Give Dr. M. Miller 6 standard slugs for special testing.

7-9-43 Canning TT D-30 Lange
Miles

XPG-423 $\frac{1}{2}$

Use of benzene is satisfactory for degreasing.

**DATE
FILMED**

7/12/94

END

4

