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PRODUCTION REPORT

ON

THE ROLLING OF TWO HUNDRED URANIUM INGOTS

AT

ALLEGHENY-LUDLUM STEEL CORPORATION

ON

FEBRUARY 9th and 10th, 1952

BY

R. S. STEWART

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AEC RESEARCH AND DEVELOPMENT REPORT

March 7, 1952

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TABLE OF CONTENTS

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A REPORT OF THE ROLLING OF TWO HUNDRED URANIUM INGOTS AT [illegible] LUDLUM STEEL CORPORATION, WATERVLIET, NEW YORK ON FEBRUARY [illegible] 19[illegible].

General

The following is a brief outline of some of the mill techniques and equipment used at Allegheny-Ludlum Steel Corporation, Watervliet, N.Y. for the rolling of uranium ingots.

The ingots are brought to a position adjacent to the salt bath on small flat cars. The flat cars hold ten ingots arranged in the order in which they are to be charged to the salt bath. An overhead crane transfers the ingots from the flat cars to the salt bath.

The salt bath has a capacity of ten ingots. Loading of ingots is scheduled so that each ingot soaks for a definite period, i.e., continuous loading is used rather than batch loading. After a suitable soaking period the ingots in turn are withdrawn from the salt bath and carried to the run-on table of the blooming mill. The temperature of the salt bath is measured with four thermocouples, one of which is at each corner of the bath.

The salt bath is a gas-fired, steel lined, brickpot type furnace having a rectangular shape. The salt used is a 45:55 mixture of lithium and potassium carbonates. The ingots, while in the furnace, are on two inclined rails, so the transfer of ingots from the loading end of the furnace to the unloading end is essentially by gravity feed.

The rolling schedule is posted on a small blackboard near the salt bath. A man stationed at this blackboard checks the loading of ingots to the salt bath to insure proper scheduling.

Ingots are withdrawn from the salt bath with the same overhead crane and steel hook that is used for loading. As each ingot is withdrawn from the salt bath, its temperature is measured with a radiation pyrometer (Brown Co., Radiamatic). The ingots are then put on the run-on table of the mill. The temperature of each ingot is measured as it rests on the run-on table.

The rolling of the ingots is done in a Birdsboro 22-inch, two-high reversing mill. Suitable pass schedules are used to roll to any prescribed billet cross section.

Facilities are available to add additional salt to the material at any time during the rolling schedule. Salt added during the rolling is added in a solid form.

After the ingot has been rolled to the desired form, the billet is conveyed on the run-out table of the mill to a position just off the run-out table. Here, measurements of the finishing temperature and the [illegible] of the billet are made.

The billets are carried to a cropping and shear station. Enough of the front and back of the billet is cropped to remove all unsound metal. The billets may be sheared, as required, to accommodate the dimensions of the salt bath at Bethlehem Steel Company's Lackawanna Works.

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PROCEDURE USED IN THE ROLLING OF THE INGOTS

The procedure that was followed in the rolling of the ingots was decided in a meeting held at the NYOO, AEC on January 31, 1952.

(a) The Material for Hanford

One hundred and twenty (120) ingots were rolled for HEW. The pass schedule that was followed is that which is outlined in Birdsboro print no. 34562, Rev. 1/22/52. This pass schedule is as follows:

Pass No.	Print Pass No.	Shape	Size	Roll Parting	Area	Reduction
1	1	BH	5-1/8 x 4	4	16.9	[illegible]
2	2	BH	5-1/4 x 3-1/8	3-1/8	14.3	14%
3	3	Edge	4-5/8 x 3-1/4	7/8	13.3	8%
4	4	BH	4-15/16 x 3-1/8	3-1/8	13.1	[illegible]
5	5	Edge	4-1/4 x 3-1/4	1/2	11.9	9%
6	6	BH	4-21/32 x 2-7/16	2-7/16	10.3	13%
7	7	Edge	3-1/2 x 2-1/2	1/2	8.6	17%
8	8	BH	3-19/32 x 2-3/16	2-3/16	7.7	10%
9	9	Edge	3-1/8 x 2-1/4	1/2	6.3	18%
10	18	Oval	2-15/16 x 1-29/32	7/32	4.775	24%
11	19	Edged Oval	2-9/16 x 2-1/16	1/4	4.15	13%

The ingots were rolled in two groups. The ingot numbers of the first group were 1-56 inclusive. The second group of ingots were numbered 102-165 inclusive.

All of these ingots were conditioned before rolling except ingots 161-165 inclusive.

In the rolling of these ingots, five (5) cobbles were produced.

A dry salt addition was made to each billet after the eighth pass.

All unsound metal was cropped from each billet after rolling.

The data on the temperature measurements made on these ingots is shown in Appendix A of this report. In recording the data of the rolling, the sequence used in rolling has been maintained in the data sheets. The temperature data for the HEW material is found on pages 1A, 2A, 6A, 7A, and 8A.

(b) The Material for Chalk River

The procedure that was to be followed in the rolling of billets for Chalk River was decided at meetings held in NYOO, AEC on January 16 and February 4, 1952. (A previous schedule had been revised in order to use ingots that had been cast after December 1951.)

The ingots used in this rolling were all of the 7,000 series.

The ingots were rolled using the same pass schedule that had been used for the Hanford material.

Rolling was done at four different temperatures, as will be noted from the temperature data sheets 4A and 5A in Appendix A.

Thirty four ingots were rolled in the group and no cobbles were produced.

The Chalk River billets are number 67 - 100 inclusive.

(When the rolling of this experimental group was underway it was discovered that the salt bath loading of ten of the old series of ingots had been started. Since it was felt that this experiment was of the utmost importance, these ten ingots were rolled into billets for FMPC for later use in the Argonne CP-6 reactor. Additional ingots of the 7000 series were then rolled to replace these older ingots for this experiment).

After these billets had been rolled, the section twelve inches from the head end of the billet was cropped to remove all of the metal that had been in the three inch cone at the bottom of the ingot.

(One of the ingots that was to have been rolled in this experiment was lost between the rolls of the salt bath. This ingot was removed at the end of the rolling and rolled as the last ingot of those rolled for FMPC.)

During the rolling of the Chalk River billets of heat 117[illegible], the temperature of the billets was determined after the 8th pass (immediately prior to the salt addition). This data has not been presented in the other data sheets and accordingly it is recorded here as follows:

INGOT	TEMPERATURE OF THE BILLET AFTER THE 8th PASS - °F
7369	1112
7364	1100
7322	1148
7366	1143
7367	1091

c. The Material for FMPC

The ingots rolled for FMPC are scheduled for fabrication into fuel elements for the ANL CP-6 reactor. Ingot numbers 57 - 66 inclusive, 166 - 200 inclusive and ingot number 96 were rolled in this group.

In the rolling of ingot numbers 57-66, the conventional schedule given in print no. 34562, rev. 1/22/52 was used. This schedule is as follows:

Pass	Print Pass No.	Shape	Size	Roll Parting	Area	Reduction
1	1	BH	5-1/2 x 4	4	16.9	16%
2	2	BH	5-1/4 x 3-1/8	3-1/8	14.43	14-1/2%
3	3	Edge	4-5/8 x 3-1/4	7/8	13.3	8%
4	4	BH	4-11/16 x 3-1/8	3-1/8	13.1	2%
5	5	Edge	4-1/4 x 3-1/4	1/2	11.9	9%
6	6	BH	4-21/32 x 2-7/16	2-7/16	10.3	13%
7	7	Edge	3-1/2 x 2-1/2	1/2	[illegible]	[illegible]
8	8	BH	3-19/32 x 2-3/16	2-3/16	[illegible]	15-1/2%
9	9	Edge	3-1/8 x 2-1/4	1/2	6.92	10%
10	10	BH	3-11/32 x 1-13/16	1-13/16	5.97	13-1/2%
11	11	Edge	2-3/4 x 1-7/8	1/2	5.0[illegible]	15-1/2%
12	12	BH	2-29/32 x 1-9/16	1-9/16	4.5	11-1/2%
13	13	Edge	2-5/8 x 1-5/8	1/2	4.214	6-1/2%
14	14	BH	2-21/32 x 1-7/16	1-7/16	3.81	9.5%
15	15	Edge	2-1/8 x 1-7/16	1/4	3.04	20.3%
16	16	Oval	2-7/32 x 1-3/8	1/4	2.72	10.8%
17	17A	Edged Oval	1-15/16 x 1-15/32	5/16	2.35	13.6%

The ten ingots were rolled without producing a cobble. Temperature data of ingots rolled with this schedule are shown on Page [illegible] of Appendix A.

The remaining thirty-six ingots were rolled using a modified schedule of the one shown above. In this modified schedule four passes were eliminated. These passes are shown below.

Pass	Print Pass No.	Shape	Size	Roll Parting	Area	Reduction
3	3	Edge	4-5/8 x 3-1/4	7/8	13.3	8%
4	4	BH	4-11/16 x 3-1/8	3-1/8	13.1	2%
12	12	BH	2-29/32 x 1-9/16	1-9/16	4.5	11-1/2%
13	13	Edge	2-5/8 x 1-5/8	1/2	4.214	6-1/2%

The thought behind this modified schedule is that pass numbers 3 and 4 are too light. The rolling of any material has shown that light passes have only a skin effect on a billet. This causes the edges of the billet to become concave. During edging passes on concave edges the corners of these edges have a tendency to spread out and eventually a seam will occur along the length of the bar. The ideal condition is to take drafts that are heavy enough to produce convex edges at all times. This means that drafts should be heavy enough to cause movement of metal all the way through the billet. Similarly, passes 12 and 13 are light and were eliminated for the same reason, although, the problem is not as serious as it is for passes 3 and 4.

Fifteen of these thirty-six ingots were unconditioned.

As a result of the elimination of these four passes, the actual pass schedule used on ingot numbers 166-200 and ingot number 97 is as follows:

Pass	Print Pass No.	Shape	Size	Roll Parting	Area	Reduction
	0		ingot size			
1	1	BH	5-1/8 x 4	4	16.9	14%
2	2	BH	5-1/4 x 3-1/8	3-1/8	14.43	14.5%
3	5	Edge	4-1/4 x 3-1/4	1/2	13.28	8%
4	6	BH	4-21/32 x 2-7/16	2-7/16	11.35	14.5%
5	7	Edge	3-1/2 x 2-1/2	1/2	8.75	23%
6	8	BH	3-21/32 x 2-3/16	2-3/16	7.80	10.3%
7	9	Edge	3-1/8 x 2-1/4	1/2	7.03	9.3%
8	10	BH	3-11/32 x 1-13/16	1-13/16	6.06	13.8%
9	11	Edge	2-1/2 x 1-7/8	1/4	4.69	22.6%
10	14	BH	2-23/32 x 1-7/16	1-7/16	4.00	14.7%
11	15	Edge	2-1/8 x 1-7/16	1/4	3.10	22.5%
12	16	Oval	2-7/32 x 1-3/8	1/4	2.73	11.9%
13	17A	Edged Oval	1-15/16 x 1-15/32	1/4	2.35	13.9%

Only one (1) cobble was produced from thirty-six (36) ingots rolled with this schedule.

It is of interest to point out that ingot 7312, the last ingot rolled for FMPC was in the salt bath for nearly fourteen hours. It will be interesting, to follow the history of slugs produced from this billet.

Temperature Measurement and Control

The following comments are included as a discussion on temperature measurement and control.

There has always been doubt in the minds of those attending the rollings about the reliability of the methods of temperature control and measurement. In order to evaluate the techniques that are being used, a test was performed to determine the variation in temperature readings obtained with a Radiamatic Pyrometer vs. a thermocouple. A piece of equipment was brought to the rolling with the view of obtaining simultaneous temperature readings with both a Radiamatic Pyrometer and a thermocouple.

Essentially, the apparatus was a holder for a short section of an uranium billet. Two holes were drilled into the section of the billet and thermocouples were placed in these holes. One hole positioned one thermocouple about one-eighth (1/8) of an inch below the surface of the section; the other hole positioned the other thermocouple in the core of the section. The Radiamatic Pyrometer was held over the section at the point where the thermocouple came within an eighth of an inch of the surface. This set up allowed three simultaneous readings to be taken on the section of the billet. A portable potentiometer was used to measure the potential (i.e., the temperature) of the thermocouples.

[illegible] billet section was heated in the salt bath. After [illegible] the [illegible] was held suspended just above the surface of the [illegible] so that the [illegible] would cool slowly. Figure 2, page 1-2B shows the cooling curve taken during one of the tests. The break in the curve is a result of lifting the ingot and allowing it to air cool.

The data shown in Figure 1 will allow us to correct the temperature data presented in this report. (NOTE - The temperature data in this report has NOT been corrected, since it is felt that much more data must be obtained in order to get an accurate calibration of the Pyrometer.)

In another experiment, tests were performed to determine the effect of the thickness of the layer of salt on the temperatures read with the Radiamatic Pyrometers. The following table shows the results of these tests:

Billet No.	Temperature	Surface Condition
2444	1040	Irregular Salt Coating
	1020	" " "
	975	" " "
	1030	" " "
2442	1090	No Salt
	1005	Salt Coating
	1080	No Salt
	1045	Salt Coating
	1030	No Salt
	1015	No Salt
2543	1070	Brushed
	1050	"
	1040	"
2443	1040	"
	1075	"
	1070	"
	1070	"
	1050	"

These results show that the temperatures measured on a finished rod are not consistent. On a finished rod, the range of temperatures measured is as much as 90°F. When the rod is brushed, the excess salt is removed and the layer of salt remaining is of uniform thickness. Even with brushing, however, the difference in temperatures along the rod is still as much as 30°F.

It has been shown in actual tests that when the copper pipe holding mount for the Radiamatic head touches the ingot, erratic readings are obtained. If this is a function of the heat conductivity of copper, it would be advisable to fabricate a holding head of nonconducting material. In addition to this it might be desirable to place two nonconducting pegs at the opening of the mount and let the pegs actually touch the ingot. It is probable that this would give more consistent results to this manual operation.

INDUSTRIAL HYGIENE REPORT OF AIR SURVEY

Scope and Purpose

An air survey was made in conjunction with the rolling operations at the Allegheny Ludlum Plant in February. The purposes of this survey were:

1. To estimate the expectable dust concentrations from rolling ingots heated in a salt bath.

2. To compare the results with those from previous surveys made by the AEC when gas furnaces were being used for heating ingots.

Summary of Results

The air dust concentrations obtained in the February survey ranged from 2.4 to 152 d/m/M^3. These were very much lower than those obtained in previous surveys.

Table I which follows is a summary of the results of recent survey. In Table II a comparison is made with previous results.

Data

Table I - Summary of February '52 Dust Results

Sample Description	No. of Samples	Concentration (2) d/m/M^3 low	high	average
1. G.A.(1) Salt Bath Area	5	4.8	26.2	12.4
*2. G.A. under pulpit 3' over run-on table while rolling	3	10.8	28.8	17.2
3. G.A. in Pulpit	2	4.8	6.0	5.4
4. G.A. Mill & Pulpit Area	2	13.2	13.8	13.5
5. Process 3' over and facing blooming mill	6	77.	152.	101.
6. G.A. on platform over blooming mill	4	2.4	120	30.3
**7. G.A. at 18" mill over runout to shear (mill not used for rolling but water spray striking billet at this point)	3	81.	139.	106.
8. G.A. along runout	2	7.2	13.5	10.4
9. Process, at shear	2	15.3	41.5	28.4
10. Process, billet stamping	2	27.5	78.	50.5
11. G.A. shear & stamping area	2	10.8	45.	27.9

(1) G.A. - General Air (Sample)
(2) Disintegrations/min/cu. metre

* Same as (2) not rolling	1	3.6
** Same as (7) not rolling	1	7.8

Table III - Comparison of February Results with those of [illegible]

	Feb. '52	Jan. '51		[illegible]	
	d/m/M³	d/m/M³	[illegible] of Feb. '52 level	d/m/M³	[illegible] of Feb. '52 level
Process-blooming mill	101.	16800	166	[illegible]	54
G.A. Mill Area	13.5	280	21	----	--
G.A. under Pulpit	17.2	-----	---	2250	130
G.A. in Pulpit	5.4	250	46	----	--

Discussion

As seen in Table I, the highest concentration found was directly over the blooming mill. This concentration of 152 d/m/M³ is 2.2 times the MAC (70 d/m/M³). (= Maximum Allowable Concentration)

The highest general air sample was in the 18" mill, about midway between the blooming mill and the shear. One sample collected here was 2.0 times the MAC, the average of 3 samples being 1.5 MAC. As noted, there was a water spray striking the billet as it passed this section of the [illegible]. To our knowledge the water had nothing to do with the process. In all probability the quenching of the billet caused a flaking of the sal[illegible] with some oxidation which increased the air concentration at this point.

Conclusions

1. The results of this survey show conclusively that the salt coating on the heated ingots is a great help in preventing oxidation with result that much lower air concentrations are found with this [illegible]tions.

2. Anything in the process which causes a removal of the salt coating before the billet has cooled will result in somewhat higher concentrations than would be found normally.

3. Though the MAC was exceeded in some of the process samples, all the general air samples were well below the MAC. It is assumed that no person in the mill area is exposed to an average concentration in excess of the MAC.

4. It is possible that no ventilation will be required on the mill; however, routine cleaning of the mill and all surfaces with which the metal comes in contact is a must if concentrations are to be kept low.

Recommendations

It is recommended that proper attachments for vacuum cleaning the mill be obtained and that the vacuum cleaning be used for cleanup following each rolling.

INGOT NO.	SURFACE CONDITION	LENGTH OF SOAKING PERIOD (min)	SALT BATH TEMP. WHEN INGOT DRAWN (°F)	INGOT TEMP. out of SALT BATH (°F)	INGOT TEMP. ON RUN ON (°F)	FINISHING TEMPERATURE (°F)
		Group A [illegible]				
[illegible]			1150			
[illegible]			[illegible]			
[illegible]			1180			
[illegible]			1190			1117
[illegible]			[illegible]			1047
[illegible]			[illegible]			[illegible]
[illegible]			[illegible]			
[illegible]			1190	1120	1103	1010
[illegible]			1185	1121	1064	975
[illegible]			1150	1153	1022	1032
[illegible]			1135	1102	1125	1020
[illegible]			1105	1133	1100	1032
[illegible]			1105	1127	1113	975
[illegible]			1185	1141	1116	1020
[illegible]		00:33	1185	1155	1029	1040
[illegible]	6 Hooks, One 2 One Inch	00:34	1180	1136	1061	1010
[illegible]	15 Small Holes	00:35	1190	1150	1044	996
[illegible]	Good	00:37	1190	1123	1104	952
[illegible]	7 Shallow [illegible] Holes	00:39	1190	1130	1104	1092
[illegible]	Good	00:40	1190	1107	1120	1000
[illegible]	Good, 2 Shallow [illegible]	00:42	1188	[illegible]	1104	905
[illegible]	Good	00:44	1188	1110	1102	931
[illegible]	Good	00:46	1185	1151	1119	1005
[illegible]	Good	00:46	1185	1156	1090	1020
[illegible]	Bad Pipe in Middle	00:47	1185	1150	1067	[illegible]
[illegible]	Good	00:47.30	1185	1162	1090	[illegible]
[illegible]	Good	00:47	1182	1162	1102	[illegible]
[illegible]	Good	00:47	1185	1152	[illegible]	[illegible]
[illegible]	Good	00:51	1188	1170	[illegible]	
[illegible]	[illegible] Shallow [illegible] Hole	00:49	1190	[illegible]	[illegible]	

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THE ROLLING OF TWO HUNDRED AND ELEVEN

URANIUM BILLETS AT ALLEGHENY LUDLUM STEEL CORPORATION

WATERVLIET, N.Y. ON MARCH 8, 1952

At this rolling, two hundred and eleven uranium ingots were rolled into billets according to the following schedule:

Pass No.	Print Pass No.	Section	Parting (in.)	Area (in^2)	Reduction (%)
1	1 - B.H.	5-1/8 x 4	4	16.90	14
2	2 - B.H.	5-1/4 x 3-1/8	3-1/8	14.43	14.5
3	5 - Edge	4-1/4 x 3-1/4	1/2	13.00	10
4	6 - B.H.	4-21/32 x 2-7/16	2-7/16	11.34	12.8
5	7 - Edge	3-3/4 x 2-1/2	3/4	9.37	17.4
6	8 - B.H.	3-27/32 x 2-3/16	2-3/16	8.40	10.3
7	9 - Edge	3-1/8 x 2-1/4	1/2	7.03	16.0
8	10 - B.H.	3-11/32 x 1-13/16	1-13/16	6.06	13.8
9	11 - Edge	2-3/4 x 1-7/8	1/2	4.94	18.4
10	12 - B.H.	2-29/32 x 1-9/16	1-9/16	4.53	10.3
11	13 - Edge	2-5/8 x 1-5/8	1/2	4.26	6.0
12	14 - B.H.	2-21/32 x 1-7/16	1-7/16	3.81	10.6
13	15 - Edge	2-1/8 x 1-7/16	1/4	3.04	20.3
14	16 - Oval	2-7/32 x 1-3/8	1/4	2.73	10.2
15	17A-Edge Oval	1-15/16 x 1-15/32	5/16	2.35	13.8

Originally, the soaking temperature of the ingots was to have been 1175 ± 15° F. During the rolling, however, duPont's representatives requested that the salt bath temperature be raised to 1210° F. The temperature of the salt was raised after the first sixty-eight ingots had been rolled.

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One other significant change in the rolling operation was made during the rolling. This change was concerned with the procedure used to add solid salt during the rolling. The first twenty-five ingots were rolled with salt addition to the billet, on four sides, after the eighth pass. The remaining billets received an additional application of salt to the top of the billet after the sixth pass.

The data gathered on this rolling are shown on pages 12 through 22. It should be noted that all the temperatures appearing in the data have been corrected in an effort to obtain true temperature readings in lieu of the recorded Radiamatic temperatures.

Temperature Measurement and Control

The tests that were made to determine the accuracy with which the temperature measurements were being measured, included the use of tempilsticks and a calibration test of the radiation heads using the test billet section shown in the sketch on page 25.

For this and previous tests, the Radiation Pyrometer heads have been calibrated by Brown Instrument Co. at their plant in Philadelphia (under their contract with NLOO for the development of a suitable radiation head).

Prior to each rolling, the heads to be used for that rolling are calibrated under black body laboratory conditions.

The calibration checks using the test billet section at the rolling site seem to indicate that -

(1) The conditions under which the heads are calibrated do not accurately duplicate the operating conditions.

(2) The standards, (used by Brown) which the heads are calibrated against, do not produce uniform results over a period of time.

It has, therefore, been determined that the heads used for any subsequent rollings will be calibrated at the rolling site using the test billet section.

As more data is compiled, it is believed that an accurate calibration factor for each 50° temperature span will be developed.

Meanwhile, the adjusted temperature readings for this rolling must be considered as reliably accurate as is possible to obtain with the data presently available.

In correcting the data, the data of test number 1, shown on page 23, has been used.

Conclusions:-

The following general conclusions may be made:

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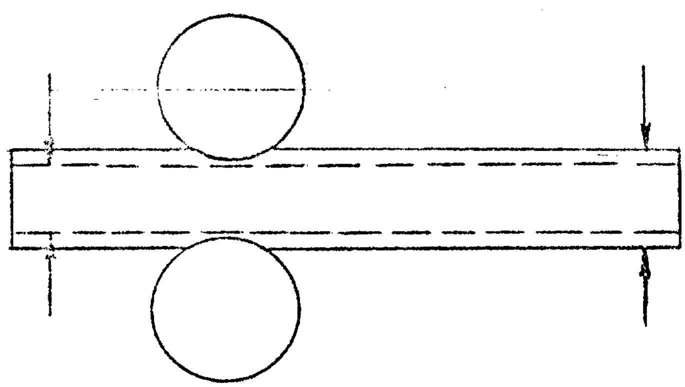
1. Salt Addition

The data show that the amount of salt added to the billets during the rolling causes a great deal of slip between the rolls and the billet. This is evidenced by the billets that have been noted as having slipped or turned down when entering the ninth pass.

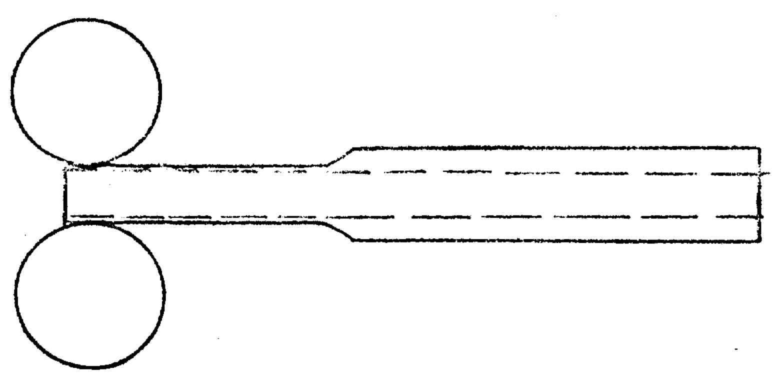
2. Tapering of Ingot (and Billet)

The tapering referred to in this report is the technique that the roller has had to resort to in order to get the ingot (billet) into the rolls. In this operation, the roller must open his rolls in order to have the ingot (billet) enter the rolls. Once the ingot (billet) was in the rolls, the roller closed the rolls down on the ingot and proceeded to taper one end of the ingot (billet). When this tapering had been done, the rolls were adjusted to obtain the correct roll parting and the ingot (billet) was then given the proper reduction. This tapering may be shown schematically as follows:

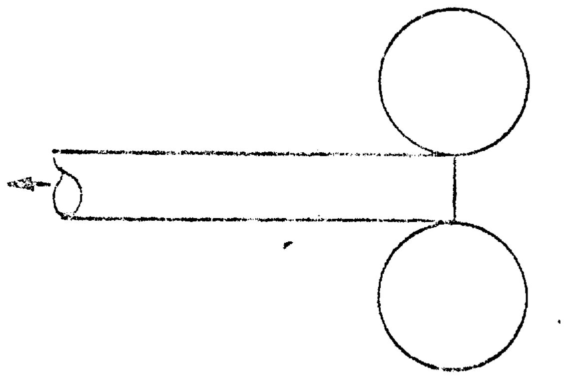
I The Rolls Compress the Ingot (Billet)



II The Ingot is Tapered



III Here the Rolls are Adjusted to Give
The Correct Parting for the Particular Pass



Essentially, it can be seen that this tapering does not result in a uniform working of the billet. In particular, the schematic representation shows that after Stage II, the lead end of the ingot (billet) receives only a light pass, whereas, the tail end receives the full pass that is specified.

It is felt that this light reduction on, say, the leading third of the ingot (billet) is instrumental in producing seams, in that it probably doesn't produce convex sides on the billet. This effect would be more detrimental as the billet is worked in the later passes.

From an examination of the data sheets it will be seen that several of the ingots have been tapered on the third, fourth, and fifth passes. If this tapering is to have any effect upon the final condition of the finished rolled bars, the effect should be noted more in the - 1 bar and the - 3 bar, than it would be in the - 2 bar. (i.e., tapering on the even numbered passes effects the - 3 bar.)

3. Flow of Uranium During Rolling

While this rolling was being performed, measurements were made to determine the section of the billet after several of the passes. The passes for which these measurements were made and the section of the billet made in these passes is given in the following table. The figures in parenthesis represent the sections that have been calculated for these particular passes.

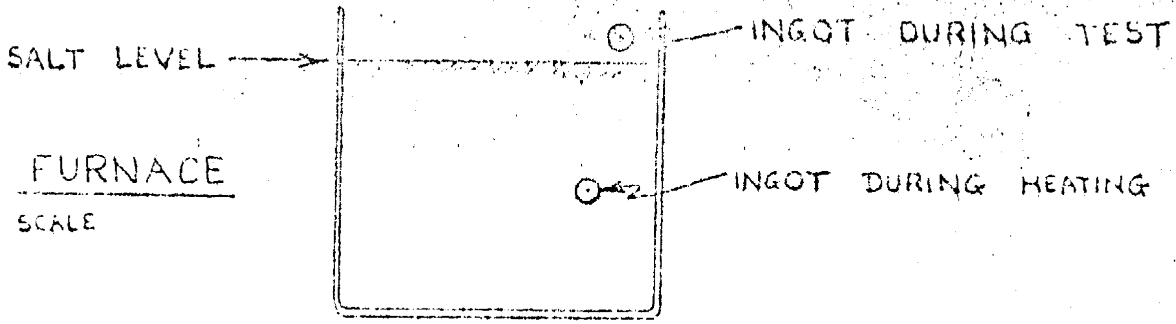
Pass No.	Print Pass No.	Roll Parting (in)	Measured Section Of The Billet
1	1	4	
2	2	3-1/8	5-3/8 x 3-1/4 (5-1/4 x 3-1/8)

Pass No.	Print Pass No.	Roll Parting (in)	Measured Section Of The Billet
3	5	1/2	
4	6	2-7/16	4-9/16 x 2-19/32 (4-21/32 x 2-7/16)
5	7	1/2	
6	8	2-3/16	3-3/4 x 2-5/16 (3-27/32 x 2-3/16)
7	9	1/2	
8	10	1-13/16	3-5/16 x 1-29/32 (3-11/32 x 1-13/16)
9	11	1/2	
10	12	1-9/16	2-7/8 x 1-21/32 (2-29/32 x 1-9/16)
11	13	1/2	
12	14	1-7/16	2-11/16 x 1-1/2 (2-21/32 x 1-7/16)
13	15	5/16	
14	16 Oval	7/32	
15	17 A	9/32	1-15/16 x 1-15/32 (1-15/~~32~~ 16 x 1-15/32)

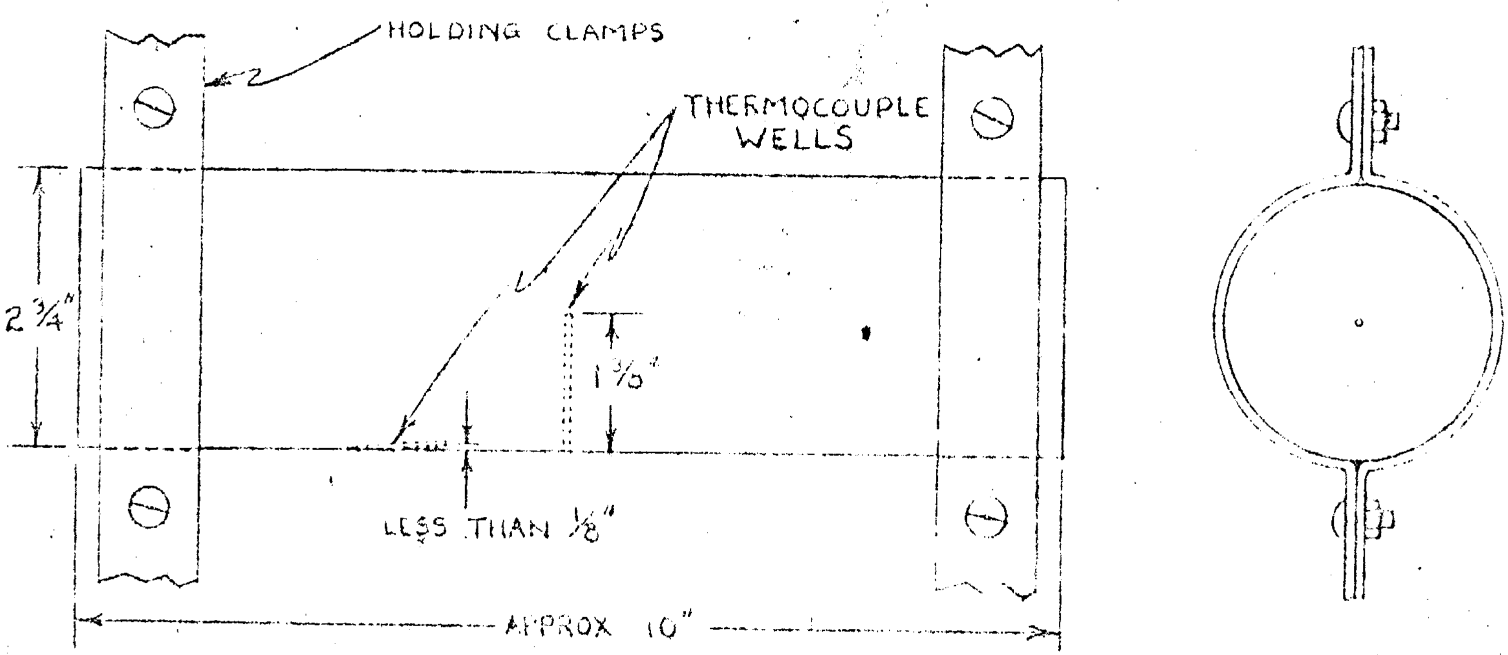
It is hoped that the remaining information necessary to complete this work can be obtained at future rollings.

INGOT FURNACE

NO SCALE



URANIUM TEST BAR



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PRODUCTION REPORT

ON

THE ROLLING OF TWO HUNDRED AND FORTY TWO URANIUM BILLETS

AT

ALLEGHENY-LUDLUM STEEL CORPORATION

ON SATURDAY, APRIL 5, 1952

BY

S. F. AUDIA

NATIONAL LEAD COMPANY OF OHIO
CONTRACT NO. AT (30-1) - 1156

APRIL 14, 1952

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THE ROLLING OF TWO HUNDRED AND FORTY TWO URANIUM INGOTS AT ALLEGHENY LUDLUM STEEL CORPORATION WATERVLIET, NEW YORK ON APRIL 5th and 6th, 1952

GENERAL

A total of two hundred and forty two uranium ingots were rolled. Two hundred and thirty two of the ingots were those representing the latest production of Mallinckrodt. The remaining ten ingots were cast at FMPC from re-melted scrap. The FMPC ingots were tapered round-cornered square ingots; the Mallinckrodt ingots were the usual round type. All of the Mallinckrodt ingots were conditioned; some of these ingots had tapered ends, others had square ends. The FMPC ingots had been scarfed in an effort to produce a smooth surface. The flash that had formed at the mold parting was, for the most part, removed, but the scattered areas of porosity, scabs and cold-shuts were not entirely removed. Fifteen of the round ingots were rolled into test billets. These test billets received a succession of passes corresponding to the modified fifteen pass schedule, such that the first ingot received only the first pass, the second ingot received only the first two passes, etc. and the fifteenth ingot received all of the fifteen passes. Seven of the round-cornered square ingots were rolled with a slight modification in the fifteen-pass schedule. The other three round-cornered square ingots were rolled into section tests. All of the ingots were soaked at $1200 \pm 15^{\circ}F$ and roughed to 1 15/16 x 1 15/32 - inch ovals. Of the ingots rolled into production, only one cobble was produced. During the rolling of the ingots rolled in the evaluation of the 15-pass schedule, difficulty was encountered with only the last billet, the back-end of which turned down in the 13th pass. Of the three round-cornered square ingots rolled into test sections, the first was to have represented the section out of the third pass, but, due to a collar mark made when rolling out of number 2 bull-head pass, the test was not considered to be representative.

A TIME STUDY OF THE ROLLING SCHEDULE

In an effort to attain the maximum production rate, of which the mill is capable, every effort has been made to reduce the handling time of each ingot. Coupled with this has been the desire to keep a constant handling time for each ingot. Reduced handling times should result in higher finishing temperatures and constant handling times should reduce the variations between finishing temperatures.

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During this rolling, certain of the variable handling times were measured for every fifth ingot that was rolled.

One significant difference was effected in the handling of ingots during this rolling. This difference was a result of the installation of an inclined, auxiliary, run-on table connecting the salt-bath to the head of the run-on rolls of the blooming mill. The use of this inclined run-on table resulted in a shorter transfer time from the salt bath to the run-on rolls of the mill. (Heretofore, the ingot was carried on a hook by an overhead crane.) The use of this table resulted in reducing the handling time of each ingot by some 15 - 20 seconds.

The time study, that was performed on every fifth ingot, gave the following data:

(i) The transfer time "from the salt bath to the run-on rolls of the blooming mill." See results in Figure 1.

(ii) The transfer time "from the head of the run-on rolls of the blooming mill to the entering of the ingot into the rolls." See results in Figure 2.

(iii) The transfer time "from the head of the run-on rolls of the blooming mill until the finishing temperature was read." See results in Figure 3.

(iv) The interval "from the time the ingot first hits the rolls until the finished billet leaves the rolls." See results in Figure 4.

Figures 1, 2, 3, and 4 are shown on page 5.

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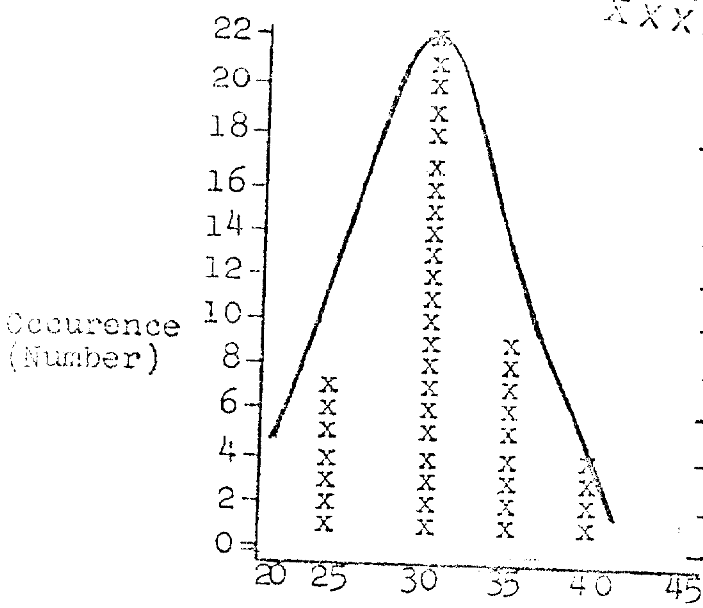
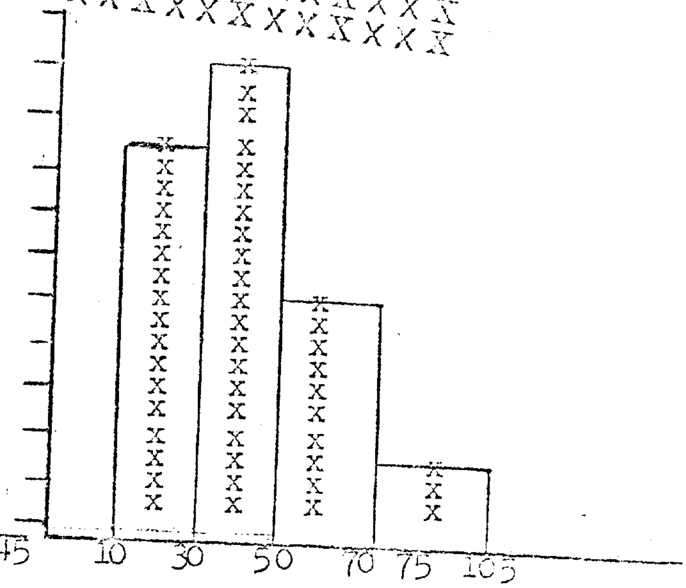
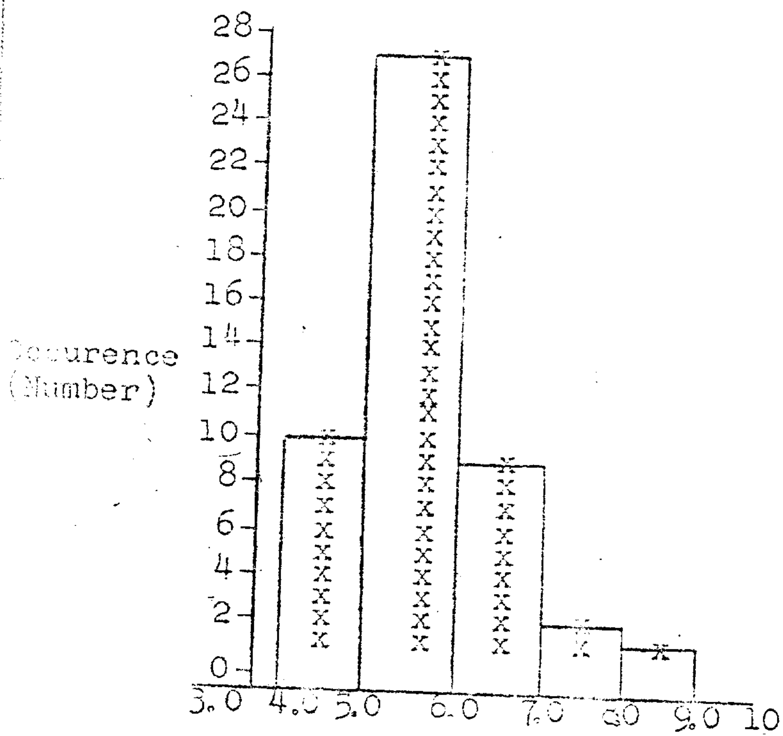


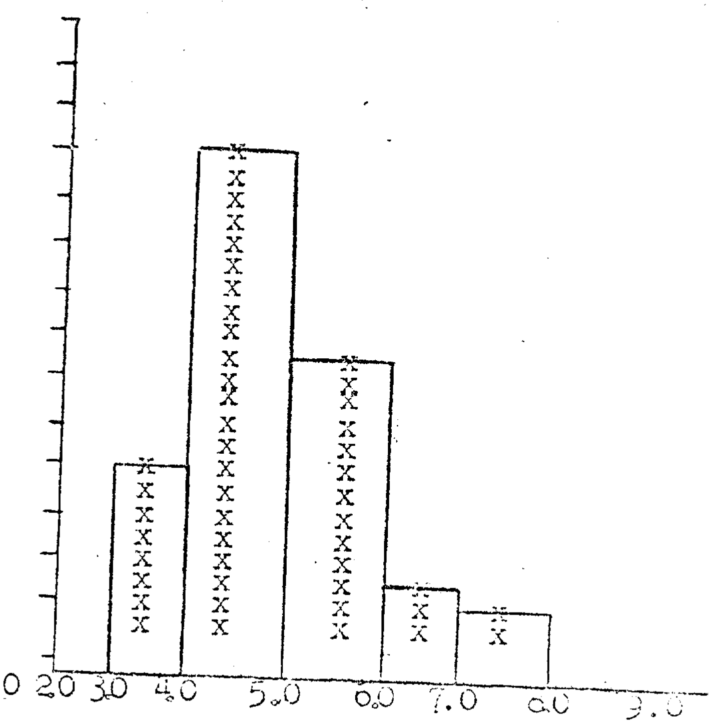
TIME - SECONDS
FIGURE 1 "INTERVAL-SALT BATH TO RUN-ON"



INTERVAL - SECONDS
FIGURE 2 "INTERVAL - HITS RUN-ON 'TIL ENTERS ROLLS"



TIME - MINUTES
FIGURE 3 - "HITS RUN-ON TO FINISHING TEMPERATURE"



TIME - MINUTES
FIGURE 4 - "INTERVAL-HITS ROLLS TO LEAVING ROLLS"

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A STUDY OF THE ROLLING SCHEDULE

(a) The Two-Hundred and Seventeen Round Ingots Rolled into Production.

In order to obtain information that would show us the magnitude of the variations in roll partings (dial readings) that might be obtained in such a production rolling, values of the roll partings (dial readings) were obtained for every fifth ingot that was rolled. Roll partings were recorded for every pass used to roll the fifteen experimental ingots. Extensive data on the roll partings used for the rolling of the ten square ingots was also recorded.

This task of perfunctorily obtaining the data on the roll partings of every fifth ingot did yield some interesting data through a closer inspection of the rolling.

One of the first changes that had to be made in the rolling was to effect a change in the alignment of the rolls to overcome a slight tendency toward cross-rolling.

Another change, that was more significant, was the change that had to be made in the roll partings to eliminate the tendency of the oval to turn down in the fifteenth pass as a result of having too much work performed on it. The last three roll partings had to be changed as shown below (NOTE - The setting of the mill is governed, to a great degree, by the mechanical condition of the roll bearings and the dial mechanism. Any changes that occur in the mechanical operation of the mill will warrant changes being made in the roll partings to compensate for these changes. Such changes, as may occur, will effect the true reading of every dial setting. The effect of these changes is, however, more noticeable in the later passes and consequently, only the later passes were changed.)

Pass Number	Parting, According to Birdsboro Print (in.)	Partings Used On April 5th and 6th (in.)
13	5/16	3/8
14	7/32	3/16
15	9/32	5/16

The changes were made approximately as follows:

(i) Pass change of the roll parting for the 14th and 15th pass was first noticed on the 4th ingot that was rolled.

(ii) Pass change of the roll parting for the 13th pass was first noticed on the 22nd ingot that was rolled.

Other interesting observations concerned the following ingots:

(A) The Production Ingots:

7789 (#6) - appeared to be over-filled after the 13th pass.

7829 (#10) - back end turned down in the 15th pass.

7830 (#11) - appeared to be over-filled after the 13th pass.

7831 (#12) - 8th pass parting light by 1/4".

7893 (#14) - 4th pass parting heavy by 5/16", 6th pass paring light by 1/4".

7901 (#20) - 4th pass parting heavy by 1/4".

7959 (#24) - 7th pass parting heavy by 1/4".

8023 (#35) - received 2 passes through the 13th pass; the first parting was 1/2", the second was 3/8".

8141 (#63) - showed a very definite over-fill running the entire length of the billet. No change, or error, in the pass schedule was noted for this billet.

8142 (#64) - the 6th pass was heavy by 1". A deep seam was noted on the crown of the finished oval.

8145 (#67) - A seam was found in the crown of the finished oval, although, no change, or error, in the pass schedule was noted for this billet.

8168 (#81) - The billet turned down in the 13th pass. The finished billet showed some signs of over-fill.

8169 (#82) - Badly over-filled at back-end for 3 feet. No change, or error, in the pass schedule was noted for this billet.

8173 (#85) - This billet turned over in the 13th pass and was straightened in the bull-head. A very slight under-fill was noted at the lead end of the finished billet where the straightening had been performed.

8183 (#93) - Passes 3 and 4 were skipped entirely. The operator forced the entry of the section out of the 2nd pass into the 5th pass in a very severe reduction. The finished billet showed a slight over-fill.

8295 (#138) - The roll parting used for the 15th pass was 13/64. (i.e. 7/64 too heavy)

8309 (#149) - Received a double pas through the 13th pass.

8361 (#152) - Billet turned down in the 13th pass. The billet was worked in the rolls in the 13th pass and discharged after a pass having 1/2" parting. (i.e. light by 1/8")

8385 (#170) - The 6th pass was light by 10/16" (i.e. was 2 13/16" instead of 2 3/16")

Almost without exception every ingot was tapered after the 3rd and 5th pass. A noteworthy exception to this, however, was the rolling of the first fourteen ingots where no tapering was observed. The tapering in the 3rd pass was found to be necessary to overcome the mushrooming effect at the ends of the billet after the first two bull-head passes.

(B) The Round Ingots Rolled in Section Tests

For those who will follow the work that will be performed on the fifteen billet-section tests, the roll partings (dial readings) used to make these tests are shown on the following page.

INGOT NO.

ROLL PARTINGS IN PASSES
(Passes are those of Birdsboro Print 34562, Rev. 1/22/52)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	7972	4														
2	7973	4	3 1/8													
[illegible]	7986	4	3 1/8	1/2T												
4	7988	4	3 1/8	31/64T	2 7/16											
5	7989	4 1/32	3 9/64	1/2T	2 7/16	1/2										
6	7991	4	3 9/64	1/2T	2 7/16	33/64	2 3/16									
7	7994	4 1/32	3 9/64	1/2T	2 7/16	1/2	2 3/16	1/2								
8	7995	4 1/64	3 9/64	31/64T	2 7/16	1/2	2 3/16	33/64	1 13/16							
9	7999	4	3 1/8T	9/16T	2 7/16	1/2T	2 3/16	31/64	1 13/16	1/2						
10	8006	4	3 1/8	1/2T	2 29/64	1/2T	2 3/16	1/2	1 13/16	1/2	1 9/16					
11	8010	4	3 1/8	15/32T	2 7/16	1/2T	2 13/64	1/2	1 13/16	1/2	1 9/16	1/2				
12	8015	4	3 1/8	1/2T	2 7/16	1/2	2 3/16	31/64	1 13/16	1/2	1 9/16	1/2	1 7/16			
13	8016	4 1/32	3 9/64	1/2T	2 7/16	1/2T	2 3/16	31/64	1 13/16	31/64	1 9/16	1/2	1 7/16	3/8		
14	8018	4 1/64	3 7/64	31/64	2 7/16	1/2T	2 3/16	1/2	1 13/16	1/2	1 9/16	1/2	1 7/16	3/8	3/16	
15	8019	4	3 7/64	33/64	2 7/16	35/64	2 3/16	31/64	1 13/16	1/2	1 9/16	1/2	1 7/16	3/8*	7/32	5/16

* The last 4 feet of this billet turned down wh[illegible] this pass.
T-Stands for Tapering or Pointing.

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It may be noted that there has been no significant deviation from the specified roll partings during the rolling of these test billets.

It is planned that examination of these sections will be made in a program consisting of three phases, namely,

(i) Visual inspection of the surface. This work will show the pass or passes that result in the most, or the least, imperfections in the sections. Pertinent observations will be made regarding the distribution of the salt and oxide layers present on the surface of the billets.

(ii) Dimensional inspection of the billets. Careful measurements made along the length of the billets will show any gross variations in billet cross-section. From these dimensions it will be possible to see significant changes in section that tend to be under-filled or over-filled etc.

A comparison of the shapes of the various billet sections with the shapes of the various passes will yield valuable information concerning the malleability of uranium metal. This comparison will show not only the malleability of the metal, but, it will also show the support that is offorded each section as it is in a pass.

(iii) Metallurgical inspection. On the basis of the information gathered in the visual and dimensional inspections, samples will be taken for macro-examination and micro-examination of the sections that are representative of those that are filled, under-filled, over-filled and those that have laps, seams and/or wrinkles.

This program is being conducted by the Technical Division of the National Lead Company of Ohio.

THE ROLLING OF THE SQUARE INGOTS

It was decided to attempt the rolling of a round corner square ingot in an effort to effect a better contact surface for entry of the ingot into the mill. Of equal consideration, was the fact that, an improved ingot could be made by casting in a round corner square mold.

The schedule used to roll the ten square ingots is shown on the following page.

INGOT NO.	ROLL PARTINGS IN PASSES - (in.)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
N 133	3 7/8	3 1/8	1/2	2 7/16	1/2	2 3/16	1/2	1 13/16	1/2	1 9/16	31/64	1 7/16	3/8	3/16	5/16
N 135	3 7/8	3 7/64	1/2	TO	TEST										
N 143	3 7/8	3 1/8	1/2	2 7/16		TO	TEST								
N 145	3 7/8	3 1/8	1/2	TO	TEST										
N 147	3 7/8	3 1/8	1/2	2 7/16	1/2	2 11/64	1/2	1 13/16	1/2	1 9/16	1/2	1 29/64	3/8	3/16	5/16
N 149	3 31/32	3 1/8	1/2	2 7/16	1/2	2 3/16	1/2	1 13/16	1/2	1 9/16	1/2	1 29/64	3/8	3/16	5/16
N 153	3 15/16	3 1/8	1/2	2 7/16	1/2	2 3/16	1/2	1 13/16	1/2	1 9/16	1/2	1 29/64	3/8	3/16	5/16
N 157	4	3 1/8	1/2	2 29/64	1/2	2 3/16	1/2	1 13/16	1/2	1 9/16	1/2	1 29/64	3/8	3/16	5/16
N 179	4	3 1/8	1/2	2 7/16	1/2	2 3/16	1/2	1 13/16	1/2	1 9/16	1/2	1 29/64	3/8	3/16	5/16
N 181	3 7/8	3 1/8	1/2	2 7/16	1/2	2 3/16	1/2	1 13/16	1/2	1 9/16	1/2	1 29/64	3/8	3/16	5/16

SECRET

These ingots had a nominal shape as follows:

small end, 4 3/16 inch square
large end, 4 27/36 inch square
body, 35 inches long
overall length, 41 inches

With roll partings of 3 7/8, 3 1/8 and 1/2 inches in the 1st, 2nd and 3rd passes respectively, a net reduction of 18%, 17.3% and 18.2% (for the large end) is effected.

The taper on these ingots was used to advantage to effect entry into the first two bull-head passes; the ingots were entered with the bottom end leading. The edging passes took the billet more readily than the sections obtained in a round ingot.

THE MEASURE AND CONTROL OF TEMPERATURE

The usual calibration tests, using the test billet section, revealed that there was practically no deviation between temperatures read by the test thermocouples and the radiation heads. The results obtained in this test are shown in the plot on Page ~~10~~. 17 On the basis of these results, the temperatures read with Head No. 1 (used to read the temperatures 'out of the salt-bath' and 'on the run-on') have not been corrected since they are within 5° of the thermocouple readings, over the range of temperatures measured. Temperature corrections have been applied to the readings obtained with No. 2 Head; these corrections have been made as follows:

FOR TEMPERATURE RANGE	SUBTRACT
greater than 1050°F	0° F
1038 - 1050° F	4° F
1013 - 1037° F	7° F
968 - 1012° F	10° F
888 - 967° F	13° F
less than 888° F	10° F

On the basis, that, the temperatures, that should have been corrected, have been corrected, it is reasonable to assume that the temperatures shown in the report are as accurate as can be obtained.

Other temperature data that was gathered included results of a temperature probe of the salt bath using a thermocouple, and experimental results to obtain information to explain the variations in emissivity that occur along a billet at the finishing end. For the sake of completeness of this report these results are summarized on the following page.

(A) The Thermocouple Probe of the Salt Bath

(i) a variation of 50°F was found in readings taken at the centre of, and the edge of the salt bath.

(ii) this data would show, that, although the controllers operating the salt bath were set at 1220°F, the actual bath temperature must be considered to be 1170°F.

(iii) simultaneous readings revealed that the thermocouples controlling the salt-bath were reading 1215 - 1232°F, while a thermocouple probe in the vicinity of each furnace thermocouple revealed temperatures in the range 1128 - 1171°F. (This condition will possibly be eliminated for the next rolling.)

(B) Variations in Emissivity of Finished Billets

It has long been apparent that the thickness and irregularity of the salt layer and the oxide layer covering the billet has been an impediment retarding the development of an accuract means of determining the temperature of salt covered and oxidized uranium ingots, billets, bars etc. In an effort to evaluate the effect of the many different surface conditions that are present in a group of rough-rolled billets, measurements were made on several billets where -

(i) salt and oxide conditions were visibly different

(ii) readings were made on these same billets at spots (about 1 inch away) where the salt had been brushed to give a smoother, cleaner, and more uniform surface. The results of these tests may be summarized as follows:

(i) In every case, readings made on spots that were covered with salt showed lower temperatures than points 1 inch away that were brushed to give a smoother, cleaner, and more uniform surface. The data are as follows:

APPROX. TEMP. OF BILLET (°F)	VISUAL CONDITION OF THE "CLEANED" SPOT	VISUAL CONDITION OF THE "UNCLEANED" SPOT	TEMPERATURE OF THE "UNCLEANED" SPOT LOWER BY (°F)
936	smooth and black from brushing	greasy, heavy salt, black surface	18
1000	smooth and black, with very little colored oxide	greasy, black, with a rusty streak	22

1002	black and turning partly to a colored oxide, brushed smooth.	heavy, rather uniform and black	28
1014	black, smooth	black, spotty salt	10
1018	black, smooth	blackish, spotted with yellowish oxide	5
1032	black, smooth	heavy, spotty, black surface	25
1040	black, smooth	heavy, yellow, powdery and oxidized	35
1130	rather heavy, brushed but not very smooth	very heavy, dry looking	60

Further evidence that more accurate temperature readings may be obtained through control toward maintaining black body conditions are indicated in the following test.

The two radiamatic heads were calibrated, and on taking simultaneous readings on one ingot, it was found that they checked within 3°F. Readings taken on several ingots showed that a temperature taken over the exact centre of the drill hole in the end of the ingot was higher, on an average by 30°F, than a simultaneous reading taken at another point of the ingot. When the head that was held over the drill hole was moved slightly to read, then, on the flat end, the temperatures of the two heads checked again within 3°F.

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CONCLUSIONS

Those who are following the work of these rollings will be informed of the progress of the evaluation of the 15 pass schedule.

The yield achieved in the rolling of this material is shown as follows:

1. The production rolling of the round ingots was 82.8% from ingot to finish billet.

2. The experimental rolling of 15 round ingots was 99.92% from ingot to finish billet.

3. The experimental rolling of the 10 round cornered square ingots was 88.6% from ingot to finish billet.

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PRODUCTION REPORT

ON

THE ROLLING OF FOUR HUNDRED AND SIXTY-FIVE URANIUM INGOTS

AT

ALLEGHENY-LUDLUM STEEL CORPORATION'S WATERVLIET PLANT

ON

MAY 2 and 3, 1952

NATIONAL LEAD COMPANY OF OHIO
CONTRACT NO. AT(30-1) - 1156

May 19, 1952

Report written by:

A. E. Guay
P. E. Merrill
C. A. Schneider
A. S. Yocco

[redacted]

Report approved by:

S. F. Audia

[redacted]

THE ROLLING OF FOUR HUNDRED AND SIXTY FIVE URANIUM INGOTS AT THE ALLEGHENY LUDLUM STEEL CORPORATION WATERVLIET, NEW YORK, ON MAY 2nd and 3rd, 1952

GENERAL

Four hundred and sixty three of the ingots represented the latest material cast at Mallinckrodt. All but five of these ingots were the regular round ingots that had been conditioned by lathe turning. Five of these ingots had been prepared by etching in phosphoric acid. The remaining two ingots that were rolled were produced at FMPC. The surface of these round ingots had been prepared by scarfing.

There were four cobbles produced during the rolling.

The billets that were made are scheduled to be rolled into bars from which slugs will be machined for the Savannah River Project.

The only significant difference in this rolling, as compared to other rollings, was a slight change in the pass schedule.

DISCUSSION OF THE ROLLING

All the ingots were rolled to 1-15/16 x 1-15/32 inch billets.

At the start of the rolling, the pass schedule outlined in Birdsboro's Print 34561 was followed. After the 14th ingot had been rolled, a change was made in the pass schedule. This change was made for the purpose of eliminating the tendency to "overfill" the section in the 13th pass through a reduction in the amount of work being done in the pass. The change consisted of a decrease of 1/32 of an inch in each of the roll partings on the 10th, 11th and 12th passes. These changes in the roll partings are shown in the table below.

PASS	SHAPE	PARTING (in.), APRIL 5th ROLLING & FOURTEEN INGOTS ON MAY 2, 1952	PARTING (in.), 451 INGOTS ROLLED ON MAY 2 & 3, 1952
1	Flat	4	4
2	Flat	3-1/8	3-1/8
3	Edge	1/2	1/2
4	Flat	2-7/16	2-7/16
5	Edge	1/2	1/2
6	Flat	2-3/16	2-3/16
7	Edge	1/2	1/2
8	Flat	1-13/16	1-13/16
9	Edge	1/2	1/2
10	Flat	1-9/16	1-17/32*
11	Edge	1/2	15/32*
12	Flat	1-7/16	1-13/32*
13	Edge	5/16	5/16
14	Oval	3/16	3/16
15	Edged-Oval	5/16 - 19/64	5/16 - 19/64

*Parting decreased by 1/32 inch.

An examination of the billet test-sections rolled at the April 5th rolling have shown that the actual reductions obtained in the 10th, 11th and 12th passes have been quite light, while the reduction in the 13th pass has been quite heavy. These changes in the roll partings have resulted in the following changes in the reduction accomplished in these passes:

PASS	SHAPE	REDUCTION (%) (As of April 5, 1952)	*REDUCTION (%) (On May 2 and 3, 1952)
10	Flat	9.0	11.0
11	Edge	9.3	9.8
12	Flat	7.8	8.3
13	Edge	20.4	17.4

*Estimated Value.

No adverse rolling condition was observed as a result of these changes. There was no tendency for the billet to turn down in any of the passes.

It was difficult to inspect the surface condition during rolling with any degree of precision. The difficulties preventing a precise examination included the salt layer covering the section and the hazard involved in the inspection. The examination that was made, however, showed the tendency to overfill the 13th pass had been eliminated.

Close examination of the finished 1-15/16 x 1-15/32 inch billets showed wrinkles on the top and bottom of the section. The sides of the section were free of any defects. It is apparent that further study of the pass schedule needs to be made if these wrinkles are to be eliminated.

The first ten ingots were rolled with a minimum of tapering. The only tapering that was done was to obtain entry into the first edging pass. However, as the rolling progressed, it was found that the tapering had to be increased. Tapering was needed most on the first, second, third and fifth pass made on every ingot. It is felt that the need not to taper the first ingots so severely is a function of the oxide layer covering the rolls at the start of each rolling. This oxide layer seems to provide a roughened surface that "bites" the billet. However, this roughened surface is soon worn away and the "bite" decreases.

The mill operators soon began to decrease the reduction on the first pass (through an increase in the roll parting, say of 1/8 of an inch) in an effort to effect faster entry of the ingot into the mill.

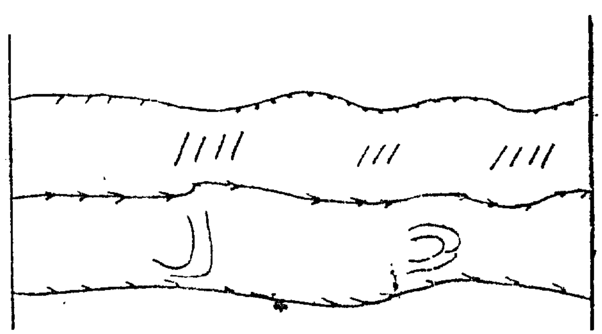
An examination of the rolls of the mill have disclosed that the first two edging passes and the flat (bull-head) pass are glazed. This smoothness is a contributing cause to slipping and it necessitates the tapering. An examination of the surfaces on the smaller edging passes indicate fire cracking has occurred. It has been recommended that the rolls be examined for the purpose of determining if dressing is necessary prior to the next rolling. It has generally been agreed that the rolls will be dressed if it could be considered to be beneficial.

Throughout the rolling, a perfunctory check was made on the roll partings used to roll every fifth ingot. The observers taking this data followed the rolling with a view to recording any significant deviations from the prescribed roll partings. A summary of this data is as follows:

[redacted]

PASS (no.)	PRESCRIBED PARTING (in.)	NUMBER OF CHECK READINGS MADE	NUMBER OF DEVIATIONS FOUND	AVERAGE MAGNITUDE OF ALL THE DEVIATIONS (in.)
1	4	376	365	+ 1/8
2	3-1/8	87	4	+ 3/32
3	1/2	93	1	- 1/64
4	2-7/16	89	3	+ 1/64
5	1/2	92	2	- 1/64
6	2-3/16	93	2	± 1/64
7	1/2	93	2	± 1/64
8	1-13/16	92	2	- 1/64
9	1/2	91	1	+ 1/64
10	1-17/32	91	0	0
11	15/32	95	5	± 1/32
12	1-13/32	91	2	+ 1/64
13	5/16	91	1	+ 1/64
14	3/16	91	0	0
15	19/64	168	17	+ 1/64

It is of interest to record the rolling behaviour of the eleven ingots numbered 8645 to 8660 inclusive. After the 347th ingot (8645) had been withdrawn from the salt bath, the apparent temperature of the salt bath unknowingly rose to 1258°F. At this time, the 348th ingot was withdrawn from the salt bath and rolled. On the first pass that this ingot received, it started to break-up. The appearance of the billet after the first pass closely ressembled "burnt" steel in that the ingot appeared to be failing intergranularly. The whole section of the billet was non-uniform along the side of the section. The non-uniform flow of the metal resulted in the formation of a billet having scalloped edges as shown in the sketch below.



Large tears were evident on the sides and the top of the billet. Numerous surface and corner checks were evident.

[redacted]

It was not immediately apparent that this was wholly a function of the temperature; that the ingot may have been un-sound was also considered. However, when the next ingot showed the same effect, steps were taken to determine the cause. The temperature of the salt bath was found to be the cause and subsequent ingots were allowed to cool on the run-on rolls of the mill until their apparent surface temperature was 1150°F (approx.). In the temperature data sheets, the readings of "temperature on the run-on" for those ingots, are the temperatures to which these ingots were allowed to cool before they entered the mill. It was of interest to note the very slow cooling rate of the ingots as they lay on the run-on rolls. This very slow cooling rate was proof that the cooling at the surface was slow because the inside of the ingot was hot and was supplying heat to the surface. It is not unreasonable to assume that the temperature gradients in these ingots would be any greater than those ingots rolled in the usual manner. It is quite possible that the temperature gradients were even less than usual because the ingot actually "soaked" on the run-on rolls.

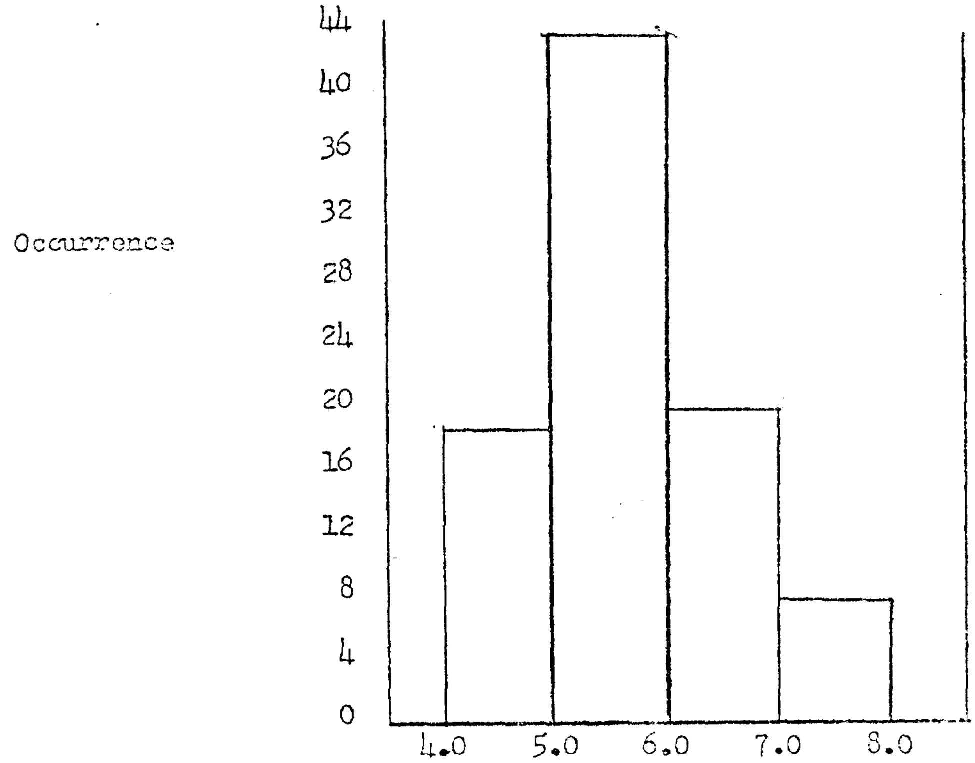
SAMPLES OF THE ROLLING

Representatives of duPont requested that (any) ten ingots be soaked at a temperature such that they entered the mill at 1100°F. These samples were to be characteristic of material rolled late in 1951. (This material is to be finished rolled at a temperature of 1100°F) Bars finished from this material are to be used as feed stock from which slugs will be machined and canned in an effort to clarify several problems encountered in previous practice canning operations. The billets that were accepted for this evaluation are numbers 8526 to 8545 inclusive.

Ten other billets were set aside for special evaluation. The ten billets 8679 through 8691 inclusive were considered to be typical of material rolled under present production conditions. These billets are to be finish rolled under conditions typical of present production practice and set aside for beta heat treating prior to machining.

A TIME STUDY OF THE ROLLING PROCESS

During the rolling, data were recorded, on every fifth ingot, to show the interval between the time an ingot emerged from the salt bath until the finishing temperature was recorded. The results of this study are shown below



TIME-INTERVAL IN MINUTES
INGOT LEAVES SALT BATH
UNTIL THE FINISHING
TEMPERATURE IS READ

THE MEASURE, RECORD AND CONTROL OF TEMPERATURE

As has been the practice, the Radiamatic heads used to record the temperatures were calibrated in the laboratory of the Brown Instrument Company before the rolling.

Two calibration tests of the Radiamatic heads were made at the rolling. These tests were made in the usual way by using a test billet-section. The first test made at noon on Friday indicated that the temperatures recorded when an ingot was taken out of the bath were correct within ±2°F. The other Radiamatic head used in the calibration test was one used for experimental readings and was not the one used to read the finishing temperatures. The result of the second test indicated that the equipment used as standards was not functioning properly and the data are therefore not included in this report.

On the basis of the results obtained in the first calibration test, all temperatures appearing in this report have not been corrected and are assumed to be correct as reported.

The calibration test billet-section that has been used at previous rollings is thought to be ready for replacement. The constant use that this section has received has left it badly oxidized. It is felt that a new section, complete with new thermocouples, is required and this new section will be available for the next rolling.

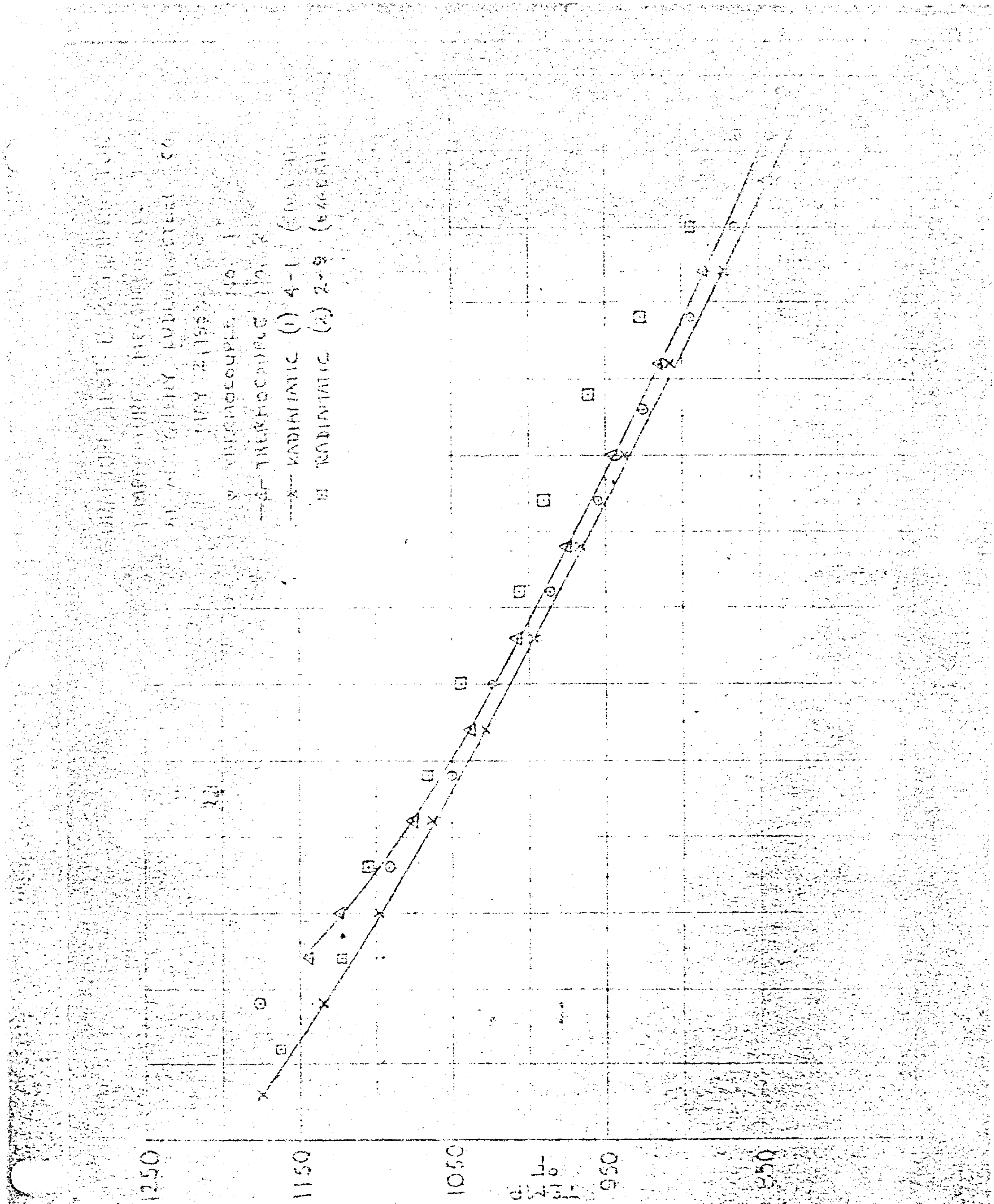
Two thermocouple probe tests of the salt bath were made for the purpose of determining the variation in temperature throughout the bath. The results of these tests are as follows:

POSITION	TEST NO. 1	TEST NO. 2
Right Front *	1175°F	1205°F
Left Front *	1175°F	1202°F
Right Rear	1176°F	1217°F
Left Rear	1190°F	1210°F
Center	1185°F	

* The Front is the discharge end.

It may be noted that the temperature of each ingot as it rests on the run-on rolls has not been recorded. When the crane was used to move the ingots from the salt bath to the run-on rolls of the mill, there was a considerable variation in the handling time that each ingot received. The recording of this temperature in previous rollings was considered to be necessary because of the fact that these handling times varied from

0.5 to 1.5 minutes. The installation of the extension to the run-on rolls of the mill has not only reduced the handling times but it has also reduced the variations in these times. Now it is felt that the delay caused in taking this reading over-weighs the knowledge gained from the reading when consideration is given to the fact that the ingots will be hotter when they reach the rolls. The reading of the temperature of every tenth ingot, as it rested on the run-on rolls of the mill, was made to determine the average loss in temperature of an ingot during the period of transfer from the salt-bath to the rolls of the mill. The average difference in the magnitude of the temperature reading of an ingot as it emerges from the salt bath versus the temperature reading on the run-on rolls has been calculated from the temperature data and found to be 21°F. It is not unreasonable to assume that the delay between the time the ingot is removed from the salt bath and the time the temperature is actually recorded, plus the delay after the reading of the temperature on the run-on rolls until the ingot enters the rolls would result in a cumulative loss of approximately 20°F. This would indicate a total apparent loss in temperature between the salt bath and the rolls of the mill to be approximately 40°F.



NATIONAL LEAD COMPANY OF OHIO
FERNALD, OHIO
DEPARTMENT:

SCALE
DATE
CHARGE
DRAWN
APPROVED

CONCLUSIONS

The time study performed during the rolling has shown that there has been a consistent handling time for all the ingots. As the rollings have progressed, steps have been taken to achieve the ultimate goal of producing billets having identical prior histories.

One significant improvement that has not, as yet, been made is to take the larger crop at back end of the billet (i.e. the top of the ingot) rather than at the front (i.e. the bottom of the ingot) of the billet. This is considered important when consideration is given to the fact that impurities in the melt, being of a lesser specific gravity than the melt, will tend to rise to the top of the melt. Thus, the "top" crop will eliminate more impure inclusions than would a "bottom" crop.

The yield of metal from ingot to finished billet suitable for finish rolling was 83.66%.

ROLLING SEQUENCE & INGOT NUMBER	SOAKING TIME (min.)	SALT BATH TEMP. WHEN INGOT DRAWN (°F)	INGOT TEMP. OUT OF SALT BATH (°F)	INGOT TEMP. ON RUN. - ON (°F)	BILLET FINISHING TEMPERATURE (°F)	REMARKS INGOT TAPERED ON PASS NO.
1-7237	100	1200	--	--	1148	3
7238	106	1193	1150	--	1122	3
7239	113	1190	1190	1166	1112	3
7240	118	1188	1154	1132	1092	3
7241	124	1185	1159	1138	1114	3
7242	134	1185	1150	1135	1000	3
7243	139	1185	1156	1122	985	3
7244	147	1183	1156	1134	--	3
7245	150	1183	1153	1129	935	3
7246	155	1183	1156		981	3
7256	59	1183	1151		1000	2,3
7259	58	1183	1148		966	3,13
7260	57	1183	1152		1002	3
7261	59	1188	1152		1114	1,3
7262	60	1190	1152		956	3
7263	56	1195	1156		983	3
17-7264	57	1200	1162		1022	3