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NATIONAL LEAD COMPANY
OF OHIO

April 25, 1961

SUBJECT: TRIP REPORT TO STAUFFER METALS COMPANY, RICHMOND, CALIFORNIA ON APRIL 4 TO APRIL 12, 1961

TO: F. L. Cuthbert, Technical Director

FROM: [illegible] Davis and [illegible] Hildenberry

OBJECTIVE OF TRIP:

The objective of this trip was to conduct a test designed to determine the capabilities of electron beam melting on the purification of uranium. A further objective of the visit was to discuss the feasibility of adapting the vacuum-locked, [illegible], ingot casting technique used at Stauffer Metals for electron beam melting to the direct casting of semicontinuous reduction product.

CONCLUSIONS AND RECOMMENDATIONS:

Uranium can easily be melted by electron beam (E. B.) melting techniques. All the advantages of E. B. melting will not be known until the metal has been analyzed. From the amount of outgassing observed, the metal should be refined to a degree unobtainable by either induction or arc melting.

Stauffer Metals would be willing to undertake the development of a casting system for the semicontinuous reduction process.

BACKGROUND FOR TRIP:

The plutonium production sites have an increasing interest in ingot metal quality. To provide the anticipated future quality of metal that will be required, the Metallurgy Department has undertaken a number of studies which will promote a more complete understanding of some of the practical aspects concerned with this problem. One of these studies involves a comparison of the effects of vacuum induction, consumable electrode electric arc, and electron beam melting on uranium quality; these processes cover the full range of vacuum furnace operating pressures for metal castings. The induction and arc melting projects have been completed and are being reported. The E. B. phase of the work was performed by Stauffer Metals Company. The work was performed under NLO purchase order No. H-15673 and approximately 600 lb of uranium was E. B. melted on a best effort basis.

PERSONS VISITED:

The following personnel were visited at the Stauffer Metals Company:

Dr. J. K. Y. Hum, Chief Metallurgist
W. G. Bauer, Technical Sales Manager
Alford Fonlevy, Project Engineer
Anthony Wormer, Furnace Operator
Jack Streitman, Production Supervisor
Harry Brown, Melt Shop Superintendent
M. P. Schlienker, Chief Engineer
D. F. Mastick, Plant Manager

DESCRIPTION OF TRIP:

The purpose of the trip was to single and double E. B. melt dingot, ingot, and pigot metal and produce three-inch diameter by approximately eight-inch long ingots.

A 30 kw E. B. furnace was used. The furnace was located in Stauffer Metals Company beryllium laboratory, which was an isolated facility. The furnace was contained in a rectangle vacuum chamber about 3 ft by 3 ft by 5 ft-6 in. It was connected through sealed ports to the vacuum system, ingot puller, power source and remote controls for the electron gun. It contained mechanisms for suspending and moving the feed rod and for moving and pulsating an ingot stool in a water cooled crucible.

The electron beam gun filament was heated with a-c power and operated at 48 volts and 9 amps. Direct current at 5 to 10 kv and 2 to 3 amps was used for melting.

The vacuum system consisted of 115 CFM Kinney mechanical pump, a 500 liter per second jet pump, a 7000 liter per second, 20 inch oil diffusion pump.

In brief, the operation of the furnace was as follows:
The feed stock was suspended by a tantalum wire from the feed drive rod and centered through the electron beam gun over the crucible. The furnace was closed and the furnace pressure reduced to 2×10^{-6} mm of mercury. The filament was heated by a-c power at 48 volts at 9 amps and the high voltage d-c power was supplied at 5 to 6 kv at 2 to 3 amps. The ingot puller cup was positioned one-half to one-inch below the crucible top, and the feed rod was lowered down into the gun where the uranium started to melt.

The beam passed at an angle through the lower end of the feed stock and focused on the crucible area. Some beams were reflected upward and assisted in heating and melting the end of the feed rod. The uranium melted and dripped into the top of the crucible at a temperature only slightly above the melting point of uranium (1133°C - 2072°F). However, when a heavy oxide layer was present on the rod surface (as was the case with pigot feed) the temperature of the uranium oxide case appeared to reach upwards of 3000°F before falling into the crucible. The liquid bath in the crucible became superheated and outgassed vigorously.

The melting rate of the uranium depended on the feed "purity" - the greater the outgassing rate the slower the melting rate. As the uranium feed outgassed and increased the pressure in the gun area to above 4×10^{-4} mm of mercury the gun ceased to operate. As the pressure in the gun area decreased to less than 4×10^{-4} mm of mercury the melting started again. Melting rates in inches per hour were based on the rate at which the ingot forms, not the rate at which the feed material was melted. Except for greater power requirements, the maximum feed rate for a metal is the same whether a 2 in. ingot or a 20 in. ingot is being produced. The cleaner the metal, the faster the melting rate.

Three types of uranium feed material were used for the tests:

a. A seven inch diameter dingot was selected at random.
b. A dirty ingot was produced from one grade III derby. and degreased drip crops. Additions of 18 grams each of Mn, Sn, Cu, and Ni and 90 grams of Zr were added to the charge.
c. Under salt melted metal was used to produce a seven inch diameter "salt melted ingot" which will be called pigot in this report.

The three types of uranium were all rolled to 2-1/16 in. by 2-9/16 in. ovals, each rod was cut to suitable lengths for E. B. melting and each piece was sampled and analyzed. The average chemical analyses of the feed material are given in Table 1.

Two melting rates were used for each type of material tested. A fast rate was established and pieces were melted at that rate and then companion pieces were melted at approximately one-half the fast rate. The number of ingots produced and feed rates are given in Table 2.

The pigot metal was the dirtiest. For this material the fast rate was only 16 inches per hour and the weight loss was 1.4 per cent.

The dingot was cleaner than the pigot and there was less outgassing and the fast melting rate was 22 in. per hour. The loss during melting decreased to 0.7 per cent.

The ingot was the cleanest metal of the three types melted and a fast melting rate of 26 in. per hour was obtained. The weight loss during melting was only 0.2 per cent.

Table 3 gives a summary of the material balance.

MISCELLANEOUS COMMENTS:

The furnace used for this work is primarily used by Stauffer Metals Company to melt beryllium. The furnace is over 5 years old and many changes have been made on it as progress has been made in the technology of E. B. melting. The crucibles and ingot puller were in need of replacement as the ingot puller frequently stuck in the crucible. During the test, the in and out travel mechanism of the gun broke and it was subsequently operated manually.

Even though the furnace was old and in need of repair, the E. B. melting was completed satisfactorily. E. B. melting is a "self control" melting operation and the melting rate has to be adjusted to the quality of the melt stock. If the furnace pressure increases beyond a critical pressure the gun will not emit electrons and melting stops.

Stauffer Metals has available a 225 kw electron beam furnace and is installing a large consumable electrode arc furnace to produce ingot sizes up to 16 in. OD. They will solicit development work in which both process are used.

The personnel at Stauffer Metals Company were cooperative in every way. Their operator, Anthony Wormer, worked many overtime hours (without pay) to complete the test.

COMMITMENTS:

None.

Herbert Davis

Herbert Davis

H M Eikenberry

H. M. Eikenberry

HD HME/elh

cc: J. H. Noyes (3)
C. R. Chapman
C. E. Polson
P. N. McCreery
R. L. Fischoff

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TABLE 1

AVERAGE CHEMICAL ANALYSES OF THE FEED MATERIAL

	Dingot	Ingot	Pigot
C ppm	10	748	271
N ppm	18	112	31
O ppm	22	94	64
H ppm	2.77	1.46	2.52
Fe ppm	158	109	165
Ni ppm	21	77	25
Si ppm	100	35	71
Zr ppm	<5	67	<5
Al ppm	27	6.0	13.2
B ppm	<.2	<.2	.8
Bi ppm	1.6	1.4	1
Cd ppm	<.2	<.2	<.2
Cr ppm	15	13	8.8
Cu ppm	3	32	19
Mg ppm	4.4	8	70
Mn ppm	14	130	11
Mo ppm	<6	<6	<6
P ppm	<20	<20	<20
Pb ppm	2	1.8	107
Sn ppm	1.8	45	2.8
V ppm	<40	<40	<40
Zn ppm	22	<20	<20
Ti ppm	<4	<4	<4
Be ppm	<1	<1	<1

TABLE 2

MATERIAL BALANCE AND AVERAGE FEED RATES

Ingot No.	Type of Feed	Date	Feed in lbs	Ingot out lb	Stub out lb	Loss	Feed Rate in./hr	Remarks
X-1	Dingot	4/4	41.1	35.0	6.0	0.1	9	
X-2	Dingot	4/4	41.2	35.2	5.8	0.2	22	
X-3	Dingot	4/5	54.2	42.0	5.7	0.5	9	First 2 in. melted at rate of 2 in./hr
X-4	Dingot	4/6	54.2	41.3	12.7	0.2	22	
T-5	X-3	4/5	48.0	31.7	16.0	0.3	9	Melted in 3 sections because of mechanical trouble.
X-6	X-4	4/6	41.3	25.1	16.1	0.1	22	
T-7	Ingot	4/7	41.2	[illegible]	6.1	0.2	15	
T-8	Ingot	4/6	41.2	30.8	10.3	0.1	26	
T-9	Ingot	4/8	53.8	43.7	10.1	0.0	11	
T-10	Ingot	4/7	53.8	42.0	11.4	0.0	22	First 3 in. melted at 7 in./hr; last 6 in. at high rate.
T-11	T-9	4/10	43.7	25.2	18.4	0.1	24	
T-12	T-10	4/8	42.0	33.4	8.5	0.1	25	
W-13	Pigot	4/10	[illegible]	35.7	15.0	0.2	9	
W-14	Pigot	4/10	[illegible]	[illegible]	8.3	0.5	16	
W-15	Pigot	4/10	52.0	41.1	11.5	0.4	15	
W-16	Pigot	4/10	52.8	38.4	13.8	0.6	6	
	W-15		41.1		18.3			
W-17		4/11		40.7		0.8	6	6 lb of scrap was produced because of stuck ingot puller. W-16 was melted on top of W-15 to make ingot W-17.
	W-16		38.4		13.7			

TABLE 3

SUMMARY MATERIAL BALANCE TABLE

		Dingot	Ingot	Pigot	Total
Primary rod weight in furnace	lb.	190.7	189.6	187.3	567.6
Secondary ingot weight in furnace	lb.	89.3	85.7	79.5	254.5
Primary rod melted	lb.	159.5	151.4	137.0	447.9
Secondary ingot melted	lb.	56.8	58.6	40.7	156.1
Total metal melted	lb.	216.3	210.0	177.7	604.0
Primary rod stubs (metal not melted)	lb.	30.2	37.9	48.6	116.7
Secondary ingot stubs	lb.	32.1	26.9	32.0	91.0
Scrap	lb.	0	0	6.0	6.0
Loss	lb.	1.4	.5	2.5	4.4
Metal returned to NLO:					
Primary ingots	lb.	70.2	65.7	57.5	193.4
Secondary ingots	lb.	30.2	37.9	48.6	116.7
Primary stubs	lb.	56.8	58.6	40.7	156.1
Secondary stubs	lb.	32.1	26.9	32.0	91.0
Scrap	lb.	0	0	6.0	6.0
Loss	lb.	1.4	0.5	2.5	4.4
Total	lb.	190.7	189.6	187.3	567.5