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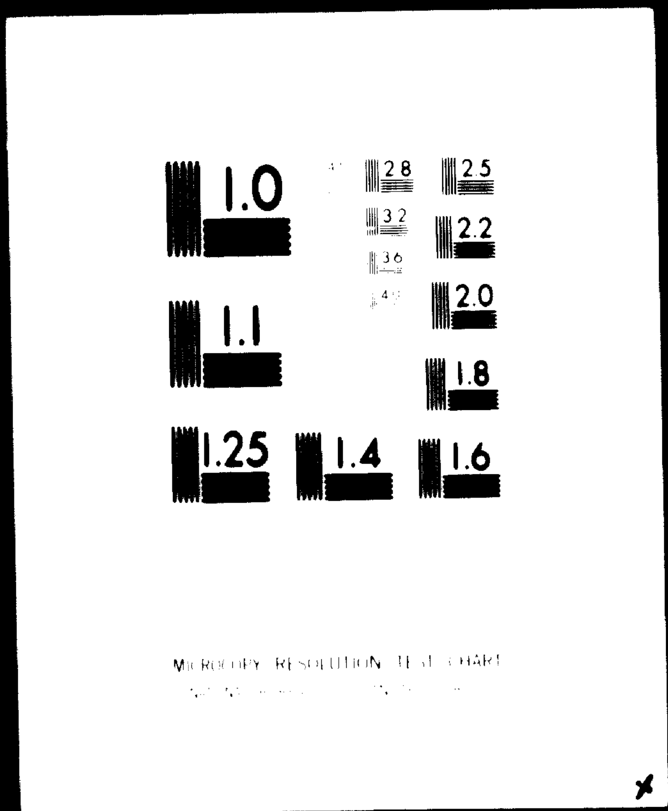

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FERENCO

FINAL REPORT

According to UNIDO Contract No.72/36 between

THE UNITED NATIONS DEVELOPMENT ORGANIZATION

and

SWEDISH FERRO ENGINEERING CO AB (FERENCO)

for the Provision of Services Relating to an Appraisal

Techno-Economic Feasibility Study of Ferro-Vanadium Production

in behalf of the INDUSTRIAL DEVELOPMENT CORPORATION (IDCO) of

ORISSA, INDIA.

February 1973

SWEDISH FERRO ENGINEERING CO AB (FERENCO)
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Contents

A. Summary

1. Introduction

Our task as Contractor in accordance with the UNIDO Contract No. 72/36 is:

To study the Elkem report of January 8, 1971 (ELKEM), covering pilot scale tests and recommendations as to the reduction of vanadiferous Orissa ores in an electric smelting furnace, alternatively including a rotary kiln for prereduction, Stage I and II. During the course of preparation of our report we have, as suggested in our quotation and as agreed with UNIDO, established a collaboration with Dastur & CO., Calcutta, India (DASTURCO) and procured their report of December 1971 on the Installation of a Ferro-Vanadium Plant in Orissa.

We find that these documents have been made up in a professional and conscientious manner and that they in our opinion constitute an important basis for further deliberations concerning the implementation of the project.

Furthermore to prepare an appraisal report on the techno-economic feasibility of carrying out:

Stage III -The production of high-grade V_2O_5 slag by blowing oxygen on to the surface of the hot metal from Stage II, kept in a shaking ladle;

Stage IV - The extraction of V_2O_5 from the slag inter alia by the soda roasting method (to be used for subsequent production of ferro-vanadium).

(Comments on Stage V, The Production of FeV).

We shall further make a general assessment of and give recommendations for all industrial operation from ore to ferro-vanadium in the appraisal report.

2. Conclusions and recommendations

Raw materials

The investigations and studies so far made indicate that the Orissa ore with the known analysis is suitable for the production of V_2O_5 and FeV according to the proposed methods.

A principal issue concerning the feasibility of the project is - as has already been pointed out by DASTURCO - that a sufficient supply of suitable ore is verified. This seems to be possible with the ore deposits available in Orissa, even if they are not located in one place, but it is obvious that the feasibility of the whole project depends on the results of future ore investigations.

The availability of ore with such analyses seems to be sufficient but hardly abundant as raw material for a plant with the planned capacity. It will therefore be necessary to carry out further detailed prospecting work to secure larger quantities of ore.

Metallurgical process and equipment

In our study we have paid special attention to the possible metallurgical processes to be used, as these will have a decisive influence on the feasibility of the project. We find that the metallurgical process as suggested by DASTURCO in their Alt. I is in principle correct with the presupposed conditions and that this also holds good for the equipment foreseen by ELKEM in their report.

The production of V_2O_5 is suitably carried out via production of pig iron in an electric furnace. The vanadium content of the pig iron is then transferred in a shaking ladle by means of oxygen blowing to a slag rich in vanadium. The vanadium oxide is extracted from the slag by soda roasting and subsequent leaching and precipitation. The V_2O_5 can then be reduced to ferrovanadium by an aluminothermical process. However, also other procedures should be considered. The vanadium slag can be reduced directly in molten condition with metallic Si and/or Al to ferrovanadium. This method is used by Bremanger in Norway. However, in this case the Si- and P-contents of the product have to be considered and also the question of patents.

The chemical treatment of vanadium slag for production of V_2O_5 is a complicated process, demanding great skill of at least part of the workers. To avoid too many complications during the running-in period it may be advisable to limit the production to vanadium slag only, in the initial stage, if feasible, and sell this slag somewhere else for further processing to FeV.

Cost calculation and profitability

Metallurgical and technical modifications as presented in our study will in our opinion not change the cost figures in any fundamental way for judging the profitability as presented by DASTURCO. Their cost calculation is therefore of basic value when the feasibility for the total project is considered.

As regards the profit to be made on the production of the V_2O_5 and the pig iron produced from Orissa ores the available data are not sufficient to calculate this profit with complete accuracy. However, the following can be said on the subject:

- The processing cost for V-slag out of pig iron and V-extraction to V_2O_5(95%) is approx. Rs 28/kg with a simultaneous decrease of the pig iron quantity from 50,000 to 48,000 tons/year. Assuming that it will be possible to sell the pig iron on the market without either profit or loss (which would depend on many factors such as price of electricity, market conditions etc.) and that the V_2O_5 can be sold at Rs 51/kg V, which is approximately the present market price, a net profit of Rs 51 - Rs 28 = Rs 23 could be obtained when producing vanadium as V_2O_5. The comparable price for V in FeV is approx.Rs 62/kg V.

B. Technical and economical data

1. General technical data

Weights and measurements

All dimensions and weights are given in the metrical system.

All weights of raw materials and process materials refer to dry weight.

Operational time

The smelter and the refining installation will be operated 24 hours /day in 3 shifts or 8760 hours/year with an estimated effective working time of 90% of 8760 hours i.e. about 7900 hours/year.

The chemical installation will be operated in 3-shift with an effective operational time of 330 days/year.

Manpower requirements

We have generally accepted the manpower requirements as suggested by ELKEM and DASTURCO.

Specifically we recommend for	men/shift	men/day	total
Shaking ladle operation	4	2	14
V_2O_5 processing plant	4	3	15

2. Products

Ferrovanadium

The full production of vanadium (V), calculated as 50% ferro-vanadium (FeV), will amount to 240 tons V/year for which figure the plant will be dimensioned in the first stage.

Pig iron

A production of 48000 tons/year of foundry pig iron will be produced. Whether the hot metal after the ladle blowing instead should be processed to steel is an open question and should be subject to further investigations.

Slag

Vanadium containing slag (2950 tons/year) is produced in the shaking ladle to be further processed to V_2O_5(85%). The slag produced from the electric furnace is of little economic significance.

3. Raw materials for smelting

Vanadium ore

The consumption of dry ore to reach the aimed 240 tons of V will be about 84,000 tons/year.

The consumption of wet ore depends on the moisture content of the ore.

For the typical ore analysis see C, page 19.

A free moisture content in the raw materials of about 8%($<100^oC$) and 3% ($> 100^oC$) may be allowed at the intake at the prereduction kiln when installed and for the reduction furnace. If the moisture content exceeds this figure a drier will have to be foreseen to be placed before the loading station at the ore preparation equipment to make sure that the feeders, screens, conveyors a.s.o. will function satisfactorily.

Coke as reduction agent

3-25 mm, weight about 0,5 tons/m^3.

Assumed consumption 21,000 tons per year (ELKEM)

Limestone	11,000	tons per year (ELKEM)
Dolomite	9,000	tons per year (ELKEM)
Quartsite	5,000	tons per year (ELKEM)

Electrode paste

4. Process materials for refining and desulphurization

Lime for desulphurisation

This amounts to 1,4% x 48000 = 720 tons/year

or

Calciumcarbide 0,8% x 48000 = 390 tons/year

Ore for cooling

about 50 kgs/ton pig iron i.e. 2400 tons/year

Sand for slag conditioning

about 0-50 kgs/ton pig iron i.e. max. 2400 tons/year

Coke or anthracite as reducing agent during desulphurising period

about 300 kgs/charge or 20 kgs/ton pig iron.

This amounts to 1000 tons/year.

Oxygen for V-oxidation

Assumed consumption 15 Nm^3/ton of pig iron.

This would give > 720,000 Nm^3/year

5. Process materials for production of V_2O_5 from vanadiumslag

See C, metallurgical process, page 36.

6. Auxiliaries for smelting and refining

Cooling water for smelting and refining

must be technically clean, not corrosive and not apt to form incrustations. The temperature of the incoming cooling water should not exceed 30°C.

A total consumption of 500 - 1000 m^3/h will have to be foreseen at this stage. The necessary pressures will vary according to the equipment that needs cooling and will have to be investigated.

The quantity that can be recirculated if necessary will also have to be investigated.

Compressed air for general purposes

6-7 kgs/cm^2. Dehydrated. A consumption of about 10 m^3/min. free air for general purposes is assumed.

Fuel oil

For raw material drier (if needed) about 2000 kgs/h = 48 t/24 h

" ladle heating " 50 " 1 t/24 h

Total for the plant about 50 t/24 h

or 18,000 t/year

Steam

For occasional needs about 2 t/h, 6 kgs/cm^2

Electrical Equipment

The electrical equipment will be designed for an ambient temperature of max. 45°C.

Electrical data as to voltage, frequencies, max. variations in voltage and frequencies, short circuiting regulations and max. motor power for direct starting a.s.o. to be specified later on.

C. Technical description of metallurgical processes

1. Survey

The required investigation is limited to one of the procedures that can be considered for the extraction of vanadium as V_2O_5 from vanadium- and titanium containing magnetite ores. The investigation is primarily based on our own experience with production of vanadium and on our activities as consultants in this field. We also want to refer to the results with the method used at Highveld in South Africa, published in the J.I.S.I. as well as to the reports from ELKEM and DASTURCO. In order to elucidate the matter in a general way we will start with a short survey of the various methods that could be used for the extraction of vanadium from iron ores.

As mentioned above the ore contains a considerable amount of TiO_2, which is often the case with vanadium bearing iron ores. If the TiO_2 content exceeds a certain limit, the ore will not be suitable for reduction in the ordinary blast furnace process. Generally a TiO_2 content up to 2% in the burden can be tolerated, but if higher, the viscosity of the pig-iron as well as of the slag will increase because of formation of titanium carbide and titanium-carbide-nitrite. They have a tendency to accumulate in the lower part of the blast furnace and thus disturb the operation. It is not possible to separate the titanium oxide satisfactorily before melting by means of magnetic separation.

When the titanium content is as high as in the Orissa ore it is consequently not feasible to carry out the reduction of such ore in a blast furnace. An electric furnace has to be used. If then the vanadium extraction is to be carried out with simultaneous pig iron production, the melting should be carried out in an electric smelter, as has been suggested here.

In order to save electric energy and at the same time increase the production of pig iron a prereduction unit can be added - suitably a rotary kiln (see below) - before the melting process in the electric furnace.

When reducing the ore directly to pig iron in an electric smelter, the main part of the vanadium content of the ore is reduced into pig iron. The pig iron is then partially oxidized in a separate process during which the vanadium is transferred to the first slag that is formed. Such oxidation could in principle take place in an ordinary bessemer converter with acid or basic lining, or in some other conventional type of steel furnace.

However, during the last few years a method has been introduced to carry out the pre-refining of the pig iron by blowing oxygen gas against the bath, which is kept intensively moving in a so-called shaking ladle. The results obtained with this method are very good and the method has proved to be preferable to other refining methods (J.I.S.I. p.336, April 1970).

The shaking ladle slag which is rich in vanadium has - after crushing and magnetic separation - been tried directly as an addition in the steel production, but unfortunately with little success. Normally ferrovanadium is used for alloy additions. The vanadium oxide is extracted from the slag by a chemical procedure (see below) and then reduced to ferro-vanadium, normally aluminothermically, to an alloy with approx. 50% V.

There is also a possibility to reduce the untreated vanadium slag directly after crushing and magnetio dressing to Fe-V by means of some aluminothermical or silicothermical procedure. One condition is, however, that the FeO-content in the slag is so low that the Fe-V-metal produced will contain a sufficiently high V-content. A procedure of this kind was developed and patented by Bremanger in Norway. The mode of procedure is that the FeO containing vanadium slag is remelted and if necessary partially reduced to such extent that a sufficient quantity of iron is separated. The fluid slag, then relatively free from iron but rich in vanadium, is reduced with a high silicon FeSi alloy. The iron content may possibly be sufficiently decreased in the slag already during the oxygen refining period, by means of a finishing treatment with a suitable means of reduction, i.e. charcoal-breeze, in the ladle before tapping. The silicothermical method could be adapted in this case, however under the condition that the slag is free from higher contents of such reducible elements that are not wanted in the final Fe-V-metal (P, Cr etc., see below). In order to decrease the Si-content in the metal to less than 5-10%, if desired, it is furthermore advisable to carry out the reduction in two stages. Instead of FeSi or a mixed FeSi and aluminium addition it should of course be possible to use only aluminium for direct reduction of the vanadium slag.

The extraction of V_2O_5 from the slag by means of chemical treatment is carried out as follows: after crushing and magnetic separation the slag, mixed with soda, will pass through a roasting process followed by leaching and precipitation of V_2O_5. The V_2O_5 is then dried to a water-free product with approx. 85% V_2O_5 which is transferred into metallic vanadium (50% FeV) through an aluminothermical reduction in a crucible furnace.

Other methods for extraction of V in iron ores have been proposed and also been used. By one procedure the ore is partially reduced by melting in an electric furnace with free burning arcs reducing in the first place the main part of iron, whereas the vanadium, together with the remaining iron, stays in the slag. Same is treated with chemicals so as to extract the vanadium.

This method has considerable disadvantages(in comparison with the process via pig iron)among which it is important that the process has to be carried out with considerably higher temperatures, owing to the relatively high temperature that is needed because of the low carbon content in the iron metal obtained in this case (approx. 1% against approx. 4% for pig iron refining). This means a higher power consumption and a larger wear of the lining; furthermore there is afterwards the higher cost for transferring the metal into pig iron with required analysis for selling purposes. Besides the iron content in the vanadium slag obtained must be kept relatively high, which makes the carrying out of the reduction more difficult and the following chemical process more expensive; moreover it can be expected that the losses of vanadium as well as iron can be relatively high. On the other hand the method has the advantage that TiO_2 can be utilized from the slag, should this be of interest (see below).

Various methods have also been used for the extraction of vanadium from high Ti iron ores, directly through chemical operations without a preceding smelting process. In the 1950-ies a method was developed at Otanmäki in Finland which is still in operation at that plant. The procedure is as follows: the ore is after concentration mixed with sodium carb. (Na_2CO_3) and the mixture is pelletized under oxidizing conditions. During this operation $NaVO_3$ is formed that is dissolved when afterwards the pellets are leached in water. From the solution the vanadium is precipitated through addition of sulphuric acid. After this treatment the remaining pellets are used for the production of pig iron. However, according to information received the pellets will be rather loose and are maybe not entirely suitable for this purpose.

The problems to utilize the iron content of the ore economically, either for production of pig iron or in some other way also refer to other direct leaching procedures. Apart from this it can also be difficult to obtain a satisfactory vanadium yield using these processes. The best yield may certainly be obtained from the Orissa ores through electric pig iron melting, also with a view to the relatively low V-content of the ore in this case. A drawback of this procedure is that no economical utilization of TiO_2 can be carried out simultaneously. However, owing to the fact that big quantities of TiO_2 are available in India the possibility of utilizing also the TiO_2 content is practically of minor interest.

From what has been stated above it would seem justified to limit our investigation to the methods of production as foreseen in the Statement of Work in our assignment:

Stage	I and II	Electro pig iron and prereduction
"	III	Oxygen gas refining of the pig iron in a shaking ladle
"	IV	Roasting and leaching of the obtained slag
"	V	Reduction of vanadium oxide to ferro-vanadium

2. Stage I and II The reduction of the ore to pig iron in an electric melting furnace

The analysis of the ore intended for the operation is calculated - according to information in the DASTURCO report - to be approx. the following:

Fe	58,2%
SiO_2	1,2%
CaO	0,1%
MgO	1,3%
Al_2O_3	3,0%
TiO_2	12,2%
V_2O_5	1,0%
P	0,03%
S	0,015%

Most likely the ore has also a minor Cr content, but this would probably not have much influence on the final analysis of the vanadium oxide.

Tests and comments

Ore with the above analysis has been tested in a pilot plant for electrical smelting at the ELKEM plant in Fiskaa, Norway. Furthermore detailed laboratory tests have been made in order to further investigate the suitability of this ore for the purpose intended. We shall not go into the details of these tests here, as they have already been thoroughly described in the ELKEM and DASTUR reports. We shall only give some points of view.

As emphasized in the introduction of our report it is not possible to reduce an ore with higher TiO_2 contents than approx. 2% in an ordinary blast furnace. If the TiO_2 contents are higher, electric smelting is necessary. Tests have proved the ELKEM furnace type to be suitable for this purpose. They give, however, no explicit answer to the question of operation costs per ton of pig iron in a full-scale plant, nor about the vanadium yield from ore to pig iron that can be calculated. In order to get this question and others clarified we have contacted ELKEM. As a result of our detailed discussions with them we have come to the conclusion that the operation results from Fiskaa and the costs calculated from these results could be the basis for a reliable economic calculation. We think it correct to count with - as has been proposed - that the process in the first stage is carried out without prereduction, the latter making the operation more complicated and implying increased difficulties to achieve undisturbed operation. The prereduction can be installed at a later suitable state of development and it will then be possible to increase the production considerably at the same time. We have in our cost calculations also considered parts of the calculation stated in the DASTURCO report, based on the results obtained at ELKEM. These statements appear in the DASTURCC report appendix 9-9 Alt.I and are reproduced below in a modified form.

The vanadium yield from ore to vanadium - pig iron is calculated to be 75%, from pig iron to vanadium slag 92%, from vanadium slag to dry vanadium oxide (with 85% V_2O_5) 82% and from V_2O_5 to 50% FeV: 90%.

The distribution of the V in the various partial processes will thus be as follows:

	V quantity	quantity of product	V yield
ore	470 tons	84,000 tons	
pig iron	352 "	50.000 "	75%
vanadium slag w. 11% V	325 "	2.950 "	92%
vanadium oxide w. 85% V	265 "	.310 "	82%
ferro-vanadium w. 50% V	240	480 "	90%
Total yield			51%

In order to produce 480 tons FeV (240 tons V) per year the total V-content of the ore should thus be 240:0,51 = 470 tons V = 840 tons V_2O_5. If the V_2O_5 content of the ore is 1%, the ore quantity has to be 84,000 tons/year and in this case the pig iron quantity will be 84,000 x abt. 0,60 = 50,000 tons. Normally these yields could be maintained as soon as the process is run in.Even higher yields could be foreseen.

3. Stage III Production of vanadium slag

Shaking ladle practice with oxygen blowing

The process is carried out in a so-called shaking ladle, in which the pig iron, whilst stirred intensively, is treated with oxygen gas that is blown in from above against the bath surface. The pig iron is transferred from the electric smelting furnace to the neighboring shaking ladle equipment into a 15 tons ladle, which is then placed on a movable table that gives an eccentric but not rotating movement. We have chosen a 15 tons ladle to simplify the practical operation and to keep overall installation cost at a reasonable level.

The reason why this treatment was chosen appears from the following: In order to achieve a maximum oxidation of the vanadium content of the pig iron without undesirable decarburization, the oxygen blowing should be carried out in a metallurgical furnace, where a proper stirring can be guaranteed, independent of the way and the course of the reaction. Tests and applications have proved that oxygen gas blowing in a shaking ladle gives the best conditions for a selective oxidation of vanadium in liquid pig iron. Oxygen gas refining of pig iron implies primarily oxidation of important quantities of iron apart from the still more easily oxidated elements Ti,Si,V,Mn and Cr. By carrying out the oxygen blowing under intensive stirring, local overtemperatures and unnecessarily high carbon- and iron oxidation are avoided. If the blowing is interrupted before the easily oxidable alloy elements are entirely oxidized and if the treatment is terminate by an extra shaking operation with addition of a reducing agent, suitably coke or anthracite, a considerable part of the iron oxide surplus in the slag can be re-reduced, which makes the vanadium content at the same time correspondingly higher. The treated pig iron that has a very low silicon content and also a somewhat decreased carbon content has to be further adjusted either through additions of carbon and silicon or possibly by continued refining to steel in an LD converter or other suitable steelmaking furnace.

The blowing technique

The pig iron from the smelting plant is if possible tapped direct into the shaking ladle to avoid unnecessary temperature losses. Another possibility is to charge the shaking ladle by means of a separate transport ladle. Big mixers should be avoided, as the oxidation of Ti can cause heavy slag skulls. During the filling of the ladle samples for analysis are taken of C, Si, Mn, Ti, V and S. The analysis has to be ready well in time before the blowing. Slag from the smelting plant must be kept back, partly because of the relatively high basicity of this slag and partly to avoid dilution of the vanadium. Guided by the analysis and the temperature of the pig iron before blowing the need of cooling means and oxygen consumption is determined. To achieve a complete vanadium oxidation with the least possible decarburization the following conditions have to be maintained:

a) The slag has to be acid all the time, i.e. basicity $CaO/SiO_2 < 0,5$.

b) The temperature should not be allowed to exceed 1350°C.

c) The oxygen blowing is to be carried out with a vertical water-cooled lance in this case with an opening of abt. 50 mm. The oxygen jet distance from the bath at rest should be 500-700 mm and the oxygen gas flow abt. 15 Nm^3/min.

The oxygen gas blowing takes place under maximum shaking operation i.e. somewhat above the critical number of revolutions that is determined by the eccentricity and the height and width of the bath. The principle is to avoid superheating and increased decarburization in connection herewith. The oxygen gas stream should not penetrate too deeply into the bath. The flow and the lance distance should all the time be moderated so as to obtain an even iron oxidation without carbon boil tendencies. Towards the end of the blowing, when the greater part of the vanadium in the pig iron is oxidized, special care should be taken. Experience shows, however, that the half-molten hard slag formed to a great extent protects the bath and, therefore, a certain braking pressure in the oxygen stream is necessary to carry out the oxidation efficiently. The ladle treatment is finished by 8-10 minutes' shaking without oxygen blowing, so as to utilize the surplus of Fe-oxides in the slag for the final vanadium oxidation. During this part of the operation a reducing agent is also added in order to further reduce the FeO-content in the slag. As the process is exothermic it is necessary to add to the bath suitable means of cooling, such as pig iron, ore or lime. If cold pig iron is added, this has to be done preferably before charging the liquid pig iron, whereas ore and lime can be added during the oxygen blowing.

Technical information

Typical normal operational data.

The shaking ladle

is calculated for a charge weight of 15 tons and is equipped with a lined lid. It should have an inner volume of approx. $5m^3$ and furthermore the design as is shown in fig. 2A. The bricklaying is made with an inner lining with a high Al_2O_3 content. The average lining consumption is calculated to be 15 kgs per ton of treated pig iron, corresponding to a lining life of approx. 60 heats.

The oxygen gas consumption

being about 15 m^3/min, is calculated to be totally 15 m^3/ton pig iron or somewhat higher. It may be possible to at least partly substitute the oxygen gas with air, owing to the highly exethermic course of the reaction. This question is worth a further investigation.

Means of cooling

If the cooling is carried out with ore a total addition of about 750 kgs in the ladle or 50 kgs per ton of pig iron is needed. Cold pig iron and scrap are preferably added before the addition of the liquid pig iron, whereas ore is added continuously during the blowing.

Sand

A certain quantity of sand, 0–50 kgs per charge or 0-3 kg/ton of pig iron may be necessary to add in order to achieve a suitable acidity of the slag.

Coke (or anthracite)

is generally necessary to add in order to reduce excess iron oxide in the slag during the after shaking period (approx.300 kgs per charge or 20 kgs/ton pig iron).

Man power

is calculated to be 4 per shift = 12 men + 1

Total: 13 men per 24 hours = 0,6/h.

The initial temperature of the pig iron

should be approx. 1200°C and after blowing approx. 1350°C.

The composition of pig iron and slag

The pig iron before and after the blowing is expected to have the following analysis:

Tab.

	C	V	Si	Ti	Mn	quant/year
Entering pig iron	4,0	0,70	0,20	0,25	0,25	50,000 t.
Outgoing pig iron	3,5	0,04	abt.0,02	abt.0,01	abt.0,01	47,000 t.

The V-content of the slag is calculated to be 11% after crushing and magnetic dressing. The complete analysis of the slag will be approximately the following:

SiO_2	30%	
V_2O_5	19,8%	11,0% V
Al_2O_3	12,0%	
TiO_2	7,0%	
MnO	5,0%	
FeO	19,5%	15,0% Fe

The separated magnetic fraction, being approx. 20% of the entering slag weight and containing approx. 1% V can be regained in the process as means of cooling.

Production of pig iron and slag

At the annual production of 50,000 tons of pig iron and the operating time 330 days, the daily production will be 152 tons. With a charge weight of 15 tons the number of charges per day will be 10, i.e. the time from tap to tap is approx. 2.4 hours.

At the above stated annual quantity of 2950 kgs V-slag (page 21) the total quantity of produced vanadium is 325 tons/year at this stage of production.

Treatment of the refined pig iron

The refined pig iron can according to what has been said above be transferred into products with marketable analyses. Obviously the oxygen refining of the hot metal can be continued in for example the LD steelmaking furnace, followed by a continuous casting machine for billets. The planned quantity of hot metal is however rather small for a rational steel production in this way. The method proposed by DASTURCO, i.e. to increase the quantity with iron from some other plant, is naturally worth considering, but it is now difficult for us to estimate what economical advantages could be achieved by such a procedure.

At this point it seems natural to plan for an adjustment of hot metal to cast pig iron with approx. 1% Si, according to the following procedure. After the vanadium blowing the hot metal is tapped into another preheated ladle of the same size and construction, which ladle is intended only for alloying of silicon and if needed an adjustment of the carbon content. At the same time efficient desulphurization can be carried out by means of addition of burnt lime and/or calcium carbide. In this way it is easy to achieve a sulphur content below 0,005%.

After additions for alloying and desulphurization the shaking ladle is entirely locked with a lid and is shaken at full speed for 10-15 minutes. Normally the temperature loss during this period will be 60-80°C. When alloying to approx. 1% Si an addition of approx. 1,5% 75% FeSi is needed. The addition is made immediately before adding the desulphurization agent. For desulphurization 0,8% calcium carbide or 1,5% finely ground burnt lime is sufficient.

During the oxygen refining the weight of the pig iron is decreased from 50,000 tons to 47,000 tons per year, the vanadium content being 0,04% (page 21). The quantity of foundry pig iron produced is estimated to 48,000 tons per year.

The above mentioned procedures, resulting in a vanadium slag with approx. 11% V and a foundry pig iron with approx. 1% Si, are shown in the flow sheet in fig. 3.

Before the chemical treatment the slag must pass through a relatively complicated crushing procedure down to a finely ground product. As the slag, owing to its half-molten consistency, has a high content of metallic iron, magnetic separation will also be necessary.

It should here be noted that the slag at this stage can very well be sold as a raw material to other producers of pure vanadium oxide and ferro-vanadium.

Stage IV Production of V_2O_5 from vanadium slag by roasting and leaching

Process

The vanadium slag produced according to Stage III is transferred from the slag storage to the chemical plant. The chemical treatment until V_2O_5 is assumed to take place according to the following schedule (fig. 4), based on practical experience from a somewhat smaller Swedish plant.

Sorting of slag

The size of the slag pieces varies from as much as 1 m diam. and downwards. Before crushing large iron pieces have to be separated by manual sledging.

Slag handling

The slag is transported by scrape loader to a jaw crusher. Owing to risk for poisoning the entire crushing equipment - the crushing raising a great deal of dust - is under suction to the filter equipment. The control cabin is overpressured with fresh air. By means of a rubber belt elevator the material is passing a magnetic separation to sort out pieces containing iron. The slag is then fed into a (40 tons) slag bin.

Grinding

The slag is ground in a ball mill. The material leaves the mill through a 3,5 mm opening and is transported via a rubber belt elevator to a wind sieve where a coarse fraction is separated from the fines. The fine material is fed to a slag storage bin. The coarser fraction is passed through a magnetic separation where the metallic iron is removed, and is then fed back to the ball mill where it is further ground. The entire grinding department is underpressurized. All the treatment of the slag as well as the vanadium solution and the final vanadium oxide are connected to the filter plant suction mentioned above.

Soda handling

Calcined (water free) soda(98-100%), delivered in 100 kgs packages, is used in the production. The storage capacity is 60 tons. The soda is crushed and transported by elevator to the soda bin.

Slag-soda mixing and treatment

By means of feed controls from the slag resp. the soda bins the charge is led batchwise via automatic scales to the mixing mill. The mill is filled with flint balls. From the output end of the mill the finished slag-soda mixture is lifted up to an intermediate bin by means of an elevator.

Nodulizing

From the intermediate bin the mixture is led to the nodulizer by means of a feed control with variable speed. In the nodulizing apparatus a certain amount of water (20^{o}) is added. The apparatus is kept clean by a slowly moving scraper. Besides there is an axle, equipped with pegs and also longitudinal, which rotates and kneads the goods. The nodulizing procedure must continuously be controlled by one man. The water addition has to be adapted to the material. Cleaning of the nodulizing apparatus has to be done normally once a week.

Roasting

The result during the procedure in the furnace is mainly depending on

1) soda content
2) formation of nodules (water content)
3) time
4) temperature
5) surplus air
6) possible presence of metallic iron
7) grain size

The time that the material is kept in the furnace can be regulated by changing the number of revolutions. The maximum temperature at the roasting should be 800°C, the normal temperature 750-770°C. The relation between time, temperature and surplus air can be regulated in the furnace. Outgoing fumes are cleaned in cyclones. The roasted nodules are transported by screw feeder and elevator to an intermediate bin for leaching.

Leaching

Approximately 12 leachings can be carried out per week. The leaching vessels are first filled with soda that circulates by means of a pump and then the material is charged into the vessels. The time for every leaching is 18-20 h. During the procedure considerable heat quantities are developed and therefore the starting temperature in the first step should not be higher than 30°C. In the second container a suitable temperature is approx. 60°C, in the third approx. 70°C and from then on approx. 80°C. As long as the outgoing soda lye maintains a specific weight higher than 1,11 it is pumped into the precipitation vessel for cleaning.

Cleaning

In the precipitation vessel for cleaning sulphuric acid for Ph adjustment to Ph 8,8 - 9,2 is added under stirring, then ammonia and magnesium chloride. These additions are needed in order to precipitate the SiO_2 and P_2O_5 contents of the solution. In the prevailing case, where the P_2O_5 content is relatively low, it is to be expected that somewhat smaller quantities than those assumed here are needed, but this has no great influence on the cost. The temperature during the precipitation procedure should be low, under 30°C. Therefore, the precipitation vessels are equipped with a cooling mantle. As soon as the precipitation has settled the clear mother lye is separated and pumped towards the precipitation vessels for V_2O_5 precipitation. The (phosphoric) silicon oxide precipitation goes to the cleansing vessels where it is diluted with water and blown with air. Then the precipitation is left for a few days so as to stabilize properly. The clear solution is used in the last step of the leaching, as incoming "water". The precipitation is checked on vanadium before being discharged.

Precipitation

The mother lye that was pumped into the precipitation vessels is heated whilst being stirred with steam from a heating coil. The solution should have a temperature of 80-100°C, near to its boiling point, in order to achieve a good precipitation. The Ph-value is adjusted by addition of sulphuric acid under stirring. When the Ph is 2,8 - 3,2, the precipitation of V_2O_5 takes place. If the solution has higher acidity the deposit will be more brick red, heavier, granular and easily filtered. When the precipitation is finished, samples of the mother lye must always be taken in order to make a laboratory analysis of non-precipitated vanadium oxide.

Filtration

Filtration is carried out with an Oliver filter. During the filtration the agitators are operating in the precipitation vessel and in the absorbing vat under the Oliver filter. In order to remove as much sodium sulphate as possible the precipitation is rinsed with hot water. In the filtrate there is the greater part of P, Cr, S and the surplus of mineral acids. The V-content of the filtrate is controlled, which gives information about the condition of the filter. Normally it is discharged directly.

Drying

The outgoing filter cake, V_2O_5, is carried by a screw feeder into a drying furnace, which is rotating and equipped with sections, , within which the material is moving. The drying is carried out with air heated by electric radiators. The furnace operates according to the counter-current principle. "Exhaust gases" coming from the furnace are passing a washing tower, where accompanying vanadium acid - if any - is dissolved in circulating sodium lye. The circulation solution is transferred to the leaching vessels.

During the drying operation the water content of the vanadium oxide is decreased from 70 to 10%. By means of feed control and elevator the dry vanadium oxide is collected in an intermediate bin for packing. This is a manual operation, and handling the dry vanadium oxide implies great health-risks. Efficient suction eliminates these risks.

The obtained dried vanadium oxide contains approx. 85% V_2O_5.

As can be seen from the above, the chemical treatment of the vanadium slag is a relatively complicated process for which is required great skill and experience from the staff. If it proves to be possible to sell the vanadium slag as such at a satisfactory price it is probably advisable to postpone the instalment of a chemical plant until the preceding steps of the production are run in and operating satisfactorily.

Typical normal operational data from a Swedish vanadium oxide plant.

Steam consumption	approx. 20 tons/ton V_2O_5	40 tons/ton V
Distribution	hot water 75°C	40%
	leaching treatment	25%
	precipitation vessel, V_2O_5	15%
	filter, V_2O_5	20%
Electric energy		
	connected load.	350 kW
Water consumption		
	50 m^3/h max. value	

Stage V Production of FeV

We shall not give a detailed description of this procedure here, such a description not being implied in our commission. However, for the sake of completeness we shall in short also deal with this procedure, in order to give an orientation as regards the total production costs as far as to metallic vanadium as FeV(50%). What is said below is based partly on our own experience, partly on other available sources in connection with this conventional method.

Aluminium is for the purpose a suitable reduction agent. It is, however, feasible to substitute a greater part of the aluminium for cheaper high silicon FeSi.

The aluminium metal can be wholly or partly scrap of some kind, such as turnings. The silicon metal can for example be 75% FeSi.

The vanadium oxide which in the preceding Stage IV is obtained in dried shape with 85% V_2O_5 can very suitably pass through a simple melting procedure (melting temperature approx. 700°) before the reduction, in order to remove further volatile impurities.

In order to regulate the iron content of the product and also the heat development during the process a certain quantity of iron is added to the burden. For this purpose the iron that is obtained at the preparation of the vanadium slag can be used.

To regulate the composition and viscosity of the slag, burnt lime (CaO) and fluor spar (CaF_2) are added. Coke breeze is also frequently added.

The course of the process is as follows:

A balanced mixture of vanadium oxide and means of reduction and other necessary supplements is melted in an open crucible, preferably of magnesite. As the course of the reaction is highly exothermic, ferro vanadium and slag are obtained in molten condition without additional heat supply from outside. The reaction is started by generating a small arc between an electrode and the bottom of the crucible. The burden is then successively fed into the crucible and melts quickly.

A method frequently used to pretreat the burden before charging in the crucible is to premelt and stir the mixture of vanadium oxide and aluminium at a temperature where both materials appear in molten condition (approx. 700°, see above), however not so high that the reduction is started. The burden pretreated in this way is then charged into the reaction crucible, where it is lit as described above.

The quantity of V_2O_5 (85%) that is to be reduced in order to obtain 480 tons of 50% FeV or 240 tons V/year is approx. 560 tons at 90% V-yield, which at an operating time of 330 days in the chemical plant corresponds to 1,70 tons/day. As the melting in the crucible is carried out very quickly, it is suitable to carry out this operation during daytime with one heat per day in a crucible with a suitable size for the purpose.

The slag obtained at the smelting has no commercial value.

The required number of workers, assumed to work only during daytime, including crushing and packing of the product, need not surpass 2 men for 8 hours.

<u>Consumption of materials and men/hours per ton of V in FeV (50%)</u>

Vanadium oxide (90% V-yield)		2320 kgs
Aluminium, turnings etc.		460 "
Ferro-silicon 75%		640 "
Iron, metallic		670 "
Lime		670 "
Fluor spar		115 "
	Total	4.875 kgs

Manpower: 2 men per 8 h. shift

D. Preliminary technical specification

for main equipment and facilities

1. Common facilities

Land	According to DASTURCO
Civil and structural work	
Civil work	According to ELKEM and DASTURCO
Structural work	" " " " "

2. Raw material handling and storage

Mechanical and electrical equipment	
Raw material handling and ore	According to ELKEM and DASTURCO
Storage consisting of	

- Transportation equipment
- Hopper
- Feeders
- Conveyors
- Bins
- Screens
- Scales
- Driving, operation and
- Controlling equipment

3. Smelting of cold charge

Stage I According to ELKEM

Smelting furnace with accessories such as:

Electrode equipment

Equipment for furnace cover

Equipment for furnace body (incl. refractories)

Cranes

Charging equipment

Ladles

Tapping equipment

Elevator

Equipment for gas cleaning plant

Secondary current supply

Transformers

Electrical equipment

Fume extraction

Spare parts

Miscellaneous equipment

Raw material handling

Tapping bay equipment

Scales

Pig casting machine

Slag handling equipment

Piping installations

Water and power supply systems

Laboratory, workshops

4. Smelting of hot prereduced charge

Note: Not included in the cost calculation   Stage II

Smelting furnace

Charging equipment

Gas cleaning plant

Raw materials handling

Equipment for handling of charge from weighing station to rotary kiln and for discharge of prereduced charge from rotary kiln.

Rotary kiln with accessories such as

Raw material feeder

Kiln

Driving station

Controlling device

Smoke chamber

Refractories

Burner installation

Instruments and control panel

Venturi dust collector

Note: An emergency drive unit may have to be foreseen depending on the stability of the electric current supply.

Refining of pig iron in shaking ladle

According to Swedish practice.

Skahing ladle plant with accessories such as:

Frame

Driving device for DC

Operating equipment

5 Shaking ladles

3 Sets of refractories

Ladle lining stand

2 Lifting yokes

Ladle heater

Exhaust and gascleaning system

2 Oxygen lance devices

Process material equipment

Foundations

Spare parts

Water and electric power supply

Piping installations

Miscellaneous

Oxygen plant

Building

Water and electric power supply

Note: Oxygen plant or Oxygen gasification plant to be considered as an alternative.

6. Production of V_2O_5 from vanadium slag

According to Swedish practice.

Crushing and slag separation

Slag storage

Scraper from slag storage to crusher

Crusher

Magnetic separators

Slag bin

Ball mill

Air separator

Roasting

Slag bin

Dosimeter

Soda bin

Mixer

Intermediate bin

Nodulizing device

Roasting kiln

Exhaust filter

Leaching

Intermediate bin

Leaching device

Storage tank for leaching fluid

Phosphorous removal

Precipitation tank

Cleaning tank for precipitate

Vanadium oxide precipitation

Precipitation tank

Filter

Drying

Furnace

Bagging device

Storage for finished product

Miscellaneous

Furnace building

Foundations and supporting structures for equipment

Piping installations

Water and electric power supply

Spare parts

B Cost calculation and comments

1. Preliminary cost calculation

All investment- and operational costs considered in this draft final report for the process equipment are at this stage only preliminary.

They have been arrived at by a critical study and a rough estimate with the application of relevant equipment specifications and cost figures given in the preliminary quotation from ELKEM and in the feasibility report by DASTURCO.

This material has been supplemented by us with information at interviews with metallurgical experts in wellknown operating companies and with current cost figures from suppliers specialized in their respective field.

It is understandable that at this preliminary stage, when the ore provision and the location of the site and its conditions have not yet been clarified, there will be some basic data missing. We have however to the best of our ability endeavoured to consider also these items.

We would in this context also mention the cost for the mining installations which have not been included in our cost calculation. We would however assume that the ore preparation with crushing, screening a.s.o. could be located at the plant site and not at the mine as it seems evident that the ore will have to be supplied from several different mines, in order to provide for an adequate supply of ore during a sufficiently long time.

There are also other costs that are not possible to judge accurately at this time, such as the costs for railway sidings and roads outside the plant, electric power supply, water supply, drainage, sewers a.s.o. For these items only a rough sum can be appropriated and we have therefore in general accepted the figures from DASTURCO for such items without comments.

We think however that by this somewhat approximate method without the aid of formal quotations it has been possible to present a credible cost level which we believe to be sufficiently accurate in order to judge the feasibility of the project.

As to the part of the implementation cost for the project which can be defrayed by Indian currency we would like to give our views as follows.

It is quite clear that such items and work belonging to for instance site conditioning, transportation facilities, civil work, buildings, machine and furnace foundations, structural steel a.s.o. can be supplied by Indian firms. This will also apply to electric power and steam supply, drainage, cooling and drinking water supply with water treatment equipment, including piping and electric conduits up to agreed connection points at the machinery and furnace installations. The engineering and detail drafting work for these installations can be made by an Indian consultant according to principal layouts and specifications to be made up by the engineering' staff or a consultant working in close cooperation with the main supplier. The drawings made by the Indian consultant will according to our experience have to be back-checked by the main supplier in order to avoid costly errors which may come to light at the erection of the equipment. The main supplier will have to include an appropriate sum for this service in his contract.

When it comes to such items as special machinery, apparatus, furnaces, electrical operational and control installations it is rather difficult at this stage to have a definite opinion even if it is only in principle as to the final outcome of such an allocation. The reason for this is as follows:

It is advisable to consider not only what theoretically can be made in India, which undoubtly is quite a lot, but also what is advisable to figure with for practical reasons.

In general can be said that a considerable amount of heavy and uncomplicated items could be made in India. This applies particularly to such items where precision machining is not involved, not because such work can not also be made in India, but with regard to that other more sophisticated parts manufactured abroad may have to be fitted in the supplier's workshop to the parts presumably made in India. This drawback may be overcome by suitable changes in the design and of the shop drawings which may not appeal to the suppliers. Such manufacture in India will therefore have to be negotiated with the supplier. We believe that a fair amount of Indian manufacture could be agreed upon this way when a deal is in sight for the supplier. The responsibility for material and workmanship will have to be taken by the Indian supplier even if drawings and specifications will have to be made up by the suppliers.

When it comes to such items and parts which are a speciality for the supplier to manufacture it is not advisable even to try to buy drawings from him for manufacturing in India, much less seek to get them free of charge.

Our experience is that if the supplier is not allowed to deliver a fair amount of hardware to supply together with all the software that has to be supplied anyway, he will not be interested in making up a quotation. The reason for this is that the supplier usually does not maintain an engineering staff for other reasons than for increasing the flow of work to his own workshop. The working load on the engineering office and the workshop must be kept fairly well in balance which may not be the case if a disproportional amount of engineering, layout and drafting work has to be done for the benefit of an Indian supplier. The supplier may therefore be reluctant to comply with the customer's proposals in this respect, even if he will be paid for his service separately, or if the cost is calculated in the price for the equipment to be delivered, which may wronly make the price look exhorbitant.

If on the other hand a consultant is engaged by the customer to do that engineering work, the result may not be equal to what the supplier could produce with his more intimate knowledge of the performance of his own equipment. We therefore think that this part of the job will have to be negotiated more in detail when the quotations are to be made up. We are naturally willing to assist you or the customer in this respect if agreed upon.

For the reasons given above we would for the moment think that about 50% of the total cost for the plant will have to be imported in foreign exchange. DASTURCO's assumption that about 75% could be supplied by payment in rupees we think a little too optimistic. Should a more reliable estimate of the total cost and the foreign exchange needed be necessary before any action can be taken to secure the approval of the monetary authorities, we would recommend that bidding documents are made up and that inquiries for preliminary bids are sent out, stressing the importance of a major part of the equipment being made in India. If we can be of any assistance please let us know.

2. Preliminary capital cost

		Estimated Total Cost	Estim. local currency
Common facilities			
a. Land	Rs	600,000	100%
b. Civil work		4,600,000	100%
c. Structural work for buildings		14,800,000	100%
	Rs	20,000,000	
Production plant			
a. Ore smelting furnace, mechanical and electrical equipment, raw materials handling and storage	Rs	22,840,000	50%
b. Pig casting machine and misc. equipment		7,350,000	25%
c. Shaking ladle plant (incl.oxygen plant) and slag processing plant		11,989,000	25%
d. Water and power supply, laboratory, workshop and unspecified		6,500,000	50%
	Rs	48,679,000	
Other costs			
Freight, customs duties(30%), erection (15%), administration, engineering, consulting, know-how	Rs	28,600,000	25%
Total capital cost	Rs	97,279,000	
Contingencies ~ 10%		9,728,000	25%
Total Prel.Capital Cost	Rs	107,007,000	

The above costs are estimated with prices on cash basis. If credit terms with deficit payments are to be considered a corresponding extra charge for interest and guaranties has to be added.

3. Preliminary operational costs

A. Shaking ladle operation to produce V-slag and foundry iron

Raw materials:

Hot metal from ELKEM furnace (50,000 t/year)

Process materials:		Price Rs/ton	Cost Rs/year
Oxygen	15 NM^3/t= 750,000 NM^3/year	à Rs 0,30	222,000
Ore	10 kg/t = 500 t/year	à Rs 35,28	17,700
Sand	3 kg/t = 150 t/year	à Rs 37,00	5,600
Coke breeze	20 kg/t =1000 t/year	à Rs 29.00	29,000
Ferro Silicon	15 kg/t = 720 t/year	à Rs2788.00	1100,000
Ferromanganese	8 kg/t = 390 t/year	à Rs1200.00	480,000
Refractories (32 and 70% Al_2O_3)			410,000
El, water, maintenance			330,000
Labour & supervision			200,000
Depreciation & interest			1180,000

A Processing cost/year Rs 3,974,300

B. V_2O_5 processing plant (capacity 265 - 300 t V/year)

Raw materials:

V_2O_5-slag from shaking ladle (2950 t/year)

Process materials:		Price Rs/t	Cost Rs/year
Soda	1200 t	à Rs 651,70	780,000
Ammonia	240 t	à Rs 600	144,000
Magnesium chloride	80 t	à Rs 500	40,000
Sulphuric acid	400 t	à Rs 460,70	183,000

Other costs:	
Grinding[1]	290,000
Roasting[1]	370,000
Leaching[1]	650,000
Direct labour	280,000
Storage, packing, loading, misc.	80,000
Depreciation and interest	825,000
B-Processing cost/year	Rs 3,642,000
A-Processing cost/year	Rs 3,974,300
A+B total cost/year	Rs 7,616,300

Total cost/kg of vanadium as V_2O_5: $\frac{7,616,300}{265,000} \sim$ Rs 28

1) including certain salaries and supervision, oil, steam, electricity, maintenance and misc.

F. Planning and final cost estimation

1. After a decision to proceed with the project has been taken a more detailed planning for taking in quotations which makes a more accurate cost estimate possible can be made. Such a planning with the necessary projecting and engineering work will in the end call for a considerably greater amount of projecting work than what has been made at this stage.

2. Such planning can be made in different ways. One method is to make up the bidding documents with only main technical data and specifications leaving out the detail engineering work at this stage. This will make it possible without too much cost at this preliminary stage to take in quotations from eligible main equipment suppliers who are capable to carry out a more detailed engineering themselves when the contract for delivery of equipment and services has been awarded to anyone of them. This flexible method will allow the supplier to apply his knowledge of his own equipment to the best advantage and may eliminate useless pre-engineering work based on assumed data for the equipment. In this way it will also be possible to obtain an early answer to the question of foreign exchange needed. The evaluation of the bids will on the other hand emphasize the need for good judgment and impartiality of the party who is going to conclude the bids.

3. Another method would be to try to find an indistrial plant supplier capable and willing to make up more or less complete bidding documents. We doubt that this method will be successful as the supplier may have to abstain from quoting for the equipment himself in order to preserve the impartiality.

4. The way of employing an engineering firm with enough background for composing complete engineering and bidding documents can also be considered. As said under 1. we think that this way may easily lead to unnecessary work and costs at the preliminary stage, as a too detailed engineering may not be warranted and may have to be redone anyway by the main supplier.

5. The planning and engineering could for local work such as civil work, building foundations, piping a.s.o. to a considerable extent be given to indigenous engineering firms, e.g. DASTURCO. This firm would then make up bidding documents and later on detail drawings for such work to suit the layouts and technical information given by the main supplier who also will back-check the local drawings. With this arrangement it ought to be possible to reduce the amount of contracts for the implementation to a minimum, which should facilitate the administration of the project and keep the costs under control.

G. Advice and metallurgical know-how

1. FERENCO is willing to continue its work with the now finished assignment either on behalf of UNIDO or the customer in making up comprehensive bidding documents according to what has been suggested under F 2., suggest bidders and, after examination of the bids, recommend a suitable main supplier. The main supplier will have to be chosen in view of his possibilities to supply not only the equipment but also the engineering and the indispensable practical operational know-how to supplement the metallurgical know-how.

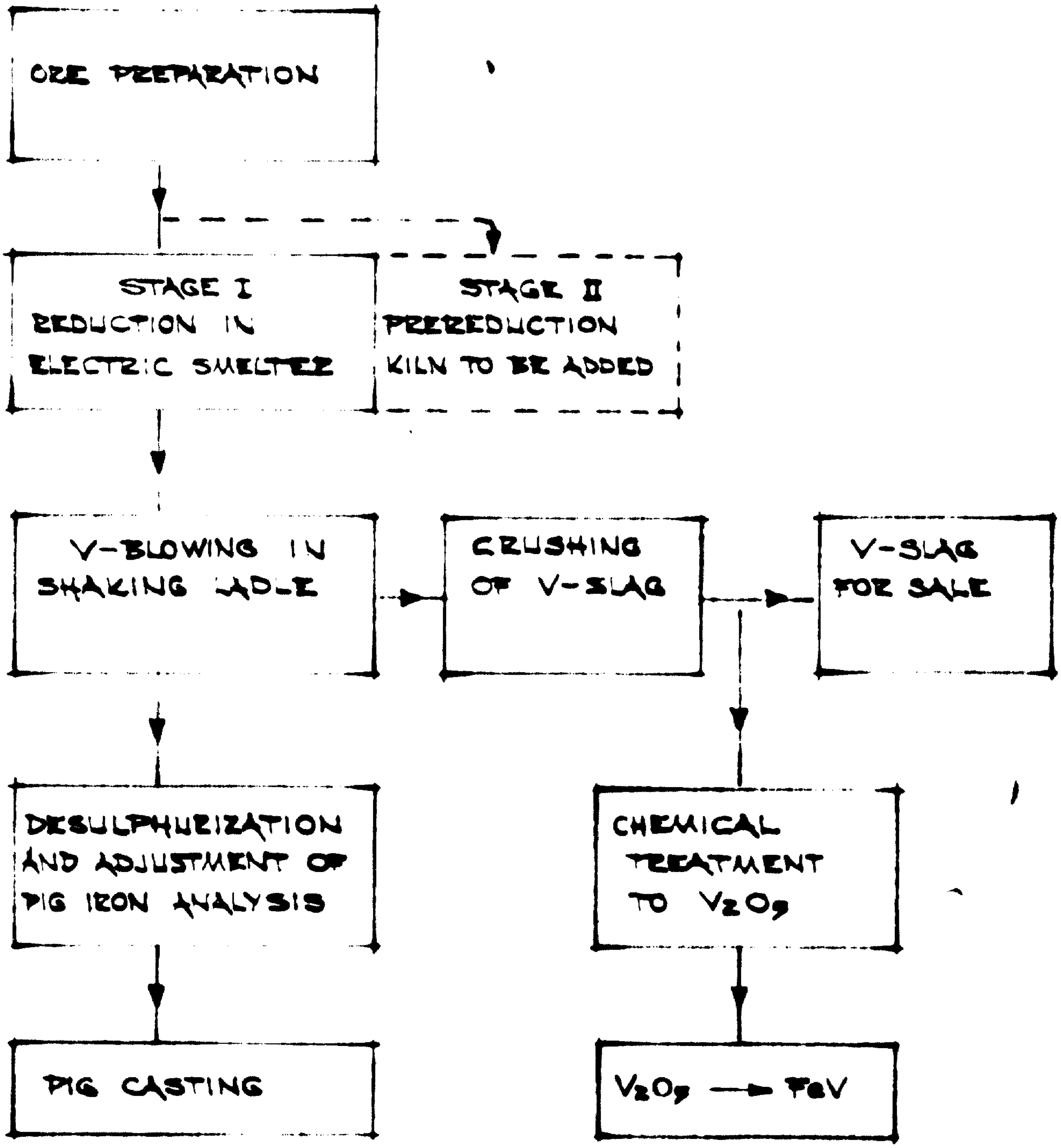
2. FERENCO is also willing to assist UNIDO or the client with further service and advice regarding neutral and capable engineering firms for the final planning and for making up complete bidding documents according to F 3. and F 4. and, if desirable, also suggest bidders and, after examination of the bids, recommend one or several acceptable main suppliers.

We will also endeavour to arrange supply of comprehensive metallurgical know-how to be placed at the disposal of the client and the main supplier, according to a separate agreement to be further discussed with the client.

Stockholm, February 26, 1973

BO KALLING
Professor of Metallurgy

ULF KALLING
Man. Director



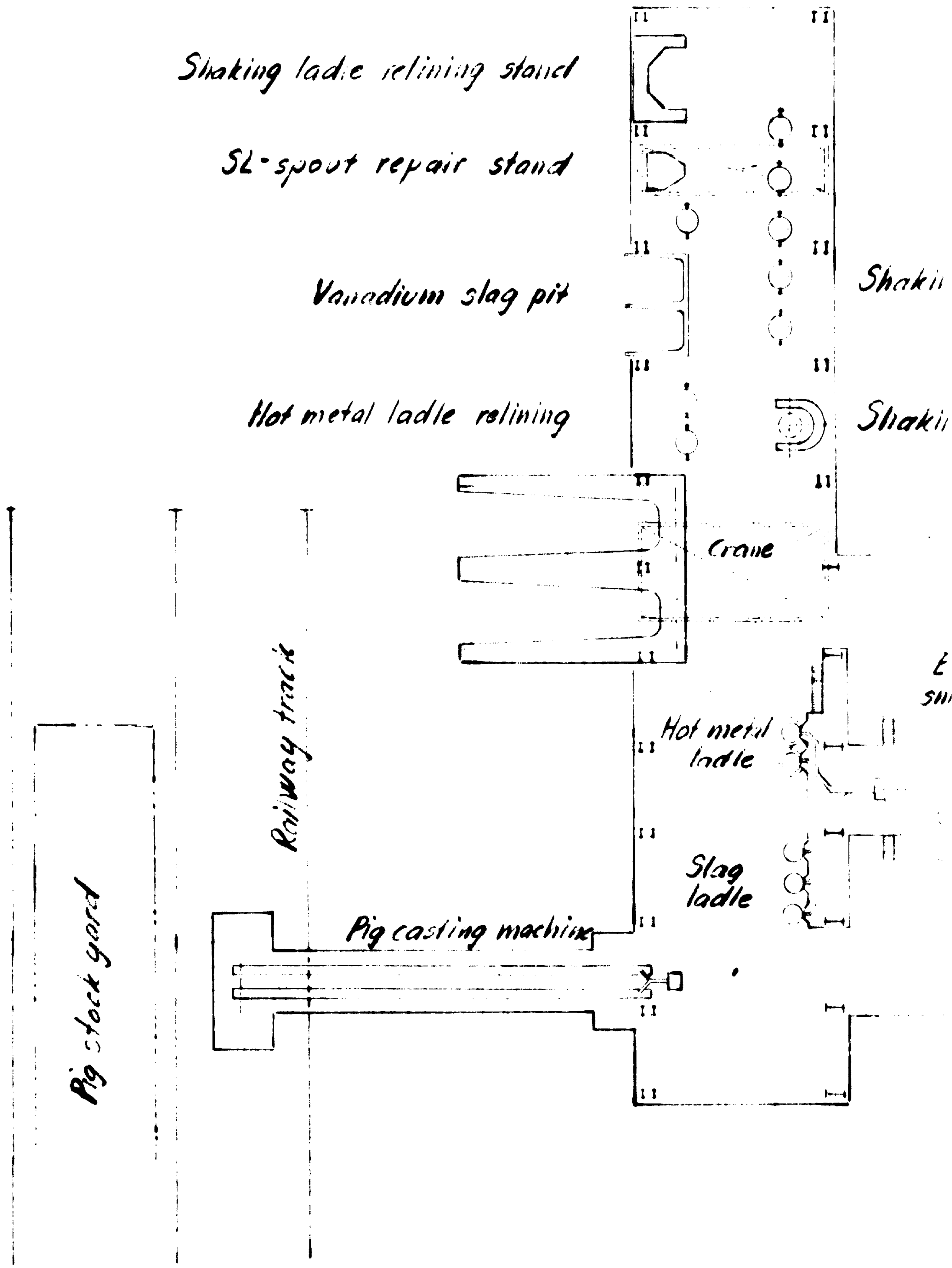
FERENCO
SWEDISH FERRO ENGINEERING CO AB

UNIDO – IDCO ORISSA V-PROJECT

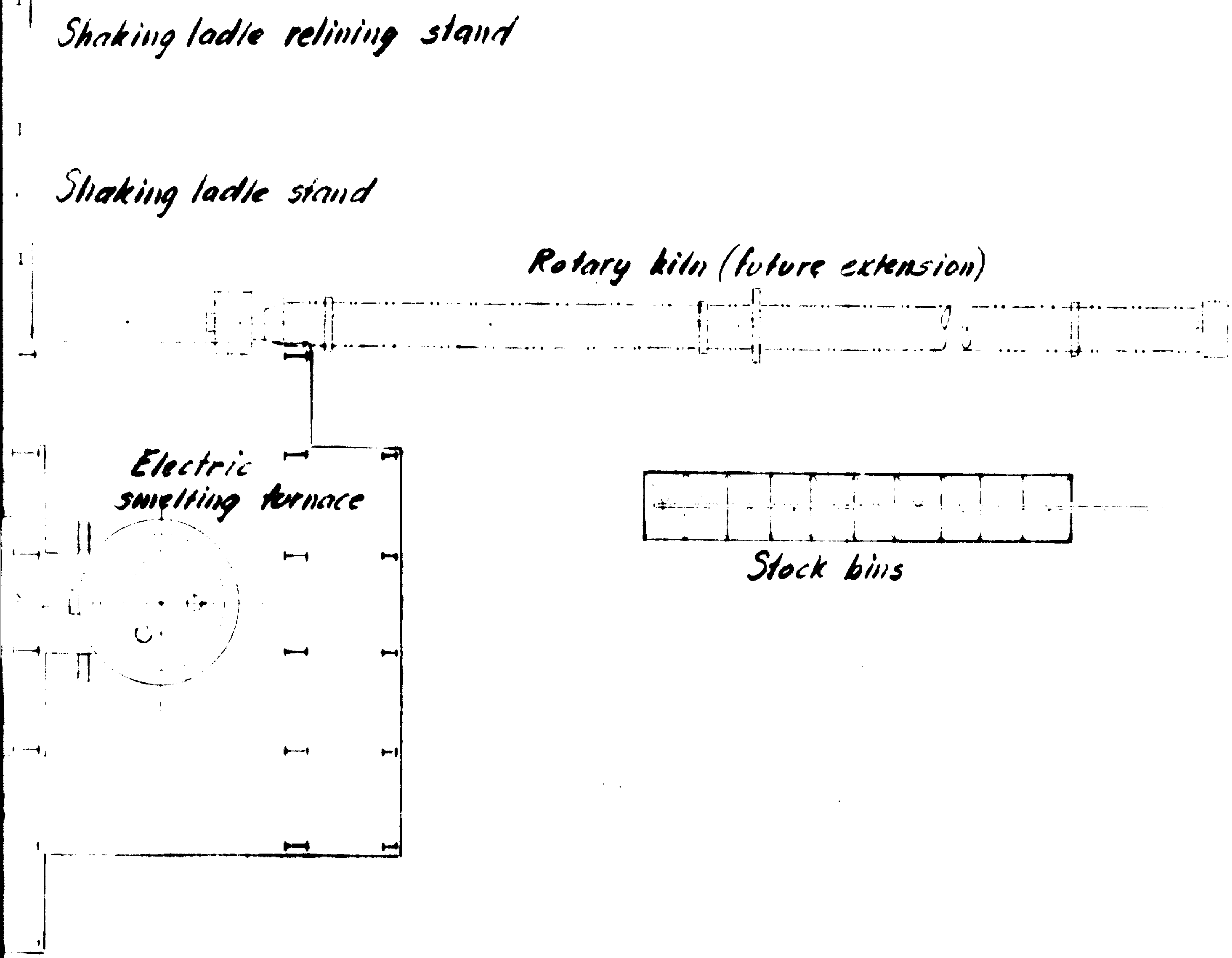
FLOW SHEET 1

STOCKHOLM 20/12-72

NR. 1.

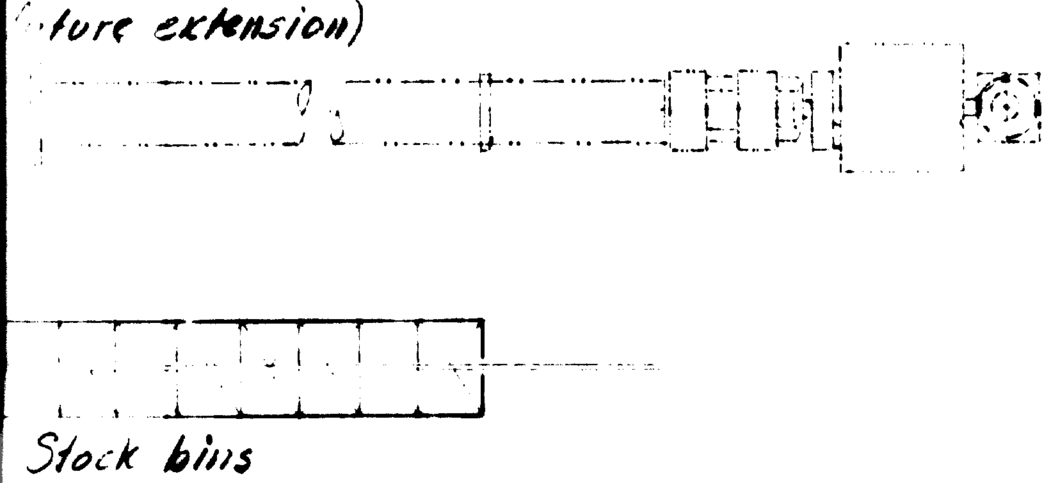

Shaking ladle relining stand
SL-spout repair stand
Vanadium slag pit
Hot metal ladle relining
Crane
Railway track
Hot metal ladle
Slag ladle
Pig casting machine
Pig stock yard

SECTION 1


Shaking ladle relining stand
Shaking ladle stand
Rotary kiln (future extension)
Electric smelting furnace
Stock bins

SECTION 2

4



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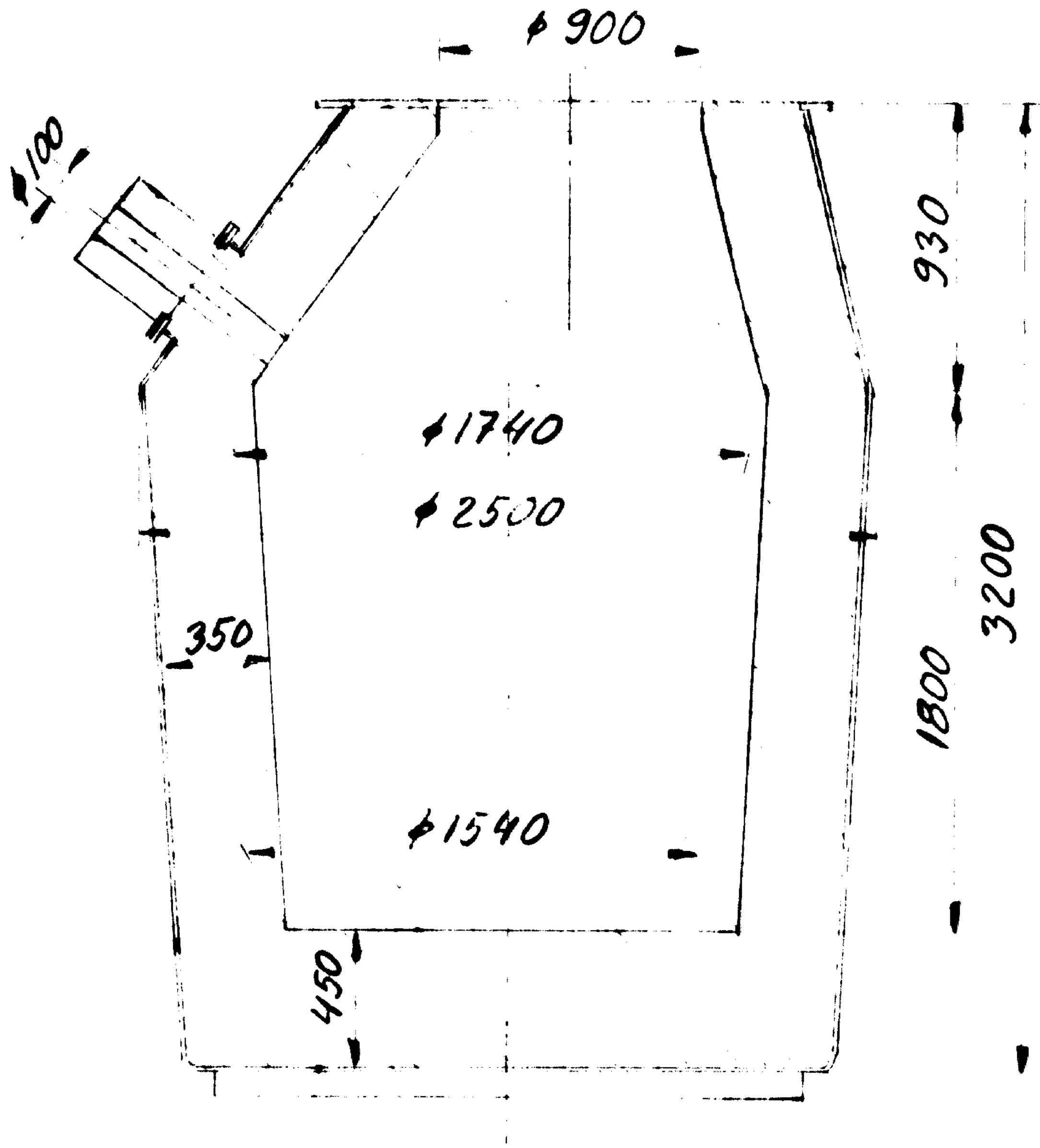
Pig Iron Plant layout

Stockholm 20/12-72

SECTION 3

Nr 2



Effective volume: 5 m³

Lining:

Conical part	350	mm	inner	lining
Cylindrical part	250	"	–"–	–"–
	100	"	outer	–"–
Bottom	250	"	inner	–"–
	200	"	outer	–"–

In the conical and upper cylindrical part alumina bricks (with Al_2O_3 about 70%); in the lower part chamotte bricks

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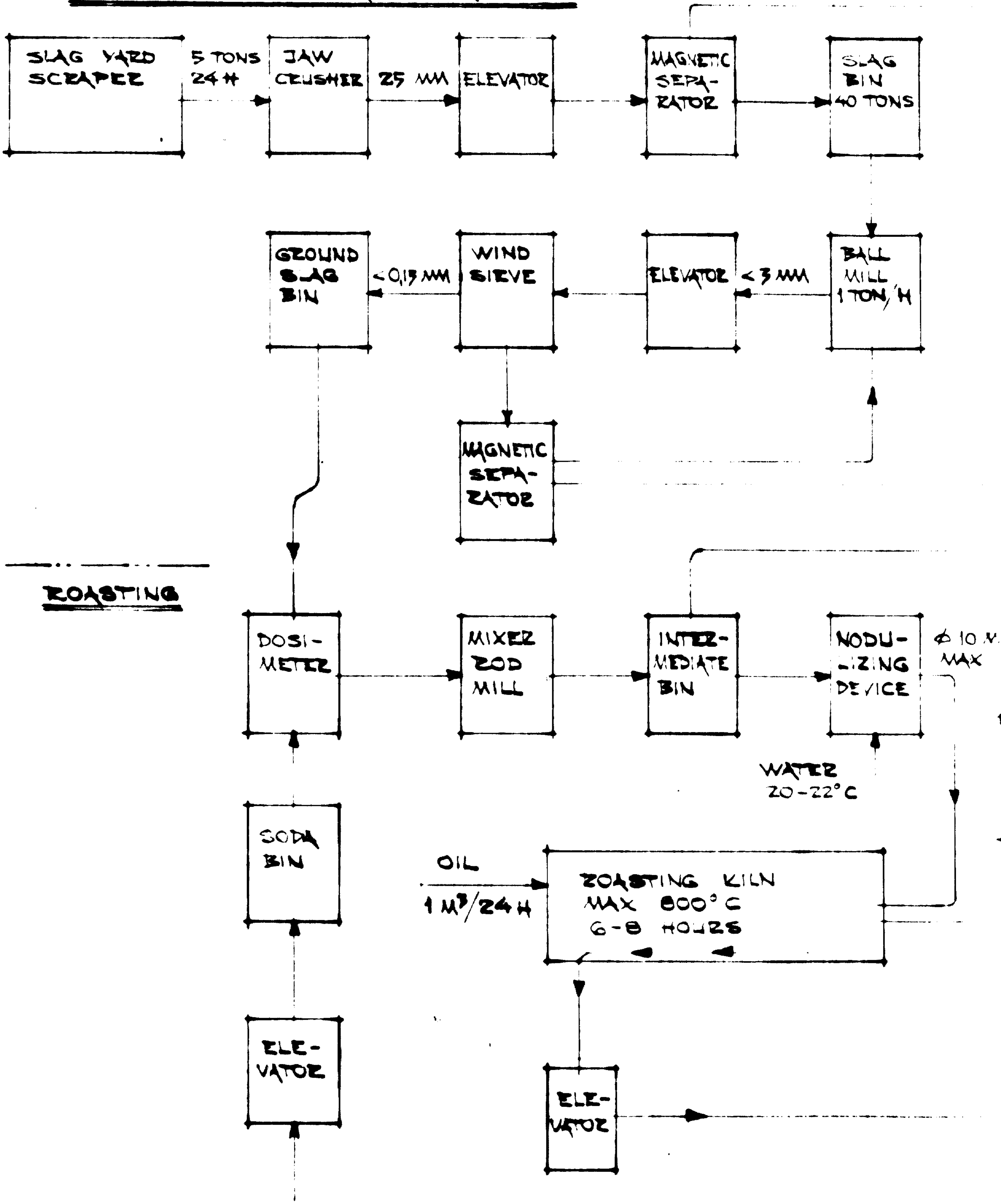
UNIDO-IDCO ORISSA V-PROJECT

Shaking ladle 15 tons

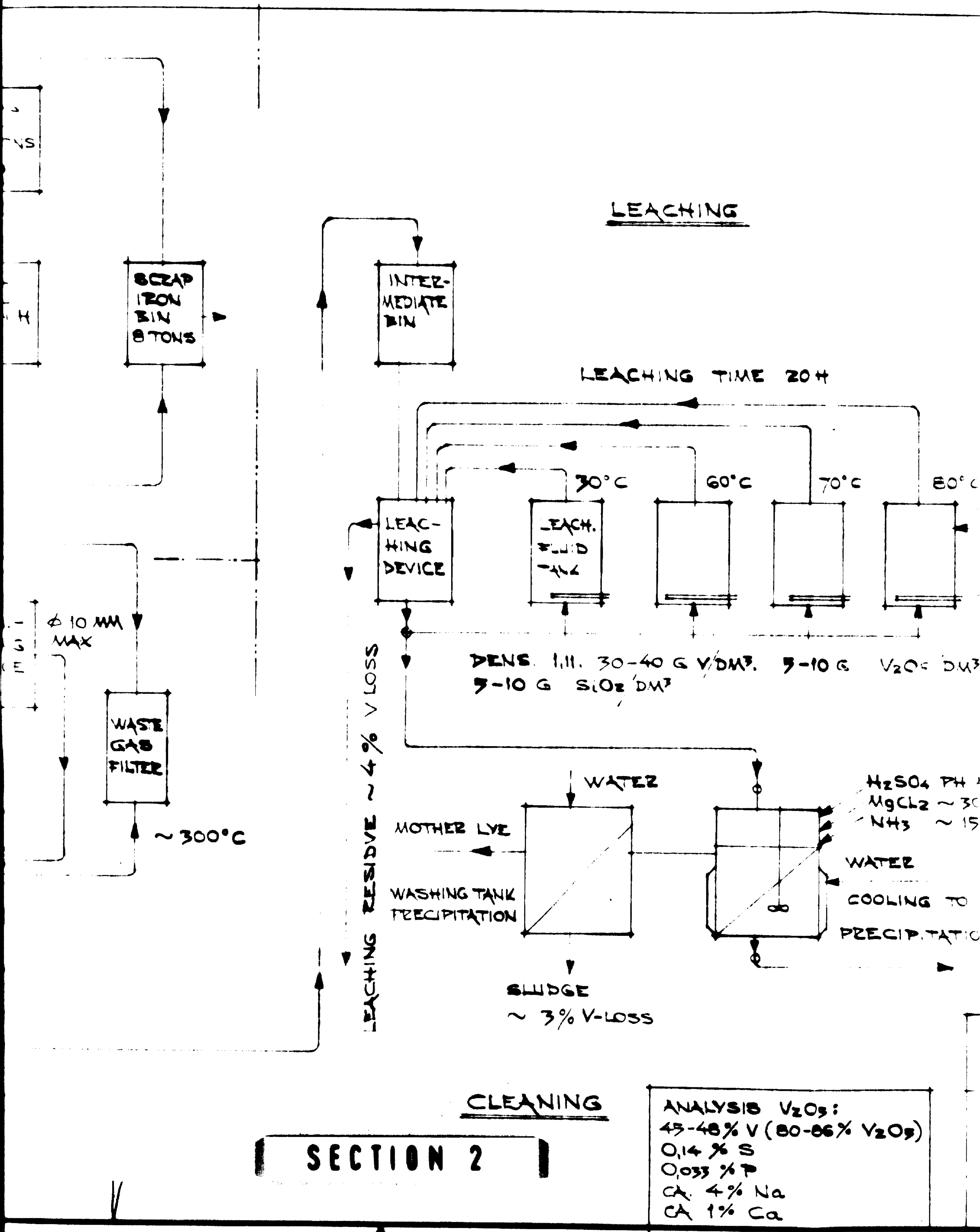
Stockholm 20/2-72

Nr 2A

CRUSHING AND SLAG SEPARATION

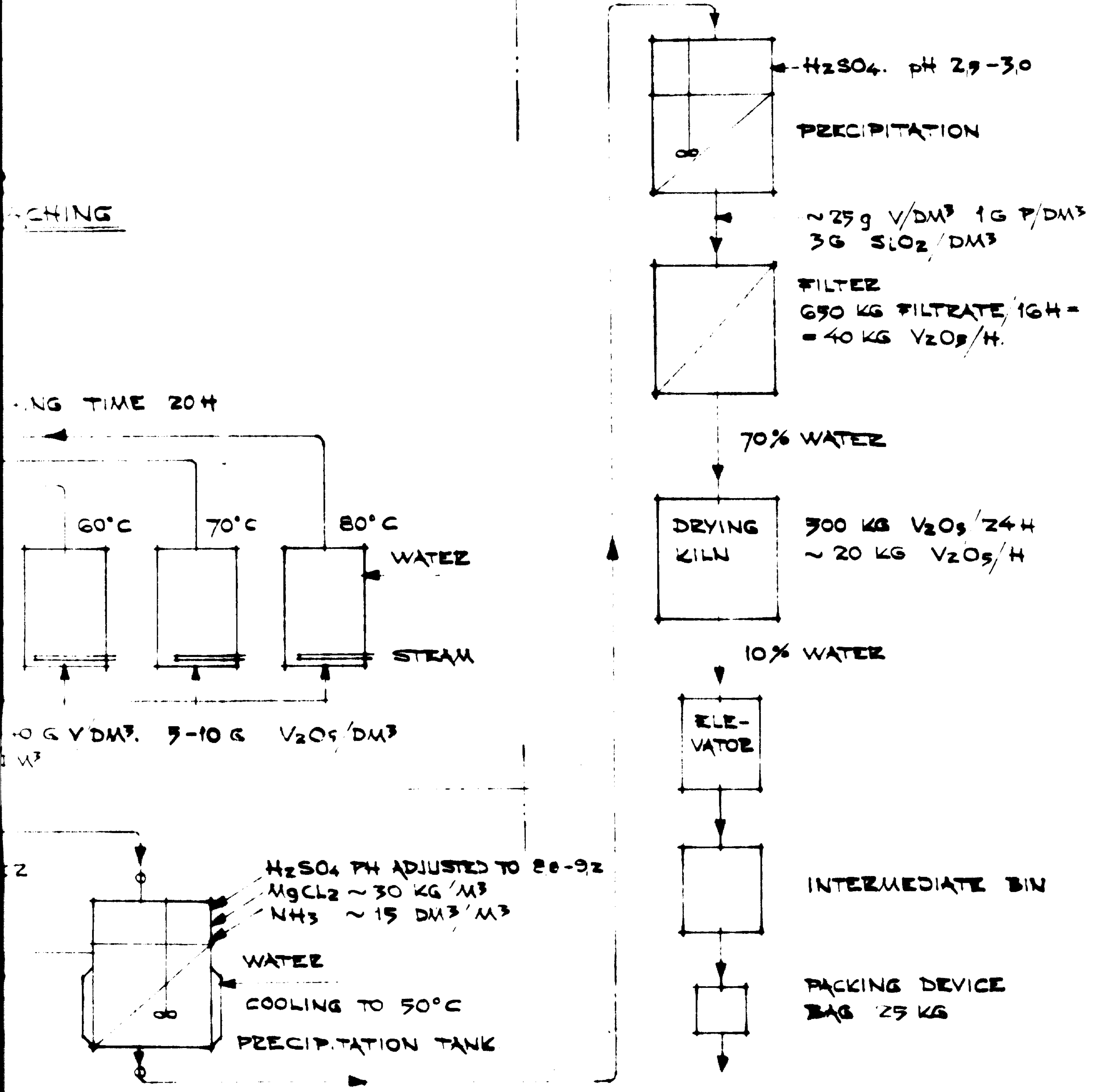


SECTION 1



LEACHING
SCRAP IRON BIN 8 TONS
INTERMEDIATE BIN
LEACHING TIME 20 H
30°C
60°C
70°C
80°C
LEACHING DEVICE
LEACH. FLUID TANK
⌀ 10 MM MAX
DENS. 1,11. 30-40 G V/DM³. 5-10 G V₂O₅ DM³
5-10 G SiO₂ DM³
WASTE GAS FILTER
~ 300°C
LEACHING RESIDUE ~ 4% V LOSS
WATER
MOTHER LYE
WASHING TANK PRECIPITATION
H₂SO₄ PH
MgCl₂ ~ 30
NH₃ ~ 15
WATER
COOLING TO
PRECIPITATION
SLUDGE
~ 3% V-LOSS
CLEANING
ANALYSIS V₂O₅:
45-48% V (80-86% V₂O₅)
0,14 % S
0,033 % P
CA. 4% Na
CA 1% Ca

SECTION 2



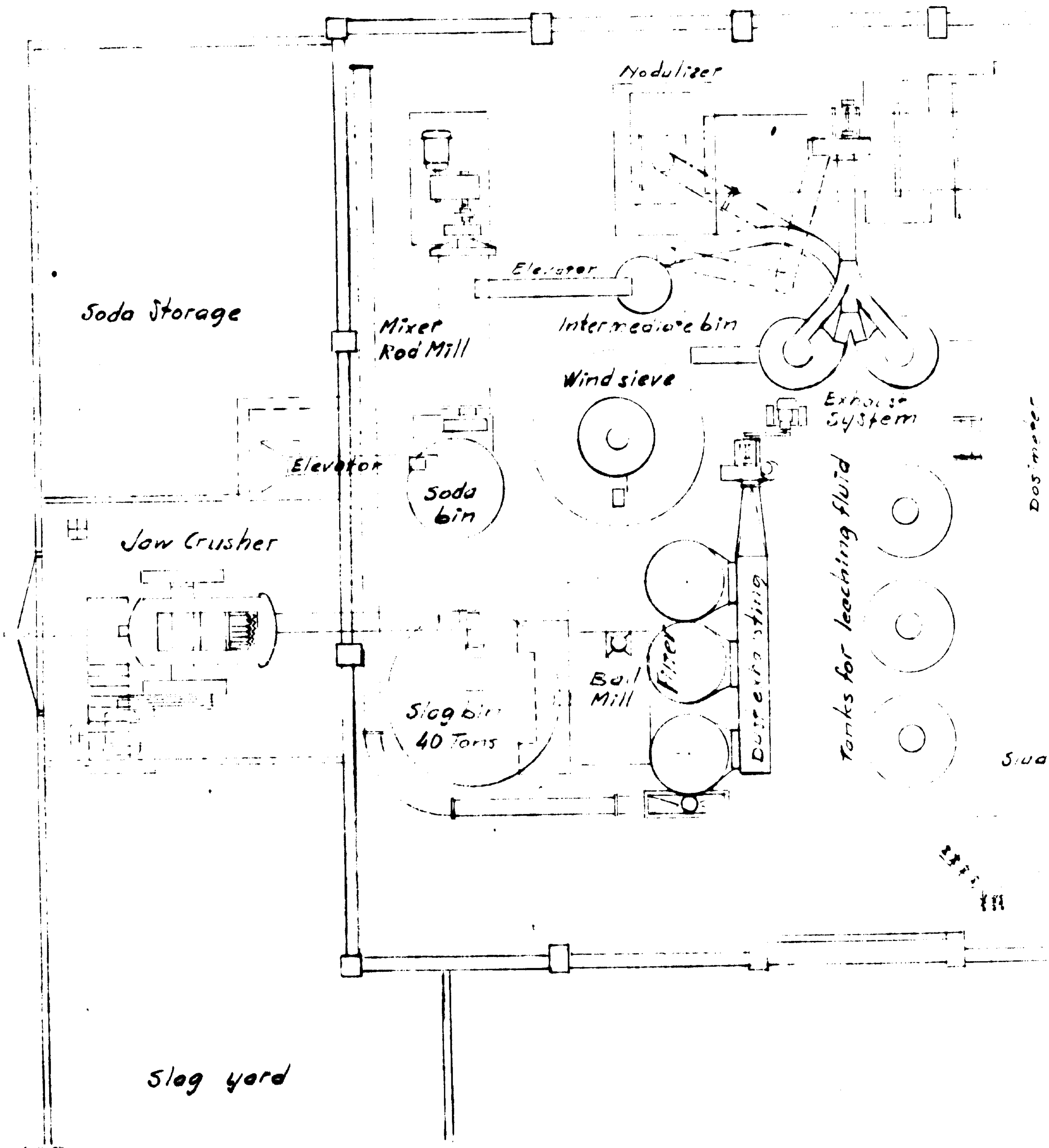
ANALYSIS V_2O_5:
45-48% V (80-86% V_2O_5)
0,14 % S
0,033 % P
CA. 4% Na
CA 1% Ca

FERENCO
SWEDISH FERRO ENGINEERING CO AB

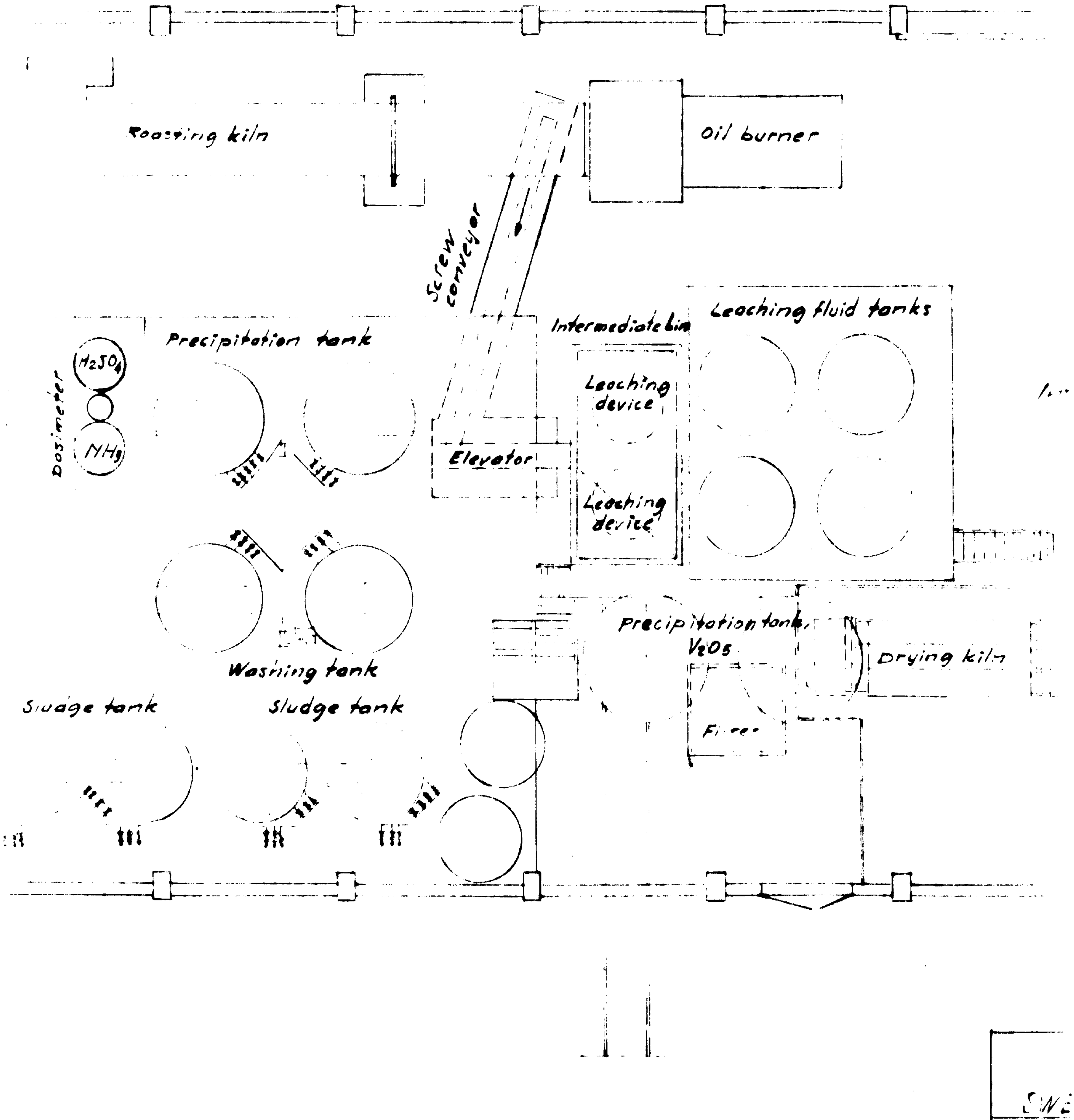
UNIDO-IDCO ORISSA V-PROJECT
FLOW SHEET 3
STOCKHOLM 20/12-72

NR. 3

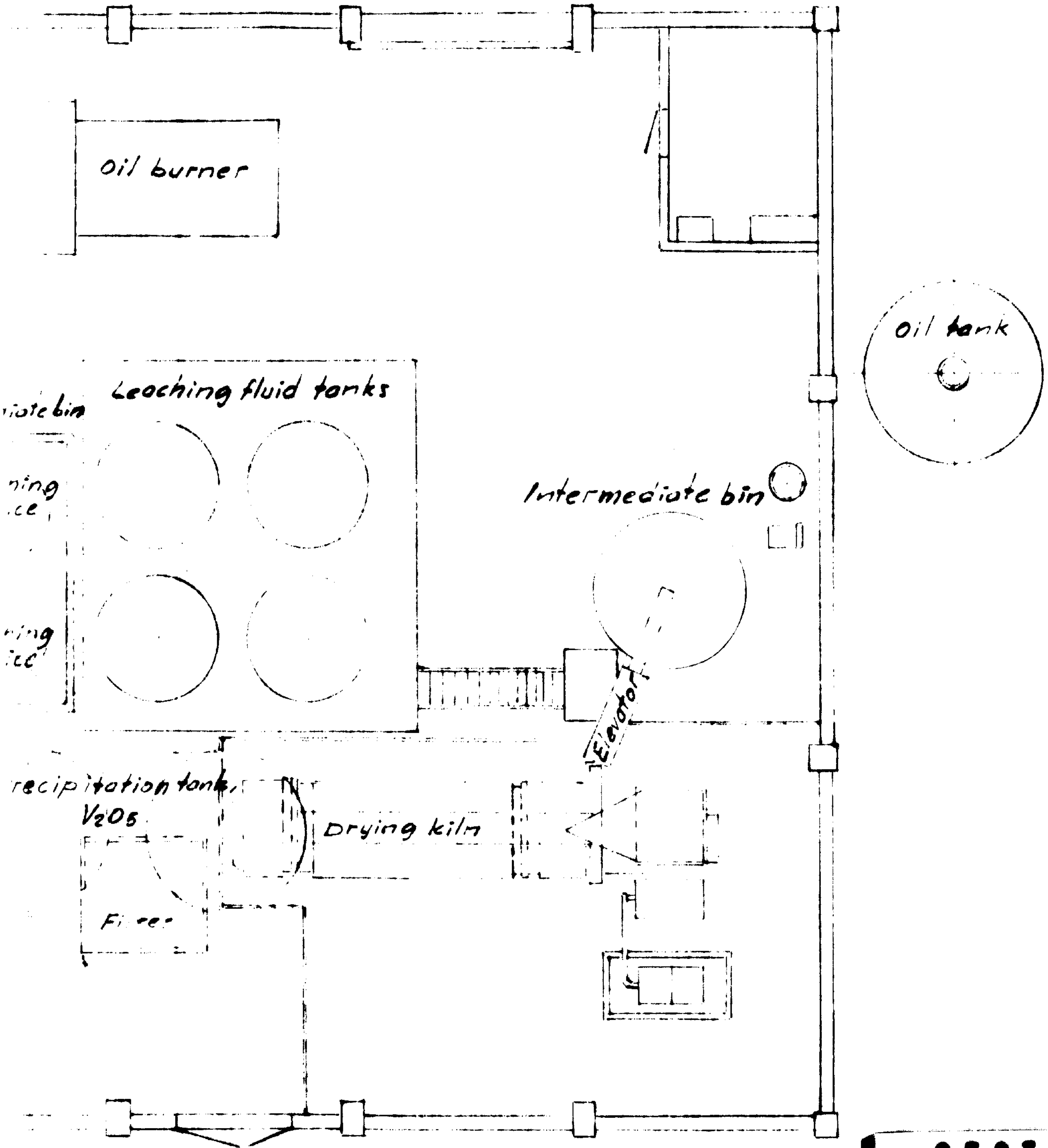
SECTION 3


Nodulizer
Elevator
Intermediate bin
Soda Storage
Mixer
Rod Mill
Wind sieve
Exhaust System
Elevator
Soda bin
Jaw Crusher
Ball Mill
Filter
Tanks for leaching fluid
Slag bin
40 Tons
Slag yard

SECTION 1


Roasting kiln
Oil burner
Screw conveyor
Intermediate bin
Leaching fluid tanks
Precipitation tank
Dosimeter
H_2SO_4
NH_3
Leaching device
Leaching device
Elevator
Precipitation tank, V_2O_5
Drying kiln
Washing tank
Sludge tank
Sludge tank

SECTION 2



SECTION 3

FERENCO

SWEDISH FERRO ENGINEERING CO AB

UNIDO-IDCO ORISSA V-PROJECT

V_2O_5 Chemical Plant Layout

Stockholm 20/12-72

Nr 4

B- 560

81.08.25