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REPORT ON A DEMONSTRATION OF THE STRATEGIC-UDY PROCESS FOR SMELTING TITANIFEROUS IRON ORES AS APPLIED TO LAPOINTE-AWATER ORES

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DATED at Niagara Falls, Ontario this 14th day of August, 1958

Murray C. Udy Research Director
~~A Notary Public~~

REPORT ON

A DEMONSTRATION OF THE STRATEGIC-UDY PROCESS FOR SMELTING TITANIFEROUS IRON ORES AS APPLIED TO LAPOINTE-AWATER ORES

by
Cecil McDonald, Murray C. Udy and Marvin J. Udy

August 12, 1958

STRATEGIC UDY METALLURGICAL AND CHEMICAL PROCESSES, LTD.
Niagara Falls, Ontario

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SUMMARY

At the request of Stratmat, Ltd. and Halmon Mining and Processing, Ltd., Strategic-Udy Metallurgical and Chemical Processes, Ltd. conducted demonstration smelting tests on a 100 KVA scale. The demonstration successfully showed that the Strategic-Udy smelting techniques can produce a satisfactory iron product from the Lapointe-Awater titaniferous magnetites at low power consumption and high conversion to metallic iron.

Extrapolations from the power data, based on previous experience, show that iron can be produced from the Lapointe-Awater titaniferous magnetites at 1500 KWH per ton of metal or less.

Over 95 per cent of the iron content of the Lapointe-Awater titaniferous magnetites is converted to metallic iron by the Strategic-Udy process. The iron product is a semi-steel (i.e. only 1.5 per cent carbon) and hence can be more readily refined to steel than conventional pig iron.

Only half of the sulphur content of the ore goes to the metal. This can be easily removed by conventional steel making practices.

Essentially all of the phosphorus of the ore goes to the metal, making its removal necessary in subsequent steel making processes.

Titanium, Chromium, and Vanadium in the Strategic-Udy process can be readily controlled in the metal to less than 0.1, less than 0.3, and less than 0.1 per cent respectively.

On the other hand, these materials can essentially all be taken from the slag to the metal. This would be desirable if the slag were to be processed to pigment. In this case these "impurities" would be removed, if so desired, from the iron in subsequent steel making processes.

The Lapointe-Awater ore is self-fluxing, giving a well-behaved slay which is non-corrosive to a magnesite furnace lining. The slag is fluid, separates well from the metal, and has only a minimum of frothing during operation.

A combination of the Lapointe-Awater ores and the Strategic-Udy smelting process may well serve as the basis of a profitable steel making industry.

INTRODUCTION

The Lapointe Awater deposit is probably one of the largest units of titaniferous magnetite in the world. The deposit is located at Melihercsik, north of Mingan, Quebec. This is about 60 miles east of Seven Islands. Because of the titanium dioxide content of this ore, it is not considered a suitable blast furnace ore. Stratmat, Ltd. and Halmon Mining and Processing, Ltd. are jointly interested in this deposit and they have asked Strategic-Udy Metallurgical and Chemical Processes, Ltd.* to demonstrate the feasibility of smelting this ore by means of the Strategic-Udy process. This demonstration, of a preliminary nature, was to be done in SUMAC's 100 KW electric furnace. Some 6500 lbs. of this material was taken out by Stratmat & Halmon engineers and shipped to Niagara Falls for the smelting tests.

* Abreviated SUMAC in subsequent references in the report.

THE PROCESS

The Strategic-Udy process is a smelting technique using combinations of rotary kilns, reverberatory furnaces, and electric arc furnaces to recover metallic values from ores. The particular ore, or combinations of ores, being used together with the relative costs of fuel and electric power dictate the exact combinations of equipment to be used. In any case, heat is conserved by not cooling the materials once they enter the process until they leave as marketable products.

A distinct feature of the process is the electric furnace smelting technique. It is not like the usual ferroalloy furnace techniques which operate with the electrodes surrounded and submerged with respect to the solid charge. On the contrary, the Strategic-Udy technique uses an open bath with electrode spacing in respect to the molten slag controlled from one-half inch above the slag to two inches submerged in the slag, depending upon the needs of the particular operation. The preheated material can then be fed directly into the hot zone so that reduction is almost immediate.

Another feature of the process is the control of differential smelting and high recovery by control of slag composition. Desired slag composition, however, varies from material to material.

Not only can it process standard high grade ores, but the Strategic-Udy process also has the advantage, should the ratio of iron to other metallic constituents be too high in the ore, or should there be impurities in the ore not wanted in the final product, selective reduction can be practiced by controlling the amount of reductant added. This gives a hot, enriched, purified slag to be further processed to the desired product. This advantage allows low grade and off grade ores to be processed to high-grade end products. Valuable by-products also result from the selective reduction; for example, high-iron manganese ores can produce iron and ferromanganese, high-iron chromium ores can produce iron and ferrochromium, lateritic ores can produce ferronickel, pig iron or steel and chromium iron, high-phosphorus iron ores can produce a small amount of high-phosphorus iron which can be refined plus a major amount of premium grade pig iron or steel, titaniferous iron ores can be so processed as to leave the titania in the slag.

Sizing of the ores is not a criterion of the process. Fine concentrates can be used. Reducing agents are not limited to special grades of coke. Anthracite, low volatile bituminous coal, coke breeze, or even certain lignites may be used.

The process as applied to the Lapointe Awater titaniferous magnetite would probably involve the following steps:

1. Calcining in a rotary kiln to 1000 to 1200°C. Some reducing agent may be added in the kiln so that the iron may be partially reduced before going to the electric furnace. This saves considerable electric power.

2. The rotary kiln product is charged hot into the smelting zone of an electric arc furnace. Controlled amounts of reductant are added here so that an iron product containing only a minimum amount of titanium will be produced.
3. This hot molten iron product will be transferred to a steel making furnace and further processed.

Only one of these steps is to be demonstrated in SUMAC's 100 KW electric arc furnace. This step is number 2 above, the electric furnace operation. It is modified somewhat from the potential commercial operation in that cold ore will be charged into the electric furnace along with all of the reductant needed for the smelting.

EQUIPMENT

A. DESCRIPTION:

The electric furnace is a 100 KVA, three-phase Lectromelt arc furnace. The transformer delivers 30 to 360 volts phase voltage at 4 to 6 volt steps. The furnace shell used for the demonstration is a tapping-type furnace, lined with magnesite brick.

B. LIMITATIONS:

Because of the cold charge, and adding all the reductant to the electric furnace, power figures are necessarily higher than those that will be commercially realized. Too, the small size of the furnace makes any power figures higher than would be commercially realized even if the previous limitation was not present. The small 100 KVA furnace has an efficiency of only about 25 to 35 percent compared to 75 percent or better efficiencies which are regularly realized in commercial furnaces. The small furnace is intended to develop chemistry and metallurgy of the process. Development of economic and design data need to be on a larger scale such as is possible in the other SUMAC facilities, which include an 80 ft. rotary kiln, a reverberatory furnace and three 1000 KVA furnaces.

OBJECTIVE OF THE TESTS

The purpose of the tests was to demonstrate the Strategic-Udy smelting process in its critical electric furnace step for the production of an iron product from the Lapointe Awater titaniferous magnetite deposit. A secondary objective was to demonstrate the self-fluxing characteristic of the ore as treated by the Strategic-Udy process.

MATERIALS USED

Two shipments of ore were received. They were crushed separately and each analyzed. The second shipment was sampled in two lots so that in all, three analyses were made. Table I gives these analyses and compares them with analyses of earlier hand samples and with some previous analyses reported by the M.A.Hanna Company. The analyses of the three present materials are quite close and are also close to the second M.A.Hanna sample in the table. Contrary to some previous beliefs,

TABLE I
COMPARISON OF ANALYSIS OF MATERIAL RECEIVED FOR SMELTING TESTS WITH EARLIER ANALYSIS OF MATERIAL FROM THE SAME DEPOSIT

Material	Fe(total)	Fe++	TiO_2	SiO_2	Al_2O_3
July 18, 1958 Shipment	44.8	22.1	11.2	6.13	11.13
August 4, 1958 Shipment (1st half)	44.6	22.7	11.7	6.38	11.08
August 4, 1958 Shipment (2nd half)	45.1	22.9	11.8	6.26	11.53
November 26, 1956 Hand Sample	51.3	NA	13.8	2.68	7.3
January 30, 1958 Hand Sample	40.2	18.5	9.9	8.34	13.0
M.A.Hanna April '56(1)	38.25	NA	12.0	11.8	6.4
M.A.Hanna Rpril '56(2)	44.4	NA	11.9	6.19	7.6

Material	CaO	MgO	P	S	Cr_2O_3	V_2O_5	Mn
July 18, 1958 Shipment	0.98	5.31	0.09	.18	1.21	0.34	0.14
August 4, 1958 Shipment (1st half)	1.09	6.01	0.10	.13	1.28	NA	NA
August 4, 1958 Shipment (2nd half)	0.83	5.46	0.09	.15	1.48	NA	NA
November 26, 1956 Hand Sample	Trace	3.0	NA	NA	NA	NA	NA
January 30, 1958 Hand Sample	1.11	6.92	0.044	.34	3.4	NA	NA
M.A.Hanna April '56 (1)	NA	NA	0.14	.03	1.29	0.29	0.16
M.A.Nanna April '56 (2)	1.46	4.65	NA	NA	NA	NA	NA

phosphorus was about 0.1% i the ore. This is not inconsistent with the one M.A.Hanna analysis. Chromium, vanadium and manganese are also present as was previously reported by M.A.Hanna.

Preparation of the material for furnacing consisted of preliminary jaw crushing followed by roll crushing to get the material to minus 3/8 inch. The material at this point was quartered and sampled for analysis.

FURNACE TESTS

In all, some 37 furnace tests were made, smelting in all some 5500 lbs. of ore. The furnace was operated continually on a 3-shift, 24 hour per day basis, one test being made right after the other. The furnace was initially preheated with a charge of large coke. This coke was removed and the first heat started. Individual charges consisted of 150 lbs. of ore and varying amounts of coal. After the charge was molten, a final coal addition was made to reduce the iron in the slag to the desired level. Because these were experimental tests and not a production run, the amount of reductant was varied from test to test to demonstrate the conditions necessary to hold the titanium content of the iron product to a minimum and, likewise, to obtain a minimum of iron residual in the slag. Because similar tests on previous ores indicated that the gangue material of this ore would give a natural flux, no additional fluxing agents were used.

Metal and slag were tapped simultaneously in these tests and allowed to separate by gravity in the chill mold. Metal samples for analyses were taken by a spoon from the tapping stream. Slag samples were taken by dipping a cold one inch diameter rod into the slag on top of the chill mold before it had frozen.

Frothing was kept below the point of causing furnace difficulties by withholding part of the reductant until the charge was molten and superheated.

In several instances, slag samples were taken from the furnace during the coal addition. These results were used for control purposes in the early heats.

Figure I shows the decrease in iron content of the slag with increasing additions of coal.

Tapping temperatures in the tests ranged from 1610 to 1690°C. The slag was fluid and flowed well, thus confirming our contention that the gangue material of this ore made it a self-fluxing slag when smelted by the Strategic-Udy process.

Some previous tests on an earlier hand sample of Lapointe Awater ore showed that the ore melted in the range of 1400 to 1500°C. This was before the iron had been reduced out of the ore. This melting temperature is low enough that a reverberatory furnace might be considered in the commercial process between the kiln and the first electric furnace. The hot charge from the kiln would be melted in the reverberatory and then transferred molten to the electric furnace. This, in effect, would conserve electric power. However, any pre-reduction would have to be forgone because the low-carbon iron

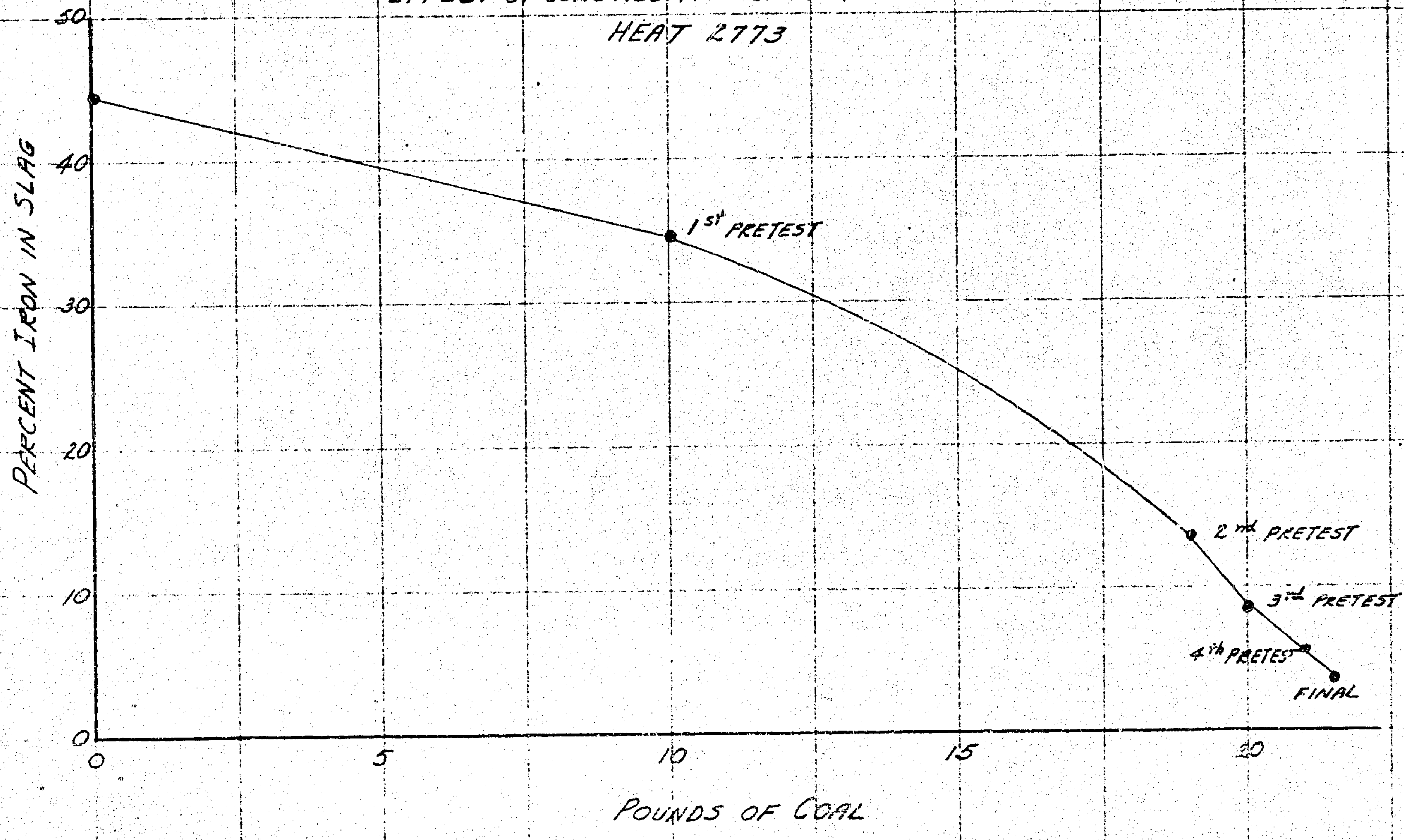
FIGURE I

STRATEGIC-UDY PROCESS

REDUCTION OF TITANIFEROUS MAGNETITES

EFFECT OF COAL ADDITION ON IRON CONTENT OF SLAG

HEAT 2773



would have too high a melting point to handle satisfactorily as molten iron in the reverberatory. Whether or not a reverberatory furnace is used, is strictly a matter of economics. Tapping time from start of charge to the next charge varies from 100 to 120 minutes. 50 to 75 lbs. of metal were tapped out each time and a final salamander of some 160 lbs. was produced. Table II is a summary of the furnace operating data including the analyses of the metal and a partial analyses of the slag. A complete analysis of a composite of the slag is also included. From the analytical data in Table II, it can be seen that the iron content of the slag can be controlled at any desired level, however, it can also be seen that the amount of iron left in the slag controls the percentage of the several "impurities" in the metal. For example, Figure II plotted from the data of Table II shows that to keep the titanium content of the metal below .1%, as may be desired, it is necessary to leave at least 2% iron in the slag. Figure III is a similar plot of data with chromium. In this case, some 6% of iron is necessarily left in the slag to get chromium below 0.3%. The point at which these "impurities" are controlled is dependent upon the steel making process that will follow the smelting operation. Many of these "impurities" are oxidized out in normal steel-making operations. If one were to further process the slag from the smelting operation for TiO_2 pigment, it would be desirable to put as much chromium and vanadium in the metal as possible so as to minimize the pigment purification steps.

TABLE II

SMELTING DATA STRATEGIC-UDY PROCESS
USING LAPOINTE-AWATER TITANIFEROUS MAGNETITES

HEAT NO.	CHARGE IN POUNDS: ORE	CHARGE IN POUNDS: Coal in Mix	CHARGE IN POUNDS: Late Coal Additions	TOTAL TIME	TAP OUT TEMP.	WT. METAL	METAL ANALYSIS: %C	%Si	%P	%Ti	%S	%Cr	%V	SLAG ANALYSIS: Wt. Slag	%Fe	Free %Fe
2773	150		16	158	1610	No metal tapped								24	3.31	
2774	150	10	10½	110	1620	" " "								40	1.30	
2775	150	10	10	110	1630	83	1.48	.36	.20	.06	.16			59	1.06	
2776	150	10	10	101	1610	58	1.30	.04	.20	.06	.16	.82	.10	54	2.34	.29
2777	150	10	10½	117	1620	65	1.42	.41	.20	.07	.16		.16	47	1.48	.18
2778	150	10	10½	110	1620	64	1.51	.32	.18	.07	.16		.13	57	1.95	.21
2779	150	10	10½	111	--	59	1.40	.80	.18	.08	.17			45	3.30	.29
2780	150	10	10	117	1635	65	1.53	.44	.18	.08	.18		.10	58	3.06	.23
2781	150	10	9½	118	1650	53	1.25	.32	.25	.08	.20	.95	.10	57	3.30	.23
2782	150	10	10½	110	1660	62	1.42	.47	.19	.06	.21		.10	58	3.66	.17
2783	150	10	10	112	--	55	1.75	.24	.21	.11	.20			55	1.78	.09
2784	150	10	10	102	1630	66	1.51	.44	.12	.096	.19	.98	.13	45	2.01	.23
2785	150	15	6	109	1620	62	1.65	1.36	.21	.24	.15		.16	42	2.37	1.24
2786	150	15	6	108	1650	61	2.37	1.33	.18	.34	.14	.55	.18	47	2.55	1.21
2787	150	15	5½	108	1660	68	2.11	1.39	.20	.34	.12			64	1.89	.18
2788	150	15	5	107	--	57	1.98	1.30	.20	.28	.13		.26	35	2.13	.59
2789	150	15	5	109	1640	71	2.17	1.29	.21	.29	.12	1.51	.26	65	1.18	.17
2790	150	15	5	109	1630	70	2.03	1.37	.17	.29	.12	1.55	.36	46	1.24	.12
2791	150	15	5	114	1620	72	1.93	1.26	.20	.20	.14		.34	50	1.65	.18
2792	150	15	5	113	1650	66	1.73	.69	.17	.09	.13			44	3.43	.11
2793	150	15	5½	114	1660	75	1.70	1.34	.20	.15	.14		.18	47	1.95	.17
2794	150	15	5½	109	1660	68	1.05	1.35	.15	.07	.13			50	2.60	.17
2795	150	15	6	113	1690	69	1.00	.72	.18	.06	.16	1.34	.17	48	2.96	.11

(continued on following page)

TABLE II (continued)

SMELTING DATA STRATEGIC-UDY PROCESS
USING LAPOINTE-AWATER TITANIFEROUS MAGNETITES

HEAT NO.	CHARGE IN POUNDS: ORE	CHARGE IN POUNDS: Coal in Mix	CHARGE IN POUNDS: Late Coal Additions	TOTAL TIME	TAP OUT TEMP.	WT. METAL	METAL ANALYSIS: %C	%Si	%P	%Ti	%S	%Cr	%V	SLAG ANALYSIS: Wt. Slag	%Fe	Free %Fe
2796	150	15	6	112	1680	65	.75	.65	.20	.11	.17			53	1.48	.06
2797	150	15	5½	116	1670	72	1.38	.56	.21	.13	.18			48	1.65	.06
2798	150	15	5	117	--	53	.83	.26	.20	.13	.18			50	2.43	.06
2799	150	15	5	120	--	60	.44	.17	.21	.04	.19		.05	52	5.33	.11
2800	150	15	5	115	--	55	.15	.08	.20	.04	.20	.17	nil	58	10.00	.23
2801	150	15	7½	113	1640	63	.72	.05	.23	.09	.22			47	5.22	.12
2802	150	15	7½	115	1630	63	1.20	.16	.27	.06	.26			49	6.32	.18
2803	150	17	6½	111	1620	74	1.36	.17	.26	.05	.21			33	3.90	.21
2804	150	18	6½	122	1640	61	1.87	1.13	.17	.25	.16			41	3.19	.34
2805	150	18	6½	120	--	51	2.15	.81	.15	.22	.15			no slag tapped		
2806	150	15	5	112	1630	48	2.39	1.50	.17	.35	.12	1.99	.28	98	2.70	.47
2807	150	15	5	108	--	72	2.10	1.22	.19	.28	.13	1.73	.15	30	2.21	.23
2808	150	15	4½	108	--	84	1.99	1.49	.10	.32	.11			82	1.06	.06
[illegible]	143	14	5½	122	1640	73	2.05	1.45	.14	.22	.12			57	.94	.06
				Drain out		261	1.92	.67	.15	.19	.14	crucible		100	4.00	

COMPLETE ANALYSIS OF SLAG HEATS 2773 - 2809 INCL.

FeO ------- 3.44%
SiO_2 ------17.84%
CaO ------- 4.86%
MgO -------13.43%
Al_2O_3 -----25.25%
TiO_2 ------31.02%
P_2O_5 ------ .012%
Cr_2O_3 ----- .86%

FIGURE II

STRATEGIC-UDY PROCESS

REDUCTION OF TITANIFEROUS MAGNETITES

TITANIUM IN METAL AS A FUNCTION OF IRON CONTENT OF SLAG

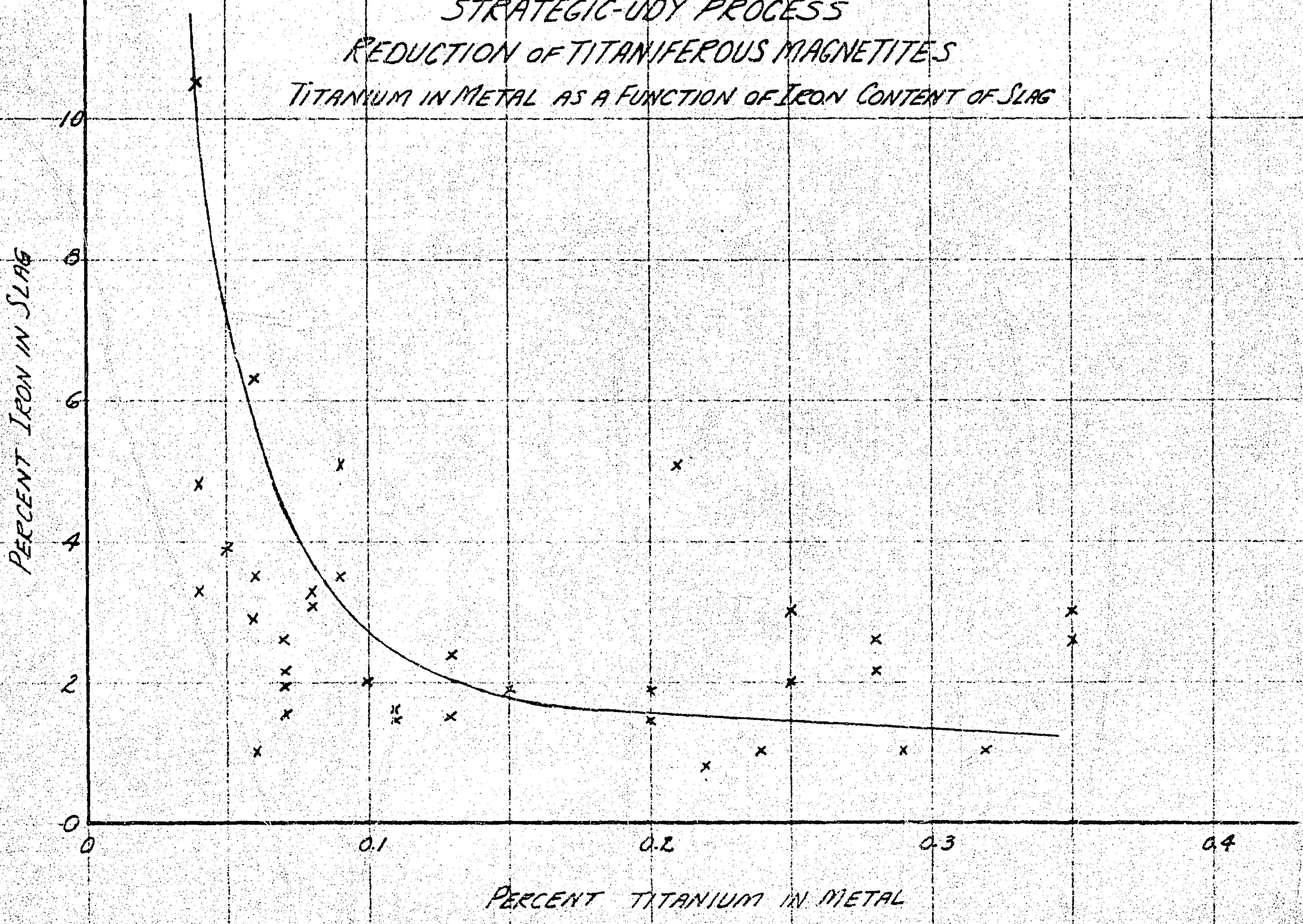


FIGURE III

STRATEGIC-UDY PROCESS

REDUCTION OF TITANIFEROUS MAGNETITES

CHROMIUM IN METAL AS A FUNCTION OF IRON CONTENT OF SLAG

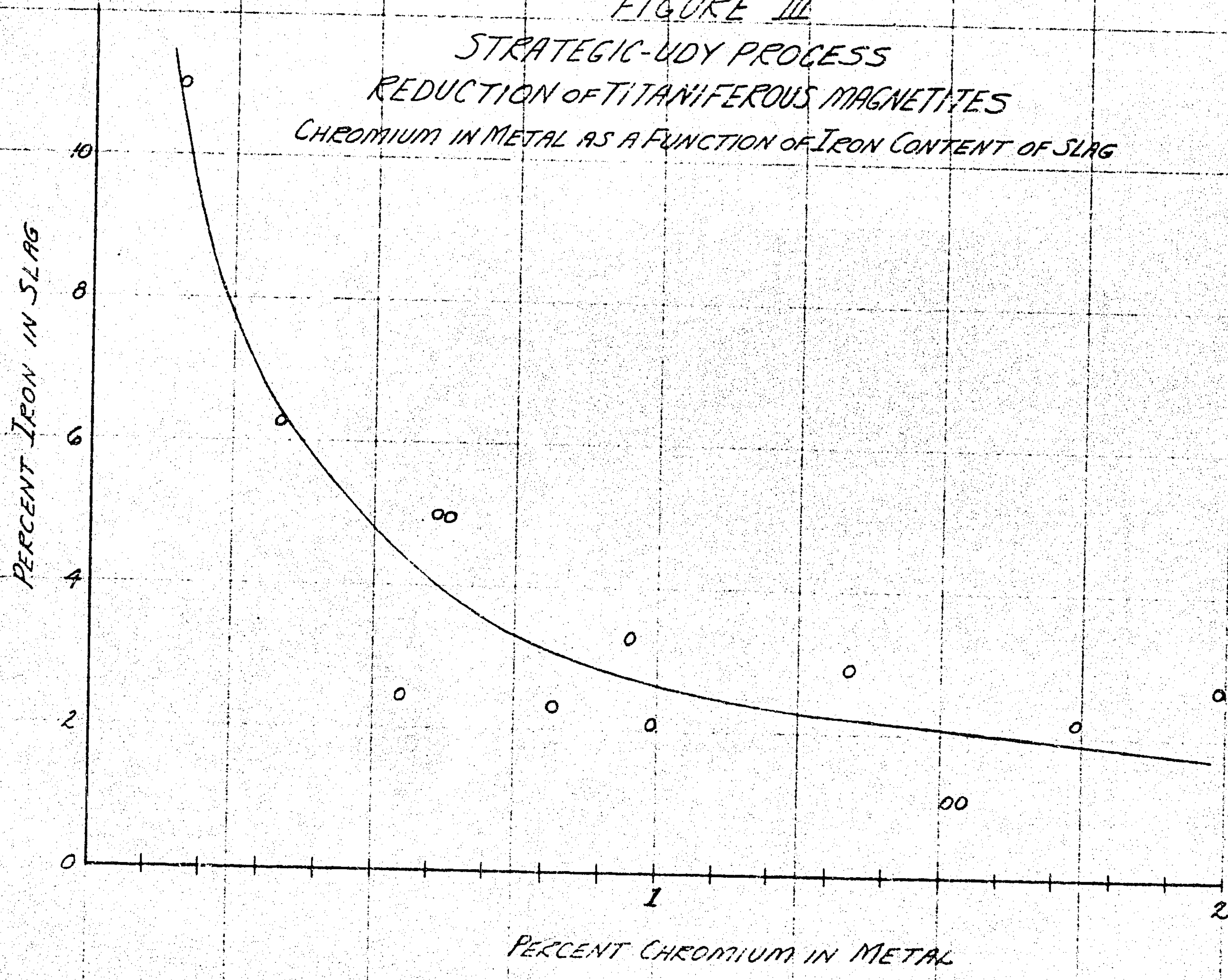


Figure IV shows information on vandium versus iron in the slag. Here again, 2% iron in the slag seems to be a desirable controlling point. Silicon content of the metal is likewise a function of iron content of the slag as shown in Figure V. Figure VI shows similar data for carbon. This is a much more scattered pattern and is undoubtedly influenced by the temperature at which reduction takes place. Figure VII shows that essentially all of the phosphorus in the ore goes into the metal and will have to be subsequently removed by a refining operation. The situation for sulfur is somewhat the same and is shown in Figure VIII. Only about half of the sulphur of the ore, however, enters the metal. This disregards any sulphur in the reducing agent.

POWER CONSUMPTION

Because of the low thermal efficiency of the 100 KVA furnace, no individual power data are given in this report. An overall figure of 5370 KWH per ton of metal is not out of line with power figures on other materials.smelted in the 100 KVA furnace and subsequently smelted on a larger scale with very satisfactory power figures of 1500 to 1800 KWhrs. per ton of iron smelted. Similar results on a larger scale of operation are anticipated for the Lapointe Awater ore.

MATERIAL BALANCE

From the furnace and analytical data of Table II, a material balance as regards iron and TiO_2 has been calculated for the 37 heats. This is presented in Table III. (see page 20 for Table III)

FIGURE IV

STRATEGIC-UDY PROCESS

REDUCTION OF TITANIFEROUS MAGNETITES

VANADIUM IN METAL AS A FUNCTION OF IRON CONTENT OF SLAG

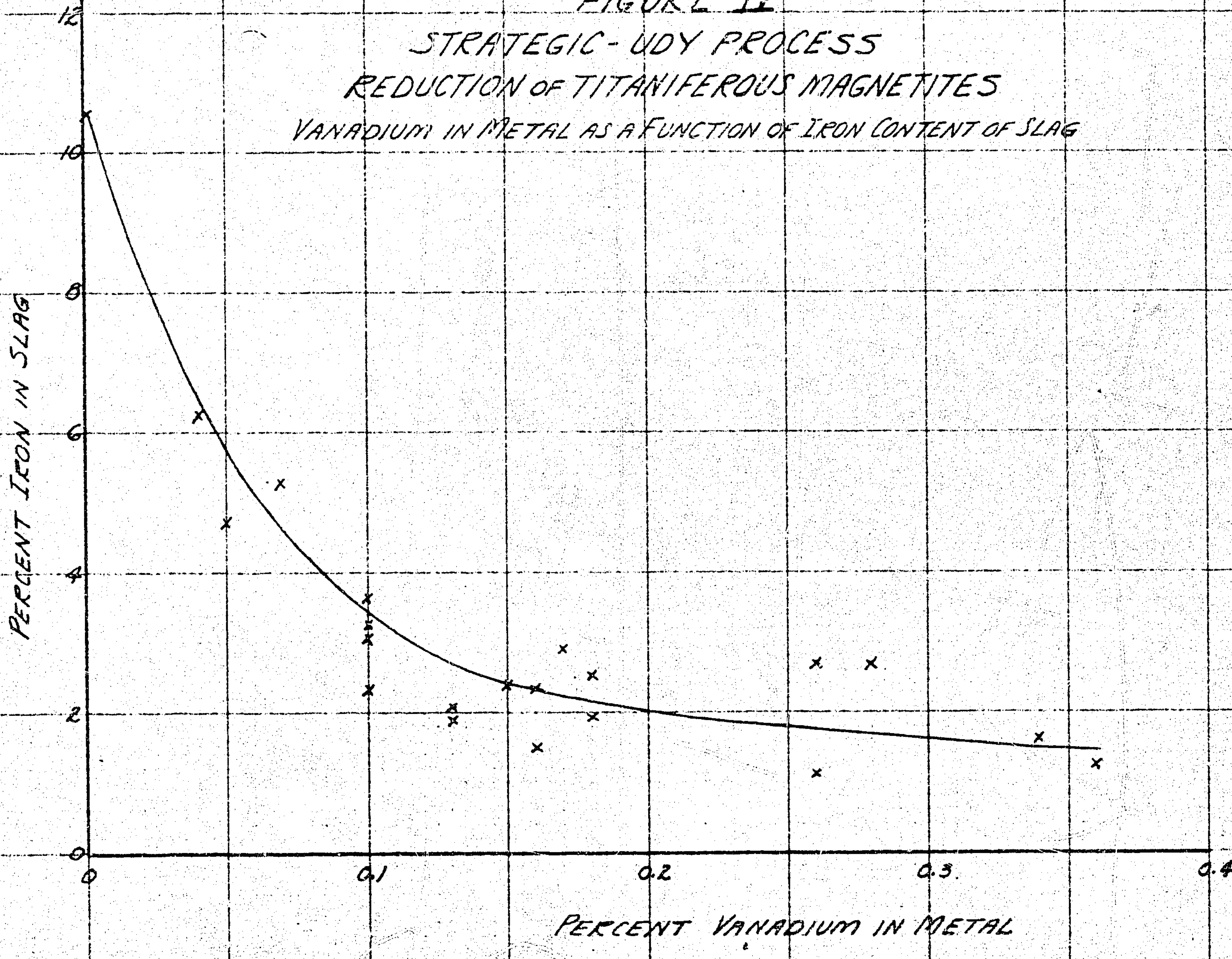


FIGURE V

STRATEGIC-UDY PROCESS

REDUCTION OF TITANIFEROUS MAGNATITES

SILICON IN METAL AS A FUNCTION OF IRON CONTENT OF SLAG

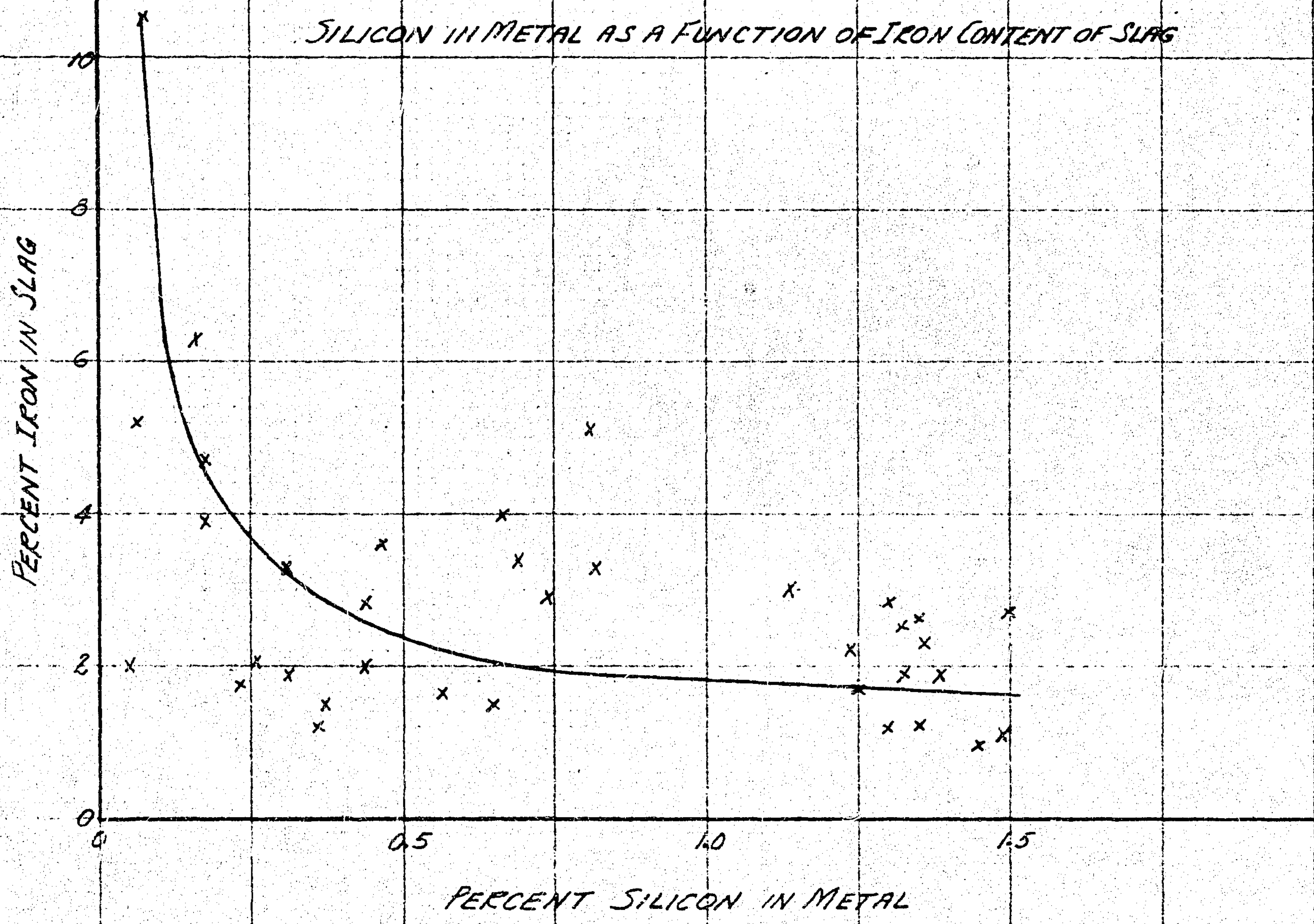
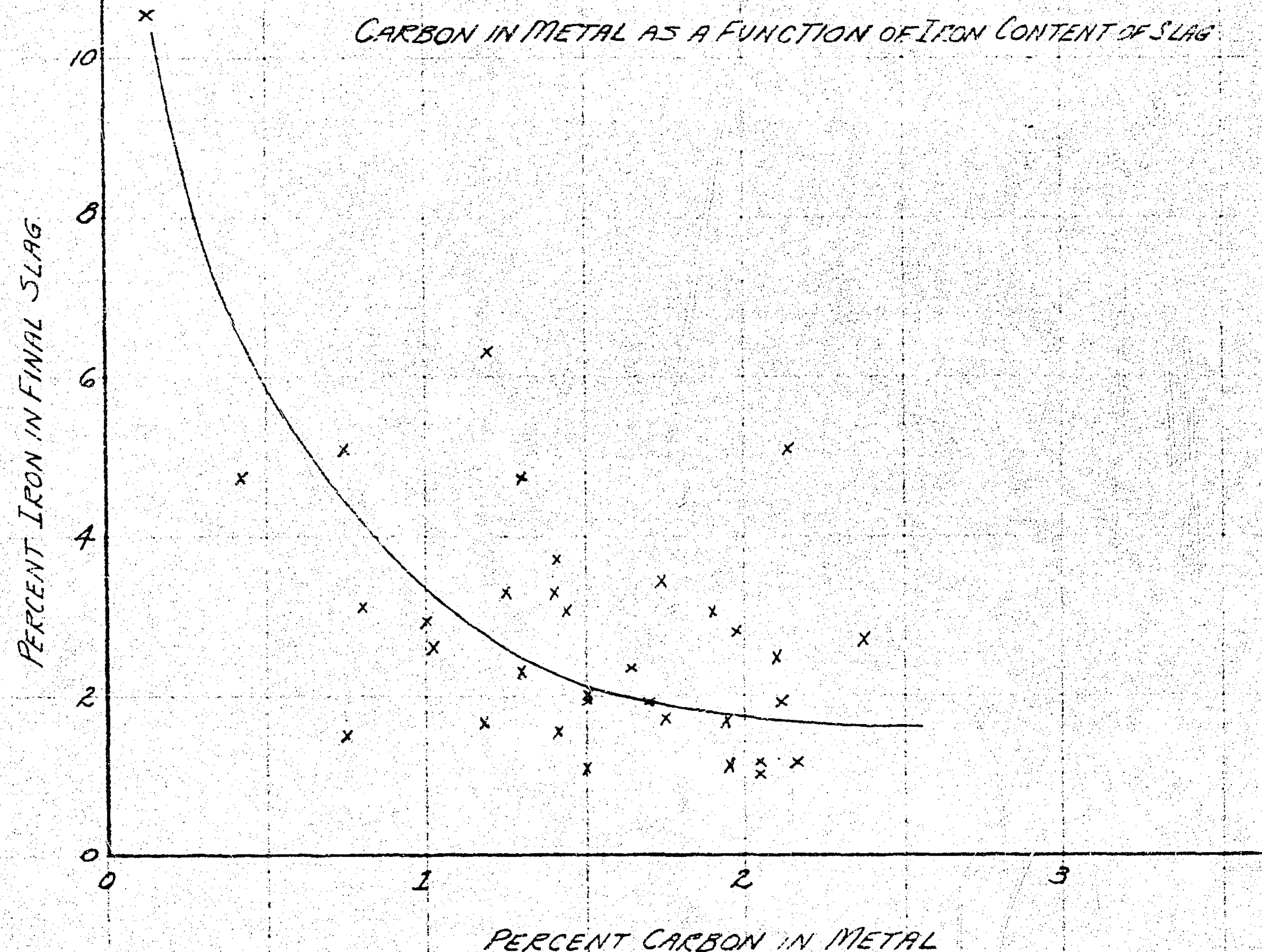


FIGURE VI

STRATEGIC-UDY PROCESS

REDUCTION OF TITANIFEROUS MAGNETITES

CARBON IN METAL AS A FUNCTION OF IRON CONTENT OF SLAG



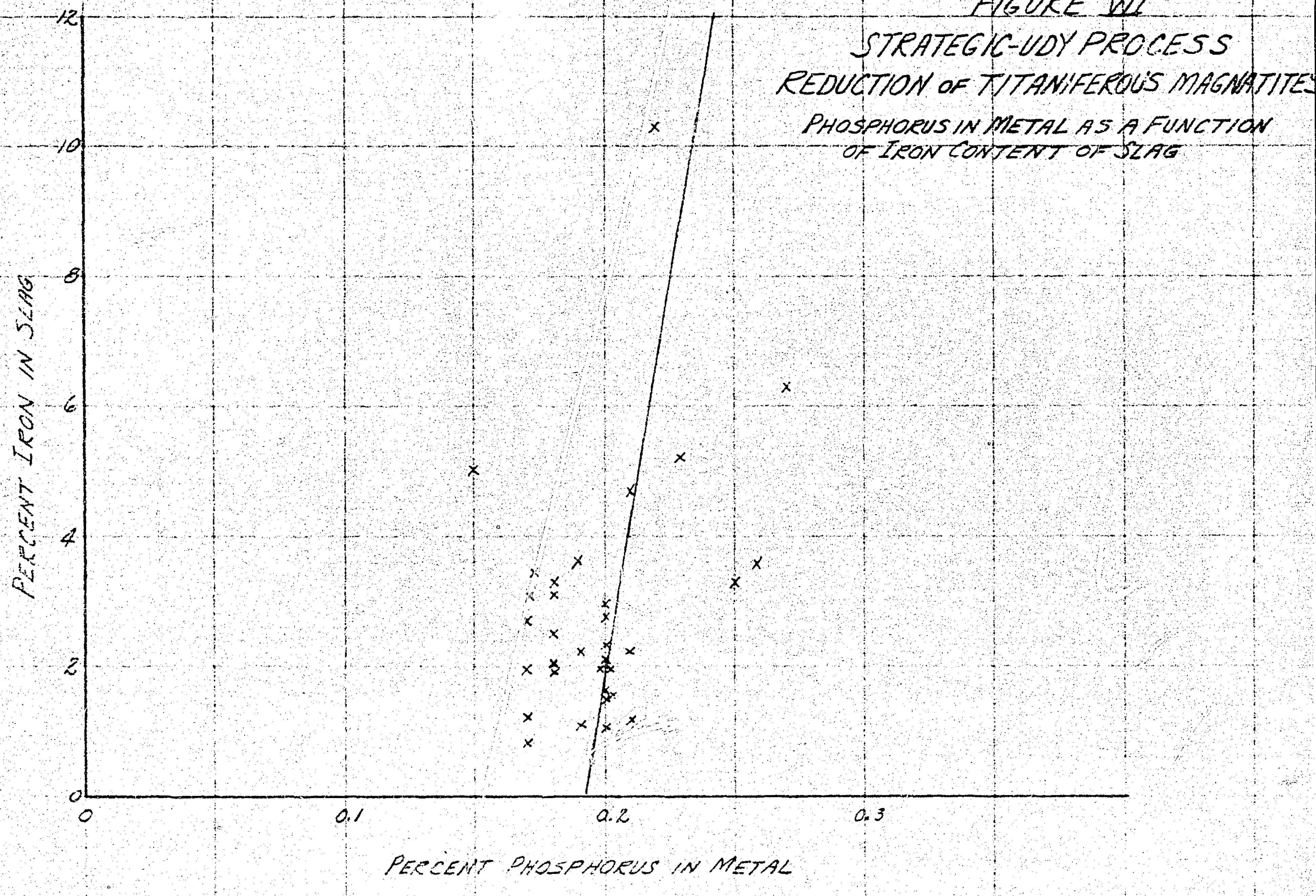


FIGURE VII
STRATEGIC-UDY PROCESS
REDUCTION OF TITANIFEROUS MAGNATITES
PHOSPHORUS IN METAL AS A FUNCTION OF IRON CONTENT OF SLAG

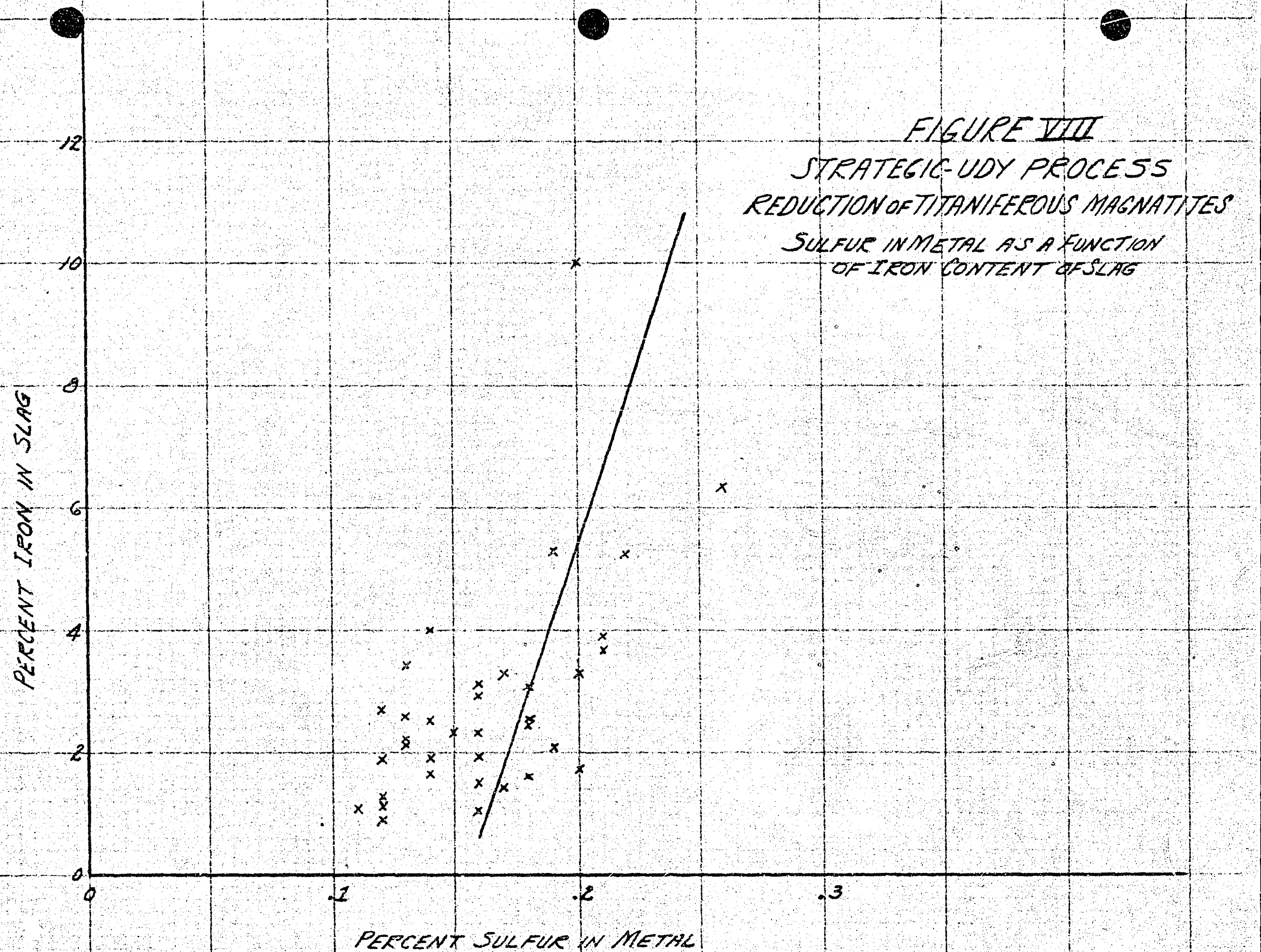


FIGURE VIII
STRATEGIC-UDY PROCESS
REDUCTION OF TITANIFEROUS MAGNATITES
SULFUR IN METAL AS A FUNCTION
OF IRON CONTENT OF SLAG
PERCENT IRON IN SLAG
PERCENT SULFUR IN METAL
0
2
4
6
8
10
12
.1
.2
.3

TABLE III

MATERIAL BALANCE

	Total Weight (lbs.)	Iron Weight, lbs	Iron Percent	Titanium Weight, lbs	Titanium Percent
Ore Charged (44.8% Fe, 11.56% TiO_2)	5543	2484.9	100	384.7	100
Metal Tapped (95.4% Fe, 0.16% Ti)	2524	2407.5	96.9	3.98	1.0
Slag Tapped (2.78% Fe, 18.61% Ti)	1935	53.9	2.2	360.1	93.6
Total Accountability	---	---	99.1	---	94.6

Some 97 per cent of the iron was recovered as metallic iron while only 1 per cent of the total TiO_2 was reduced to metal. This amount of TiO_2 reduced to the metal would be lower in a production run where varied experimental data are not being sought as in the present study.

CONCLUSIONS

The Lapointe-Awater titaniferous magnetites can be successfully smelted by the Strategic-Udy Process with low expendature of power and over 95 percent conversion of the iron content to metal.

The Lapointe-Awater titaniferous magnetites contain gangue material of such a nature that they are self-fluxing in the Strategic-Udy method of smelting .

Strategic-Udy technique can control the "impurities" of the slag (Ti, Cr, V) by control of the iron content of the slag. They can be put into the slag or into the metal at will.

Essentially all of the phorphorus and half of the sulfur from the ore enter the metal by the technique used in the demonstration. These can be refined from the metal by conventional steel making practices. Ti, Cr, and V, if the process is operated to put them in the metal, can likewise be removed by conventional practices.

The metal produced is a semi-steel, that is it has less carbon (1.5 per cent) than pig iron (3.5 per cent) and hence from this standpoint would be easier to refine to steel.