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Volume 12-B

**"Present Practices in the Uranium Foundry
at Iowa State College"**

December 1945

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For The Atomic Energy Commission

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PRESENT PRACTICES IN THE URANIUM FOUNDRY AT IOWA STATE COLLEGE*

Work done by F. H. Spedding, H. A. Wilhelm, C F Gray and
Richard Thompson

Paper written by B F Gray

In the few months following the discovery at Iowa State College Laboratory that graphite could be used as a crucible and mold material, rapid advances were made in the process for melting and casting uranium. The early experimental work and pilot plant developments for casting uranium have been discussed in an M.F.R. report ⁽¹⁾ which gives the developments from early June 1942 up to and including the first valve-pour model casting unit, the forerunner of the present equipment at Iowa State College Laboratory. Shortly after the first successful use of the valve-pour unit, the casting of uranium changed from an experimental pilot plant stage to a production operation. The urgency with which castings of uranium metal were needed at this period had prompted the further development and expansion of the process to its present stage. This report will review the present methods, procedures, and equipment employed in the uranium foundry at Iowa State College Laboratory.

The plant at Iowa State College grew under the pressure of the war emergency. Time was often the deciding factor; consequently as the process developed construction and expansion were carried out towards the end of getting into and stepping up production as early as possible with whatever available means would meet the time requirements. Therefore, some possible improvements in plant design and procedure that were recognized during this

*Based on CF-609, CF-640, CF-686, CF-751, CF-816, CF-891, CF-954, A-1015, A-1020, A-1041, A-1054, A-1060.

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period were not used, but would be incorporated in plans for a new foundry, for uranium casting. Such plans would include a number of minor changes in the present procedures and designs as discussed in this report.

When large scale production casting of uranium was started, all metal was cast into ingots that could be cut into small solid cylinders 2.25 in. in diameter and weighing from 4.5 to 7 lbs. each. These cylinders were referred to as "eggs". Later developments in handling and shaping metallic uranium made it possible to cast larger cylinders (4.25 in. in diameter by 13.5 in. in length) of the metal for extrusion. These large cylinders are referred to as "billets". Recently the specification for length of some billets was doubled, or increased to 27 in. These two sizes of billets are referred to as "single length billets" (about 130 lbs.) and "double length billets" (about 260 lbs.). Later specifications called for billets 4.25 in. in diameter by a maximum length of 22 in. The 27 in. billets are cut in two merely to keep under the 22 in. maximum which can be handled by the present extrusion press. A billet is produced by cropping the upper end from an ingot of the proper size and cutting off a five pound egg that is cast on the lower end of the ingot. The top cropping of the ingot removes the pipe and any slag or scale that has been poured from the melting crucible. In general, about 15 to 20 lbs. of metal are removed from an ingot in forming a billet. For the 27 in. billet the ingot usually weighs 275 to 280 lbs., which means that for a good casting yield the charge in the crucible is about 285 lbs. of crude uranium bisulphate. The processes for producing the 22 in. and 13.5 in. billets are identical except that smaller charges and equipment can be used for the latter.

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To produce the single length and double length billets, casting units were developed for use with 9 in. and 15 in. I.D. hoist type induction coils. The 22 in. billets are produced in the double length casting unit. Power is supplied to either unit by a 40 KW Ajax mercury arc converter. The single and double length casting units are similar and are mounted on carts which can be moved under the induction coil, which is then lowered around the unit and into the proper position for heating the crucible containing the metal. The equipment is so arranged that when the movable casting assembly is in position for heating, a stationary vacuum pump line can be connected to the casting assembly.

The casting procedure for both units is to load a specified amount of crude uranium into a graphite crucible having a graphite valve disc in its bottom. The loaded crucible is supported on a graphite spillway that rests on the ingot mold, also made of graphite. The crucible section is insulated with specially prepared sillimanite radiation shields. A closed-end quartz tube is placed over this insulated portion and sealed to a water-cooled base by a rubber gasket. Then the system is evacuated to a high vacuum and the graphite crucible containing the metal is heated by a high frequency induction coil.

After the uranium has melted, the temperature of the metal is raised above its pouring temperature and then cooled down under a vacuum. In the pouring operation, the graphite valve disc in the bottom of the crucible is forced up from the valve seat by means of a graphite valve rod connected to a steel push-rod whose mechanism is operated from outside the vacuum system. This motion causes the disc to float to the top of the molten uranium, which then flows through the valve hole and the spillway, into the graphite mold where it solidifies to form an ingot.

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After the casting unit has cooled and been unpacked the heat number is stamped on the surface of the ingot for later identification. The finished billets are made, as we have seen, by sawing the 5 lb. egg off the bottom and cropping the top. In the following section, the equipment and each operation will be discussed in detail in the approximate order in which crude uranium biscuits are received, packed, melted, cast, and the ingots cut into finished billets. A flowsheet of the operations is shown in Figure 1.

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The crude magnesium-reduced uranium is received in the form of thick discs, referred to as "biscuits". These biscuits are produced in two sizes for the 9 and 15 in. casting units. The smaller biscuits, for the 9 in. casting unit, are about 3 in. thick and about 5 to 5.5 in. in diameter, and weigh about 40 lbs. The larger biscuits, for the 15 in. casting unit, are 2.5 to 3 in. thick and 8.5 to 8.75 in. in diameter and weigh about 125 lbs. The biscuits are produced in steel bombs with packed-lime walls. Occasionally, biscuits are oversize due to knobs and fins on the sides.

Some difficulty was encountered in casting the oversize biscuits. The inside diameters of the crucibles for the 9 and 15 in. induction coils are 5.50 and 8.75 in., respectively. A biscuit having a diameter equal to or nearly as large as the inside diameter of its crucible will expand on heating and possibly crack the crucible wall. Molten uranium will flow through a cracked wall very rapidly and a great deal of metal is lost in such cases. To eliminate the possibility of cracking the crucible all biscuits are passed through a gage corresponding to its size and the oversize biscuits separated. The two gages for the two sizes of biscuits have inside diameters of 5.375 and 8.625 in. and a length of 3 in. All

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The flowchart illustrates the layout of a magnesium processing plant, detailing the sequence of operations and material flow. The process begins with **CRUDE BISCUITS FROM MAGNESIUM REDUCTION**, which are weighed on **SCALES** and moved to **STORAGE** (containing crude biscuit, scrap, slugs, croppings, and sawdust). From storage, materials are weighed on **SCALES** and sent to the **LOADING AREA**. The **LOADING AREA** is equipped with **VACUUM PUMP** and **NEW INSULATION**. Materials are transported via **CARTS** to **VACUUM TESTING** or the **INDUCTION HEATING AND CASTING** area. The **INDUCTION HEATING AND CASTING** area includes a **40 KW AJAX MERCURY ARC CONVERTER** and a **VACUUM SYSTEM**. Castings are then moved via **CARTS** to the **COOLING AREA**, which has **COOLING WATER** and a **VACUUM PUMP**. From the **COOLING AREA**, materials are transported via **CARTS** to the **UNPACKING AREA**. The **UNPACKING AREA** includes **COOLING WATER** and a **VACUUM PUMP**. Materials are then moved via **CARTS** to the **CLEANING** area. The **CLEANING** area is equipped with **UNBROKEN INSULATION** and **SLUGS AND SCRAP**. Cleaned materials are weighed on **SCALES** and sent to the **GRAPHITE SHOP**. The **GRAPHITE SHOP** includes **NEW GRAPHITE RODS** and **NEW AND RECONDITIONED PARTS**. Graphite parts are weighed on **SCALES** and sent to the **BURNOUT FURNACE**. The **BURNOUT FURNACE** includes **USED GRAPHITE PARTS** and **BROKEN INSULATION**. Burned parts are weighed on **SCALES** and sent to the **POWER HACK SAW**. The **POWER HACK SAW** includes **INGOTS** and **UNFINISHED EGGS**. Sawed materials are weighed on **SCALES** and sent to the **CUTOFF LATHE**. The **CUTOFF LATHE** includes **TURNINGS** and **DEGREASING**. Lathe materials are weighed on **SCALES** and sent to the **DETERMINATION OF DENSITY AND WEIGHT** area. The **DETERMINATION OF DENSITY AND WEIGHT** area includes **EGGS** and **BILLETS**. The **DETERMINATION OF DENSITY AND WEIGHT** area is equipped with **SCALES** and **CHEMICAL SAMPLES**. The **DETERMINATION OF DENSITY AND WEIGHT** area is also equipped with **IMPURE DROSS D-2**, **PURE DROSS D-6**, **FLUORIDE CONTAMINATED DROSS D-7**, **BROKEN GRAPHITE C-4**, and **BROKEN INSULATION C-6**. The **DETERMINATION OF DENSITY AND WEIGHT** area is also equipped with **CHEMICAL SAMPLES** and **EGGS**. The **DETERMINATION OF DENSITY AND WEIGHT** area is also equipped with **BILLETS**.

Figure 1. Flowsheet of casting operation.

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biscuits are checked for size with the above gages as they are weighed into the department. Biscuits which will not pass through the gages are sawed into smaller pieces or the small protuberances are hammered down. No difficulty with cracked crucibles was experienced after the biscuits had been checked in this manner.

The most efficient method for storing the small biscuits is to have two rows of bins, one on top of the other and the bottom row about 30 in. above the floor. Each bin is about 18 x 18 x 18 in. and is built to support 1200 lbs. There are 20 bins for storing the various production lots of biscuits and miscellaneous pieces of uranium weighing less than 50 lbs. that have to be recast. These miscellaneous pieces consist mainly of "croppings" that are cut from the finished billets, small "slugs" which are the result of occasional casting failures where the metal solidifies in the crucible, and small pieces of "scrap" metal that are taken off the billets and out of the molds and spillways.

Steel construction is much better for the bins than wood because wood wears down too rapidly under the continual handling of biscuits. Steel has another advantage in that the operators can handle and slide heavy uranium pieces on it much more easily than on wood. With this arrangement and a cart, one operator can easily handle the 40 lb. biscuits by hand.

The large 125 lb. biscuits and miscellaneous pieces weighing more than 50 lbs. are stored on a steel covered table about 2.5 ft. high, 3 ft. wide and 12 ft. long. The table is surrounded by a 10 in. guard and is also divided into sections by a guard of the same height. This table is built to support 700 lbs./ft. and is serviced by a 500 lb. capacity electric hoist on a monorail running lengthwise over its center. Space is provided

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for the delivery cart under the hoist so that the large biscuits can be lifted by the hoist, with a special gripping device, and placed in any location on the table.

Because of the scarcity of metallic uranium a very careful check is kept on all metal. Each biscuit checked into the casting department is accompanied by a ticket bearing its number and weight. All scrapings and slugs are stamped with the number of the casting run. The pieces of scrap are not numbered but are weighed carefully each day and stored in the bins.

The main part of each charge is made up by selecting biscuits from the same reduction lot to give a weight slightly less than the total required weight. Then enough scrapings or other small pieces of uranium are added to the biscuits to give the required charge weight within 2 lbs. When the correct weight of uranium is selected, the weight of each piece is checked on a Toledo dial scale, with the incoming weight and the number and weight of each piece copied on the casting sheet. These scales are also serviced by the above mentioned hoist on the monorail.

The dial scale employed is able to stand the rather rough treatment of weighing uranium better than any other scale tested, though it is not as accurate as a beam scale. As a result, dial scales are used for all inter-departmental weighings and beam scales for all incoming and outgoing weights for the plant. The ordinary beam scale calibrated for 0.01 lb. will not retain its accuracy unless some special precautions are taken. These precautions will be described in the latter part of this report.

The graphite crucibles, molds and miscellaneous parts are kept in a storeroom adjacent to the loading area. The graphite parts for the small 9 in. casting unit are shown in Figure 2. Of these parts, the crucible (C),

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Figure 2. Graphite parts for 9 in. casting unit.

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valve disc (D), spillway (E), mold (H), and egg cup (J) are thoroughly inspected for defects such as cracks and worn surfaces by the graphite machinists⁽³⁾. These parts are then assembled with the egg cup pinned in the bottom of the mold. The crucible, spillway and mold assembly are further checked for line-up of the thermocouple and valve rod holes. In the pre-assembly and checking in the graphite department, the valve disc is ground in on the valve seat by rotating the disc on the seat. A screw-driver inserted in a drill press engages the slot in the valve disc to provide the rotating action. The complete assembly is delivered as a unit to the graphite storeroom at the foundry. Before packing, this assembly is checked again by a casting room operator. If any defects are found the entire unit is returned to the graphite shop for reconditioning. This procedure results in very uniform and dependable assemblies. The other parts, top (A), crucible extension(B), valve rod (F), cupola (G) and mold base (I), do not require close checking and are taken from the graphite storeroom as needed by the foundry workers.

The graphite parts for the large 15 in. casting unit are shown in Figure 3. These parts are made with closer specifications than the parts for the 9 in. unit, hence the only assembling done in the graphite shop is grinding the valve disc into the valve seat of the crucible and assembling the egg cup (N) and the upper section (L) and lower section (M) of the mold. The most important point in the last operation is lining up the mold cavities of the two parts. The other parts are supplied separately and selected from the storeroom as needed by the casting operators.

A stock of sillimanite insulation shields, which are described in another report⁽⁴⁾ in Volume 12-B, is kept in special shelves near the loading area. To facilitate the loading and unloading of insulation, the

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Figure 3. Graphite parts for 15 in. casting unit.

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shields can be taken from or piled on a cart which is moved adjacent to the casting assembly. Broken insulation is replaced from the shelves.

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As will be described later, uranium hack saw chips are used in the packing operation. These chips are removed from the hack saw; cleaned, dried, passed over a magnetic separator, and stored until used. More chips are produced than is necessary for the minimum amount needed for packing each charge of metal. Since the excess sawdust has to be re-cast, it is much more convenient to add the small excesses to each run than to make special charges of sawdust alone. For measuring the correct amount of sawdust a group of ten containers was made which would hold from 0.5 lb. to 2.75 lb., by 0.25 lb. intervals. That container is selected which will use up the sawdust at the rate at which it is being produced.

The above supplies and storerooms are all conveniently adjacent to the loading or assembling area. Here both the 9 and 15 in. casting units, which are similar and operated on the same principles, are assembled. Since the 9 in. unit was developed first it will be described first and then those parts of the 15 in. unit which differ from the 9 in. unit will be discussed.

A detail assembly sketch of the 9 in. unit is shown in Figure 4. A water-cooled brass base (31) is mounted on a welded steel cart (40). The cart is mounted on soft rubber-tired casters (41). The brass base (31) is cooled by water circulating through connections (32). It is important that the outlet water connection extend nearly to the top of the water containing space in order to prevent air from collecting in this area. A 1/4 in. I.D. tube (29) is soldered into the base (31) for thermocouple (20). In Figure 4 this tube and the thermocouple are rotated into the

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Fig. 4. 9 in. casting unit. (1) Closed end quartz tube, (2) sillimanite insulation lid, (3) graphite cupola, (4) graphite lid, (5) graphite crucible extension, (6) small piece of uranium, (7) induction coil, (8) sillimanite insulation shields, (9) graphite crucible, (10) uranium biscuits, (11) uranium sawdust, (12) uranium dioxide, (13) graphite valve disc, (14) graphite spillway, (15) graphite thermocouple sleeves (16) spillway orifice, (17) spillway lip, (18) evacuation hole, (19) graphite valve rod, (20) thermocouple (rotated into cross-section view), (21) rubber gasket, (22) graphite mold, (23) steel valve rod, (24) water-cooled extension, (25) graphite egg cup, (26) graphite mold base, (27) steel cross arm, (28) steel guide bar, (29) thermocouple tube, (30) rubber gasket, (31) water-cooled brass base, (32) water-cooling connections, (33) 2 in. plug, valve, (34) 2 in. service tee, (35) steel valve rod, (36) testing and relief valve, (37) 2 in. plug, (38) steel valve rod sleeve, (39) rubber sleeve, (40) welded steel cart, (41) soft rubber tired casters. (Section U-U does not show cross-section of bottom uranium biscuit).

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plane of cross section and are shown as a broken line. The exact position of the thermocouple is given in sections V-V, W-W, X-X, and Y-Y. A 2 in. service tee (34) is screwed into the bottom of the base (31). The service tee is connected with the 2 in. plug valve (33) by means of a 2 in. nipple. A small plug valve (36) is welded to the side of the nipple, for testing the system for leaks and for releasing the vacuum after cooling. A 2 in. plug (37) which is drilled for a sleeve (38) is screwed into the bottom of the service tee (34). A guide bar (28) is pressed into the base (31). Both the guide bar (28) and the sleeve (38) are drilled on the center line of the assembly for a 5/8 in. push rod (35) so that the push rod can be moved freely up and down while rigidly held in position. The motion of this rod into the vacuum system is sealed by a rubber tube (39) which covers the external junction between the sleeve and push rod. The push rod bearing surface in contact with the rubber tube is greased with Cello-Seal. This device for transmitting push and pull motion into a high vacuum system proved highly successful in production at Iowa State College Laboratory. Since it is not possible to mount a push rod in the center of the graphite assembly, a steel cross-arm (27) is fastened to the upper end of the push rod to provide it with sufficient offset to place it under the steel valve rod (23). The parts of the casting unit described above are permanently assembled, and the remaining parts are built up and disassembled with each run.

In building up the casting unit, the thermocouple (20) is adjusted to the correct height and sealed vacuum tight with Pyseal wax at its exit from the brass tube (29). The base is then cleaned, and mold base (26) and the lower steel portion of the valve rod (23) are placed in position. After the mold (22) is placed on the mold base, the 1/4 in.

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graphite valve rod (19) is inserted into the mold (22). On account of the offset valve rods (19 & 23) a spillway (14) is necessary to carry the molten uranium from the valve in the crucible to the mold. The cross section of the channel in the spillway is larger than the valve opening in the crucible, while the orifice (16), or outlet from the spillway, is slightly smaller. This arrangement produces a slight build-up of metal in the spillway and causes the molten uranium to be forced straight down in pouring instead of against the side of the mold. The lip (17) is placed on the orifice of the spillway to keep the molten metal from running back under the spillway and thence down the side of the mold. When drops of molten uranium come in contact with the cold mold wall, they solidify and sometimes adhere to the wall. As the molten metal in the mold rises above these drops, some of them do not weld to the billet, thereby producing an unsatisfactory surface on the ingot. Although this difficulty was encountered it was never serious and was corrected by the methods outlined above.

Some 3/8 in. slanting evacuation holes (18) are drilled into the spillway to provide space for the air in the mold and spillway to escape when the vacuum is initially produced. The molten uranium is prevented from running down the valve rod at the point where the rod passes through the spillway by using a graphite sleeve which is slightly smaller than the graphite push rod. The graphite push rod is sanded lightly with fine emery cloth until a close working fit is obtained with the sleeve. The graphite valve rod is cut off at such a length that its end will be about 1/8 in. below the bottom of the valve (13) when assembled. At this point the mold is surrounded with sillimanite insulation shields (8), and the gasket (30) and water-cooled extension (24) are placed in position. (6)

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After the above operations, the crucible is set on the spillway and the valve disc is properly seated over the valve hole. To insure against occasional faulty valves and valve seats, a small amount of uranium dioxide (12) is sprinkled around the edge of the valve, to seal any small leaks. If large amounts of uranium dioxide were used for this purpose it would be carried through with the molten metal upon pouring to form small pockets in the cast billet. The valve and uranium dioxide are covered with uranium sawdust (11) from a power hack saw. The uranium biscuits (10) are placed on this sawdust to prevent the valve from being lifted by air rushing from the mold upon evacuation of the system. As pointed out previously the use of uranium sawdust for this purpose gives a further advantage in that it furnishes a means of recasting the sawdust without making special runs.

Charges of uranium biscuits are made up within 2 lbs., plus or minus, of a definite weight calculated to give a certain length of finished billet. A charge usually consists of four biscuits weighing approximately 40 lbs. each and a piece of cut biscuit, or some "tops" which are produced by cropping the top ends of cast ingots. The biscuits are lowered one at a time into the crucible by means of an 18 gage wire with the ends held securely by a large pair of pliers. Used chromel and alumel thermocouple wires prove very satisfactory since they will stand the repeated flexing from pulling the wire out after a biscuit is in place. Various mechanical devices for directly gripping the biscuits were investigated, but none were found satisfactory on account of the irregular surfaces and the maximum clearance of $1/8$ in. between the biscuit and the crucible. Usually the charge of metal extends above the top of the crucible (9). It is necessary then in most cases to use a

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graphite extension ring (5) which is placed on top of the crucible to completely enclose all the metal in a melting chamber. The graphite extension rings are cut from the good tops of discarded crucibles. This practice permits the crucible to be shorter and thereby saves a great deal of graphite. The crucible is always large enough to hold the molten charge easily.

After the charge of crude uranium metal is placed in the melting chamber the graphite lid (4) is placed on top of the crucible extension and the sillimanite insulation shields are built around and above the chamber. The top is insulated with a sillimanite lid (2). The closed end quartz tube (1), completely enclosing the insulated melting chamber, is placed on a rubber gasket (21) which is greased slightly with Cello-Seal. With the 2 in. plug valve closed, connection is made to a test vacuum pump through the small side valve (36) to test the assembled unit for leaks. When the system has been made vacuum tight, the side valve is closed and the unit is then moved to the heating position where the 2 in. plug valve is connected to the main vacuum pumping system by means of gasketed flanges. Next, the water connections are made to the brass base and water-cooled extension, and the thermocouple is connected to a pyrometer. Then the induction coil is lowered around the quartz tube and adjusted to the proper height for heating. This coil is 16 in. in length and 9 1/8 in. in I.D. It is constructed of 26 turns of 1/2 in. annealed copper tubing and is mounted on a vertical 1/2 in. pipe in such a manner that it has vertical movement and about 180° horizontal rotation. The coil and its mount are counterbalanced to facilitate its movement. Heavy electric leads connect the coil to an Ajax mercury arc converter.

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The most satisfactory heating procedure for the 9 in. unit is as follows:

1. Set the bottom of the induction coil at the same height as the bottom of the spillway.
2. Heat the crucible at the maximum rate of the converter which is about 37 KW until the thermocouple registers 1300°C .
3. Raise the coil 5 in. and heat for 5 to 10 min. at the same rate.
4. Lower the coil to the starting position and reheat to 1300°C at about 37 KW.
5. Turn off the furnace and lower the coil $9\frac{1}{2}$ in. from the starting position while cooling to 1265°C .
6. Pour by an upward motion on the valve rod (35), which raises valve disc (13), when the temperature reaches 1265°C .
7. Immediately after pouring, heat at 20 KW for 6 min. ⁽⁷⁾

Usually all of the biscuits melt in Step 2 although occasionally the top biscuit, which is partially above the heating zone, will adhere to the side wall of the crucible or crucible extension and will not fall down and melt with the others. If a biscuit does adhere it is melted in Step 3. By watching the temperature recorded by the thermocouple the operator is able to determine whether a biscuit has adhered in the top of the crucible or crucible extension. If the temperature drops immediately with the beginning of heating in Step 3 it is due to molten uranium from a biscuit lodged in the top of the crucible or the biscuit itself dropping into molten uranium in the bottom of the crucible, which has been heated to a higher temperature. If the temperature falls only very slowly, no biscuit has been trapped in the top of the crucible or crucible extension. The length of this heating period, which is left to the discretion of the

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operator, is very short for the latter case. Step 3 cannot take place before Step 2 because molten uranium will run around the bottom biscuit, solidify, and break the crucible when remelted in the next step.

In Step 4 all the molten uranium is brought up to 1300°C so that the light impurities will have a better opportunity to float to the top of the molten metal while cooling to the pouring temperature of 1265°C . Lowering the coil $3\frac{1}{2}$ in. and heating at 20 KW for 6 min. as described in Steps 5 and 7 gives the ingot a "hot top", thus reducing the size of the pipe that forms in the top of the ingot. After the hot top heating is completed the 2 in. plug valve is closed; the water, thermocouple and vacuum lines disconnected, and the unit moved to the cooling line where it is allowed to cool for 2 or 3 hrs.

The 15 in. casting unit is similar in many respects to the 9 in. unit; however, there are notable differences in both the construction and method of assembling. A detailed assembly sketch of the 15 in. unit is shown in Figure 5. This large unit is necessary to cast the double length billets. Rubber tired, welded steel carts of the same design as employed for the 9 in. unit are used to hold the water-cooled steel mold jacket (25). The graphite mold consists of two parts (18) and (27) with an egg cup (28) in the bottom section. To simplify the construction of the graphite parts, the steel push rod is placed on the side and has two offsets (14) and (20). The water-cooled extension (17) is similar in design to the one used for the 9 in. unit. In this unit the thermocouple connection (36) is brought out through the side of the water-cooled extension.

Heating the larger 15 in. unit with the 40 KW Ajax mercury arc converter required a definite change in the insulation. With a 12 in. outside diameter crucible and the same amount of insulation as used for the 9 in.

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unit, the temperature could be raised to about 1250°C only with the maximum rate of heating, after about 5 hrs. Sacrificing inductive coupling, a 10 in. outside diameter graphite melting crucible was introduced in order to provide space for another layer of sillimanite insulation shields around the crucible. Under these conditions the temperature of the crucible could easily be raised to 1300°C in 2 hrs. at the maximum rate of heating. In both of the above cases, the crucible was packed with a charge of crude metal. As a result, two layers of sillimanite insulation shields (3) and (4) are used, as shown in Figure 5. The inner shields (4) are divided into six segments and the outer shields (3) into three segments. Half shields for this unit, similar in design to those used with the 9 in. unit, are too fragile because of their large size.

Another important change in design from the 9 in. unit is the use of a layer of K-30 insulating brick (31) between the spillway and the mold. This insulation barrier reduces the time required to bring the crucible up to temperature. A cover plate (34) is added to the top of the mold to support the K-30 insulation brick. To prevent brick dust from falling into the mold and molten uranium from coming in contact with the K-30 brick, a chimney (32) is added to the cover plate and a funnel (11) to the spillway. A steel spacer ring (35) is added between the inside ledge of the water-cooled extension and the outside of the cover plate to prevent the crucible and mold from swaying inside of the quartz tube (1), water-cooled extension (17), and water-cooled mold jacket (25). The thermocouple is held in place and at the correct height in the bottom of the crucible by a steel screw in the graphite collar (33).

In the 9 in. unit the graphite valve rod is shaped down to fit the

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Fig. 5 15 in. casting unit. (1) Closed end quartz tube, (2) sillimanite insulation lid, (3) outside sillimanite insulation shield, (4) inside sillimanite insulation shield, (5) graphite cupola, (6) graphite crucible lid, (7) graphite crucible extension, (8) graphite crucible, (9) graphite valve disc, (10) graphite spillway, (11) graphite spillway funnel, (12) graphite valve rod sleeve, (13) graphite valve rod, (14) upper steel cross arm, (15) rubber gasket, (16) water connection, (17) water-cooled extension, (18) upper part of graphite mold, (19) upper steel valve rod, (20) lower steel cross arm, (21) rubber gasket, (22) steel valve rod sleeve, (23) rubber sleeve, (24) lower steel valve rod, (25) water-cooled steel mold jacket, (26) welded steel cart, (27) lower part of graphite mold, (28) graphite egg cup, (29) rubber tired caster, (30) thermocouple, (31) insulation brick, (32) graphite cover plate chimney, (33) thermocouple collar, (34) graphite cover plate, (35) steel spacer ring, (36) thermocouple outlet, (37) 2 in. plug valve, (38) relief and testing valve.

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1/4 in. valve hole by sanding it lightly with fine emery cloth. This method is unsatisfactory for the 1/2 in. graphite valve rod (13) used in the 15 in. unit, since the hand sanding often produced an egg shaped rod and molten uranium will run down between the valve rod and valve rod sleeve (12). This is corrected by reaming the valve rod sleeve with a 1/2 in. reamer, and turning the valve rods on a lathe to 0.497 in. $\pm$ 0.002 in. This tolerance does not allow metal to flow through but does allow an easy working fit.

The biscuits for the 15 in. unit are about 8 1/2 in. in diameter and weigh about 125 lbs. They are lowered into the crucible with a steel packaging band attached to an electric hoist. Again the clearance between the biscuits and the inside of the crucible is too small to permit the use of a gripping device.

The 15 in. unit is heated with an induction coil that is 17 in. in length and 15.25 in. I.D. The coil is constructed from 1/2 in. annealed copper tubing and has 29 turns. It is mounted in the same manner as the 5.25 in. coil previously discussed.

A satisfactory casting procedure is as follows:

1. Set the bottom of the coil even with the bottom of the spillway.
2. Heat at maximum rate of converter or about 37 KW until the thermocouple records a temperature of 1300°C.
3. Reduce heating rate and hold the temperature of 1300°C from 5 to 10 min.
4. Turn off induction coil, cool to 1265°C and pour by pushing up valve rod at least 1.75 in.

Experiments using a crucible of the same dimensions but with the side wall constructed of glass, the bottom of graphite, and a hollow valve

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disc of balsam wood indicates that the valve must be raised at least 1.5 in. before it will float to the top when water is used to fill the crucible. The ratio between the density of water and the density of the special balsam valve used in these experiments is approximately the same as the density ratio for molten uranium and graphite.

The step for melting biscuits which stick in the upper part of the crucible is omitted from the above procedure for the 10 in. crucible since this difficulty is not encountered. The long ingots produced with the above procedure generally have larger pipes than the short ingots made with the 9 in. unit because more metal is involved and because no provision is made for giving the long ingots a hot top. The large diameter of the crucible on top of the mold, the length of quartz tubes, and the extra insulation needed for the 15 in. unit, make the hot-topping of these longer ingots more difficult than for the single length ingots. To eliminate the pipes in ingots for the double length billets the castings are made about 30 in. to 31 in. in length and the section containing the pipes is cropped off. Without decreasing the efficiency of the casting operation, the thickness of the top cropped from the longer ingots can be twice that of tops cropped from short ingots. After pouring the metal; the water, thermocouple, and vacuum lines are disconnected and the unit moved to the cooling line where it is connected to another vacuum line and cold water lines. Here the 15 in. units are allowed to cool for 3 to 4 hrs. No difficulty is ever encountered during the transfer from the heating position to the cooling position.

The vacuum for the casting operation is produced with a 100 c.f.m. Stokes Vacuum Pump equipped with a centrifugal clarifier and as an additional precaution a 2 in. Staynew Vacuum Filter is used in the line to

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protect the pump. In the cases where very slaggy biscuits are cast, a great deal of silica is deposited in the vacuum pump. This is thought to be due to the hydrolysis of silicon tetrafluoride which could be formed in the hot crucible and would not be stopped by the Staynew Vacuum Filter. To prevent the suspected silicon tetrafluoride from entering the pump, a bypass absorption tower is placed on the vacuum line. The absorption tower consists of a 6 in. pipe packed with moist caustic covered charcoal lumps about pecan nut size. The charcoal is covered with caustic by pouring a very concentrated solution over it and letting the excess drain off. It is kept moist by the addition of a little water in the intake end of the absorption tower. Although the maximum vacuum is limited by this arrangement, no more trouble was encountered with the deposition of silica on machined surfaces of the vacuum pump. The temperature of the water solution in the absorption tower is usually about 0°C at the low pressures of the vacuum employed.

Casting is ordinarily carried out under a vacuum of from 200 to 1000 microns. No decrease in casting yields is noted with pressures as high as 2000 microns, but pressures higher than that reduce the yield to some extent. In all runs where cast uranium is recast, the absorption tower is cut off and better vacuums are obtained. A Stokes McLeod gage is used for measuring the low pressures.

Usually about 37 KW is the maximum heating rate for the converters except immediately after the electrodes have been renewed and the mercury cleaned. It is necessary to replace the electrodes in the mercury pots and clean the mercury at least every two or three months. To insure long life for the electrodes it is necessary to completely dry the mercury pot and mercury before reassembling. A small amount of water in the

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spark pot will seriously erode a new pair of electrodes in two or three days.

Two sizes of inductors, or furnace coils, are used, as previously described. Both are constructed from annealed copper tubing and cooled by water circulated through the tubing. Enough potential is produced in the steel cart during heating to make grounding the cart necessary. It is also necessary to wrap the leads together from the converter to the induction coil to prevent their overheating and destroying the insulation.

The cooling line consists of a vacuum manifold, water connections, and a drain for waste cooling water. The vacuum on this line is produced by a 100 c.f.m. Kinney Pump protected by a Staynew Vacuum filter. After both the 9 and 15 in. units have cooled sufficiently on this line, they are disconnected and moved to the unloading area. In unloading, the quartz tubes are removed first, by a hoist equipped with a special grip manufactured by Kellems Products, Inc. of New York. This grip is constructed of wire mesh which tightens under tension and loosens under compression. The 9 in. quartz tubes can be safely removed by hand; but a Kellam's gripping device makes handling easier. In the case of the larger and heavier 15 in. quartz tubes, the use of a gripping device is imperative in protecting the quartz tubes from the breakage which was common in hand operation.

The remaining unpacking operation for both the 9 in. and 15 in. units is the same in most respects. After the removal of the quartz tube the unbroken sillimanite radiation shields are transferred to the movable insulation cart for re-use. The cupola, crucible lid and crucible extensions are transferred to the unloading table. The crucible and spillway from both the 9 in. and 15 in. units are transferred to a "burnout" furnace which will be discussed later. A long handled clamp is used for

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transferring the crucible and spillway containing the burning slag to the burnout furnace. This clamp consists of an 8 ft. length of gas pipe with a gripping device on one end and a short crossarm on the other and for a handle. It is supported by a chain fastened to the ceiling, which makes it a first class lever. The connection between the clamp and chain is such that the clamp can be rotated to invert the hot crucibles in the burnout furnace.

In the further unpacking of the 9 in. unit, the mold and ingot are placed on the unloading table by means of an electric hoist on a mono-rail. On the table, the mold is inverted and removed from the ingot by hand. When unpacking the larger 15 in. unit, the mold cover with its chimney is also transferred to the unloading table, and the top section of the graphite mold is removed by hand. The ingot and lower section of the mold, including the egg cup, are lifted from the water-cooled mold jacket by the electric hoist and moved to the unloading table. Here the lower section of the graphite mold is removed by hand from the lower end of the ingot while it is still suspended from the hoist. In cases in which a mold sticks on an ingot, tapping the mold with a rawhide hammer usually loosens it. After being lowered to the table, the ingots from both the 9 and 15 in. units are numbered according to the numbers on the casting sheets which have followed the crude charge through the entire process. Numbers are stamped in such positions that each part of the ingot will bear a complete number after it has been cut into the separate parts as shown in Figure 6. All sharp points or fins on the edges of a casting, or at the line where the two molds joined, are hammered down. All loose or semi-loose pieces of uranium on top of the ingot are knocked off and placed in a special scrap box. Any metal which has splattered and stuck to the cupola, crucible lid, mold cover, mold, and mold cover chimney

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Figure 6. Location of numbers on an ingot.

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is scraped off and placed in this box. These graphite parts are then transferred to the loading table for re-use. The contents of the "scrap-box", miscellaneous small pieces of uranium, are carefully weighed each day in order to account for all element.

After unpacking the cart is returned to the packing area and re-conditioned for another run. In production several carts are employed and kept in circulation throughout the cycle of loading, heating, casting, cooling, and unloading. Since the "bottleneck" of the entire operation is the heating and casting period, packed units are always kept available to connect to the heating system. Each of the two heating systems used consists of one induction coil connected to an Ajax converter, and a Stokes Vacuum Pump as described above.

All graphite which might stick to the ingot is removed by steel chip blasting or wire wheel buffing. The large ingots are handled and moved by rolling, hauling on carts made for the purpose, or by the monorail hoist. After cleaning, the ingots are transferred to a power hack saw for cropping. The egg and the top which included the pipes, are cut off as indicated in Figure 6. Then the egg is placed in a cutoff lathe and faced to the correct length. A portion of the turnings from this operation is taken for a chemical sample. The specifications for the egg sample are $2 \frac{1}{4}$ in. $\pm 1/16$ in. in diameter, no voids or pockets of foreign material, and 1900 ± 50 g. in weight. Specifications for the finished billets are as follows:

- (1) Diameter $4 \frac{1}{4}$ $\pm 1/8$ in.
- (2) Maximum length $13 \frac{1}{2}$, 22, or 27 in. depending on size being made.
- (3) No closed pipes or voids.

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accuracy required a pair of beam scales of high sensitivity was selected and proper measures were taken to protect them. A special steel rack was made to hold the billet on the scales. This rack is supported on four springs which can support the weight of the billet. Further, the billets are lowered slowly into this rack with an electric hoist. With this arrangement a pair of Fairbanks Morse beam scales calibrated to 0.01 lb. and with a capacity of 300 lbs. has stood up for over a year without repair. Weights of as much as 250 lbs. can easily be duplicated within a few hundredths of a pound on the above scales. After weighing, each billet is packed in a separate wooden box, which is banded with steel strap, and appropriately identified for shipping.

Since the cost of graphite is a major factor in the overall production cost, a special study was made on methods for conserving it. After each run all of the graphite parts are saved, if possible, for another run, with the exception of the valve disc, valve rod, and valve rod sleeve. The last three consume very small amounts of graphite and are discarded after each run. Since cupolas, crucible covers, mold covers and mold cover chimneys do not need checking by the graphite machinists, they are stored on the packing table as mentioned above for further use. The slag and metal remaining on the walls of graphite crucible extensions from both units are burned out, if necessary, and the graphite parts also stored on the packing table. All other parts for both the 9 and 15 in. units are checked in the graphite shop before being used again. Molds from both sizes of units are checked for cracks, visually. The condition of the interior surfaces is also checked. The height of the molds for the 9 in. unit, which is carefully checked during the first inspection, is very important since it affects the position of the thermocouple relative to the crucible. Any

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molds which are badly gouged on the inside are discarded. After checking the molds, the egg cup is checked for chipped edges where the egg cavity meets the ingot cavity. Quite often a portion of this edge adheres to the ingot and is pulled away. In case the egg cup has been chipped in this manner it is renewed and the molds and egg cups are then ready for another casting.

As described earlier the crucible and spillway are transferred to a burnout furnace in which they are inverted. The spillway is removed by placing a wooden block against its rim and tapping it gently with a hammer. Then a large, bushy gas flame is directed into the crucible. The slag and metal residue, which have adhered to the walls very tightly, oxidize and drop out in the form of a fine black powder which is mainly U_3O_8 . This black powder is referred to as "dross". To reduce breakage it is important that the crucibles are transferred to the burnout furnace while hot. Crucibles containing red hot residues quite often crack when exposed to cold air for short periods. Both the interior and exterior of the crucible are heated in the burnout furnace. After all of the residue is oxidized and most of it has fallen out, the crucible is cooled and all the remaining oxide brushed and blown out in a ventilating system connected to a cyclone separator. Special precautions are exercised to reclaim all oxidized slag or dross so that the uranium can be recovered from it. The crucible is checked for cracks by visual inspection and by sounding. An unsound crucible will not ring clearly when struck. The bottom is checked for flatness. If the metal in the spillway has pulled out a small piece of graphite from the bottom of a crucible, which might cause it to leak molten metal between the crucible and spillway, the crucible is discarded. The valve surface, on a crucible which has passed

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the inspection, is then re-faced sufficiently that a new valve disc can be ground in to seal it.

The spillway is placed on a special wooden block and all recastable uranium metal adhering to it is removed by means of hand tools. Then the spillway is transferred to the burnout furnace and the remaining metal and slag coating burned off. The excess oxide powder is also brushed from the spillways before they are sent to the graphite shop for reconditioning. There they are checked for cracks and for the smoothness of the top machined surface. It is necessary for this top surface to be plane and smooth so that its contact with the flat bottom surface of the crucible will provide a seal and prevent the molten uranium from running between the surfaces. As previously stated the valve rod sleeve, or bushing, is renewed in spillways for both units. The spillway funnel for the 15 in. unit is re-used if not broken; however, it is nearly always broken in chipping loose the small drops of uranium adhering to it and to the spillway. Consequently, nearly all 15 in. spillways are fitted with new spillway funnels.

After inspection in the graphite shop, all the parts for the 9 in. unit except the valve rod are assembled, checked for operation, and sent to the casting department as complete units. The parts for the 15 in. unit that are inspected and reconditioned by the graphite machinists are sent to the casting department individually and there assembled into complete units by the casting operators.

The consumption of graphite per pound of finished metal produced is an important factor since it accounts for a major part of the total casting cost. The shortage of graphite during the development of the casting process made the conservation of graphite very urgent. The

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molds and crucibles account for over 90 per cent of the total graphite consumption. The other major parts do not require as much graphite, and can quite often be fabricated from ends too short for making molds or crucibles. Under standard production, the graphite consumption varies from 0.10 to 0.16 lb. of graphite per pound of finished uranium. In cases where considerable development work is being carried out, the consumption varies up to as high as 0.45 lb. of graphite per pound of finished metal.

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Bibliography

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- (1) Spedding, F. H., Wilhelm, H. A., and Gray, C. F., "Early Methods for Casting Uranium at Iowa State College", reported in M.P.R. Volume 12-B.
- (2) Spedding, F. H., Wilhelm, H. A., and Moller, W. H., reported in CT-2712 (June 26, 1945) and "Production of Uranium Metal by Reduction of UF_4 by Magnesium" reported in M.P.R. Volume 12-B.
- (3) Spedding, F. H., Wilhelm, H. A., Hall, H. and Gray, C. F., "Machining of Graphite and Special Operations" reported in M.P.R. Volume 12-B.
- (4) Spedding, F. H., Wilhelm, H. A., Calderwood, T. and Gray, C. F., "Radiation Shields and Their Fabrication" reported in M.P.R. Volume 12-B.
- (5) Spedding, F. H., Wilhelm, H. A., and Gray, C. F. reported in A-1041 (June 16, 1944)
- (6) Spedding, F. H., Wilhelm, H. A., and Gray, C. F. reported in CT-751 (June 24, 1943)
- (7) Spedding, F. H., Wilhelm, H. A., and Gray, C. F. reported in CT-686 (May 22, 1943)
- (8) Spedding, F. H., Wilhelm, H. A., and Gray, C. F., "Developments in Cutting and Machining of Uranium at Iowa State College" reported in M.P.R. Volume 12-B.
- (9) Spedding, F. H., Wilhelm, H. A., and Gray, C. F. reported in A-1054 (August 1, 1944)
- (10) Spedding, F. H., Wilhelm, H. A., and Gray, C. F. reported in A-1020 (December 15, 1943)

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