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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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DESIGN OF THE USIBA STEEL PLANT IN BRAZIL WITH A VIEW TO THE MASSIVE UTILIZATION OF SPONGE IRON IN THE CHARGE OF THE ELECTRIC FURNACES[1]

by

Luis Arpad Driesel
(USIBA, Brazil)
and
Bernard Lacoste
(Fives Lille-Cail, France)

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SUMMARY

Near Salvador in the State of Bahia, USIBA is about to start up the first steel plant in northern Brazil. This plant will produce in its first phase 300,000 tons per year of billets by continuous casting. An extension programme provides for tripling this capacity in successive phases and for future diversification of the plant's range of production.

This plant can be classified as a mini-steel plant, in view of the basic design principles selected, including the following main design features :

- Location on the coast, thus allowing for the development of a marine terminal for unloading the ore carriers and conveying the ore direct to the plant
- Choice of the direct reduction - electric furnace formula
- Selection of the HyL process as the method of producing sponge iron
- Use of a 20 ft dia. UHP (ultra high power) electric furnace
- Choice of the IRSID continuous sponge-iron charging system
- Installation of a six-strand continuous-casting machine producing 80 x 80 mm to 160 x 160 mm billets.

The three last points are developed in the paper.

1/ - GENERAL

In order to accelerate the industrial development of north-east Brazil by providing a basic industry for that region, the USIBA (USINA SIDERURGICA DA BAHIA S.A.) steel plant was located at ARATU, near SALVADOR, in the state of BAHIA.

An enterprise controlled by the shareholders of SUDENE (SUPERINTENDENCIA DE DESENVOLVIMENTO DO NORDESTE), USIBA was initially designed, on the basis of the " mini-steel plant " formula, for a production level of 300000 tons of steel per year. The general design of the plant, however, will allow for carrying through an extension program which may attain an annual capacity of over 1 million tons of finished products. In order to carry through this program successfully, the whole plant substructure is already at this stage designed with a view to that final capacity.

A production process based on criteria centered on the use of regional and national raw materials and resources has been adppted which includes the following :

- Pellet reduction unit using natural gas - production of sponge iron with a high metal content and low gangue, phosphorus, and sulphur contents (unit to be in operation by September 1973)

- Melting and refining solid charges consisting of sponge iron and scrap in the UHP Electric Arc Furnace

- Production of liquid steel (furnace in operation April 1973)

- Continuous casting production of billets (semi-finished 80 x 80 mm to 160 x 160 mm from 3 to 10 meters in length, of carbon and low-alloy steels (in operation April 1973)

- Rolling and finishing production of round bars, wire rod, and small shapes (installation in progress)

The raw materials and utilities available are as follows :

PELLETS

- high iron and low gangue, phosphorus, and sulphur content pellets, supplied by COMPANHIA VALE DO RIO DOCE, brought by sea from the installations of that Company at VITORIA, State of ESPIRITO SANTO, and unloaded at a special private marine terminal

GAS

- from the oil fields existing in the area, furnished by PETROBRAS, and conveyed by a 6.2 kilometer gas pipeline for the exclusive use of USIBA

- ELECTRICAL POWER The electrical power available in the aera is supplied by CHESE (COMPANHIA HIDRO-ELECTRICA DO SAO FRANCISCO) by means of a 220 KV line 6 kilometers in lengbh

- <u>Process water</u> is supplied by EMPRESA BAHIANA DE AGUASE E SANEAMENTO-EMBASA through a 600 mm diameter pipeline 4 ½ kilometers in length, for USIBA's exclusive use.

- <u>The interior scrap</u> comes from the plant production facilities and the <u>exterior scrap</u> is purchased in the area.

The plant location was chosen in consideration of the following factors :

- <u>Coastal situation</u> - the present trend toward location of new steelmaking units near the coast has been followed, in order to benefit from the advantages afforded by sea transportation of the main raw materials (i.e. mainly for supplying the pellets by means of ore carriers) and possibly for direct loading of USIBA products for destination a long distance away (e.g. for export).

BAIA DE TODOS OS SANTOS, one of the largest bays on the Brazilian coast, was suitable for this purpose.

- <u>Proximity to an industrial center</u> the CENTRO INDUSTRIAL DE ARATU, located in the vicinity of the city of SALVADOR, provided the required basic facilities.

- <u>Availability of skilled labor and technicians</u>
The proximity of Bahia State Capital, Salvador, fully covered requirements in this field. Salvador is a city with a population of over one million, and possesses highly developed educational facilities including colleges for technicians

and engineers

- THE AVAILABILITY OF NATURAL RESOURCES AND RAW MATERIALS
- electrical power, water, natural gas, limestone, and ferro-alloys, afforded by this area, was an additional reason for locating the plant in the Salvador region.

In addition to this combination of advantages as regards the choice of the Bahia State and in particular of the industrial center of ARATU in that state, the large potential market in this area, with the prospect of integrating the project completely into the North-East Brazil Development Plan, represented a further favorable factor.

Figures 1 and 2 give an idea of the location of the plant.

USIBA entrusted the Direct Reduction Unit Project to the Swindell-Dressler Company, who are covering the engineering of the HyL process developed in Mexico.

The steel plant project and the supply of the main equipment, after issuance of an international call for bids, were awarded to a group of French firms, with FIVES LILLE CAIL as pilot contractor.

The considerable amount of detail design work for the installations has been effected by COBRAPI (" Companhia Brasileira de Projetos Industriais ").

Brazilian industry has been given the responsibility for

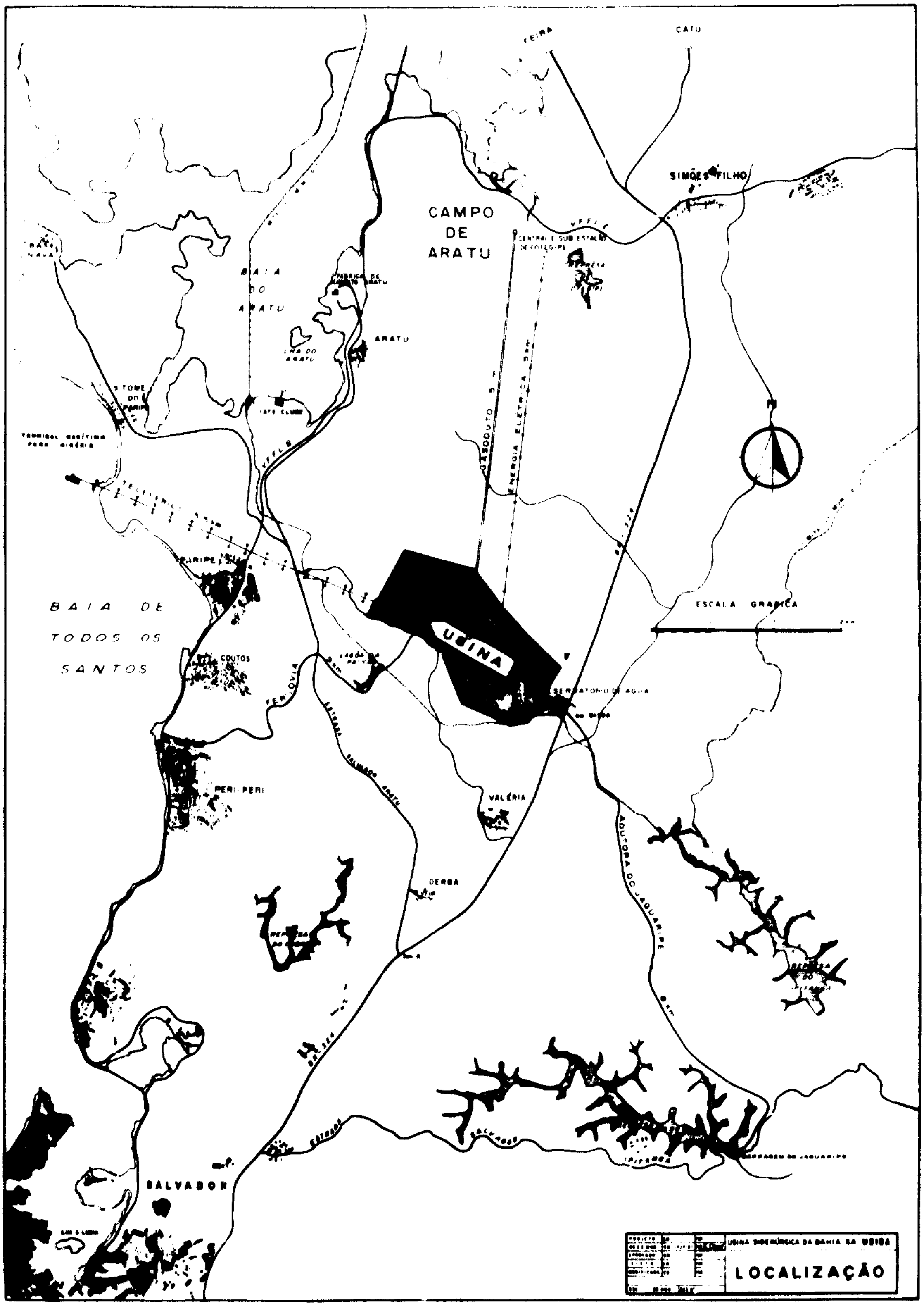


Fig. 1 - Location of USIBA plant

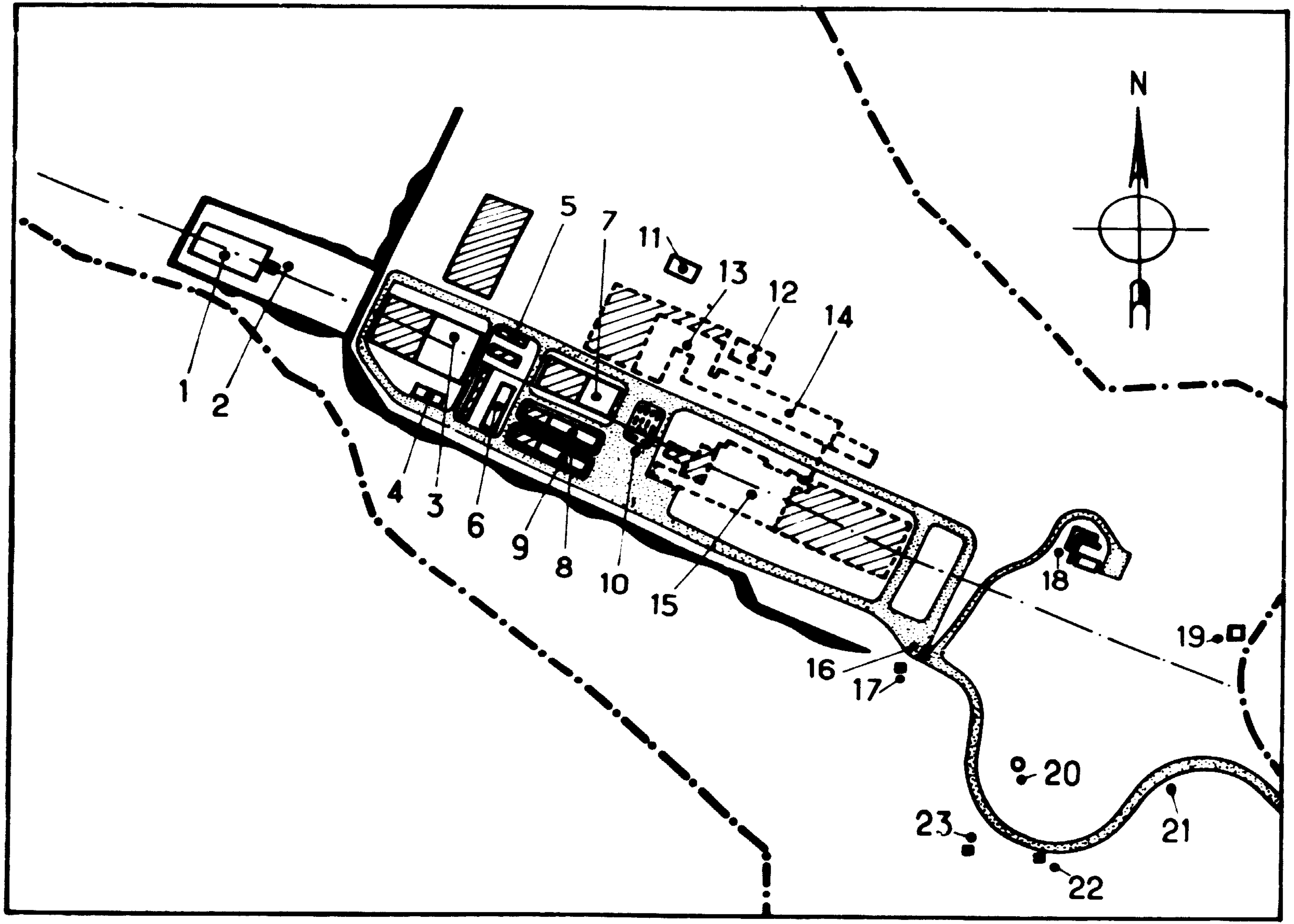


Fig. 2 - General layout of USIBA plant. 1. Ore stockyard, 2. Ropeway terminal, 3. HyL direct reduction unit, 4. Vehicle shop, 5. Offices and dressing rooms, 6. Storage, 7. Foundry, 8. Mechanical maintenance shop; 9. electrical maintenance shop; 10. Offices, laboratories, & dressing rooms 11. Water treatment, 12. Substation, 13. Continuous casting, 14. Hot rolling, 15. Cold rolling, 16. Main entrance 17. Restaurant, 18. Main offices, 19. Weather station, 20. Water tower

furnishing part of the materials and equipment, in particular the structural steel (approximately 7,000 tons) and the various shops and auxiliary systems.

The construction of the plant and the erection of the equipment were carried out by regional and national companies under the supervision of USIBA and of the foreign firms who furnished the equipment.

2/ - GENERAL DESCRIPTION OF THE FIRST PHASE

In the first phase, the plant will be equipped with the following main installations :

2.-1 A MARINE TERMINAL

In accordance with modern trends and in consideration of the facilities provided by TODOS OS SANTOS bay, the solution of a dock in the open sea was chosen in preference to that of a port with a dredged access channel. This terminal includes essentially a mobile tower for unloading the ore carriers (draft up to 30 feet), a conveyor system, and a stacker in a stockyard.

The pellet unloading tower has the following features :

Manufacturer.............	FIVES LILLE CAIL
Capacity.........	600 tons per hour
Bucket capacity	3,800 liters
Boom	18.5 meters
Hoisting height	28.5 meters
Hoisting capacity	17 tons

The conveyor system supplied by POHLIG-HAECKEL DO BRASIL S.A is over 1,100 meters in length and is equipped with 36 " wide belts.

The terminal stockyard allows for stockpiling up to 55,000 tons of ore.

The pellets will be brought from the terminal to the plant stockyard by road a distance of 8 kilometers in the first phase. A 5 ½ kilometer cable belt system is to be provided in the future.

2.-2 HyL process - Direct Reduction Unit

The capacity of this unit is approximately 650 tons per day, using CVRD oxydized pellets. For information purposes, may we recall that the HyL process was initiated and developed in Mexico, in the first place at the Monterrey Plant of the Hojalata y Lamina Steel Company. Four units are at present in operation in this country in the Monterrey and Puebla HyL plants and at the TAMSA plant in VERA CRUZ. A fifth 1,100 metric-tons-per-day-capacity unit is currently under construction at Monterrey.

The USIBA HyL shop will be the first direct reduction unit of this type developed out side Mexico. At the instigation of USIBA, intensive sponge-iron reduction and melting tests were undertaken previously at the Monterrey Plant on a consignment of pellets supplied by COMPANHIA VALE DO RIO DOCE, in order to simulate the operating conditions of the future plant. The results of these tests fully confirmed the validity of the choice of the HyL direct-reduction process.

2.-3 - ELECTRIC FURNACE STEELMAKING SHOP including essentially :

- An electric furnace with a rated capacity of 100 tons
- a continuous-casting machine for producing billets with sections up to 160 x 160 mm

These two installations are the largest of their type to be installed in Latin America to date.

In order to avoid the current disturbances on the existing system, the plant will possess an anti-flicker type electrical installation including a very high-capacity synchronous balancing device.

2.-4 - AUXILIARY INSTALLATIONS including :

- Ore and scrap storage bays
- Process and potable water supply system with reservoir, settling tank, water treatment and softening units, cooling and distribution towers, pump house, etc.
- Main 46 MVA substation and overhead and underground distribution lines
- Compressed air, GLP, oxygen, steam, and fuel-oil installations
- Sewer system for waste water and rainwater
- Mechanical and electrical maintenance shops
- Stores
- Laboratory and administrative buildings
- Road system

3. - EXTENSION **Apart** from adding a unit for rolling non-flat products (round bars, wire rod and

small shapes) to the present installations, USIBA has an extension plan which takes into consideration the following factors :

- Availability of the area required for increasing production capacity on the basis of a rational lay-out, excluding the danger of interference with the units already built and involving a large reduction in the final cost of the capacity installed

- Prospects of development of the national iron and steel market in line with the iron and steel plan at present being carried through and with the Brazilian Government's export aims.

The extreme flexibility of the lay-out, facilited by the considerable size of the available ground (USIBA possesses a building lot with an area of 350,000m2), provides a multitude of extension possibilities which will be determined on the basis of the most modern steelmaking techniques and the most appropriate marketing policy.

For the steelmaking shop itself, a possible alternative based on the planning grid of the present lay-out and allowing a final installed capacity of over 1,200 000 tons per year be attained, is shown in Figure 3.

4.- DESCRIPTION OF THE STEELMAKING SHOP

4.-1 Building

The electric furnace steelmaking shop is installed in a metal building including four parallel bays, as follow :

- the scrap and sponge-iron storage and handling bay
- the electric-furnace charging bay
- the steel pouring bay
- the billet removal, storage, inspection, and conditioning bay.

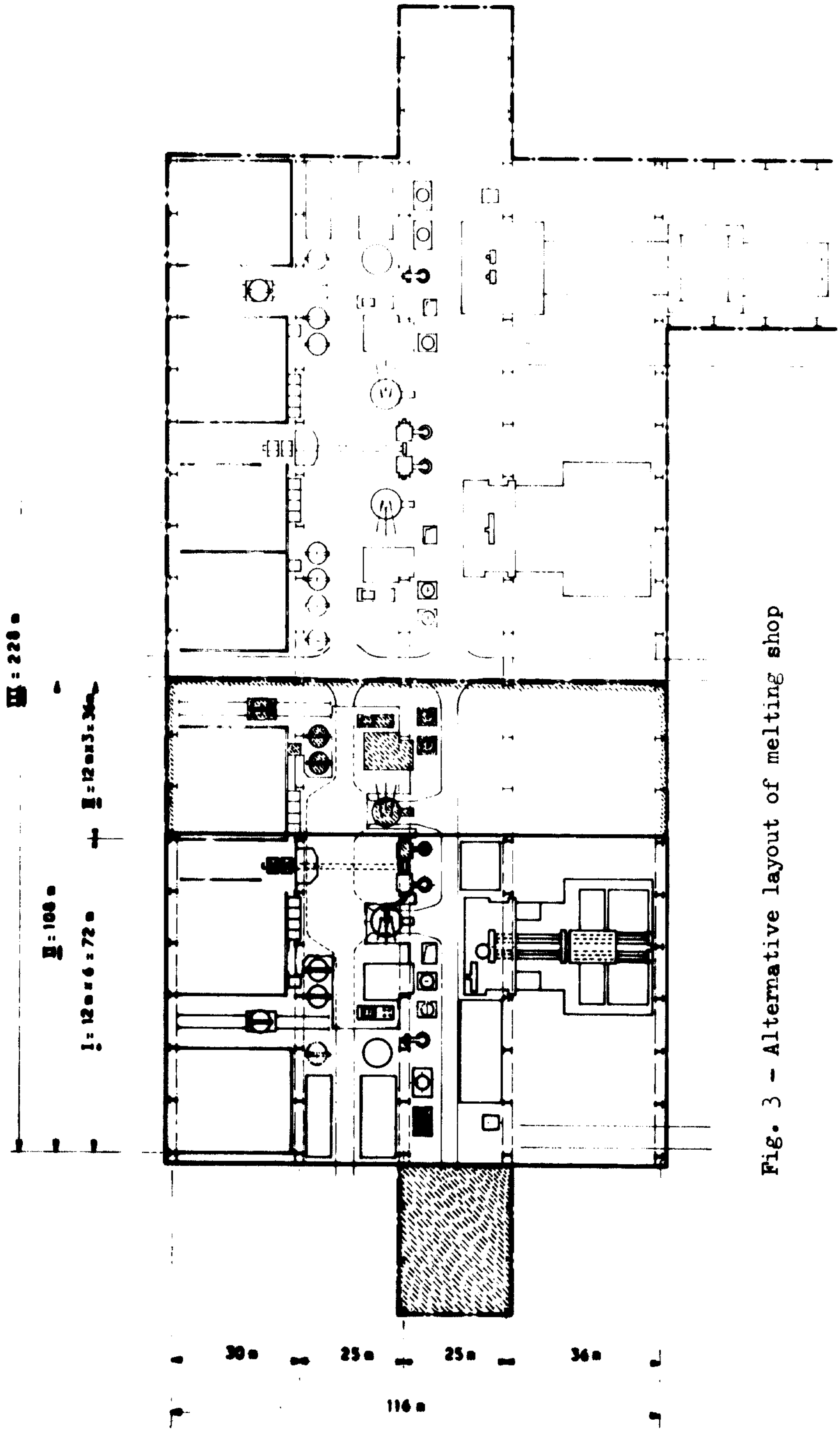


Fig. 3 - Alternative layout of melting shop

The basic plan of the building was designed in France, the structural steel detail design and the construction were effected respectively by COPRABI and FEM, a structural steel plant which is a Division of C.S.N. (Companhia Siderurgica Nacional).

On account of the climatic conditions in the Salvador region special arrangements were made during the ventilation design work to provide for natural ventilation of the building.

4.-2 Steelmaking facilities

The USIBA Steelmaking shop has certain special features, among which we may mention the following :

- Use of an Ultra High Power (UHP) electric arc furnace
- A continuous sponge-iron charging system feeding the furnace with a massive charge of pre-reduced sponge iron pellets at a rate which can attain over 80 % of the total metal charge.

- Slag removal by means of a conventional car (traxcavator)

- Use of the system of injecting carbon powder into the metal bath to keep its carbon content to the required level, according to the IRSID process.

- Use of steel ladles with slide nozzles

- Use of a six-strand continuous-casting machine producing billets up to 10 meters in length with cross-sections up to 160 x 160 mm

Figure 4 shows the general lay-out of the steelmaking shop in its initial phase.

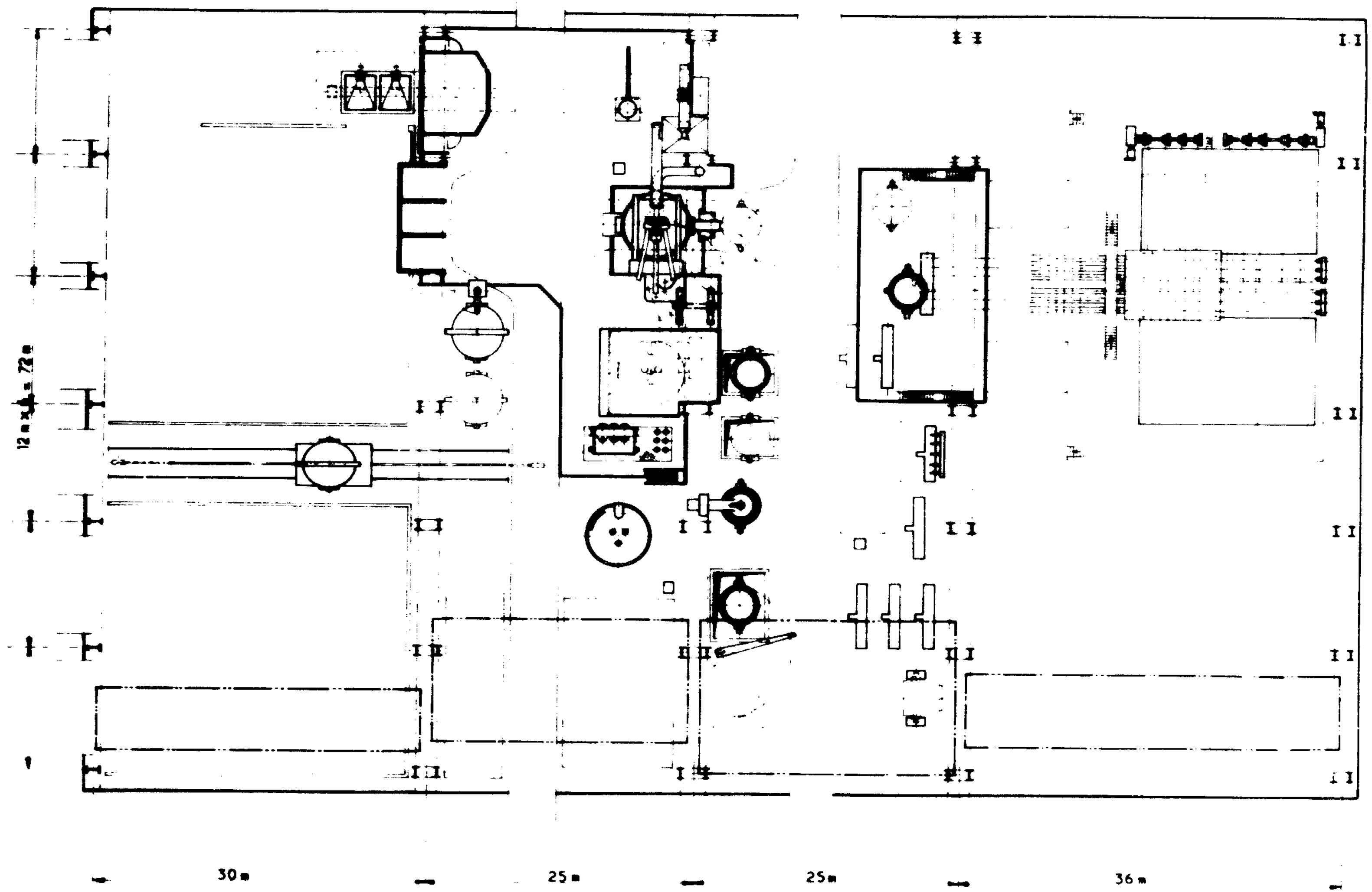


Fig. 4 - General layout of steelmaking shop in initial phase

The transverse sections are shown in Figures 5 and 6.

To emphasize the fact that the USIBA steel plant has been primarily designed with a view to high productivity, we shall now examine in more detail the three most characteristic features of the plant, namely :

- The electric furnace
- the sponge-iron continuous-charging system
- the continuous-casting equipment

5.- ELECTRIC FURNACE

The electric furnace, built by Stein-surface in France, is of the LECTRO-MELT UHP (Ultra High Power) type and has a rated capacity of 95 to 120 metric tons per heat with an inside diameter of 20 feet (6.10m). It is equipped with 24 " (610 mm) diameter electrodes providing an actual available power of 350 kW per ton of metal charge.

The metal charge of the furnace will consist of 20 to 40 % scrap and 60 to 80 % sponge iron. The scrap, charged by a bucket carried by a 100 mt capacity overhead travelling crane, will constitute the initial metal charge after the roof has been swing to one side.

The electric furnace, which ranks as one of the largest built up to now, has the following features :

- total triangulation of the conductors between the transformer and the electrode clamps, guaranteeing satisfactory balancing of electrode power

- Water cooling of the flexible electrode power supply cables and of all parts of the furnace exposed to heat

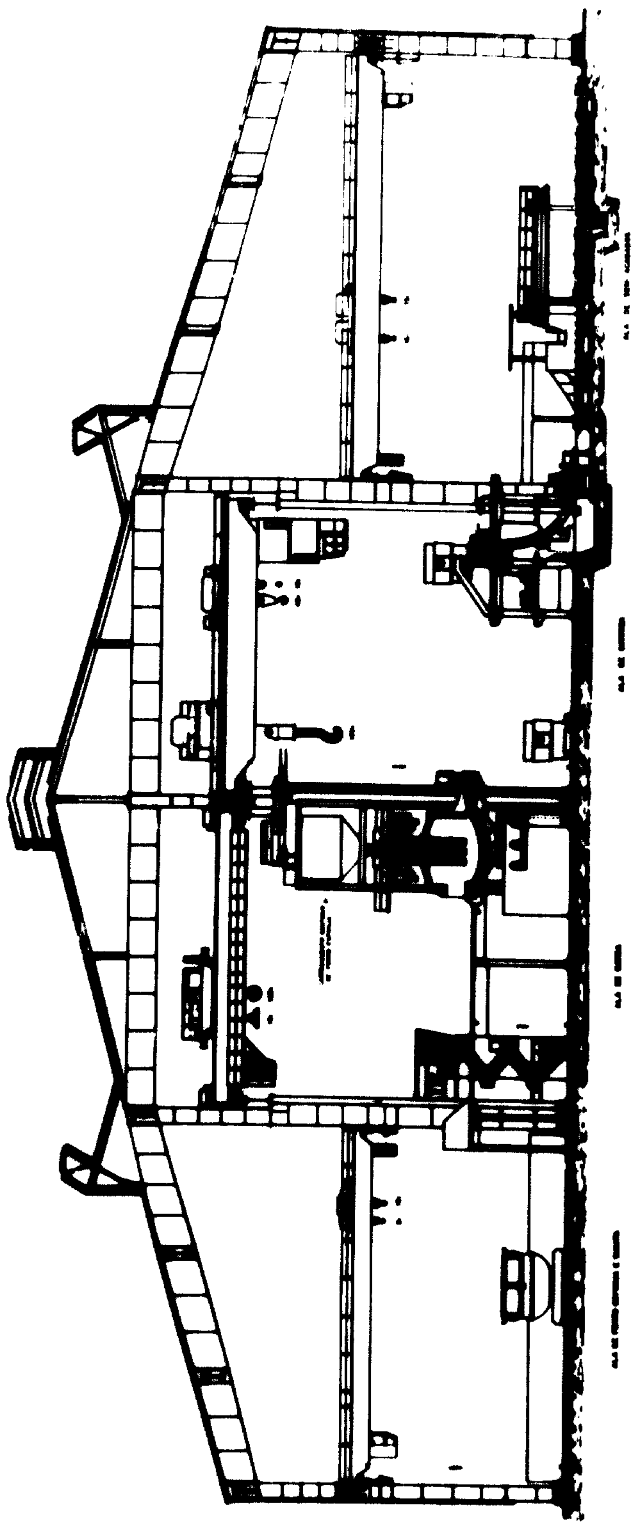


Fig. 5 - Transverse section of steelmaking shop

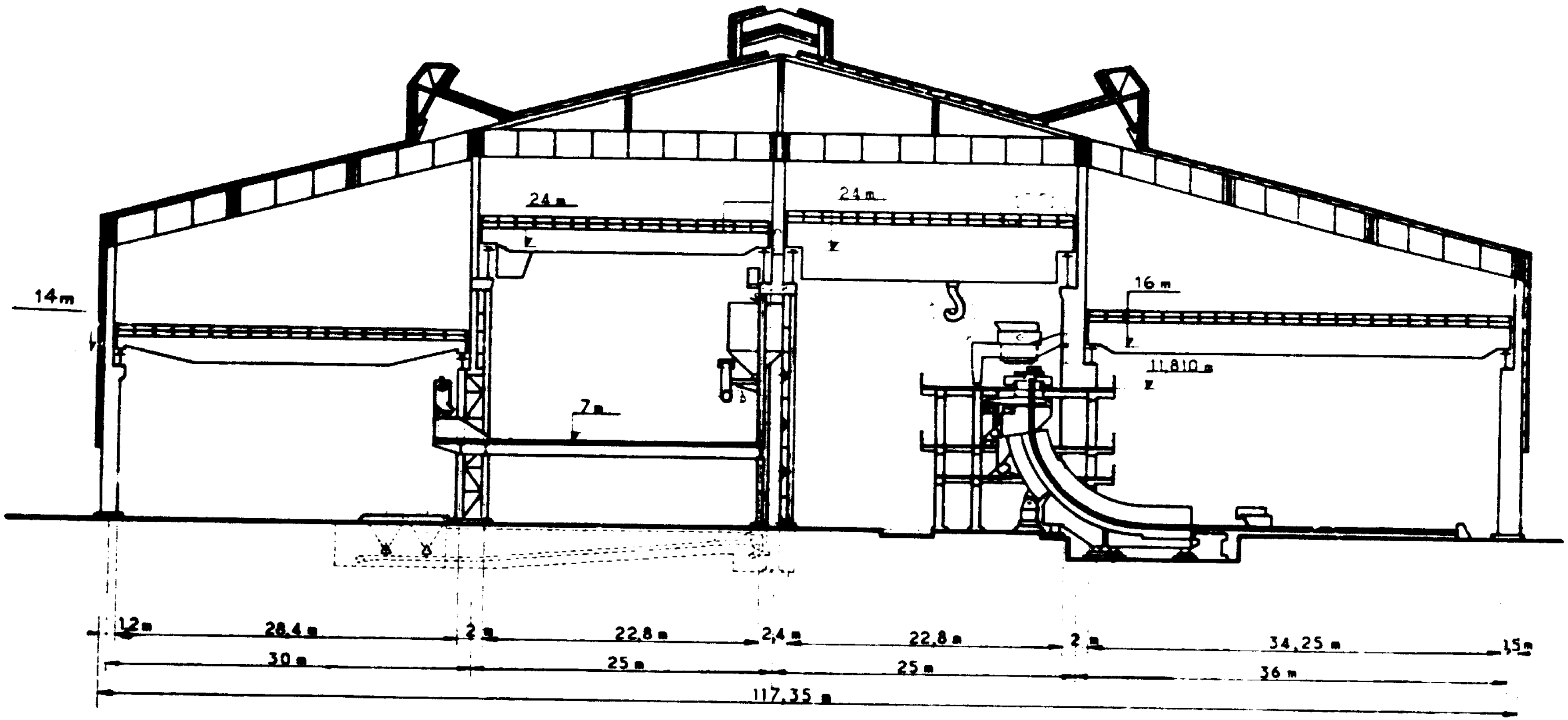


Fig. 6 - Transverse section of steelmaking shop

- On-load tap changer with programming of power consumed

At the highest tap, i.e. 520 volts, the transformer is able to deliver a maximum current of 48,000 amperes, corresponding to a maximum power of about 30 MW, with a power factor of about 0.7. This results in a specific power of about 525 kVA available for melting with a 90 ton charge.

- Electrical equipment of furnace and auxiliaries designed to keep the mains system voltage fluctuation level (" flicker ") within the limits required by CHESF.

Considering the low short-circuit capacity of the power supply network in the Salvador region, a 40 MVA synchronous balancing device was installed, capable of delivering the reactive power required for the operation of the furnace at present in position and providing for the needs of a second furnace to be installed later on. The electrical equipment of the furnace and the synchronous balancing device are furnished by JEUMONT-SCHNEIDER.

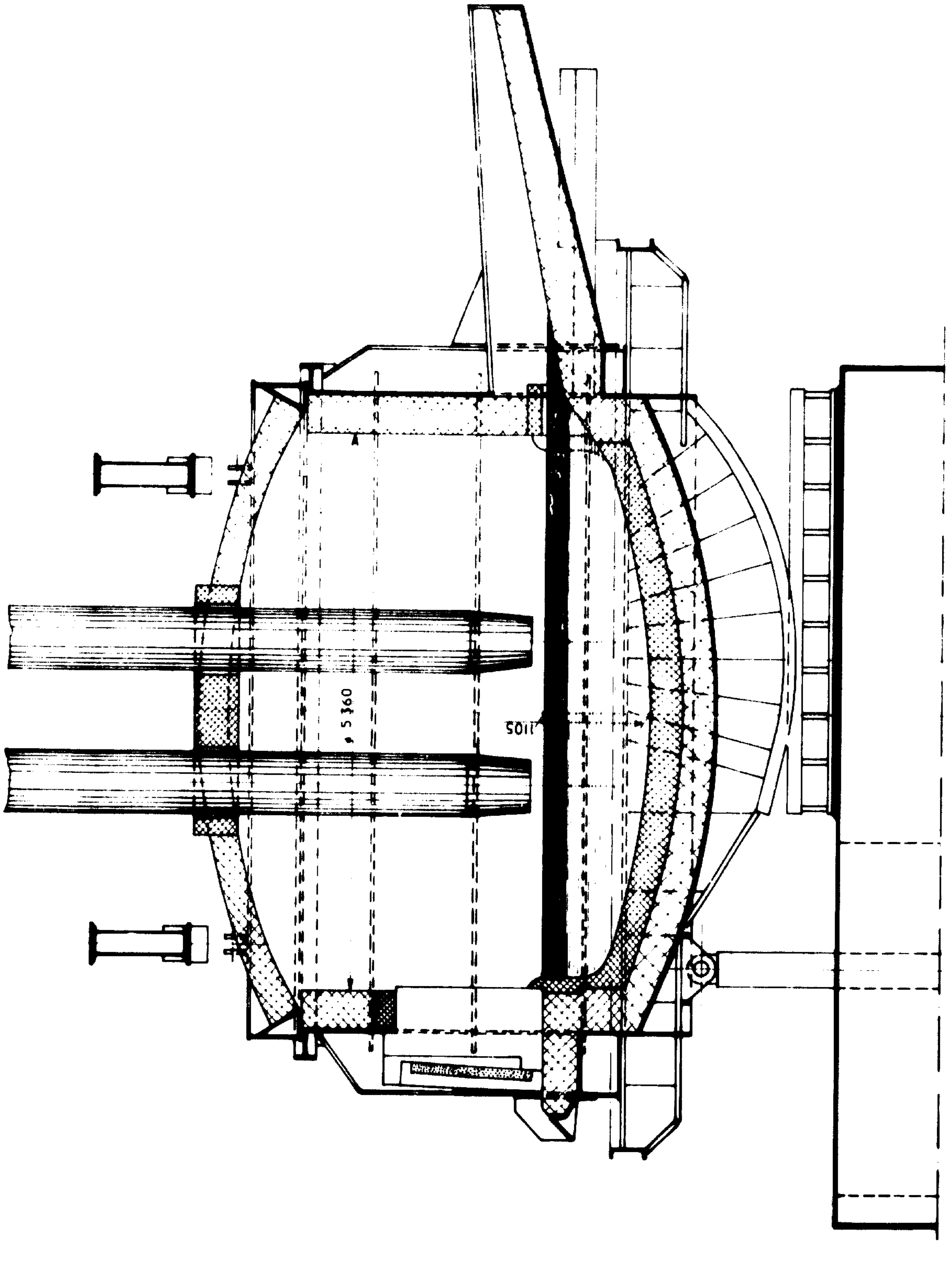
- A furnace fumes collection and purifying system has been installed, which not only improves the operation of the furnace but also eliminates atmospheric pollution hazards.

Figures 7 and 8 represent the furnace in section and the overall electrical schematic diagram.

6.- CONTINUOUS SPONGE IRON CHARGING SYSTEM

6.-1 General comments

The sponge-iron charging system may be batch-type, effected by bucket, as in the case of a scrap charging system. This method necessitates several charging operations and the arc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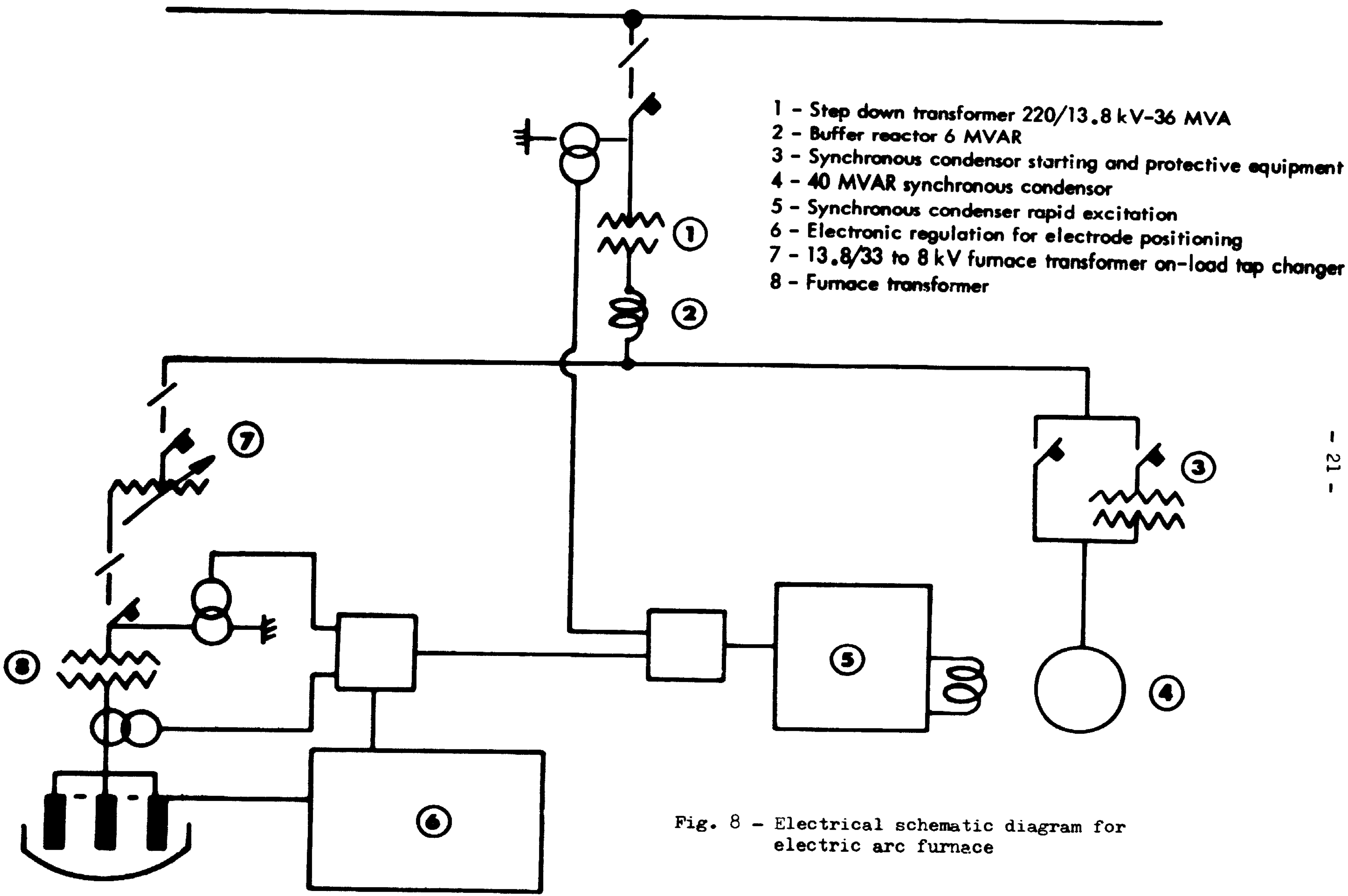

Fig. 8 – Electrical schematic diagram for electric arc furnace

has to be interrupted and the roof sw ng aside each time.

Some plants charge the sponge iron through a door at side.

This method obviates interruption of the arc, but the raw material is charged asymmetrically. The most rational method is symmetrical top charging through the roof.

There are two ways of carrying out this operation, as follows :

- continuous sponge-iron charging by three independent chutes running across the furnace roof to the rear of electrodes.

- continuous sponge-iron charging by one chute runnion across the center of the roof, inside the ring of electrodes.

The second method, developed and finalized in France by the Iron and Steel Research Institute (IRSID) in its pilot plant at MAIZIERES-LES-METZ, was finally selected by USIBA.

6.-2 The IRSID System

The IRSID method consists of introducing the sponge iron through the center of the roof, from whence it drops between the three electrodes and forms a heap on the molten metal bath. The volume of this heap is kept as constant as possible until the sponge iron has melted completely.

The sponge iron floats on the metal-slag interface, partially surrounds each electrode and has no tendency to extend toward the furnace walls (Fig. 9). Under the effect of the arc, sponge iron surface melting takes place, but the continuous supply of the material ensures constant renewal of the solid charge maintained in the centre bet the electrodes.

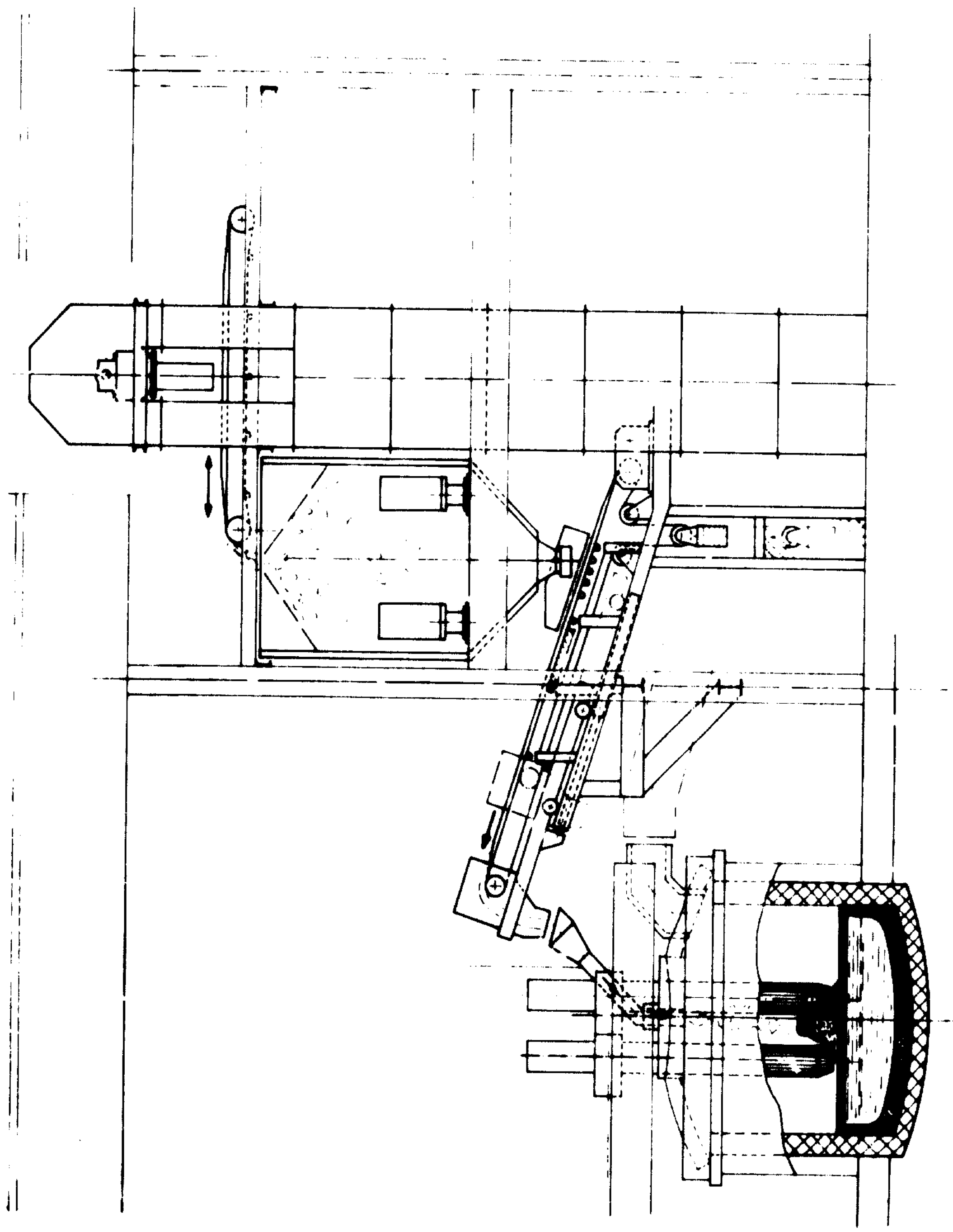

Fig. 9 - IRSID continuous sponge-iron charging system

The general configuration of the heap allows the best use of arc power ; in addition the heap protects the furnace walls by forming a screen against the intense radiant heat of the arc developed under each electrode.

During the first sponge-iron melting phase, the operation of the electric furnace is kept as far as possible at a constant temperature. Hovewer, the supply of sponge iron can be regulated by controlling the level of radiation by means of a calorimeter located at a point on the furnace sidewalls.

As soon as the slag has formed, a " boiling " effect developes in the metal bath around each electrode and forms a screen against heat radiation from the arc. It is then possible to begin to decrease the charging rate gradually, allowing the temperature to rise little by little.

The IRSID method provides the following advantages :

- Improvement of the electric furnace productivity.

The bucket only has to be filled once for charging the scrap ; this is done before the operation of the furnace starts. No interruption of the melting process has to be allowed for.

- the continuous sponge-iron charging mechanism is very greatly simplified, as charging only takes place at one point.

- better control of flowrate, and consequent simplification of operation.

- value of method from both the metallurgical and operational points of view

- Mirimizing of wear hazards for sidewall refractories.

6.-3 Operation

Three main phases may be noted, as follows :

first phase :the furnace is charged by the bucket with scrap weighing up to 20 or 30 % of the metal charge. The melt-down is started up. Around each electrode, a " well " forms in the interior of the mass of scrap. The furnace thermal efficiency therefore remains high, as practically the whole of the arc radiation is intercepted by the metal charge.

Taking as basis usages in other facilities, the initial metal charge may be mixed type including, for example, 20 % scrap and 20 % sponge iron in the total charge. The sponge iron, as it fills up the interstices in the mass of scrap and covers it over, ensures slow and regular furnace operation and at the same time affords increased refractory protection. For this reason, the scrap stockyard, the sponge iron bay, the overhead travelling crane, and the transfer car have been designed to allow use of mixed charges.

Second phase : After having reached 60 % to 70 % of the total power required for melting the charge, continuous charging of the sponge iron is started. Sponge iron will be charged at a practically constant rate until the end of the melt-down phase. The rate, programmed beforehand, is kept constant in order to obviate changes in the volume of the material floating on the surface of the metal bath. During this period the carbon content of the metal is kept constant. Adjustment being effected by injection of carbon powder. As soon as the slag forms, the sponge iron charging can be slowed down.

Completion of melt-down is indicated by sudden rise in the bath temperature.

Third phase : The third phase is conventional in electric furnaces. It consists of slagging-off the majority of the slag, which to a large extent comes from the gangue in the sponge iron. The metal temperature continues to be increased until the desired level is reached, the necessary adjustments being simultaneously effected with a view to producing the grade of steel it is desired to obtain (see below).

6.-4 Sponge-iron continuous charging system

1/ - Charge preparation (cf. Fig.10)

The sponge iron which is stored in the Raw Materials Bay is fed to the bins by a pay loader. Vibrating feeders supply a belt conveyor installed in an underground gallery. The sponge iron is transferred from the conveyor to a sling-type elevator and deposited in a 60 m3 capacity furnace feeding bin. The same equipment will subsequently be used for feeding a second furnace.

2/ - ELECTRIC-FURNACE CONTINUOUS CHARGING SYSTEM

The sponge iron is conveyed, by means of a vibrating feeder installed under the bin, to a belt conveyor which brings it to the charging equipment (chute) located on the furnace roof. A weighing system allows the weight of the sponge iron in the bin and the flow rate at which it is charged into the furnace to be checked at any moment. The charging facility located in the center of the roof is of stainless steel construction and, with a diameter of 300 mm, can instantaneously release substantial charges of sponge iron. The charging pipe is suspended from the electrode supporting structure. Figure 11 shows the detail in section of the furnace charging facility at the level of the roof.

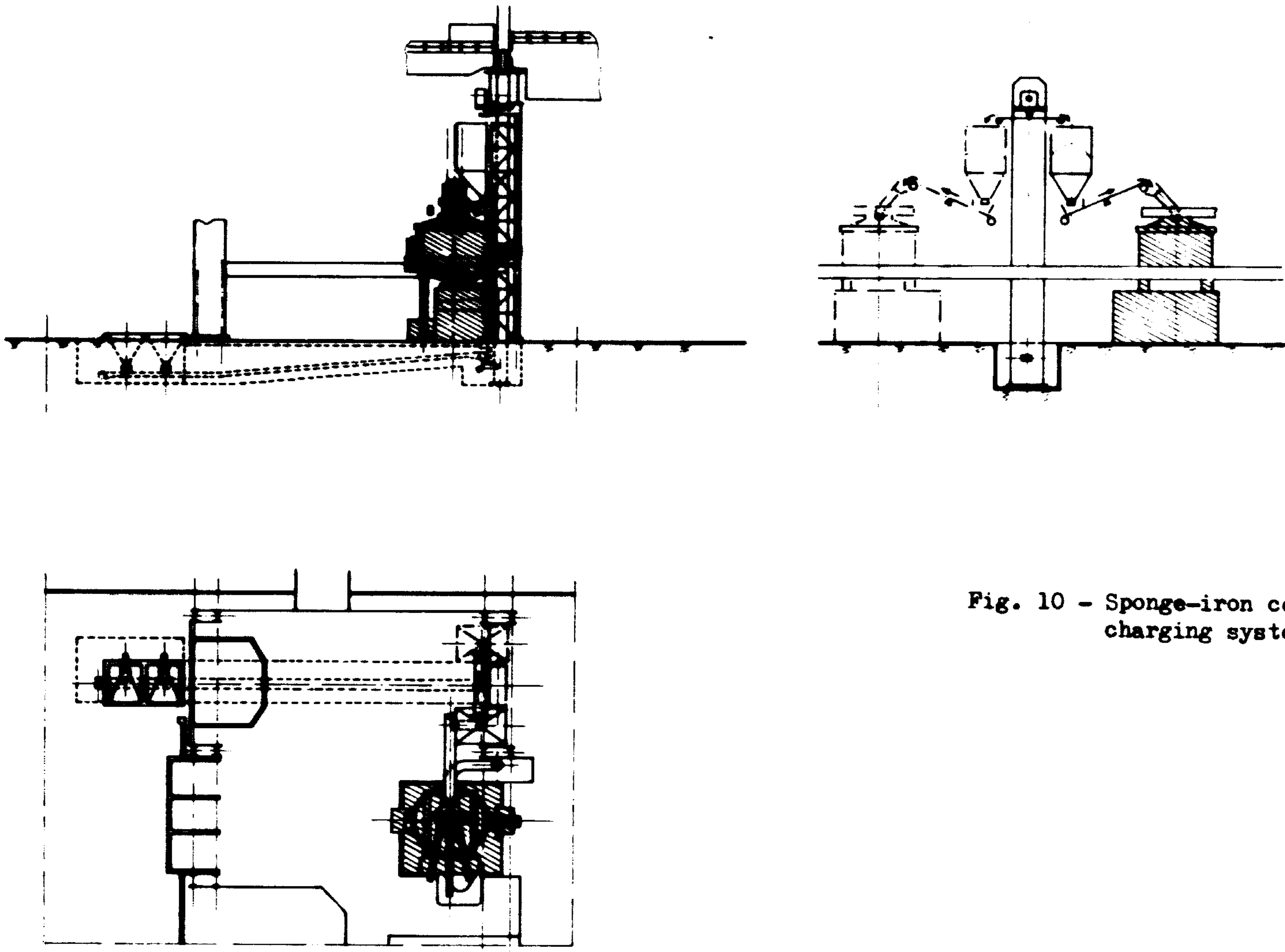

Fig. 10 - Sponge-iron continuous charging system

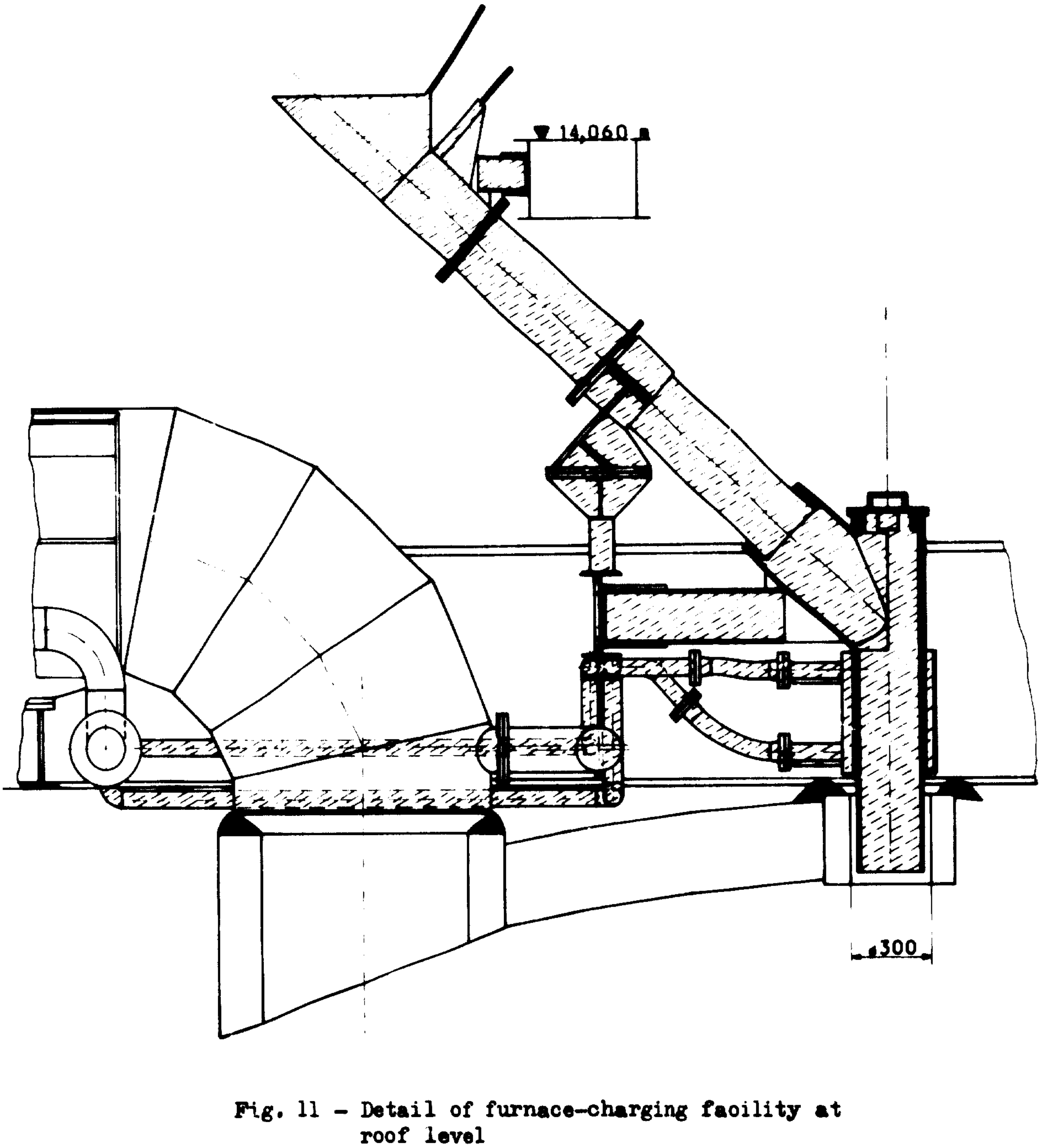

Fig. 11 - Detail of furnace-charging facility at roof level

3/ - QUALITY OF THE SPONGE IRON

On the basis of the results of the tests already carried out at Monterrey, the pellets furnished by C.V.R.D. (made from Itabira hematite), will be converted into sponge iron having the following properties :

- Total Fe - 86 to 92 %, according to the gangue content of the pellets
- Oxygen - 3 to 3,5 %
- Carbon - 2,2 to 2.4 %
- Metallization rate - 85 %
- Particle size - 3/8" to 5/8"

Efforts will obviously be made to reduce the sponge iron oxygen content as far as possible and to use low gangue content pellets, with a view to thermal efficiency in the refining phase.

7/ - POURING EQUIPMENT

This equipment has been selected to comply with the high productivity criteria of the electric furnace. It includes the following.

7.-1 - A teeming Crane - FLC design and manufacture.

SPECIFICATIONS :

. Span	22,8m	
. Hoisting speed	laminated hooks 40 ton hooks	4 m per minute 6 m per minute
. Hoisting capacity	laminated hooks auxiliary hooks	180 metric tons 40 and 10 mt
. Long travel speed		70 m per minute
. Trolley speed	main trolley auxiliary trolley	30 m per minute 60 m per minute

7/.2 - Pouring ladles capacity 100 to 120 mt equipped with sliding nozzles (INTERSTOP, model 3 for nozzles up to 75 mm)

7.-3 A billet continuous-casting machine (Figure 12)

FIVES LILLE CAIL design and manufacture.

This six-strand machine is capable of casting carbon steel and low alloy steel billets with sections 80 x 80 mm to 160 x 160 mm

This capacity permits absorbing the whole of the electric-furnace batch charges. It will be possible to adapt it subsequently to take the equipment required for a sequence-casting system covering charges from four or more furnaces. The installation is low-head type with a 1.1 meter straight section and a curved section with a curve radius of 5 meters.

The withdrawal speed, which varies according to the grade of steel cast and the billet section, can reach 4 meters per minute.

The constructional features of this machine are as follows :

- Steel ladle weighing system mounted on the pedestal, indicating at any moment the weight of the liquid metal remaining to be poured

- Thick-walled high-efficiency ingot molds, with a life of over 1,000 casting operations. This type of mold was selected on the basis of the grades of steel for casting and on account of its low maintenance requirements.

- Automatic monitoring of liquid metal level in mold
- Roller apron under ingot mold, in two parts. This arrangement permits rapid dismantling and facilitates maintenance and repair work on the first part under the mold.

- Ingot mold reciprocating mechanism, with variable stroke amplitude and frequency

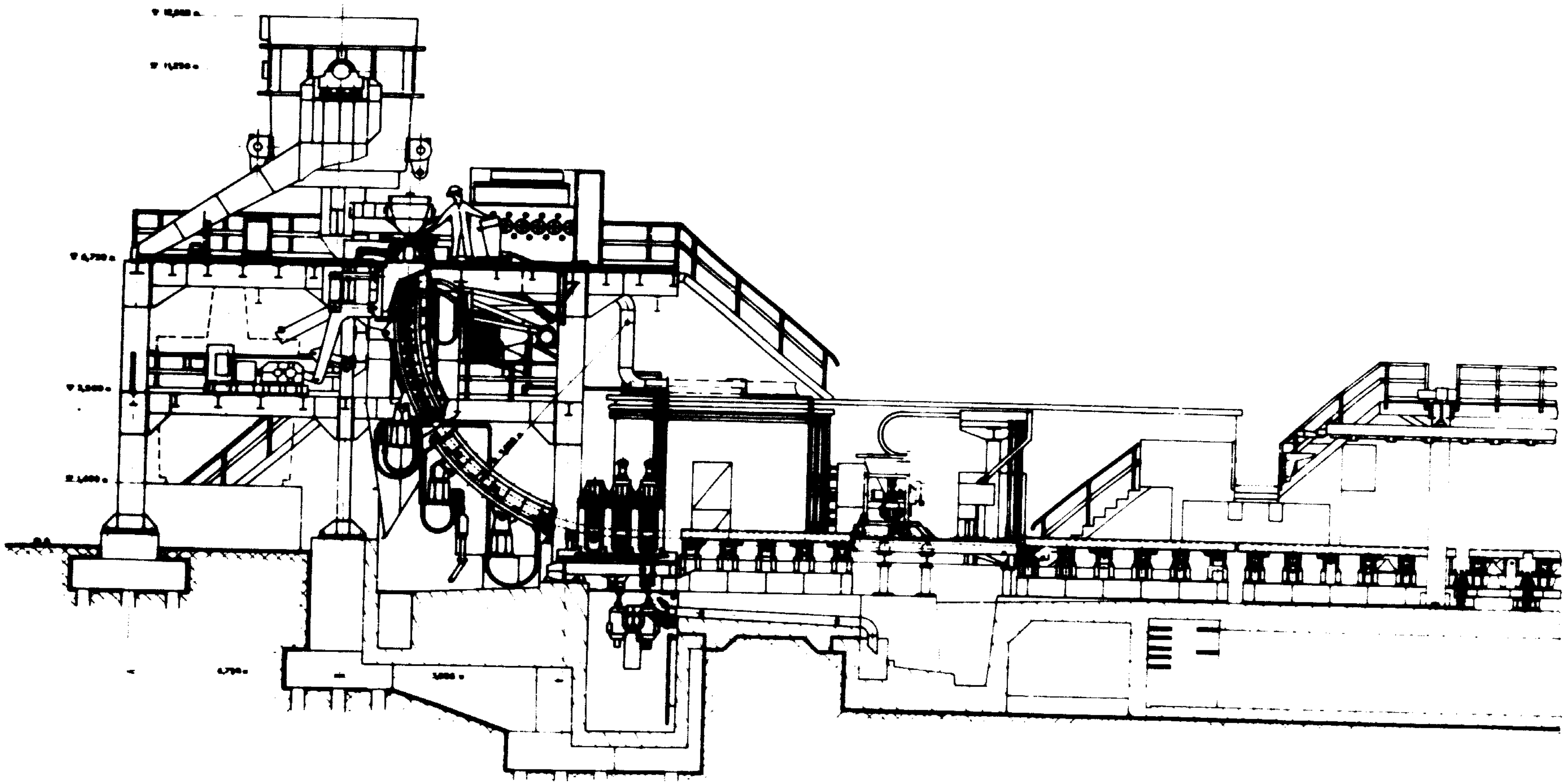

Fig. 12 - Cross-section of continuous-casting plant

- Withdrawal unit with rise of upper rolls driven individually by hydraulic cylinders.

- Cut-off of billets by automatic oxycutting machine with length programming

- Billet run-out, pushing, and pulling system making it possible to receive products 3 to 10 meters in length.

This installation is the largest of this type installed in Latin America.

8.- CONCLUSION

The USIBA steel plant ranks among the " Mini-steel plants " which have a high capacity. The recent start-up of the plant should rapidly confirm the validity of the solutions selected, especially in the technological field of continuous charging of very high percentages of sponge iron and from the productivity point of view, with a unit combining a 100/120 ton capacity U H P electric furnace and a six-strand continuous billet-casting machine.

The first stage was carried through in friendly cooperation by Brazilian and French engineering offices and companies under the responsibility of a single Pilot contractor, in close collaboration with USIBA personnel whose contribution was indispensable.

The size of the steel plant equipment together with the choice of the most modern techniques, such as direct reduction, UHP electric furnace, and continuous casting, place USIBA in the front rank as the largest industrial enterprise in northern Brazil, definitely oriented toward the future.

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