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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

INTEROFFICE MEMORANDUM

To: Mr. E. Balazs, Head
Metallurgical Industries Section
Division of Industrial Operations

Date: 27 January 1986

From: for D. Gardellin, ~~Acting~~ Head
Purchase and Contract Service
Division of Industrial Operations

Ref.: RK/sb

Subject: Final Report - SI/ETH/84/801 - Electric Arc Furnace Steel Making - Contract No. 84/103

1. In accordance with the stipulations of paragraph 2.10 c) of Contract No. 84/103, Tesco Consulting Engineering, Hungary have provided this Office with eight (8) copies in English of the final version of their report on the subject project.

2. We are forwarding herewith six (6) copies in English of the Contractor's report under consideration.

3. We would appreciate your reviewing this report as soon as feasible and your advising this Section of its acceptability.

4. If the Contractor's report is acceptable, copies should be distributed in accordance with the instructions contained in the UNDP Policies and Procedures Manual (UNDP/PPM/TL/2 of 27 January 1978, Section 4.0, paragraph 5, pages 9-14).

5. Please note that:

   a) one (1) copy of the Contractor's report is being sent to Registry for their own records, and that

   b) one (1) copy is being sent to Mr. E. Rennert who, upon perusal, will transfer it to the Library for micro-filming.

6. We would also appreciate your completing and returning the enclosed copy of the "Evaluation of Contractor's Performance" form.

cc.: Mr. E. Rennert (with one (1) copy of the report under consideration)
Registry (with one (1) copy of the report under consideration)

V.83-59064

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terv

Ethiopia.

TECHNICAL ASSISTANCE IN
ELECTRIC ARC FURNACE STEELMAKING
SI/ETH/84/801
ETHIOPIA

Final report

Prepared for the Government of Ethiopia by the United Nations Industrial Development Organization acting and executing agency for the United Nations Development Programme

Based on the work of TESCO/HUNGARY, as subcontractor

United Nations Industrial Development Organization
Vienna

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ANNEXES

Explanatory Notes:

The value of the Ethiopian currency in United States dollars is given herewith:

One US Dollar = 2,07 Ethiopian Bir

S U M M A R Y

Post Title: Technical Assitance in Electric Arc Furnace Steelmaking

Project Number: SI/ETH/84/801
The obove project was conceived in the year 1985 as a part of UNIDO'S programme of Technical Assistance to the Least Developed Countries.

Purpose of the Project: To provide technical assistance for improving existing scrap handling, quality control, steel melting practice and to establish proper Metallurgical Laboratory.

Duration: The three experts fielded for 9 man-month /Annexure A/ from February to May 1985.

Main Conclusions and Recomendations
Although it has been a long time since the plant was commissioned the production is carried out nearly according to the original technology introduced upon commissioning the electric arc furnace, however, adjustments have been found to be needed.

The level of production could be improved if up-grading of both scrap handling, steelmaking and teeming of ingots; rolling practice quality control as well as preventive maintenance were implemented.

On the other hand manpower training also should be given priority, taking into account local resources and assitance via government bodies and international organizations like UNIDO.

I N T R O D U C T I O N

Project Background

The Government of Socialist Ethiopia has recognized the acute needs of up-gradation of electric arc furnace steelmaking at the Ethiopian Iron and steel Foundry under the jurisdiction and control of the National Metal Works Corporation.

Started in 1961, the factory is located 20 km from Addis Ababe; produces steel nails, plain and ribbed reinforcement bars and steel wire netting. On two-shift basis, about 12.000 tonnes of reinforcement bars /6-32 mm dia/ and 4.000 tonnes of nails were produced in 1984 a total workforce of 450 including supervisors.

The molten steel is bottom-poured through a central trumpet into 14 pencil ingot moulds. The pencil ingots /85-90 kg/ are then reheated and rolled in a merchant mill into rounds to be used either as reinforcements or for further processing into wire coils for nail production.

The steel scrap is purchased from various sources in the country and is heteregenous in character. No facilities have been used for its classification, segregation and preparation; and nor for quick chemical analysis and control of the steelmaking process in the electric arc furnace. Visual inspection of the fractured surfaces of broken samples hasbeen the only method employed to determine the carbon content.

As a first step for the establishment of a full-scale metallurgical laboratory, a spectrometer has already been purchased.

As far as the location of the new laboratory is concerned the Metal Works Corporation has located funds for the erection of a laboratory building at the Ethiopian Iron and steel Foundry.

Work done on this field

Previously experts from Ziscosteel /Zimbabwe/ carried out a Draft Report on: Assesment of the Operations at the Ethiopian National Metal Works Corporation's Steel Plaut in January 1985.
Project number: UNIDO P 84/48-SI/RAF/84/804

Training

Moreover the day to-day practical advices and on-job consultations through direct participation in the production processes classroom training programme also was commenced /see Annexure C, D, E, F/ and helped the better understanding to the neccessity of up-grading production techniques.

On weekly basis, in the programme not only the Scrap Processing, Electric arc Furnace Steelmaking but the Furnace Operation and the Quality Control were also involved.

Participated by engineers, technicians and sometimes artisans great interest was shown. The many questions put by attendants created fruitful discussions. In each case on job training with practical approach followed the classroom meetings which was warmly

welcomed by the staff.
Via this opproach it was simplier for the Ethiopian counterpart to understand the necessity of modification of technologies concerned.

Altogether 13 lectures were held with the participation of 6-8 people.
This kind of workshop training showed that the local personnel needed such a programme.
They were very active in putting questions of different level.
As a result of the training programme engineers learned e.g. to read the drawings of the control system of the electric arc furnace, the necessity of load calculation in steelmaking, how to separate different kind of scrap, how to analyze carbon content of the steel in the existing gas volumetric laboratory etc.
With the invitation of expatriate experts such training programme advised to be repeated.

Recomendations

1./ Allocation of a bailing machine to the scrap yard is basically important in the continuous supply of bailed light scrap. One unit arrived to the site during the assignment of experts and the bailing of light scrap was commenced improving electric arc furnace operation, hence charging time shortened.

2./ Scrap segregation can only be carried out efficiently if a team fully engaged in the scrap business takes over this job. It is recomended to allocate a separate team for scrap processing.

3./ Containers which might contain explosives and non-metallic materials such as tyres are advised to be separated at a remote place of the scrap yard. The containers prior to cutting should be checked by an expert from the gas filling station and the content released.

4./ Heavy steel scrap can not be charged directly to the electric arc furnace in sizes more than 600 mm. Therefore, torch cutters using oxygen and acetylene should be applied. It is recomended to secure these gases since no other methods exist to process heavy steel scrap.

5./ A Gas-Volumetric Laboratory had been established together with the melting shop, in order to assist steelmaking process by analyzing elements such as Carbon, Sulfur, Manganese etc. This laboratory had been out of use prior to the arrival of experts for four years and was put back on its feet in one month. Actually four Ethiopian engineers learned how to analyze, the carbon content of steel samples.
The quality of steelmaking cculd only be improved if its chemical composition especially the carbon content were analyzed furing the melting process in the electric arc furnace.

Separate chip making unit should be set up producing steel chips from samples taken in the course of steel making for analyzis in the laboratory. Speed of analyzis has got high priority, and the result of analyzis should be available in a short time giving promt informations to melters about the exact carbon content of molten steel.
It is therefore advised to have the laboratory staff well-trained. Assistance for this purpose may be gained from the Ethiopian Standard Insitute.

6./ As first step in up-grading the existing Gas Volumetric Laboratory a there was a stock-taking of chemicals, equipment, and auxiliary materials done.

For carbon and sulfur analyzis everything was available, however, certain equipment, instruments and chemicals were found to be ordered for the modernization of the laboratory such as hardness tester, analytical balance, standard chips etc. /see Annexure B/.

7./ For securing fast chemical analyzis of molten steel, finished products, and scrap the Metal Works Corporation purchased a Spectrometer which was being stored in the storehouse.

Commissioning of it is of primary importance.

According to recomendation a probe taking die was made suitable for producing probes to the spectrometer when operating.
This die was used, however, for taking samples of molten steel from which carbon was analyzed in the gas volumetric laboratory. Melters learned how to use this die.

Other details such as probe preparation, energy and water supply, manning, location of the Spectrometer were advised to be carefully planned.

8./ Establishment of a Full-Scale Laboratory.
In the first phase, it was recomended, to analyze carbon and sulfur in the modernized existing laboratory /Gas Volumetric/ until the Spectrometer Laboratory would start operation.

As soon as the Spectrometer is running smoothly it will take over the job of analyzis of carbon and other elements of both scrap, liquid steel, and finished products from the Gas Volumetric Laboratory which after this will remain standy-by.

Different alternatives of laboratory errangements were discussed and it was agreed to set-up a Full scale Laboratory attached to the office building.

9./ Purchasing of a tensile testing machine is basically important for the cestification of rolled products. This also could be installed in the new laboratory building.

10./ Before tapping molten steel from the Electric. Arc furnace its temperature should be known exactly since the quality of pencil ingots is very much effected by the value of temperature of the liquid steel.

For exemple overlapings occour if the temperature is low; this kind of defect remains on the surface of the end products viz. concrete bars reducing the mechanical strength.

Purchasing of a temperature checking instrument which can show the exact temperature of liquid steel was recomended. Its use is very quick and does not require high qualifications.

11./ A preventive maintenance is expected to secure smooth running of the Electric Arc Furnace and other machinery.
The maintenance system basing on daily, weekly, menthly and yearly activities was recomended.

12./ For securing proper monpower a comprehensire training programme was advised to carry out.
Maximum involvement of local resources and practical approach should be taken into account.
Suggestions are as follows:

a./ From the management of the factory two-there delegates are advised to carry out a study tour in countries where similar steelmaking is going on.

b./ It is obvious that a really efficient technical assistance is needed in the plant. This could be secured if one UNIDO expert arrived to the site every year for at least 2-3 months giving assistance in solving current technological difficulties.

c./ Under the umbrella of UNIDO workshop programme on core metallurgical industries are held every year in different countries. It is recomended that the factory should delegate engineers to this event.
Taking into account that this year it is going to be organised in Hungary it was advised to present 2-3 engineers who could also visit steel plants similar production is going on as in the Ethiopian Iron and Steel Foundry.

d./ In the training programme of local staff the maximum involvement of local resources should be involved.
The Ethiopian Standard Institute, the Faculty of Natural Scineces at the Addis Ababa University and the Ministry of Mines Minerals and Energy all have potential resources could be utilized in the factory.
E.G. contra analysis of the steel can be carried out both at Faculty of Natural Sciences and Institute of Standards.
They could be involved in regular training of the laboratory personnel too.
On the other hand the Ministry of Mines Minerals and Energy was ready to analyze burnt lime and limenstone used in steelmaking in the Electric Arc Furnace.

The recomendation is to conclude agreement with these parastatals.

e./ There is possibility for engineers to participate short term workshop training programme in Hungary under the bilateral agreement between Ethiopia and Hungary.
As recomended for direct contact the management of the factory should approach the representative of TESCO-Technical and Scientific Engineering Company of Hungary in Addis Ababa.

Cooperating Counterpart

The Ethiopian Iron and Steel Foundry was the cooperating counterpart.
From the beginning experts received every assistance required for doing the job from the factory management.

They were all the time cooperative and ready to accept proposals and introduce them. There were fruitful discussions with them and without their active support working programme could not have been done to the extent as it was.

Objectives of the Project

a./ To improve the existing scrap handling practice and specially the entry, quality control, procurement, segregation, shemical composition and preparation.

b./ To imrpove the steel melting practice, and particulary the quality control.

c./ To establish a proper metallurgical laboratory with appropriate equipment and facilities for quick chemical analyzis.

I. MAIN DUTIES OF THE PROJECT DOCUMENT

During the mission the duties of experts were: to provide day-to-day practical advices and on-the job training through direct participation in the production processes.
As a result of their work, in co-operation with the national counterpart personnel both the level of productivity and especially the quality of steel would be noticeably improved.

The experts, and particulary the Team Leadred, and the expert on metallurgical laboratory equipment/operation will be expected to advise the counterparts on proper specification, layout, manning and other pertiment problems to establish a full-scale laboratory.

II. ACHIEVEMENTS OF IMMEDIATE OBJECTIVES

Achievements of the assignment were in close relation with the objectives of the mission.

In the course of the field-work, however, due to the introduction of running the electric arc furnace and the rolling mill in separate shifts because of the weakness of power line from the substation, some technology modifications to improve quality of steel could not be introduced. The melting furnace was operating in the second and third shift.

Scrap handling with the use of bailing machine improved; and the carbon content of scrap was analyzed in the up-graded laboratory. When preparing the charge it is good to tnow what is the carbon content of the charge approximately and if necessary iron castirgs are added to assure required value of carbon.

The existing laboratory, which had been out of use, for many years, with the involvement of national counterpart personnel was put back on its feet copable to analyze carbon and sulfur content being able to serve scrap segregation and steelmaking.

For the establishment of a full-scale metallurgical laboratory experts advised proper specification, layout, manning and other relevant informations /see chapter FINDINGS/.

According to a programme a training course was held which included laboratory staff training, direct participation in the production processes and classroom-training. /see Annexure C, D, E, F/.

Technological instructions and production-technical documentation applied through the everyday on the job training were presented in e.g. Annexure G.

III. UTILIZATION OF PROJECT RESULTS

A./ Scrap handling practice and its quality control

Arrangements were made by the factory management to allocate one bailing machine which upon its arrival to the premise commenced pressing the light scrap immediately.

The quality control of scrap was improved by the introduction of Poldi-type hardness tester, spark testing, and permanent magnet as well as carbon and sulfur analysis in the upgraded gas-volumetric laboratory.

Due to the shortage of oxygen supply heavy steel scrap was not processed at all. Iron casting breaking should be solved at a unit erected for this purpose.

It was agreed with the management of the factory that a satisfactory solution of scrap handling would be to assign a team fully engaged with segregation and processing. However, this team was not set-up. On technological aspects the best solution, as it was recomended, to have a scrap Processing Plant outside the premises of the Ethiopiom Iron and steel Foundry from where only processed scrap would arrive for steelmaking.

B./ Establishment of a proper Metallurgical Laboratory

For the set-up of a proper Metallurgical Laboratory steps have been made as follows:

- A Spectrometer has already been purchased, which after commissioning will take over the job from the gas volumetric laboratory and will be able to carry out quick analysis of elements such as Carbon, Sulfur, Manganese, Silicon, Phosphorous, Chromium, Molibdenium, Nickel, Copper etc. serving scrap segregation, steelmaking process and grading concrete bars and other final products.

- The National Metal Works Corporation has located funds for the construction of a new laboratory building where the Gas Volumetric the Spectrometer Laboratories and the Tensile Testing Unit with Probe Preparations Shop will be implemented.

- National counterpart personnel were trained by the experts to carry out carbon and sulfur analysis in the Gas-Volumetric Laboratory which was put back to operation with the involvement of the local personnel. This laboratory is capable to serve production of steel until the Spectrometer will have been commissioned, however certain modernization is needed.

- In order to modernize the existing Gas-Volumetric Laboratory/Quality Control UNIDO has earmarked JSD 4000 for purchasing equipment and standard samples /see Annexure B/.

- Some of the would-be Laboratory staff had received special training in Spectrometer Laboratory activities. For the updating of their knowledge Faculty of Natural Sciences at Addis Ababa University and Ethiopian Standard Institute can be approached.

C. Electric Arc Furnace Steelamking

- Prior to steelmelting the weight of steel scrap charge should be known for to be sure that there will be enough liquid steel when teeming of ingots and for making calculations of metallurgical purposes. The weighing bridge for measuring was recomended to mend and before experts left it was in use again.

- In order to be able to monitor the efficieny of steelmelting process a "Melting Log" for easy to follow recording system was discussed and handed over. /see Annexure G/.
  Its introduction will provide essential data for the on going assesment of production features.

- Slag removing technique was improved by the introduction of using a special tool which was made according to experts design.

- When the oxidation is to be finished and no further carbon is expected to leave the liquid steel the reaction is stopped by adding Silicomanganese to the steel bath. Prior to doing this oxidised slag should be removed. It was achived however only when experts were monitoring the steelmaking process.

- For the complete deoxidation experts advised to put the Ferrosilicon into the furnace rather than into the ladle and to put broken pieces of Aluminium castings selected from the scrap. This suggestion was introduced too for some time, however, its practical introduction should be checked at each charge.

- The temperature control of liquid steel before tapping, the preheating of ladle, more careful mould assemly viz. complete elimination of sand and mortar residue, mechanical cleaning and lime wash or black wash tratment of moulds should be solved to improve the quality of steel ingots, hence the quality of concrete and smooth bars.

However the fully introduction of recomendations for improving production processes might face failure if cost effective, items e.g. Hardness Tester, Analytical Balance, Tensile Testing machine, Temperature Control Device can not be involved in the budget and/or if they are not enforced to use in the daily operational activities.

IV. F I N D I N G S

A. Scrap Handling

The Ethiopian Iron and Steel Foundry has been given priority to utilize the scrap of different origin, converting it into ingots from which coils /raw material for nail production/, and reinforcement bars are manufactured.

1. Source of Scrap

Charasteristic and sources of scrap /see Annexure H/

- Ligth Scrap: from Crown Corks, Oil Refinery, Ethiopian Household Utility.
- Medium Heary Scrap: suppliers are the Ethiopian Highway Authority and Private Suppliers.

- Heary Scrap: sources are Government Enterprises and Private Suppliers
- Miscellancous Scrap: from Private Dealers.

2. Scrap Processing

Scrap segregation and processing was not carried out when experts arrived to the factory. The scrap was piled up in the premises of the factory and charged into the electric arc furnace in bulky form by the use of electro magnet causing longer tap-to-tap time and higher energy cost.
There was an alligator shear functioning occassionaly, cutting only the rolling mill returns. This equipment should be used for cutting medium steel scrap of sizes appropriate to the capacities of the machine.

More than 40 per cent of scrap coming to the factory was very light /see Annexure I/. Its bailing to the size, max 600x400x400 mm which can fill the melting furnace properly was needed; for which purpose a ˈe bailing machine arrived. This unit is advi to function in two-shift basis.

The heavy steel scrap can only be cut by torch cutters, which needs a good supply of oxygen and acethylene.

Cast iron processing: Technologicalwise cast iron is a carburizing material in steel production, when pig iron or coke powder are not available.

The iron castings should be broken by steel ball dropped by electromagnet at the end of craned area fanced by wooden plates.

Highly alloyed iron and steel, cast iron and those items found reusable should be removed and stored separately.

Non-forrous Metals:

Since the presence of non-ferrous metals such as Copper, bronze, aluminium with steel scrap going into the furnace is not allowed their removal needs careful attention.

- Aluminium castings: After segregation and preparation aluminium castings can be used as deoxidazing material in the ladle improving the efficiency of deoxidazing.
- Other non-ferrous materials: such as copper bronze, lead etc., have to be carefully segregated from steel scrap and stored at a separate place without any processing. It is the non-ferrous industry which will utilize them.

Alloyed Steel and Cast Iron: Highly alloyed steel and cast iron scrap are used in the alloyed iron and steel production unless their chemical composition is acceptable in the steel making process for making mild, medium or high carbon pencil ingots in the Ethiopian Iron and Steel Foundry.

For ecample if only the manganese content is high it may be charged but if there are chronium, titanium, molibdenium etc. in the scrap it should be stored separately for future utilization.

Elimination of containers might contain explosives or dangerous liquids or gases is one of the most important things to do in the course of scrap segregation. These vessels were suggested to be stored in a fonced area farest from every building and dismantled by an expert coming from the gas filling station.

Scrap Proseccing Team

For securing a steady supply of processed scrap for the melting shop it is recomended to set up a team fully engaged in segregation an processing of scrap. At least 10 people should be involved.

The team is organised of 1C people. The manning is as follows:

ONE - Team Leader
TWO - Torch Cutters
TWO - Mobile Crane serving Workers
ONE - Specialist selecting and collecting reusable components
TWO - Workers engaged in removing aluminium castings and other non-ferrous materials
TWO - Workers preparing the aluminium castings to be used in the deoxidation process of steelmaking.

Layout of Scrap Processing

A great area is covered by scrap in the premises of the plant. Scrap processing can be done at different places simultaneously.

Light Scrap Processing: Mobile bailing machine should process the piled light scrap both in the craned and apen area. Beles from the latter will be transported in containers by mobile crane to charge preparation close to the melting shop.

Medium and Heavy Scrap Processing: Segregation and processing are carried out by torch cutters, and processed scrap is also transported to the EOT craned area by mobile crone.

Machines and Equipment

For the time being for scrap processing there are

- ONE, Mobile bailing machine /Operating/
- THREE, Torch cutting equipment - not used since oxygen is in shortage
- ONE, Alligator shear - Operating but it is processing only the rolling mill returns
- ONE, Mobile crane - Operating
- ONE, Crusher steel ball for braking iron castings - Not used.

Additionally an other Alligator Shearing Machine is required for cutting medium size steel scrap of flat characteristics.

Classification of scrap can be now performed by

- Visual inspection

- Spark Testing
- Hardess testing
- Carbon and Sulfur analysis in the existing up-graded Gas-Volumetric Laboratory.
- Using permanent magnet in order to separate forrous and non ferrous materials.

Scrap classification will be more efficient as soon as the Spectrometer is operating.

3. <u>Charge Preparation</u>

Scarp was charged unprocessed into the electric arc furnace by the use of electro magnet by which non desired materials e.g. pressure vessels, automobile schock absorbers filled with oil etc., might also go in being able to cause explodings. This charging system is unsatisfactory and creating longer tap-to-tap time and rising energy costs.

There were two charging buckets but only stand-by, rarely used since with unprocessed scrap it can not be filled.
The weighing-bridge was out of order. Its repairing was strongly recomended, and its involvement in charge preparation was commenced, therefore, the weight of steel scrap required to have enough liquid steel for teeming of ingots could be calculated.

The introduction of a revised "Melting Log" being able to keep steelmaking under strict control was recomended. /see Annexure G/.

Charge Composition

Only processed steel scrap and cast iron the carborizing material, can be the compounds of the charge.

Baled Scrap: Light mixed scrap is ba ed to the size of 600x400x400 mm.

Medium and Heavy Scrap: prepared by torch cutters, alligator shear in the size of max 500x300x300 mm.

Cast Iron: This carbon carrying material should be broken to the sizes of not more than 300x300x300 mm

The charge composition together with other important data are registered in the Electric Arc Furnace Melting Log. /see Annexure G/.

Charge Calculation

Only estimation and not calculation was existing with charge preparation.
For example, sometimes iron casting was not added at all and after the scrap was melted and the carbon content found too low electrodes were deepened for carbon pick-up which method is very expensive.
Charge calculation was recomended to introduce soonest.

The total weight of metallic charge equals with the weight of ingots to be produced, sprue and runners and heat loss i.e.:

Weight of charge = Wight of ingots + Weight of sprue and runners + heat loss

Weigth of Ingots: with one melt altogether 56 pieces of ingots of 85 kg each are teemed making a total of 4760 kg.

Weight of Sprue and Runners: is estimated to be approximately 100 kg.

Heat loss: in the course of steelmaking oppr. 8 per cent heat loss is calculated making a figure of 420 kg.

When calculating the charge the basic principle should be to have about 0,2 to 0,3 per cent higher carbon content in the scrap to be melted than in the final composition.

This can be gained by adding cast iron which has got a carbon content of 3 to 4 per cent comparing to that of 0,10 to 0,30 % of steel scrap.

Charging

The furnace roof swings aside and the charging only by bucket should be done as quick as possible, otherwise the furnace cools down and its reheating to working temperature needs excess energy input.

The furnace roof and the electrade clampings should be cleaned off the dust as soon as the charging is completed.
Normally with one bucket the total weight of charge can not be put into the furnace. The second one with the balance weight will come when the first quantity is semi melted.

B. Steelmaking Technology in the Electric Arc Furnace

The whole process of steelmaking was found to be based on long years of workshop experience rather than following a precisely controlled technology. The implementation of controlled steelmaking was commenced by providing day-to-day practical advices and classroom training during the assignment.

1. Melt-down Period

The furnace was charged full of light scrap, and the roof left in lifted position for about 20 minutes of melt down period.
It was recomended to close the furnace right after the charging is over, since the center roof lifting and swinging mechanism can be damaged if the roof is not in the lower position when the furnace is operating.

In the course of steelmaking the value of power consumption is related to the tapping of transformer and reactor. It is obvious that not more than the real need should go in the furnace, therefore, from the start of melting the scrap upto tapping the position of transformer, reactor and length of arc schould be according to the demand /see Annexure K/.

For 10-15 minutes only 60 per cent of total transformer loading capacity should be introduced reducing the heavy direct heat effect of arc on the roof.

The burnt lime used for slag forming both at the end of melt-in and later during oxidizing was very dusty containing moisture too.
The effect of this powderous lime are:

- it is increasing the valume of dust leaving the furnace
- a good part of it is rising to the roof reducing the lifetime strongly of silica and slightly alumina bricks.
- The moisture of the lime will be absorbed by the liquid steel in the form of oxygen and hydrogen, destroying the quality of steel.

It is recomended to use burnt lime of lumpy type.
The quality of lime stone was all right.

First Probe: at the end of melt-down liquid steel is poured onto the surface of a steel plate. Cooled down in water the fractured surface of broken somple gives information of the carbon content for the melters.
This method is unsatisfactory.

As a first step a probe taking die was made and by its use the analysis of carbon of molten steel was commenced in the up-graded laboratory.

However, this laboratory will be able to carry out quick analysis if local laboratory personnel have got more practice and the laboratory upgraded.
The best solution is reached when the Spectometer will be in operation.

2. <u>Oxidizing:</u>

Basing on the estimation of carbon content shown by the probe, melters start adding limestone, burnt lime and if carbon content found high mill scale.

Since the exact carbon content is not known this method of oxidizing can not be controlled.

For the control of the speed of carbon removal it is neseccary to know the value of carbon content and the temperature of steel.
It is recomended to commission the Spectrometer as soon as possible.

During oxidation, for purifying purposes appr. 0,2 to 0,30 % schould be removed, this is the reason why iron casting must be added to the charge.

Second Probe: Melters took the second probe out when they thought the carbon content was right. When it was too low electrodes were deepened into the liquid for carbon pick-up in switched off position.
This is a very expensive way of carburizing. Further probes were taken out until the carbon content was found to be the final composition.

Slag Removal:
Slag should be removed after ten minutes of oxidation and at the end of oxidation by the use of slag removing tool. This method was not applied.

Carburizing: When the speed of oxidation of carbon is too high more carbon has been removed than necessary. In this case the carbon pick-up can be done by the following ways:

- Adding crushed electrodes: when applying this method slag has to be removed then grained electrodes thrown to the surface of liquid steel.
- Deepening of electrodes: the power is switched off and the electrodes are deepened into the steel. This method is rather expensive and instead of doing this in the scrap charge iron casting should be mixed.

3. Deoxidation

For blocking further oxidation of carbon 50 kg Silicomanganese was added into the furnace and 15 kg of Ferrosilicon into the ladle. It was recomended to remove the whole amount of oxidized slag than adding Silicomanganese and Ferrosilicon into the furnace; and finally pieces of aluminium castings should be added into the ladle when tapping the steel.

From commencing deoxidation until the start of teeming the time passed was not more them 5 minutes which was not enough for inclusions to leave the steel for the slag. This time should be longer.

4. Tapping of Steel

Steel was tapped into cold ladle. 15 kg of Ferrosilicon went to the stream of steel and finally silica sand sometimes moistures added to the surface of slag.

Instead of sand lime should be added.
In order to improve surface quality of ingots requirements were advised to be fulfilled prior to teeming viz.:

-- Temperature of steel at tapping should be 1580°C. Purchasing a launce-type temperature measuring device is necessary.
-- Preheating the ladle to 600-700°C. A ladle preheating unit is easy to set-up with the use of local resources.

C. Teeming of Ingots

With one ladle 14 moulds were filled with liquid steel making a total of 56 pencil ingots. Sand was dropped into moulds during the assembly of mould set which would be captured by liquid steel causing defects in steel ingots.
The inside surface of moulds was not treated at all. Mechanical cleaning if required and for lime/black wash coating after each teeming would improve the lifetime of moulds and result smoother surface to the pencil ingots which is finally the surface of rolled products.

At the end of teeming steel remaining in the ladle was carried back to the melting furnace and if the temperature was not high enough it solified on the bottom of the ladle, and its removal needed oxygen and damaged the refractory lining seriously.
This problem will be passed over when the temperature measuring device is introduced.

D. Refractory Linings and Graphite Electrodes

Refractories and electrodes are among the top cost bearing items.

1. Furnace roof: is made of silica or alumina bricks Lifetime of it can be longer as specified herewith
   - Cooling ability of the bricks is reduced by the dust accumulated on the outside surface. It should be removed after each melt.

   - The powder-like burnt lime, the slagging material should not be epplied since a good part of it reaches the inside surface of the roof and reacting with the silica bricks it forms calcuimsilicate of low melting point, hence the lifetime of the roof is shortened.

   - Replacement of the electrode cooling rings is advised which will cool the roof bricks around the grophite electrodes, extending their lifetime.

2. Bottom and wall of the melting furnace:

The bottom and wall lined by dolomite will last longer if they are sepaired after each melt.

3. Ladle

The ladle was lined with alumina bricks, repaired with kaoline-mortar and dried by oil burner. In many cases solified steel semained on the bottom of the ladle and its removal damaged the refractory lining.

he lifetime of the ladle can be extended if the following recomendations fulfilled:

- Preheating to 600-700 °C before each topping is necessary. A simple oil burner would do.
- Repairing should be carried out carefully.
- The formation of accretion should be eliminated by higher tapping temperature, because its removal is very ifficult and breaks the lining.

Due to power supply difficulties the electric arc furnace was sorking in the second and third shift. Every morning the furnace lining cooled down and excess energy was needed to raise its temperature again to furnace operating value, making the cost of production higher.
It is advisable to run the furnace in three shifts.

4. Graphite Electrodes

Electrode consumption was found high and it could be reduced in the following ways:

- Electrode cooling rings /water cooled/ should be raplaced. By their use the heat effect of the flame coming out of the furnace through the three holes of the roof is considerably reduced and the electrodes outside the furnace will not be burning.

- Electrodes should not be used for carburizing the liquid steel if the the carbon was found very low. Electrodes are cost effective items in steel making their consumption influences strongly the cost of steel production.

E. Operation of the Electric Arc Furnace

1. Capacities

However, commissioned in 1961, the 5-ton capacity electric arc furnace was in a rather good condition. From the 15 kV-line through a reaktor the 2620 kVA transformer supplied energy for melting steel scrap.

Due to the limited availability of power the yearly production of pencil ingots was less thom the nominal capacity.

Capacity figures:

Nominal acapacity: 10.300 tpy /3-shift/
Production of ingots: /1983/1984/
5.200 tpy /2-shift/
Target of ingot production: /1984/1985/
6.000 tonnes/2-shift/

2. Operation techniques:

Af start-up of melting, for at least 20 minutes the roof was not seated hence reducing the lifetime of roof lifting and swinging mechanism.

One of the most important things to do with the electric arc furnace is to give adjustments to the control system of electrode moving mechanism /Electrodes were operating very slow./. Instruments for this purpose did neither exist in the steel foundry nor at EELPA-Ethiopian Electric Power Authority, therefore it was racomended to seek for foreign assistance.

Despite the periods of metallurgical processes in the furnace required different volumes of electric power, this need was not fulfilled, viz. the reactor was all the time full-tapped, and the position of transformer tap changer was varied according to the long years of experience rather than to the real demand. /see Annexure K/.

3. Condition of different Units of the Electric Arc Furnace

Furnace Body: Its solid state was preserved, only the cradle seats seemed to need replacement.

Roof: Water cooled, however, could not be seated in the sand bed on the rim of furnace body, because the quiding steel belt was deformed. This has to be repaired.

Door and Tapping Canal: Door frame was watercooled but the moving part did not close properly in down position. Repairing is necessary, since in the course of deoxidation air should be kept away from the furnace inside atmosphere.

Electrode Supporting System and Conductors:

Graphite electrodes firmly held by bronze headed clamps and connected with water-oil emulsion network, were moved up and down by supporting arms the movement of which was interrupted if air bubles were not released from electrode moving cylinders before each cold start.
Maintenance workers are expected to release the air.

The elbows of copper conductor tubes were being bent by both the heat reflection of the furnace and the weight of flexible copper cables close to being able damaging themselves when electrodes are in the lowest position. It is advised to change the positions of bracings first and to shaps elbows in right angle.

Roof Lifting and Swinging Mechanism:

It was functioning properly, however, being vibrated when furnace roof was not seated during the melt-down period. This negative effect can be reduced if the furnace roof is seated after the charging is over.

Floxible Cables:

Performance of these copper flexible cables was good, but the missing insulating rings should be put back. The fact is if too many of rings are lost on the cables short cut may happen between them damaging themselves.

Cooling System:

Furnace roof, electrode holding clamps and slagging door frame were watercooled. Adequate network supplied fresh water for cooling purposes.
Electrode cooling rings were missing and their replacement was recomended.

Oil Emulsion Network:

Movements of roof liftig and swinging, furnace tilting, electrode moving and holding, door moving were all controlled by water-oil emulsion system under pressure maintained by safety pressure tank which were served by pumps.
There were there types of problems shich should be solved

- Sealings at many joints of the network should be changed for new ones. As a result of releasing of oil-water emulsion

the conrete-cabins under the furnace were filled by it which had been dangerous if any drop of liquid steel could have reached there.

- In the safety pressure tank no proper volume of air cushion was formed which should be existing for emergency case if by electric cut-off pumps stop functioning.

- Steel frames supporting the electric motors and pumps did not have fixed camection, and there was a vibrating effect existing which could couse damages both to the electric motors and pump.

Transformes and Reactor:

Both were found in good condition. For better function recomendations were given es tollows:

- Tapping of the transformes and reactor in the course of steelmaking should be according to technobgical requirements /see Annexure K/.
- The reactor has to be switched off after the steel scrap is completely melted.
- Transformer on the other hand should be loaded adequately to power demand.

Measuring and Indicating Instruments:

The kilowatt register and indicating instrument was ouf of order. This device gives useful informations of the changing of electric energy consumption in the course of steelmaking, if it is working.

With the involvement of electric maintenance workers experts dismantled the kilowatt register and gave advices on how to repair it. Some weeks later mending was completed but registrating paper was not available.

4. Preventive Maintenance

The lifetime of the electric arc furnace and its accessories is very much dependent on the maintenance system applied.

Af the Ethiopion Iron and Steel Foundry there was a maintenance basing on routine practice. Experts recomended that preventive maintenance had to be worked out basing on daily, weekly, monthly, and yearly schedules /see Annexure L, M/.

The existing electric maintenance shop was not furnished with special instruments and spare parts of basic need such es toroid transformer, current generator, resistance measuring bridge, isolation tester etc.
E.g. two of the three electrodes were working very slowly influencing the electric symetry and the length of melting time. With the help of a well equipped maintenance shop this problem could have been solved.

In the proposed modernized Electric Maintenance shop the manpower demand will be as follows:

ONE	-	Electrical Engineer
TWO	-	Technicians
THREE	-	Skilled Workers
TWO	-	Unskilled Workers

Main activities of this staff would be:

- checking and repairing of instrumens /E.G. Voltage, Current, KVA and kWh indicating and registering instruments concerned/.

- Maintenance of protection relays and circuits.
- Controlling the function of temperature measuring instruments and thermocouples.
- Checking and repairing if required the circuit breakers and high tension parts.
- Checking and maintaining electric motors of cranes and other machines.

F. Quality Control

The implementation of a Full Scale Laboratory in order to achieve the requirements demanded by the Standards of rolled steel Products issued by the Ethiopion Standard Institute was urgenthy needed. The nucleus of the laboratory could be formed by metallurgically trained currently employed people. The activities of this unit should cover the quality control of scrap regregation and steelmaking, temperature measuring of liquid steel and preheated ingots and tensile testing of the finished rolled products.

Being aware of the capacities for the establishment of a good quality control system the following practical approach was implemented.

1. Assesment of Existing Resources

   When arriving in the works experts found a gas-volumetric laboratory which had not been working for 4 years. Originally it was commissioned in order to carry out the chemical analyzis of steel scrap, liquid steel during steelmaking and rolled product.

First of all the availability of chemicals and facilities was checked and it was found that all the chemicals and facilities required for analyzing carbon and sulfur existed /see Annexure N, O/. These two elements should basically be known in steelmaking practice.

However, for the modernization of this laboratory /Annexure P/ certain equipment and chemicals should be purchased /see Annexure B/.
For example the balance was damaged, although it was working but not precisely. In a continuous basis of operation this balance could not work properly.
UNIDO has already allocated funds for purchasing items needed and when they are available this old gas volumetric laboratory would be prepared for routine analyzis of carbon and sulfur of steel scrap, liquid steel and rolled products.

With the resources available, Ethiopian engineers learned practically how to analyze carbon. Due to the short period of assignment experts could not upgrade the function of this gas volumetric laboratory to a level being able to serva steelmaking process. The reasons were as follows:

- Probe preparation could not be solved.
- Because of the lack of longer experience the carbon analyzis could not be routine-like and it took longer time than it could have had to be in order to supply the exact value of carbon to melters in at least 15 minutes.

Although the estimation of carbon content of liquid steel by the visual inspection of fractured samples continued, but experts had a probe taking die made and by its introduction carbon content of liquid steel prior to tapping was analized occassionally.

Also, samples of steel scrap and iron Castings, imported billets and rolled products were analyzed for carbon.

For the control of the function of the existing laboratory sample chips were taken to the Institute of Standards.

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The Institute of Technology at Addis Ababa University was approached and it carried out precise wighing of chips taken from the factory for testing the function of balance in the laboratory. This was a fairly good help in the start-up of putting bock this old laboratory on its feet.

In scrap segregation by using a hardness tester good informations con be gained to indentify the kind of material and its approx tensile strength which is very much influenced by the content of elloys. In the laboratory a Poldi-type hordness tester was found and testing of different kinds of scrap es well as rolled products were carried ont with the involvemental local personnel.

2. Establishing a Full Schale Metallurgical Laboratory

A quick and reliable laboratory should supply control data for product improvement e.g. for correlation processing of liquid steel, scrap could be regregated more casily. And at last but not least the final testing viz. chemical composition and mechanical testing e.g. tensile and yield values will be done in this laboratory which will issue the certificate of rolled products.

Alternative No.1 for full-scale Metallurgical Laboratory

The Gasvolumetric Laboratory and the Spectrometer Laboratory are located in separate places. Since the spectrometer is capable to do every analysis required, the Gasvolumetric analyzer is a standby and ready to get in any time if disturbances hoppen to the spectrometer and for controlling spectrometer ocassionally.

a./ Gasvolumetric Laboratory: remains in the existing building; facilities and chemicals should all the time be in good condition and available.

- The present analytical balance has to be changed to a new, gauged one on a rigid /concrete/ table with shock absorbing ground.
- For producing steel chips one table-type drilling machine equiped with hard-metal tool /∅ 4 mm/.
- Every twentieth melt is analysed by gasvolumetric method for carbon analysis as well.
- If the spectrometer is out of order, Gasvolumetric Laboratory takes over the job immadiately and carries out the analysis of carbon and sulfur.
- To fulfil the present and future demand the next items have to be purchased and stored with present chemicals:

standard steel chips	500 g/bottle
sublimated iodine	250 g
chromic acid /Cr/VI/oxideg/	1000 g
carbon tetra-chloride	5 litres

Equipment and accessories

ONE-equipment for C- and S-analysis

ONE-oxigen bottle /high purity O_2/ with stand and reducer

ONE-cupbord with safety locking and fire-proof walls for chemicals /some of them are poisonous and dangarous/

ONE-table to hold the qasvolumetric analysing system with under self /2,2x0,8 m/

ONE-table wolded from steel profiles and plates with under self to hold samples, tools, glass-wares serving the analysis process, to prepare solutions and store these provisonaly /2,0x4,0 m/

ONE-cupboard with standard locking for spare parts of the furnace, porcellain boats and spare parts of the analysing system /glass ware, hoses, plugs etc./

ONE-double sink with two water taps

ONE-electric resistant heater

ONE-glass container for porcellain boats with dessicating

ONE-laboratory balance /0-125 g/

ONE-barometer applicable to local barometric pressure with is approx. 570 Hgmm.

Area of Gasvolumetric Laboratory: 4,5x3,0 m

Electric facilitias:
- three sockets /220 V A.C., 4 A/ for illumination in balance and equpments
- one socket /220 V A.C. 16 A/ grounded for furnace
- illumination: 500 lux

Forms of diary of carbon analysis in the laboratory and to certificate results /see in Annexure T/

List of chemicals stored in the laboratory /see in Annexure N/

Arrangement of facilities see in Annexure P/

b./ Spectrometer Laboratory: allocated in the office building. It will consist of two rooms: one of them will be the spectrometer laboratory and the other one a probe prepairing unit. The two rooms will be arranged side by side with strictly separated atmosphere /see Annex Q/

Facilities of Spectrometer Laboratory:

ONE-ESA 4 sequential spectrometer

ONE-Analytical balance /ganged, see also at gasvolumetric laboratory/

ONE-rigid /concrete/ table with shock absorbing ground supporting balances serving all the laboratories

ONE-argon bottle /Argon 97 % + hydrogen 3 %, high purity/ with pressure reducer and standard fixing

ONE-blower to keep the room temperature between the prescribed limits

ONE-stereo microscope /binocular/

ONE-table for holding samples and tools serving the spectrometer as well as the stereo microscope

ONE-cupboard for spare parts of the spectrometer and storing documentation

ONE-writing-table for the engineer, chief of laboratory and quality control

ONE-booksolf for technical books, standards, manuals

ONE-water tap with sink

Electric connection facilities:

ONE-socket /220 V A.C. 5 kVA, 25 A with eart connection/ for the spectrometer with protecting breaker

ONE-voltage stabilizer /220 V A.C. 5 kVA output/

FOUR-sockets /220 V A.C. 4 A each/

c./ <u>Probe preparing workshop</u>

Facilities of probe prepairing unit Annexure R.

ONE-rapid cutter for prepairing testpieces for spectrometer

ONE-grinder/polisher machine to prepare samples for spectrometer

ONE-laboratory furnace /max temperature: 1200 ^{o}C/ for theat treatment of samples

ONE-drilling machine /table type/ with hard metal tools /Ø 4 mm/ for preparing chips for gas volumetric analysis /see also at gasvolumetric laboratory/

ONE-wooden workshop table

ONE-workshop vice

ONE-set of trols to operate and maintain laboratory equipments

ONE-cupboard to store spare parts, accessories and supply

ONE-water tap with sink

Electric connection facilities:

ONE-socket /220 V A.C. 1 kVA with earth connection/ according to the cutter's manuel

ONE-socket /220 V A.C. k VA with earth connection/ according to the manual of grindes/polisher machines

ONE-socket /220 V A.C. 1 kVA with eart connection/ according to the manual of drilling machine

ONE-socket /220 V A.C. 16 A with eart connection/ according to the manual of furnace

THREE-sockets 220 V A.C. 4 a for other purposes

Illumination: 1000 lux

General note: the supply voltage in the steel Foundry 380/220 V A.C. 50 Hz

Alternative No.2 for full-scale /complex/ Matellurgical Laboratory

Both the Gasvolumetric and Spectrometer Laboratories are in the same building /Annexure V/. The area close to the office building is sufficient for the erection of a Metallurgical Laboratory.

The full-scale Metallurgical Laboratory consist of the units as follows:

- Spectrometer Laboratory
- Gasvolumetric Laboratory
- Tensile Testing /mechanical testing/ Laboratory
- Probe Preparing Workshop

The staff of the full-scale metallurgical laboratory:

ONE-engineer
TWO-technicians
ONE-mechanist
ONE-unskilled worker

Facilities of spectrometer and gasvolumetric laboratories as well as probe preparing unit integrated in to the full-scale metallurgical laboratory are listed under alternative 1.

Facilities of Tensile Testing Laboratory are given herewith:

ONE-tensile testing machine on shock absorbing ground with 100 kN minimal loading capacity
ONE-hardness testing machine on concrete slab basement with HB and HV measuring capabilities
ONE-portable hordnass tester /Poldi/ with twenty master rods

ONE-large rigid table made of wood to store samples, tools, spare parts

ONE-large workshop vice attached to the table

ONE-large cupboard for spare parts, accessories, books and documentation of laboratory work

ONE-table

For electric connection:

ONE-socket /220 V A.C. 16 A/ in accordance to the manual of tensile testing machine

FOUR-sockets /220 V A.C. 4 A/ for hardness tester and other purposes

Forms of certification of laboratory results see in Annexures S, T, V.

a./ <u>Equipment and materials to be purchased for alternative No.1 Full-scale Metallurgical Laboratory and their prices</u>

<u>Gasvolumetric laboratory:</u>

ONE-cupboard, fireproof with safety locking	280	ETB
ONE-barometer /scaling from 500 Hgmm	85	"
ONE-double sink with two water taps	250	"
chemicals:		
- 250 g of sublimated iodine	20	"
- 1000 g of chromium /VI/ oxide	20	"
- 5 liters of carbon tetra-chloride	35	"
- 500 g/bottle of standardt steel chips with C-content 0,05, 0,10, 0,20, 0,30, 0,40, 0,50, 0,60 w %	120	"
	810	ETB

Spectrometer laboratory:

ONE-analytical balance /LB-1050/	2950 ETB
ONE-rigid table for balances	200 "
ONE-argon bottle with fixing and reducer	300 "
ONE-blower /window-built/	150 "
ONE-stereo microscope /binocular/	1400 "
ONE-cupboard for spare parts etc.	300 "
ONE-bookself	300 "
ONE-water top with sink	200 "
	5800 ETB

Probe preparing workshop:

ONE-rapid cutter machine /Metasecan/	10472 ETB
ONE-drilling machine to make chips	2000 "
ONE-laboratory furnace	2500 "
ONE-wooden workshop table	300 "
ONE-workshop vice	40 "
ONE-set of tools	200 "
ONE-cupboard	300 "
ONE-water tap with sink	200 "
	16012 ETB
	22622 ETB

b./ Equipment and accessories to be purchased for Alternative No.2 full-scale Metallurgical Laboratory

Taking into account that in this alternative the gas-volumetric laboratory and the spectrometer laboratory together with probe preparing unit with their furnishing would be shipped from locations detailed under alternative 1., what is additional in alternative 2 is the tensile testing laboratory. The estimated prices of equipment and accessories needed for this unit are given hereto:

ONE-tensile testing machine Annexure Z /200 kN, EU 20/	44000	ETB
ONE-hardness testing machine /HB and HV/	4000	"
TWENTY-mater rods for POLDI hardness tester	300	"
ONE-rigid wooden table for samples, tools etc.	500	"
ONE-workshop vice	78	"
ONE-cupboard for spare parts	300	"
	49178	ETB
Building budget for full-scale met.lab.	40000	ETB
	89178	ETB
Budget from Alternative No.1	22622	ETB
TOTAL MET.LAB. COST	111800	ETB

G. Manpower Training

Workers were working on the basis of experience adopted during the period when italian experts were teaching them. Engineers after graduation commenced practical experiance most of them in this factory. Taking into account that there was no other steelmaking plant in Ethiopia no chance existed for comprehensive training.

Moreover the day to day proctical advices and on-job contultations through direct purticipation in the production processes, classroom training also helped the better understanding of the necessity of up-grading production techniques /Annexure C, D, E, F/.

Althogether 13 lectures were held covering scrap processing, electric arc furnace steelmaking, furnace operation, and quality control. Classroom program was followed by site consultations.

These fruitful discussions raised many practical questions such as: what were the bad effects of non terrous metals if they would be charged into melting furnace, what was the advantage of putting proper quanlity of iron castings into the charge. Why was the electrode consumption so high, what would be the effect ot too low or to high tapping temperature etc.

Every engineer of the plant were involved in the training programme and they also helped transferring explanations of practical knowledge to workers in the scrap yuard, meltinq bay and maintenance shop.

The monagement of the factory welcomed the proposal of a comprehensive training programme which could involve the following areas:

1. In the UNIDO workshop training programme two-three engineers should be participated.

2. Utilizing the possibilities in the bilateral agreement between Ethiopia and Hungary engineers might get proctical training for 3 to 6 months in a steel plant in Hungary.

3. Other African countries e.g. Zimbabwe having simililar steel plant could be approached to recieve engineers for study tour.

4. Faculty of Natural Sciences at the University of Addis Ababa, the Institute of Standards could take a share in the training programme of laboratory staff and make control analysis if required.
   The Laboratory under the ministry of Mines Minerals and Energy was prepered to analyse limestone and burnt lime used in the Ethiopian Iron and Steel Foundry. This parastatal body as Mr.M.Negao, Laboratory head explained was ready to give any assistance required /Annexure X/.

5. A UNIDO expert in srap processing, steel making and quality control is advised to work in the factory for at least 2-3 months every year helping local staff maintraining good production techniques.

V. C O N C L U S I O N S

It was obvious that the up-grading of the production line in the Ethiopian Iron and steel Foundry was in urgent need in order to meet the requirements of standards of final products viz. concrete bars.

The most suprising impression was, upon arrival, the scrap yard where steel scrap mixed with partly non-ferrous metals such as aluminium, bronze etc and items containing dangerous materials viz. containers arrived to. Segregation and processing did not exist. Without amy preparation steel scrap was charged to the melting furnace in bulky form by electro magnet which was unsatisfactory. Af the and of the second month of assignment a bailing machine which we had requested for when arriving arrived, and the bailing of light scrap was commenced. This improved the charge preparation and charging time shortened.

The accumulation of huge amount of scrap in the premises was disturbing transport movements and effective scrap segregation and preparation would be more effective if a separate Scrap Processing Plant could handle the scrap business, which would supply only processed scrap for the Steel Foundry. As advised first a technical report should be carried out by the help of UNIDO.

The Gas volumetric Laboratory after one month was put back on its feet and the carbon analysis of steel scrap, liquid steel and concrete bars commenced with the involvement of Ethiopian engineers. This laboratory become capable for carrying out analysis, however its modernisation was to be important. For financing suplementory equipment and chemicals needed UNIDO allocated funds. As soon es modernisation is completed this gasvolumetric laboratory would be in a position to serve production line, until the Spectrometer Laboratory which is capable to analyse much more elements than the existing gas volumetric laboratory will be commissioned.

The satisfactory final solution, however, would be as suggested that a Full-scale Metallurgical Laboratory Consisting the gas Volumetric Unit the Spectrometer, Probe Preparation Unit and a Tensile Testing Room as a complex should be established in a separate building. The management expressed it as a good idea and they told that funds had already been put into the budget for a new laboratory building.

During its first phase of running a laboratory an expert delegated by UNIDO was advised to supervise activities in the laboratory.

On the other hand it seemed that the factory was in a need of technical assistance by sending a specialist on the field of scrap processing steelmaking and quality control on a short timo basis every year.

One of the most importatnt things to do is working out a special practical oriented training programme. Both the international organisations like UNIDO, Economic Commission for Africa etc. and local parastatals such as Faculty of Natural Sciences af Addis Ababa University and Institute of Standards should be contacted for assistance in training of engineers and workers. An other source of help for the training programme could be under government agreement between Ethiopia and an other country concerned.

ANNEXURE A

WORKING PROGRAMME

1./ Arriving to the site - Ethiopian Iron and Steel Foundry

Mr.Ferenc Zsigovics, Expert in Electric Arc Furnace steel making, team leader, 4 February, 1985

Mr.Laszlo Palinkas, Expert in Electric Arc Furnace handling and electrical maintenance 11, February, 1985

Mr.Antal Bacskai, Expert in metallurgical laboratory equipment/operation and quality control 25, February, 1985

2./ Scope of services

To provide day to day practical advices and on-job training through direct participation in the production process covering the following areas

- scrap segregation and processing
- laboratory operation
- steel melting process and teeming of ingots

3./ Appointments with relevant Authorities and Institues

- Ministry of Mines and Minerals
- Ethiopian Standard Institute
- UNIDO office, Addis Ababa
- National Metal Works Corporation
- Ethiopian Electric and Light Power Authirity
- Ministry of Industries

ANNEXURE A

4./ Expiry of assigment

- late April or/and early May

ANNEXURE B

Specification of laboratory/quality control equipment and chemicals for the modernization of existing laboratory

	Estimated Price /USD/
ONE-Hardness tester Type: Diatestor	2200.-
ONE-STEREO Binocular Microscope	750.-
ONE-Analitical Balance Type: LB-1050	1400.-
ONE-Barometer	55.-
TWENTY-Master Rods for Poldi hardness tester	150.-
EIGHT BOTTLES-Standard Steel Chips 500 g per bottle with carbon contents of 0,1 to 0,8 percent	60.-
ONE BOTTLE-Cast Iron Chips	10.-
250 q Sublimated iodine	10.-
1000 g chromic ocid /Cr_2O_7/	12.-
5000 ml Carbon tetrachloride	18.-
USD:	4665.-

Ex works Europen suppler

ANNEXURE C

ON - JOB TRAINNING

A comprehensive trainning programme can secure trained manpower for the smooth running of a production line.

However, as far as on-job training is concerned during the expert's assignments a special course was implemented.

Moreover the day to day practical advices and on-job consultations through direct participation in the production processes, classroom training also helped the better understanding of the neccessity of up-grading production techniques.

Altogether 10 engineers attended this trainning programme.

The Following subjects were discussed in the classroom programme

Scrap Processing
Electric Arc Furnace Steelmaking
Furnace Operation
Quality Control /Metallurgical Laboratory/

/For detailed programme see Annexure D and E/

ANNEXURE D

Detailed Programme of Training

1. Scrap Processing
   - a/ Source and type of scrap
   - b/ Segregation of
     - cast iron
     - non-ferrous metals
     - alloyed iron and steel
     - non metallic components
     - dangerous items and materials
     - reusable items
   - c/ Processing techniques namely, Bailing, torch cutting, alligator shearing, and breaking.
   - d/ Chemical laboratory involvement in segregation.

2. ELECTRIC ARC FURNACE STEELMAKING
   - a/ Charge preparation and calculation.
   - b/ Steelmaking in Electric Arc Furnace.
   - c/ Refractory linings.
   - d/ Teeming of ingots.

ANNEXURE E

3. ELECTRIC ARC FURNACE IN OPERATION

a/ High tension units i.e. transformer, reactor, protection devices.

b/ Low tension parts busbars, flexible cables, graphite electrodes.

c/ Control system, measuring of voltage and current; moving of electrodes; hydraulic system.

d/ Power consumption during steel making.

4. QUALITY CONTROL

a/ Importance of metallurgical laboratory

b/ Traditional ways of carbon analysis and temperature control.

c/ Carbon and sulfur analysis in the existing laboratory.

d/ Factors influencing the quality of ingots.

e/ Full-scale metallurgical laboratory spectrometer and gas volumetric analysis.

ANNEXURE F

TIMING OF CLASSROOM TRAINING

Date	Lecturer	Subjects
March 5, 1985	A.BACSKAI	1/ a, b
March 7	F.ZSIGOVICS	2/ a
March 8	A.BACSKAI	4/ a
March 11	A.BACSKAI	1/ c, d
March 12	L.PALINKAS	3/ a
March 13	A.BACSKAI	4/ b, c
March 15	F.ZSIGOVICS	2/ b
March 21	L.PALINKAS	3/ b
March 28	F.ZSIGOVICS	2/ c
April 5	L.PALINKAS	3/ c, d
April 15	F.ZSIGOVICS	2/ d
April 18	A.BACSKAI	4/ d
April 26	A.BACSKAI	4/ e

ANNEXURE G

ELECTRIC ARC FURNACE MELTING LOG

Date Starting Time	Melt No. Finisching Time	Ladle No.	Shift No. Duration of Melt:
Steel Category: Mild	Medium	Hard	

SCRAP CHARGE:

Steel Scrap .... Kg
Cast Iron for
Carburing .... Kg

Total .... Kg

ALLOYS:

Ferrosilicon /FeSi/ ... Kg
Siliconmangenese /SiMn/ ... Kg

SLAG FORMING MATERIALS:

Limestone /Ca_2CO_3/ .... Kg
Burnt Lime /CaO/ .... Kg

OXIDIZING MATERIAL

Mill Scale .... Kg

Chemical Composition of Alloys:

Fesi:	SiMn
Si = 75 %	C = 2 %
Al = 2 %	Si = 16 to 20 %
Fe = 23 "	Mn = 65 to 75 %
	Pmax = 0,03
	Smax = 0,03

ELECTRIC ENERGY METER READING

	Meter 1 /KWH/	Meter 2 /KWH
Start of Melting		
After Tapping		
Consumption		
Total Consumption		KWH

CHEMICAL ANALYSIS:	
%	C, S, Si, Mn, P
First Probe	
Second Probe	
Final Composition	

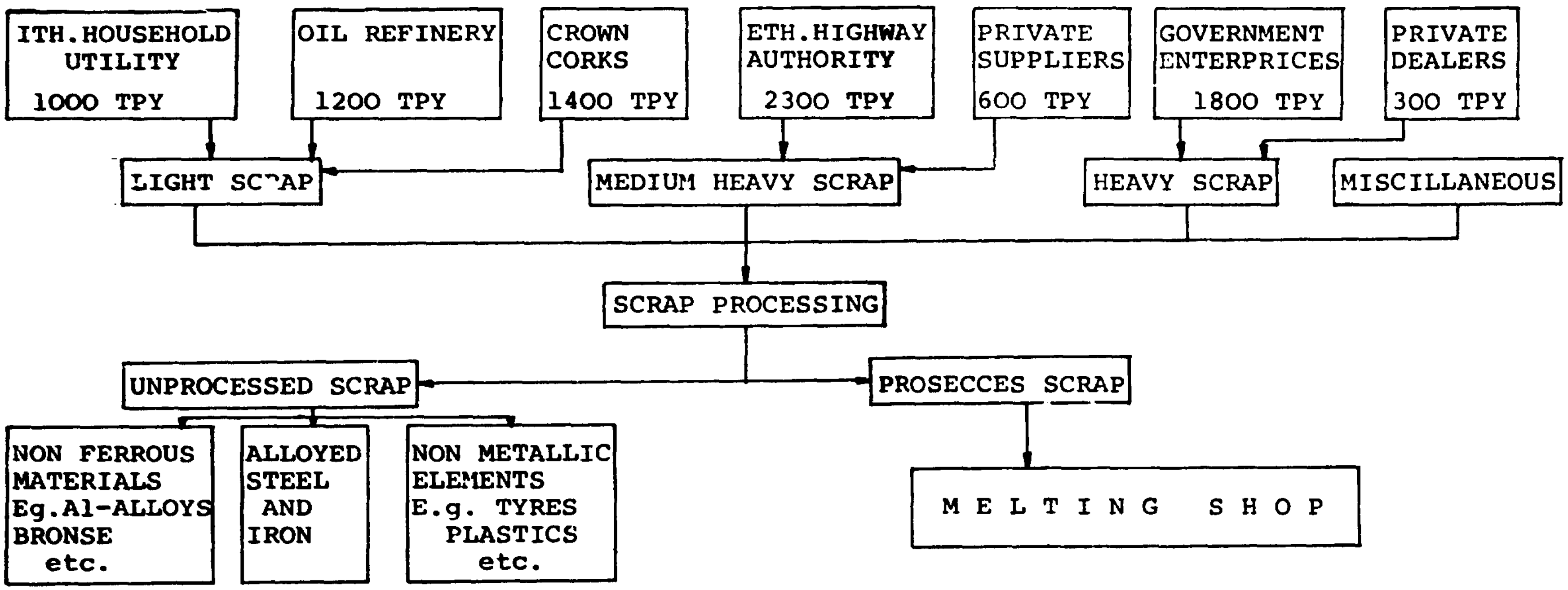
BREAK-DOWN TIME:	
Reasons	Duration /Min/
Electrode Extension	
Roof Change	
Repair of Wall	

Shift Foreman

Production Head

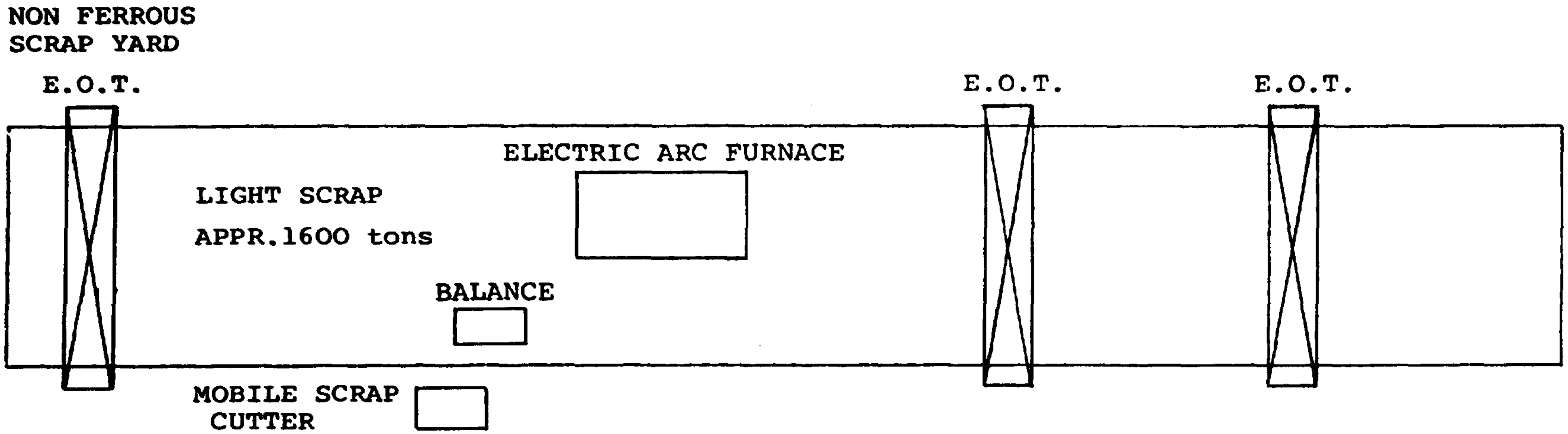
ANNEXURE H

SCRAP FLOW DIAGRAMME



ANNEXURE I.

CHARACTERISTIC OF SCRAP AND LAYOUT OF EXISTING SCRAP PROCESSING



MEDIUM HEAVY SCRAP

SCRAP PROCESSING:

- TORCH CUTTING
- SCRAP CUTTING /SHEARING MACH/
- MOBILE CRANE INVOLVEMENT

MEDIUM HEAVY SCRAP

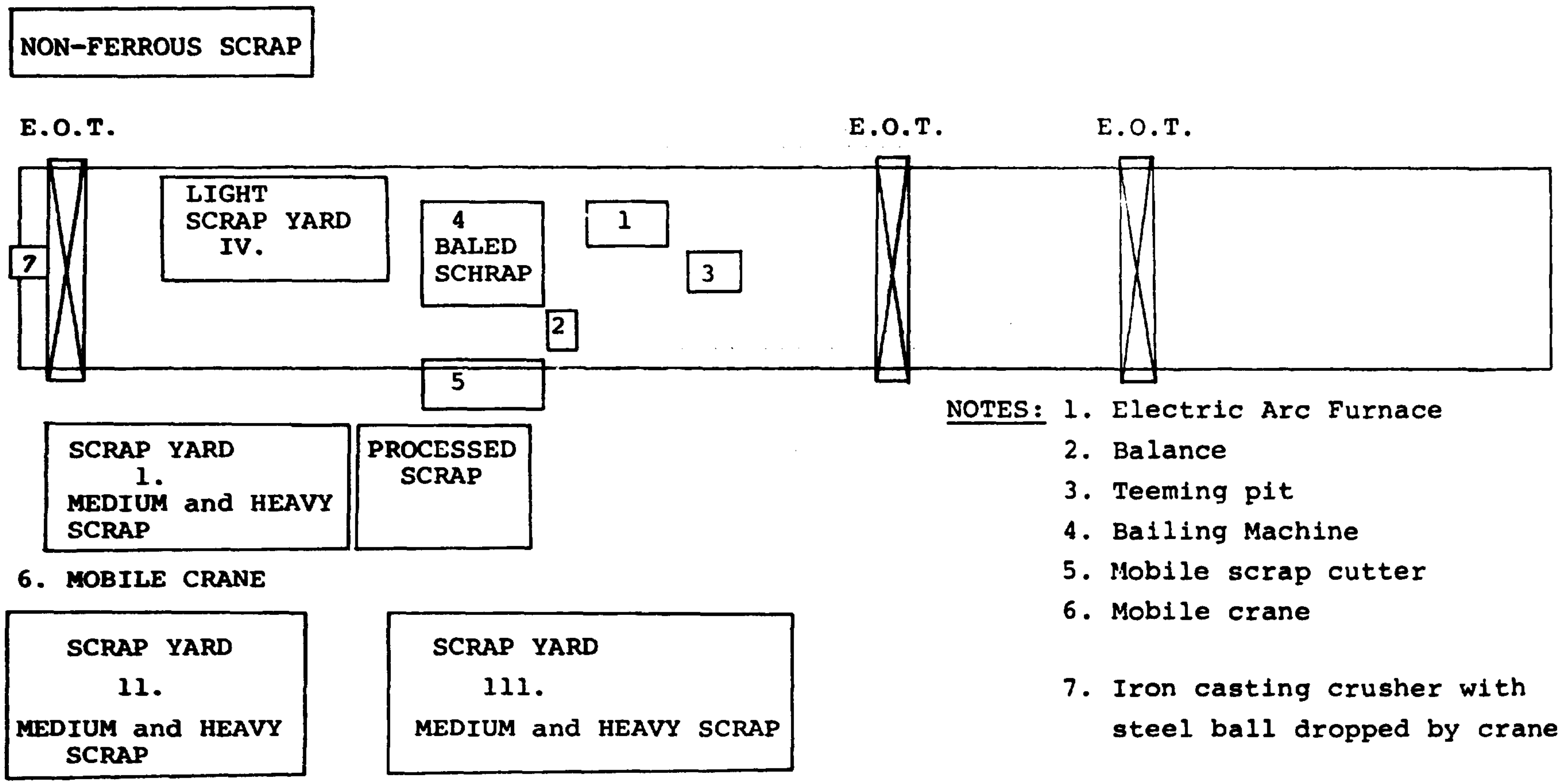
MEDIUM, HEAVY AND LIGHT SCRAP

WEIGHT OF SCRAP APPROXIMATELY:

LIGHT SCRAP	:	1800 tons
MEDIUM SCHRAP	:	700 tons
HEAVY SCRAP	:	600 tons
TOTAL	:	3100 tons
NON-FERROUS	:	150 tons

ANNEXURE J

PROPOSEDLAYOUT OF SCRAP PROCESSING



NOTES:
1. Electric Arc Furnace
2. Balance
3. Teeming pit
4. Bailing Machine
5. Mobile scrap cutter
6. Mobile crane
7. Iron casting crusher with steel ball dropped by crane.

ANNEXURE K

POWER TAPPING DURING STEELMAKING

1. MELT - IN: - Commencement of melting: for 10 minutes

60 % of full power is lot-in
Reactor: in full; position 1
Transformer: position 4
Length of Arc: shortest; position 8

- Electrodes are woll-in the scrap
Reactor: in full; position 1
Transformer: in full; position 6
Length of Arc: medium; position 4

2. OXIDATION: The total charge is liquid, oxidation starts
Reactor: switched off; position 4
Transformer: medium; position 3
Length of Arc: shortest; position 8

3. DEOXIDATION: The Temperature is raised a litle.
Reactor: switched off; position 4
Transformer: position 4
Length of Arc: shortest; position 8

4. BEFORE TAPPING: For 5 minutes temperature is increased before tapping
Reactor: switched of; position 4
Transformer: position 6
Length of Arc: shortest; position 8

ANNEXURE L

Preventive Maintenance to the Electric Arc Furnace

1. Daily Task:

   To check:
   - temperature of cooling water
   - condition of electrode clamps
   - oil temperature in transformer and reactor
   - condition of pumps and safety tank
   - moving speed of electrodes
   - condition of instruments and flexible cables
   - whether there is air in the oil-water emulsion system.

2. Weekly Control of:

   - Furnace tilting and roof lifting and swinging mechanism.
   - Cleanless of electric board and connection points e.g. push bottoms, instruments.
   - Instruments and if they do not work properly change them.
   - Flexible cable connections and insulating materials.
   - High tension isolator moving parts.
   - Condition of greasing and lubricating.

3. Monthly Check-up of:

   - Grounding system
   - Protection system
   - Current relays
   - Temperature measuring and V, A, KW, KWh metering instruments
   - Condition of oil emulsion and clean the tank if the substance of emulsion is not acceptable.

ANNEXURE L ctd.

4. <u>Yearly Maintenance means:</u>
   - Desmantling of all moving parts; change items if neccessary.
   - Laboratory testing of the oil in the transformer and reactor, and recondition it if its insulating character is found less than required.
   - Once a year the circuit braker is undergoing a complete checking.

ANNEXURE M

Instruments and Equipment the Proposed Mainitenance Shop is furnished with

Measuring Device-to control protection relays

- Voltage Stabiliser - Voltage: 220 V;
  Current: 20 A minimum /AC/
- Toroid Transformer - Voltage: 3x380 V/3x0-220 V
  without taps
- Instruments to measure - V, A, W, VAr with
  Laboratory accuracy of
  at least 1 %
- Current Generator - from 0 to 20 A /AC/
- Voltage Supplier - to control the
  /pt-R+Rh-Pt
  Ni-Cr-Ni thermocouples
- Resistance Measuring Bridge
  /Wheatstone or Thomson bridge/
- Resistance wires of different types ie.
  Manganium, tantal etc.
- Tachometer to check the rotation of electric
  motore
- 3-Phase Measuring Instrument
- Direct Current, DC, Supplier
  Raging Current from OE 550 A
  Voltage from 0 to 24 V
  It can be used for Battery charging as well
- Isolation Tester /Megger type/ Voltage ranges:
  500 V, 1 kV; 2 kV
- Isolation Resistance Measuring Instrument
- Grounding Resistance Measuring Instrument
- Portable Instrument
- Standtools of many use.

ANNEXURE N

CHEMICALS FOUND IN EXISTING LABORATORY

CHEMICALS	CONCENTRATION	QUANTITY
PHOSPHORIC ACID, H_3PO_4	85 %	2000 gr
HYDROCHLORIDE, HCl	NIL	2500 gr
POTASSIUM HYDROXIDE, KOH	85 %	7000 gr
AMMONIUMPERSULFURICUM $/NH_4/_2 S_2O_8$	98 %	2000 gr
SODIUM CHLORIDE, NaCl	NIL	500 gr
SODIUM CARBONATE, Na_2CO_3	NIL	4000 gr
TIN POWDER, Sn	99 %	8000 gr
SODIUM ARSENICOSUM, $NaASO_2$	95 %	500 gr
METILORANGE		300 gr
METILBULE		150 gr
SODIUM HYDROXIDE, Crystal, NaOh		4000 gr
SODIUM HIDROXIDE, Liquid, NaOh		6000 gr
POTASSIUM IODIDE, KJ		2000 gr
POTASSIUM IODATE, KJO_3		500 gr
STARCH		300 gr
POTASSIUM DICHROMATE $K_2Cr_2O_7$		500 gr
MERCURY, Hg		
SULFURIC ACID, H_2SO_4	96 %	6000 gr
SILICON		50 gr
GREASING AGENT		20 gr
OXYGEN In tank		AVAILABLE:

ANNEXURE O

FACILITIES AVAILABLE

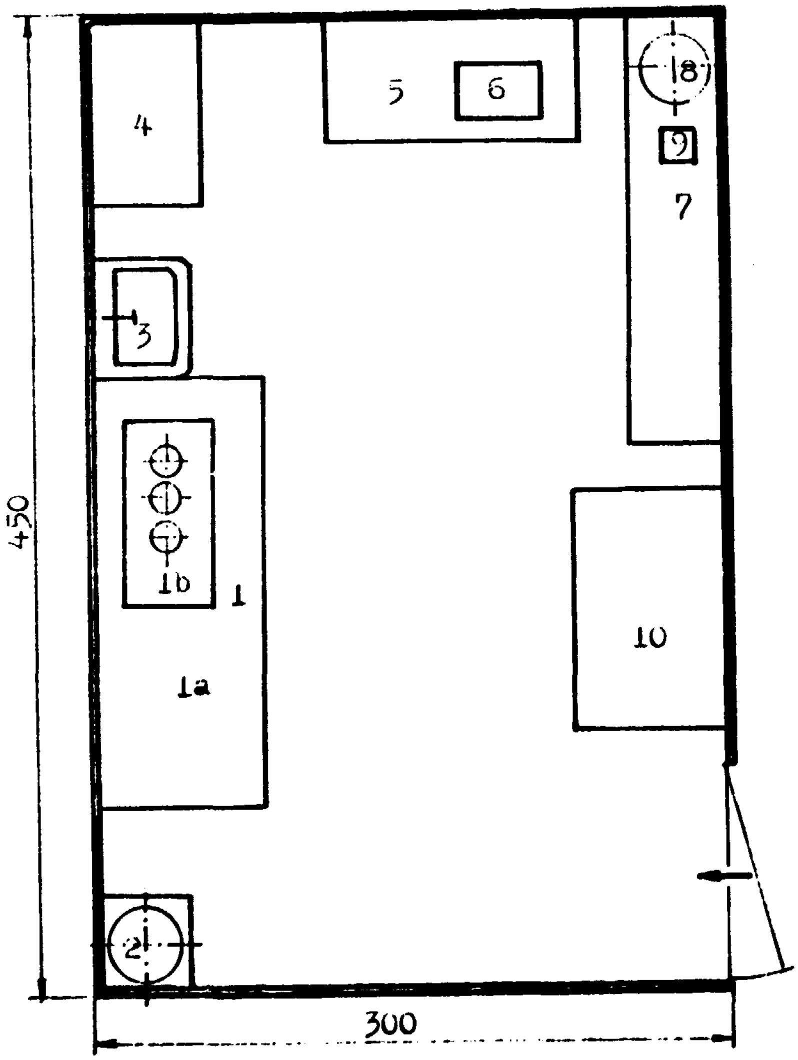
ONE - Balance measuring from 0 to 125 gr.
ONE - Analitical Balance
ONE - Combustion furnace with
TWO - Spare Thermometer, from 0 to 1500°C
THIRTY - Spare silite rods.size Ø 8 x 180 m.m
Electrical resistance 4,2 ohm
ONE THOUSAND AND EIGHT HUNDRED - Poscelaim cambustion boats
TWENTY-TWO-Procelaim Combustion tubes.size 26x20x600 m.m
ONE-GLASSWARE Assembly for volumetric Carbon analysis
SPARES - For another two assemblies and Glassware Spares.
ONE - Glassware Assembly for Surfur analysis
SPARES - For another ONE Assembly and Glassware Spares
ONE - Glass container with desicoating salt for keeping dry combustion Beats

GRADUATED CYLINDERS, FUNNELS, TITRATING GLASSES

ONE - BAROMETER /Mercury is missing/
ONE - Thermometer from 18 to 50 °C
ONE POLDI-type from hardness tester
ONE - Plastic container for distilled water, capacity 20 littres
ONE - Plastic Container for distilled water capacity 10 lit.
ONE - Oxygen bottle
ONE - Pressure with built-in Flow meter.

ANNEXURE P

GASVOLUMETRIC LABORATORY: EXISTING

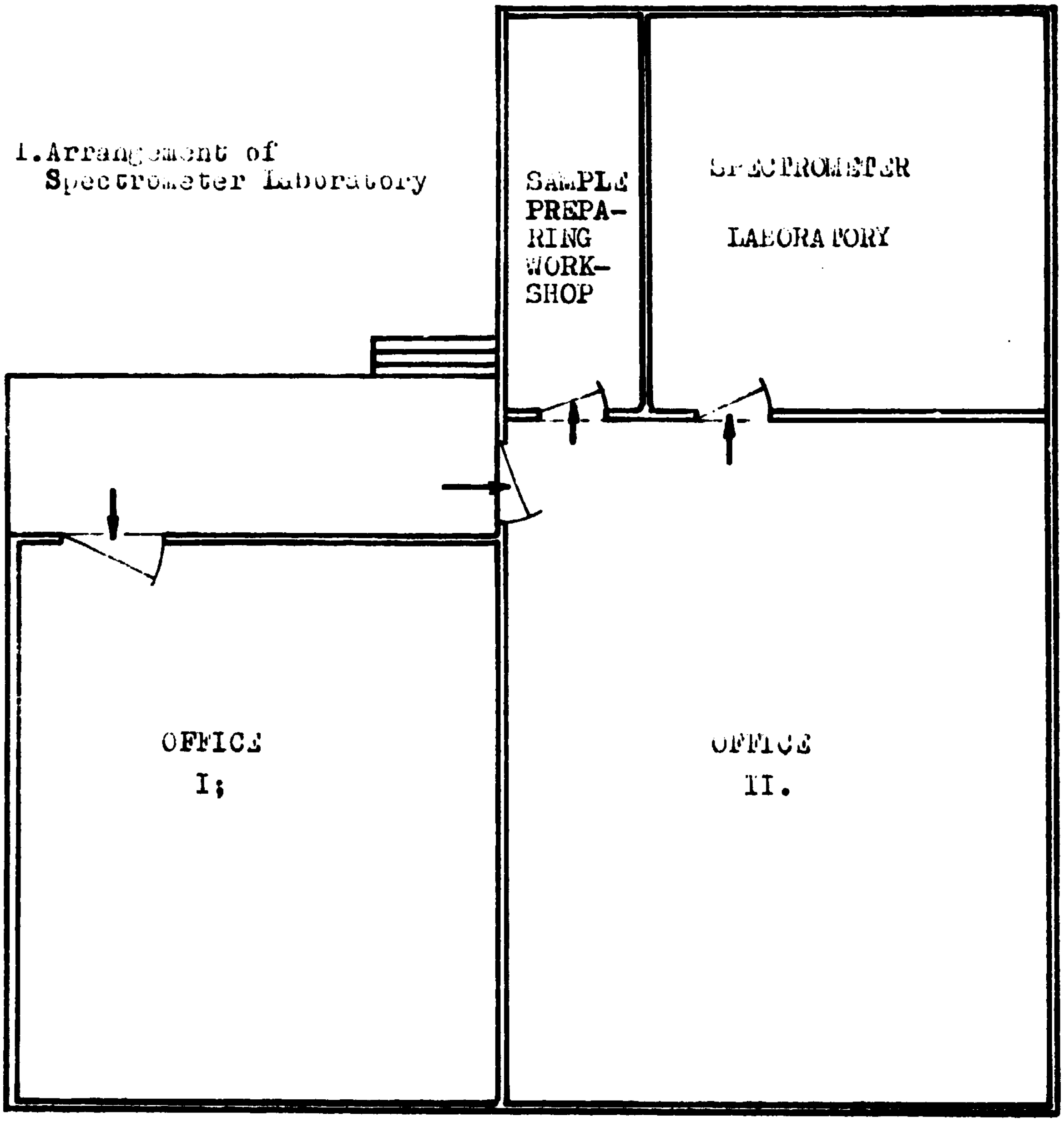


1 Table to hold gasvolumetric analysing system /with under self/
1a Tube furnace to burn sample chips
1b C, S analysing system /BICASA/
2 Oxigen bottle in fixing stand
3 Water tap with porcellain sink
4 Cupboard to store chemicals
5 Table to hold analytical balance and samplex
6 Analitycal balance
7 Table with welded structure with under self to hold samples /as brought in/ and glasswares on the under self
8 Glass container
9 Laboratory balance /C-1253/
10 Writing-table

ANNEXURE Q/1

LAY OUT OF THE FULL SCALE METALLURGICAL LABORATORY
/Alternative No 1/

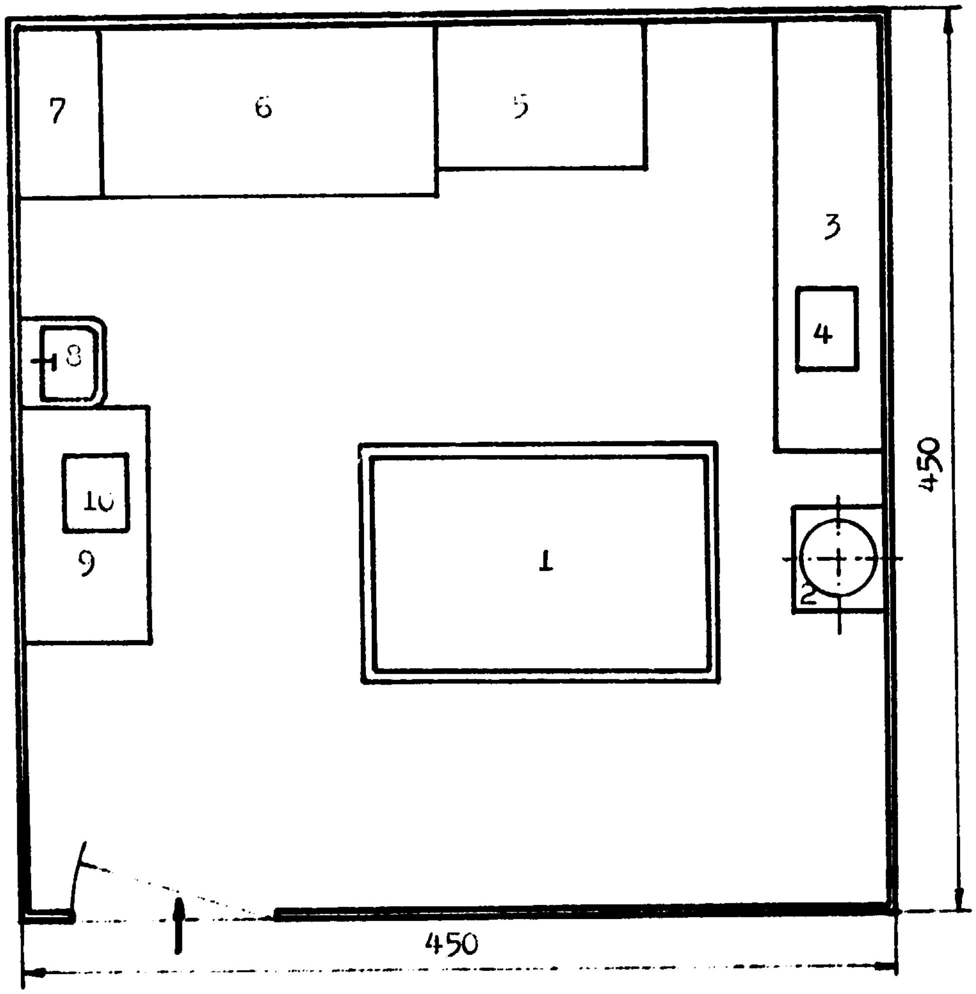
1. Arrangement of Spectrometer Laboratory



2. Gasvolumetric Laboratory /existing/ in located at the end of fence production building

SPECTROMETER LABORATORY

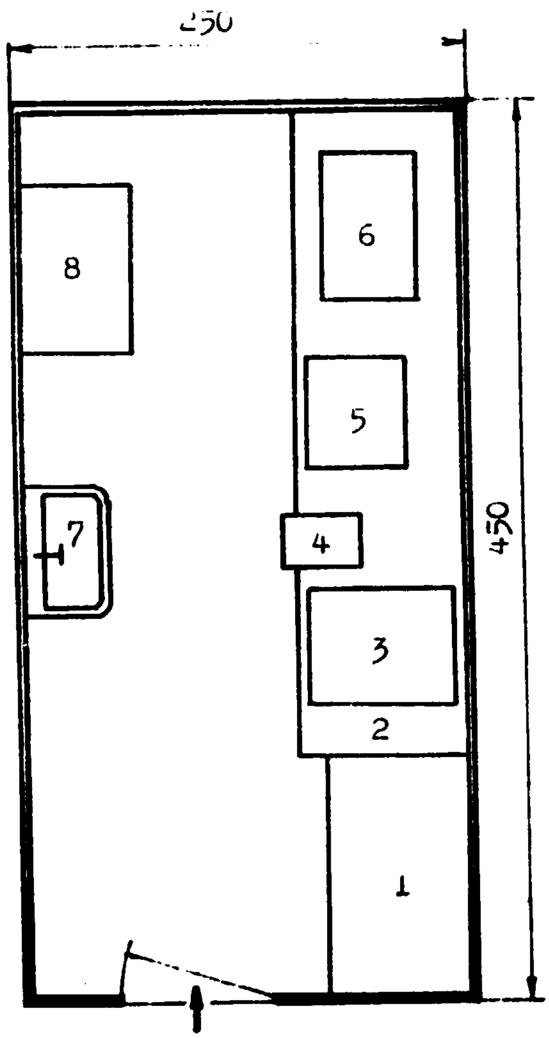
/ in existing and future building /



1. ESA 4 Sequential spectrometer
2. Argon-bottle with fixing
3. Table for samplex, tools etc /2,0x0,5m/
4. Binocular microscope
5. Cupboard for spare parts, documentation
6. Writing -table
7. Book shelf
8. Water tap with sink
9. Rigid table /concrete/
10. Analytical balance

ANNEXURE R

SAMPLE PREPARING WORKSHOP
in existing and future building



1 Cupboard for accessories
2 Workshop table /3,0x0,8m/
3 Drilling machine
4 Workshop vice
5 Laboratory furnace
6 Polisher/grinder machine
7 Water tap with sink
8 Rapid cutter

AKAKI
Steel Works

ANNEXURE S

CERTIFICATE FOR SPECTROMETRIC AND
GAS VOLUMETRIC ANALYSISES

Marking of samples	Chemical composition /weight %/										Registration Number
	C	Mn	Si	P	S	Cr	Ni	Cu	Mo	Al	

Notes: ....

Datum: ....

Signature: ....

ANNEXURE T

DIARY
of carbon analysis /volumetric/

Registration Number	Marking on the samples	Quantity of chips	Reading scale on the burette	Barometric pressure	Temperature in the burette	Multiplying factor	C content	Notes
		g		Hgmm			%	

ANNEXURE U

Certification of Tensile Test

Material: ....

Registration Number	Marketing of testpieces	Dimension of the testpieces								Loading at yielding	Maximal loading	Yield strength	Tensile strength	Elongation	Reduction in area
		before testing				after testing									
		diameter thickness	width	cross section	measuring length	diameter thickness	width	cross section	measuring length						
		mm	mm	mm^2	mm	mm	mm	mm^2	mm	N	N	N/mm^2	N/mm^2	%	%

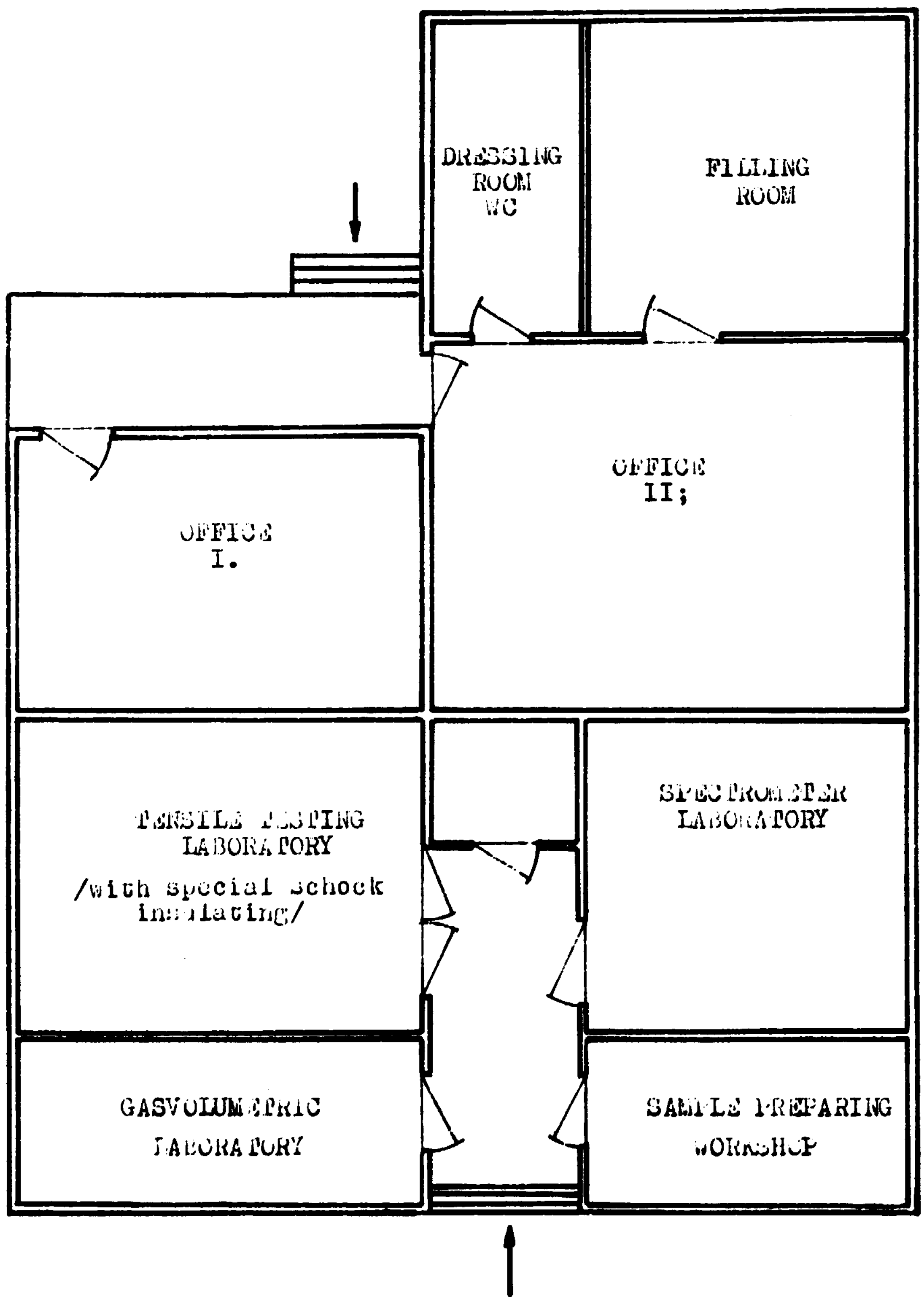
Notes:

Datum: ....

Signature of
Testing personel: ....
Supervisor: ....

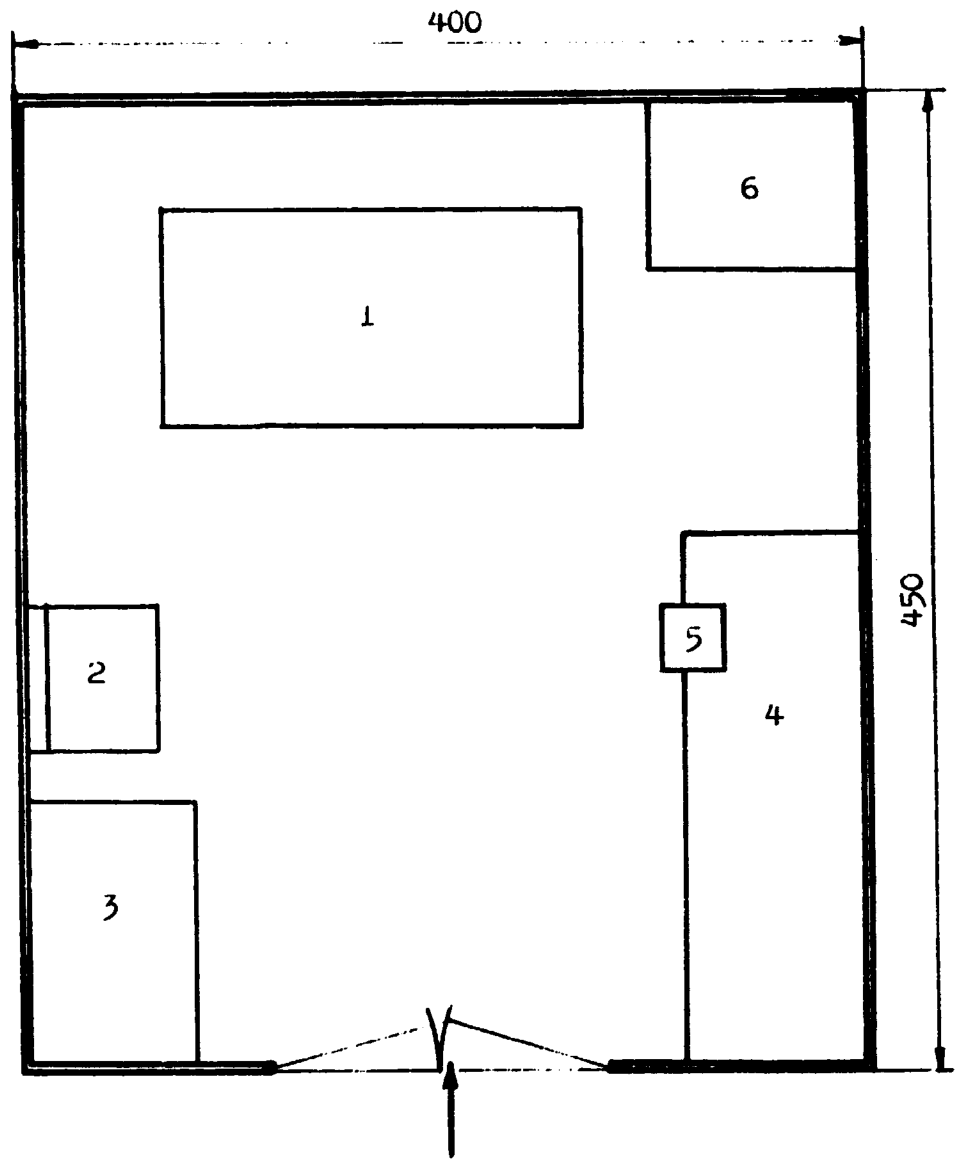
ANNEXURE V

LAYOUT OF THE FULL SCALE METALLURGICAL LABORATORY
/Alternative No 2./



ANNEXURE Z

TENSILE TESTING /MECHANICAL/ LABORATORY



1 Tensile testing machine
2 Hardness testing machine
3 Writing table
4 Workshop table
5 Workshop vice
6 Cupboard

ANNEXURE X

People were met

1. National counterpart Personnel-Ethiopian Iron and Steel Foundry

Mr.B.Abdissa, Plant General Manager
Mr.W.Tadesse, Technical Head
Mr.D.Wondimu, Maintenance Head
Mr.G.M.Getachen, Production Head
Mr.T.Daniel, Rolling Mill Engineer
Mr.E.Errenso, Melting Department Head
Mr.A.Tefera, Administration Head

2. Institutes, Organisations

5 February 1985 - Mr.S.Gebreab, Deputy General Manager
National Metal Works Corporation

5 February 1985 - Mr.K.J.Mahalingan, UNIDO Metal Processing Export, Addis Ababa

13 March 1985 - Dr.Nigussie Retta, Head of Chemistry Department
University of Addis Ababa, Faculty of Natural Science

16 March 1985 - Mr.M.Negao, Laboratory Head
Mr.A.Aseffa, Geological Survey Head
Ministry of Mines Minerals and Energy

22 March 1985 - Mr.J.Afewerk, Technical Head
Ethiopian Standard Institute

26 March 1985 - Mr.Vencatachellum, UNIDO Senior Industrial Adviser Addis Ababa

11 April 1985	- Mr.C.Chibsa, Chief Engineer, Division of Electrical Workshop Ethiopian Electric Power Authority
29 April 1985	- Mr.Vencatachellum, UNIDO, Senior Industrial Adviser
29 April 1985	- Mr.Assefa, Director of Planning, National Metal Works Corporation

I. Velev/rg
2 February 1984

ATTACHMENT II

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
SUBSTANTIVE TERMS OF REFERENCE

Project No.: SI/ETH/84/801

Project Title: Technical Assistance in Electric Arc Furnace Steelmaking

A. General Background Information:

The Ethiopian Iron and Steel Foundry is one of six factories in the Addis Ababa region under the jurisdiction and control of the National Metal Works Corporation. Started in 1961, the factory is located 20 km from Addis Ababa, produces steel nails, plain and ribbed reinforcement bars and steel wire netting. On 2-shift basis, about 12,000 TPY of reinforcement bars /6-32 mm dia/ and 4,000 TPY of nails are being produced within a total workforce of 450 including supervisors.

The molten steel is bottom-poured through a central trumpet into 14 pencil ingot moulds. The pencil ingots /85-90 kg/ are then reheated and rolled in a cross-country merchant mill into rounds to be used either as reinforcements or for further processing into nails and wire coils.

The steel scrap is purchased from various sources in the country and is heterogenous in character. No proper facilties exist for its claccification, segregation, control and preparation. Likewise, no proper facilities exist for the quick chemical analysis and control of the steelmaking process in the electric furnace. Visual inspection of the fractured sur faces of broken samples is the only method employed do determine the carbon content, which method is crude and unsatisfactory.

The Government has recognized the above acute needs of up-gradation, and, as a first step, has earmarked funds for a spectrometer. Further, a full-scale metallurgical laboratory is planned to be established.

B. Aim of the Project

/i/ To improve the existing scrap handling practice, and specifically, the entry, quality control, procurement, segregation, shemical composition and preparation;

/ii/ to improve the steel melting practice, and particularly, the quality control;

/iii/ to establish a proper metallurgical laboratory with appropriate equipment and facilities for quick chemical analysis.

C. Scope of Contracting Services

The contract work will consist of field mission of a team of three highly experienced engineers, namely:

- Expert in electric arc furnace steelmaking - Team Leader - overall operation, mechanical and electrical maintenance, scrap qualification, collection and preparation;
- Expert in furnace operation and electrical maintenance;
- Expert in metallurgical laboratory equipment/operation,

of the duration of three months each, to provide day-to-day practical advice and on-the-job training through direct participation in the production process. As a result of their work, in co-operation with the national counterpart personnel, both the level of productivity, and especially, the quality of steel would be noticeably improved.

The experts, and particularly the Team Leader, and the expert on metallurgical laboratory equipment/operation will be expected to advise the counterparts on proper specification, layout, manning and other pertinent problems to establish a full-scale laboratory.

The experts will alsobe expected to set out their findings and recommendations in a Final Technical Report, to be submitted to UNIDO on behalf of the subcontractor.

D. Required Inputs

a./ The three experts, as described above, should be fielded at the earliest possible time. The total input of the subcontractor's field work will thus be 9 man-months.

b./ The subcontractor will render to his experts all relevant backstopping as appropriate. Manuals, technological instructions and other working production-technical documentation, which is to be applied through the everyday on-the-jog training, is included in the contract price, to be later presented to the project.

c./ The subcontractor is expected to include in the Final Report the basic design of the metallurgical laboratory with a preliminary calculation of costs.

E. Sequence of Work to be carried out

Prior to their departure to the duty station, the subcontractor's team should be briefed, either in Vienna, or at the subcontractor's Headquarters, whichever is more convenient, by relavant UNIDO representatives.

The following time schedule is envisaged:

Activity	Dates
1. Award/conclusion of contract	A
2. Briefing of Subcontractor's team	A + 15 days
3. Fielding of experts	A + 20 days
4. Intermediate report	A + 30 days
5. Termination of field work	A + 110 days
6. Submission of Draft Final Report /DFR/	A + 140 days
7. UNIDO's and Government's comments on DFR received by subcontractor	A + 160 days
8. Submission of Final report	A + 175 days

F. Reports

a./ Intermediate report, containing the experts' initial findigs, and recommendations, and the specification of supplementary laboratory/ quality control equipment, for US$ 8,000, to be purchased through the project, should be prepared in three copies, in English, according to paragraph E.4 above.

b./ Draft Final Report should be provided in three copies, in English, according to paragraph E.6 above.

c./ Final Report should be submitted in eight copies, in English, according to paragraph E.8 above.