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UNITED NATIONS

INTERREGIONAL SYMPOSIUM ON THE APPLICATION OF MODERN TECHNICAL PRACTICES IN THE IRON AND STEEL INDUSTRY TO DEVELOPING COUNTRIES

11-26 NOVEMBER 1963

05478

STEEL SYMP.1963/
Technical Paper/A.22
18 September 1963

Original: ENGLISH

ELECTRIC STEEL MELTING

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Premise

The subject concerning electric furnaces is too wide to be dealt with during one only conference, without running the risk of becoming excessively slow and tedious for the patient auditors or without omitting many information and data of some importance in this particular process of steel manufacture.

We have therefore restricted our explanation to a particular aspect of the electric furnace which fits in well with the scope of the Symposium to which we have been invited: that is the use of the electric furnace for the manufacture of steel in developing countries as well as its suitability to the locally existing economical and industrial conditions.

I. Basical principles of the electric furnace and its development

The threephase electric furnace is essentially based on the Joule effect, that is on the heat produced by the electric current run through the charge, and in a minor way only, on the irradiation effect of the arc resulted between charge and electrode; therefore it descends direct, even with its structural modifications, from the Heroult prototype and not from Stazzano furnaces, where the thermal effect was secured by the arc irradiation directly resulting among the electrodes.

The first industrial type arc furnace was put into operation by Heroult in France, in the Savoy, during 1899; the first furnaces were of stationary type, of a very limited capacity, in the region of one ton, fitted with manual adjustment and were used, owing to the rather high specific consumption (800-1000 kWh/ton) as well as the high cost of the electric power, for the production of high grade steels which were very difficult to produce otherwise.

Successively, the productive capacity has more and more increased, raising to 10, 20, 50 tons and finally, during these last 20 years, it reached limits of 200 tons charge.

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Whilst the old type furnaces were fitted with shells of a diameter up to 3 mts. and had a maximum installed power of 3000 - 4000 KVA, by increasing the charge capacity the dimensions have increased up to 7.5 mts. and the power reached 40,000 kVA, as a consequence the electrodes' diameter have risen from 100-110 mm. to 600 mm. owing to the manufacture of synthetic graphite electrodes.

The arc electric furnace consists of a metallic shell lined with refractory material and placed on a cradle which enables oscillation. Said shell is fitted with one or two doors and one pouring spout; its upper part is covered by a vault of refractory material having, as a rule, three holes allowing the passage of the electrodes and also there may be an additional hole for the fumes suction whenever a substantial amount of oxygen is used.

Each electrode is supported by a mobile jaw clamp whose opening is controlled by a pneumatic or hydraulic system, the clamp is connected to a column by an horizontal arm.

The three electrode sets, viz.: column, arm and electrode are subject to up and down movements according to the resulting arc current generated; such movements are controlled by automatic governors of hydraulic or electromechanical nature.

The electrode arms are connected to the feeding transformer by means of copper cables and bars; the furnace transformer picks up the high voltage current from the mains, lowering or raising it to values within limits from 90 V. and 500 V.

The technological improvements which permitted to increase the charge capacity from one ton up to 200 tons are as follows:

(a) Installation of transformers always with a bigger power and having higher power per ton of furnace capacity, a 65 tons furnace has nowadays a specific power of 300 kVA per ton.

(b) The adoption of more efficient and fully automatic control systems; same can be either electro-hydraulic or electro-mechanical type (Figures 1 - 2 and 3).

(c) The manufacture of graphitated synthetic graphite electrodes. In fact, the use of these electrodes, which are far more light than the Söderberg's, have enabled the construction of slender and light structures for the electrodes and have, as a consequence, simplified any control problem.

The compactedness of said material as well as the low resistivity ensure a good and continuous operation which will result in an increase in the furnace output per hour, whilst its low consumption, about 5 + 6 Kg/ton of steel, has favourably affected the economical side of the process in question.

(d) The construction of top charged type furnaces. Formerly the furnaces used to be charged by hand, in a second time the charge used to be made, always through a door, by means of open-hearth chargers and later on was adopted the top charged type by means of bottom opening buckets. This practice allows the reduction of charging times as well as the furnace heat losses, also allows a substantial increase in the compactedness of the charges and consequently permitting a reduction in the number varying between 2 and 4.

(e) Refractory materials used in the construction both of the shell and the roof. The shell linings which were formerly made with acid material (silicon dioxide) have now been replaced either by a chrome-magnesien material or by dolomite prefabricated blocks. With this method the linings have a longer lasting life, that is, from 40 - 50 heats to about 200. At present the material used for the hearth consists either of sintered magnesite or calcined dolomite in powder form. At present hearths will last for almost 3000 heats. As far as it concerns the roofs, these are no longer constructed with pure silica, but are instead built with a silica-aluminous material having a 70% of alumina (Al_2O_3) content, whilst the central part between the electrode holes are formed of a pressed plastic refractory material with more than 80% alumina.

A further factor which has enabled an increase in the furnace production was the use of oxygen during refining, whilst the improvement consisting in the use of gas-oxygen burners during the melting phase will permit an increase in the output per hour which is already above 10 tons/h in a 45 - 50 tons furnace, using oxygen only during refining.

All the above mentioned improvements which have speeded up the furnace running, have enabled a reduced consumption, in particular the electric power (560 + 580 kWh/ton of rimmed steel ingots) as well as the electrodes' (5 + 6 Kg/ton of steel).

Said improvements have also permitted the production by electric furnace of carbon steel at a competitive price in respect to the same produced by the open-hearth furnace.

The main advantage in the use of an electric furnace rather then open-hearth's or oxygen blowing system, is in its suitability to produce a wider range of steels. In fact, due to its particular charcteristics and its tendencially reducing property, it enables to produce steels having a smaller oxygen content, hence of a higher grade; also, compared with air blowing converters, it enables to produce steel almost free from nitrogen.

The possibility to adopt a dual slag process, the first one being oxidizer and the second reducing, enables it to produce high grade carbonium steels as well as the complete range of alloyed products. The following steel types are therefore produced by electric furnace:

- Rimmed carbon steel, semikilled steel and killed steel
- Low-alloy structural steel
- Mangenese steel
- Silicon steel (5% silicon content)
- Aluminium steel (4.5% aluminium content)
- High speed steel suitable for tools and all range of stainless highly alloyed and heat resisting steels.

II. Iron and steel industry and electric power production in developing countries

The structure of the iron and steel industry in developing countries is characterized by the presence of numerous small and medium sized plants, which will probably account for a notable percentage of the production also in future.

To make the meaning of "small, medium and large sized plant" clear, we consider "large sized" those steel plants having a yearly production of over 300,000 tons, and "medium and small sized" the ones with a capacity below this figure.

The reason for this tendency towards small and medium sized steel plants are several, and vary in the different countries, according to economical and general conditions. Tentatively they may be generalized and summarized as follows:

- difficulty of concentrating large capitals of different sources on the same promotion, and above all the non participation, or very small contribution, of the fractioned capital which, in industrially and economically highly developed countries, generally forms the bulk for the most important promotions.
- In Latin America, that we consider to be a very interesting example of an area in phase of development, the great iron and steel projects are generally promoted by the State and financed with public capital, while in the same field private initiatives usually build small or medium sized plants.
- Developing countries are characterized by a low consumption of iron and steel products; in Latin America, for instance, the consumption in 1962 was 43 Kg. pro-capite. Consequently although high percentual increases are to be expected (and occur in fact), at least for many years the absolute value increase will be rather limited; this makes it advisable to build plants of sizes corresponding to the increase of the market.
- The initial small or medium size of many iron and steel plants, either already existing or under way, ensures an harmonious development by successive steps, proportioned to the necessary increases of capital and the rise of the demand.
- The large iron and steel plants are generally suitable for mass production, whereas in developing countries the consumption is not only low, but also much differentiated; so that small and medium sized plants are better suited to the market needs.

If we examine the situation of the electric power production, which is a very important factor for the iron and steel industry, we see that in developing countries there are particular conditions, that it is advisable to point out.

In these countries the production and distribution of electric power are usually reserved to the State: consequently programs are studied and carried out not only for present necessities, but also in view of short and long term requirements; i.e. the electric power plant is considered an infrastructure of public utility, and as a factor for the promotion of other industrial activities, which are possible only if electric power is available. Under such conditions the capital invested in the electric power plant shows a profit only after several years, and moreover in the sale of electric power the State can make very advantageous rates, at so called "political" prices, because it can apply very low amortization and profit rates, being recompensed by a direct income deriving from the sale of electric power, and by an indirect income deriving from the arising of other activities.

Another interesting characteristic of developing countries is the fact that generally large reserves of unexploited hydraulic power are available; therefore there is a definite tendency to build hydroelectric plants.

The example of Venezuela and Mexico is significant: although these countries have a considerable production of hydrocarbons, the hydroelectric power plants built in the past years or now under way definitely outnumber the thermoelectric power plants.

In view of the subject we are dealing with, we wish to stress the fact that hydroelectric plants are usually characterized by large investments for civil and hydraulic works, and by comparatively small investments for the purchase and installation of equipment; and that generally the first phase covers all works necessary to harness the hydraulic power which is naturally available, and the partial purchase of generator groups.

The purchase of equipment can be completed by successive steps, in accordance with more accurate previsions of the rise of the demand.

It should be noted that, for reasons of investments and efficiency, the present trend is to divide the total capacity of an electric plant into few high powered units.

All these factors have created a good availability of electric power in developing countries. In fact every new power plant generally reaches its maximum production capacity only after some years, and the same thing occurs in every subsequent expansion.

With regard to the characteristics of the consumers' requirements, it is known that hydroelectric power plants, fed either by flowing water or by tanks, are more sensitive to the load factor than thermoelectric plants; and the consumers show the same sensitivity, having to pay higher fixed charges for hydroelectric power than for thermoelectric power.

We have seen that developing countries usually have a good availability of comparatively low priced electric power; but although this is a very important factor, it is not the only one which is necessary to ensure the success of a steel industry.

According to the various processes used, an activity on this field must have constant and economical sources of supply of iron ore, coal or coke, scrap, fluxes, final additions and water.

The use of iron ore and coal is characteristic of integrated plants: the present trend of design engineers is to consider a yearly production of 500,000 tons as the minimum capacity for an integrated plant.

The latest experiences and the most modern techniques (increase of agglomerate percentage, increase in blast furnace size and productivity, use of oxygen converters) are raising this minimum capacity to a yearly production of 1,000,000 tons of steel.

It is evident then that the integrated process, requiring a massive use of iron ore and coal, is not the most suitable for small and medium sized plants. But also leaving aside for a moment the size of the plant, we must consider the external facilities for the supply of raw materials.

In the first place, the quantity of necessary raw materials varies notably according to different processes; for the integrated, using good quality ores and coal and considering a 75-80% percentage of hot charge, approximately 3000 Kg. of raw materials (iron ore, coal, fluxes, final additions, scrap) are required for the production of 1000 Kg. of steel, whereas in the cold charge process only 1200-1250 Kg. approximately of raw materials are needed to obtain the same quality of steel.

The iron ore and coal may be either produced locally or imported from abroad. In the first case, large investments are necessary to exploit the ore deposits or local beds (infrastructures, extraction plants, classification and first preparation); in the second case large investments are also necessary to make port facilities for the unloading of ships transporting the raw materials. In both cases these installations, in order to be economical and efficient, must be built for large production, and therefore they are disproportioned to the type of industry we are now considering.

It is evident that for a starting up steel industry, or based on small sized plants, to be independent from iron ore and coal supplies is an advantage: of course it is necessary to face and solve the problem of the supply of scrap.

Developing countries, or those which have a steel industry of limited dimensions, with a production lower than the consumption, generally should have a good quantity of iron scrap accumulated in the course of time. In this case the problem will consist in organizing the collection of the scrap, and in arranging for the selection and preparation phases; it will also be advisable to make agreements with local centres which continuously discard scrap, such as railways, oil fields, transformation industries, etc., to purchase this scrap.

Needless to say, if this material is exported, the necessary steps must be taken to stop this escape of scrap.

If local supplies are not sufficient, the remaining scrap will have to be imported from abroad; experience shows that it is advisable to have at least two sources of supply, either because the customer is in stronger bargaining position, and because two or more sources of supply are more capable of overcoming the inevitable and unforseeable crises that for particular economical and political circumstances occur in the market of this raw material.

The steel plant managers must make clear contacts, with regard to prices, parameters for the calculation of price variations, and type of scrap to be supplied; they should also make arrangements for an efficient inspection in the ports of embarkment, so as to ensure that the material shipped conforms to contract specifications.

After all we have stated above, it seems to us that the electrical furnace is very suitable for steel production in developing countries. In fact the electric furnace meets well the requirements and conditions which are characteristics of these countries; it is suitable for small or medium sized plants, it is sufficiently elastic for a large range of products, it can be adapted for production increases by gradual steps, it does not require iron ore and coal or coke, and it needs a large quantity of electric power with a relatively high load factor, naturally at low price (approximately US$ 0.01/kWh).

III. The actual rôle of the electric furnace in countries having different industrial levels

The increase in the output capacity of the electric furnaces has proceeded parallely with the expansion of their use, to the detriment of the open-hearth furnace with small capacity and cold charges, also in the production of common steel. This has been made possible by the actual reduction of the cost of electric power and its greater availability, by the increased production capacity consequent to the mentioned improvements and by the lower cost of charges in the electric furnaces.

All this finds confirmation by a closer view of the actual structure of the steel industry in the United States as well as in the other countries of the CECA.

There is nowadays in the United States a great number of non integrated steel works with a production varying from a few tenths of thousands of hours to more than half a million tons per year, some of these producing common steel for concrete bars and structural steel; some of these are located in eccentric positions with respect to the integrated steel production centres, thus facing market and production conditions similar to those typical of the developing countries.

There is seemingly still a great possibility of expansion for the electric steel industry in the United States as it is confirmed by the increased production of electric steel which stepped from 8.4% to 9.5% on the total production from 1960 to 1962.

Similar considerations can be drawn for the countries of the CECA. In fact, if we take into consideration the statistics of the last ten years production, it is possible to note a considerable increase in the production of electric steel (see Table No.1).

Although strictly connected to the increased production of high quality carbon steels (see Table No.2) part of which however are still produced with the open-hearth furnace, as well as to the production of alloy steels (see Table No.3) almost exclusively produced with the electric furnace, this increase is still partly due to the percentage of common steel produced with the electric furnace instead of the open-hearth furnace with cold charges.

TABLE 1

PRODUCTION OF INGOT STEEL BY ELECTRIC FURNACE (1,000 tons)

Year	West Germany		France		Italy		Holland		Belgium		Luxembourg		C.E.C.A.	
	ton	%	ton	%	ton	%	ton	%	ton	%	ton	%	ton	%
1953	570		686		1509		114		162		50		3111	
1954	732	3.6	834	7.8	1681	39.9	133	14.2	165	3.3	49	1.7	33[illegible]	[illegible]
1955	988		961		1988		136		220		69		[illegible]37[illegible]	
1956	1226		1039		2202		140		347		81		503[illegible]	
1957	1423	5.1	1118	7.9	2512	37	185	15.6	422	6.7	74	2.1	57[illegible]	[illegible]
1958	1602	6.1	1277	8.7	2323	37	169	11.8	269	4.5	75	2.2	571[illegible]	[illegible]
1959	1876		1282		2611		189		300		86		63[illegible]	
1960	2174	6.4	1501	8.7	3179	38.6	202	10.4	438	6.1	81	2.0	7575	10.[illegible]
1961	2365	7.1	1572	8.9	3506	38.4	116	10.1	458	6.5	75	1.8	6092	11.[illegible]
1962	2567	7.9	1523	8.8	3692	38.9	205	9.8	441	6.0	64	1.6	8491	11.7

TABLE 2

PRODUCTION OF HIGH GRADE CARBON STEEL INGOTS (1,000 tons)

Year	West Germany	France	Italy	Benelux	CECA
1953	453	405	298	54	1210
1954	464	404	380	69	1319
1955	548	558	350	104	1560
1956	729	542	351	125	1747
1957	746	609	385	109	1849
1958	577	587	369	52	1585
1959	597	448	454	67	1566
1960	796	597	558	94	2045
1961	730	604	630	112	2076
1962	646	567	585	94	1892

TABLE 3

PRODUCTION OF HIGH GRADE ALLOYED STEEL INGOTS

Year	West Germany	France	Italy	Benelux	ECSC
1953	703	435	224	31	1393
1954	925	512	238	28	1703
1955	1288	563	324	59	2234
1956	1397	667	350	71	2485
1957	1235	696	416	67	2414
1958	1317	683	483	51	2534
1959	1554	661	500	61	2776
1960	2069	848	755	95	3767
1961	2012	912	904	98	3926
1962	1773	889	729	100	3491

Confirmation of this can be found by examining Table No. [illegible] with the number of electric furnaces and open-hearth furnaces operating in the CECA from 1953 to 1962. It has to be noted that the decrease in number of the open-hearth furnaces is restricted to small units. The electric furnaces inactive at present are mostly obsolete ones or furnaces with a limited capacity.

CECA's forecasts reaching as far as 1965 foresee a further expansion of the electric steel up to a maximum of 10.[illegible] million tons per year equal to 10.[illegible]% of the total steel production. This improvement is justified by the increased production of high grade steels and by the ever increasing availability of low quality light scrap that will be found on the market at convenient prices owing to the expansion of oxygen converters where the use of scrap is rather limited, and corresponding in quality and quantity to the home scrap. The technical development of blast furnaces makes the use of light scrap less advantageous.

The electric steel industry may play the same rôle, with respect to the oxygen converters, played by the open-hearth furnace with respect to the Bessmer converters.

Besides, it has been foreseen to install electric steel works in those zones of the CECA which are eccentric to the main production centres, thus presenting economical and ambient characteristics similar to those prevailing in the developing countries.

Further considerations can be drawn on the structure of the Italian industry and its recent development. The apparent consumption pro-capite has gone from 86 Kg. in 1953 to 245 Kg. in 1962 which means that in a lapse of time of 10 years Italy has surged from its previous condition of underdeveloped country to that of a country with a considerable industrial level. Here are some data: the 1953 production was as follows: 1,143,000 tons cast iron and 3,500,000 tons steel of which 1,509,000, equal to about 43%, electric steel. In 1962 the cast iron production increased to 3,564,000 tons and the steel production to 9,48[illegible],000 of which 3,697,000 tons, equal to 39%, electric steel. The ratio cast iron/steel has moved from 32% to 37% keeping still well below the average of the CECA which is about 75%, but it is hoped that a further improvement of this index will be possible in the near future.

TABLE [illegible]

NUMBER OF OPEN-HEARTH FURNACES AND ELECTRIC FURNACES

Year	Open-hearth furnaces Electric furnaces	West Germany	France	Italy	Total [illegible]
1954	**Open-hearth furnaces:**				
	existing	217	124	75	[illegible]
	operating	178	71	50	[illegible]
1962	existing	202	94	[illegible]	[illegible]
	operating	113	65	50	[illegible]
1954	**Electric furnaces:**				
	existing	128	126	182	[illegible]
	operating	118	85	128	359
1962	existing	182	130	185	[illegible]
	operating	145	108	152	[illegible]

It is possible to observe that whereas in the initial stage the production of electric steel through the use of scrap which requires lower investment per ton of steel produced had experienced a great impulse, there is at present a noticeable trend towards the production of integrated steel. The first method is normally followed by private companies, the other one is typical of the Italsider concern, which is practically a Government owned Institute.

A similar situation both from the economical and technical point of view can be found in the Latin American and in the developing countries. Table No. 5 gives the total production of steel of the Latin American countries, the quantity of electric steel produced and the percent referred to the year 1962.

IV. Comparison between the electric furnace and other systems - possibility of integration

Before drawing up a comparison between investments and production costs referred to the different steel production systems, it is necessary to anticipate and stress that such a comparison is merely indicative, based as it is on the average value of the necessary investments, the cost of raw material and consumption materials.

The following prices have been assumed:

- scrap	US$	30.00	per ton C.I.F.
- pig iron (imported)	"	65.00	" " "
- coke	"	30.00	" " "
- electrodes	"	560.00	" " "
- power	"	0.010	per KWh
- workmanship	"	1.00	per hour

all other items being based on the actual prices in force in Italy.

Objects of this comparison are: the electric furnace, the L.D. converter fed with hot-blast cupola pig iron and the cold charged open-hearth furnace, this latter process having an historical value, for three different production stages, that is 100,000 + 250,000 and 400,000 tons/year.

The comparison has been purposely restricted to the above productions, since over 500,000 tons per year it is no more convenient to produce steel from scrap iron in comparison with the integrated plant. In an integrated plant a set of cupola furnaces could possibly supply part of the pig iron under particular conditions of the scrap market.

TABLE 9

PRODUCTION OF STEEL IN THE LATIN-AMERICAN COUNTRIES (YEAR 1962)

Country	Total Production tons	Electric Steel tons	%
Argentine	644,047	11,791	1.8
Brazil	2,554,720	564,721	22
Colombia	156,065	41,487	26.6
Chile	527,206	32,077	6.1
Mexico	1,712,000	660,284	38.4
Peru	71,284	70,224	98
Uruguay	8,567	—	
Venezuela	142,179	73,616	52
Total	5,818,344	1,455,274	25

Table 6 shows the conclusions reached, without a detailed analysis of the single items. The investments required for the L.D. steel plant include cupola furnace and oxygen plant. Depreciation has been rated 10% per annum.

It can be easily understood that since [illegible] reduction has been taken into consideration, where the difference of [illegible] may definitely influence the economicity of a given process, our investigation has not reached extreme results, however in our opinion it has clearly focused the convenience to adopt the electric furnace process in a plant with a yearly output of less than 400,000 tons (see drw.4)

From 400,000 tons and above the L.D. process is preferable on account of the greater possibilities of integration offered.

Under particular conditions of the financial market, the lower investment requested for its realization, besides a lower production cost, may constitute a determining element in the choice of the process (see drw.5). The utility of the electric furnace may fade under particular ambient and raw material market conditions. Nevertheless it is important to underline two more factors in favour of the adoption of the electric furnace, which cannot be put into real value but definitely influence the overall utility and desirability of the process:

1. easier operation which means the necessity to employ a less skilled workmanship. This is important in developing countries
2. possibility to produce any type of steel. Here again we have an advantage for developing countries where the existing market conditions do not allow for a differentiation or specialization of the steel production, whereas the request for high grade steel increases together with the industrial development.

The easy operation of the electric furnace is a consequence of the improvements both mechanical and electrical applied.

The operation is safer thanks to a number of factors such as modern construction of transformers, the employment of air blast or deionizing cells switchgears, efficient protection, quick and safe adjusting systems as well as the use of easy-to-handle control panels.

TABLE 6

TABLE OF INVESTMENTS AND COSTS FOR STEEL MAKING

Production Level ton/year	100,000			250,000			[illegible]00,000		
Process	E.F.	L.D. + cupola	O.H.F.	E.F.	L.D. + cupola	O.H.F.	E.F.	L.D. + cupola	O.H.F.
Investment per ton/year US$	30	50	50	22	34.5	36	20	27.5	30
Depreciation 10% US$/ton	3.00	5.00	5.00	2.20	3.45	3.60	[illegible]	2.75	3.[illegible]
Charge cost US$/ton	42.70	56.79	51.13	42.78	55.10	51.13	42.7[illegible]	54.65	51.13
Conversion cost US$/ton	29.88	19.54	22.23	25.83	15.90	16.26	25.36	14.32	17.[illegible]
Ingot total cost US$/ton	72.66	76.33	73.36	68.61	71.00	69.39	68.16	[illegible]	[illegible]

The operation is simpler, with an almost non existing possibility of mistakes thanks to the oleodynamic system for lifting and rotating roof furnace tilting, and safety and clamping devices incorporated in the control circuits. The operation is also quicker thanks to the top charging system which compared to door charging and requires also less skill from the workers.

All refractory works such as shell firebrick lining, spout lining and roof construction are rather simple and quickly done. Most of them could be performed by the same ironworkers with the assistance of a small team of bricklayers.

The preparation of electrode columns is easier thanks to the improved manufacture of electrodes, to the use of tapered nipples and the use of tighting devices fitted with dynamometer.

The electric furnace can be easily stopped and started again without any damage being caused to the installation and the firebrick lining. This allows a one day stop every week for the usual maintenance work.

The open-hearth furnace on the contrary, cannot be easily handled in this way because of the difficulty of the initial heating and the consequent expansion of the various components which makes it necessary to maintain the heat also during the weekly or fortnightly stop for maintenance.

The combustion and the inversion time must be carefully checked and so does the pressure and temperature of the hearth as well as the flue temperature, the slag chambers, recuperators, the fumes and the depression at the foot of the stack which require a constant control.

The fuel oil pumping units, the natural gas decompression units, the burners and their regulators, the air pipes and atomizing steam pipes, the slag chambers, recuperators, fumes stacks and the base of the stack call for an expensive and continuous maintenance.

The reconstruction of a furnace means about 45 days work and the employment of skilled personnel so that in the long run it is preferable to entrust the work to specialized companies generally active in industrially developed zones.

As regards the converters, we would stress a few difficulties both of installation and maintenance, such as the delicate air and oxygen conveyance and the suction, cooling and fumes purification systems.

Also from the technological point of view the electric furnace shows definite characteristics of simplicity and easy operation.

The electric furnace allows good slag control, simple oxidation, carburation and recarburation, control of both temperature and the possibility to quench the bath in the furnace or in the ladle.

In the open-hearth furnace the melting and the refining phases must be carefully followed by skilled personnel to have the metal absorb the necessary heat, to correct the slag, to correctly proportion the quantity of oxidizer, which calls for an adequate preparation of the bath so as to avoid excess heating of the basin and reach thus a correct carbon content, a correct bath temperature and a sufficient slag basicity.

To operate the converters, the workers must be particularly skilled since based on the type of charge, the analysis of the desired quality of steel, the blow time and the flame colour, they must decide about the addition of slag and the time and limit of refining.

So far we have taken into consideration the electric furnace fed with cold charges, mainly consisting of scrap, and the advantage deriving from the independence from the supply of other raw materials such as iron ore and coal. Certain circumstances however, though not strictly economical, such as the necessity to reduce the importation of scrap to improve the balance of trade of the country, or the necessity to reduce the use of scrap to produce a quality of steel devoid of impurities as far as possible, may suggest the integration of the steel plant. As it is well known, for medium and small sized plants the adoption of a blast furnace would not be suitable because of the high installation and production costs involved.

Based on the experience acquired in this field, it is possible to declare that the adoption of the electric smelting furnace and the new methods of direct reduction represent the best solution for the small and medium plants.

The electric smelting furnace system has been widely known and employed for many years. The requirement for every ton of cast iron produced is 2400 to 2600 kWh and 400 to 450 kg. of coal. It is apparent that the electric smelting furnace is an advantage there where there is a large availability of electric power at low cost (4 to 5 mills/kWh) and where it is possible to obtain supplies of coal at convenient price even if not in large quantities.

Various methods have been lately studied and experimented to preheat and prereduce the ore charge with a view to decrease the consumption of electric power and increase on the other hand the smelting furnace productivity and exploit more rationally the furnace gases (about 600 to 700 cu.m/ton of pig iron, with 2500 to 2800 Cal/cu.m.).

There are no news of any of these systems successfully employed on an industrial scale in the steel industry.

The electric arc furnace may be fed up to 50% with hot metal, better if preceded by a pre-refining phase.

The results obtained after various experiments show the following differences with respect to the cold charge operation:

- reduction of electric power consumption,
- reduction of pouring time, with a consequent improvement of the arc furnace productivity,
- increase in the oxygen consumption,
- increase in the consumption of refractory material used to line the furnace and crown.

Although iron ore direct reduction methods have been studied and experimented for a good many years, only after the second world war this processing has experienced a real boom developing real interest in the world of the steel industry. We must anticipate that most of these processes are still in an experimental stage. However, some of these processes applied on an industrial scale have given good technical and economical results. We would further like to stress that these direct reduction methods request for their application some basic conditions, i.e. availability of natural gas in large quantities and low price (consumption of about 600 cu.m per ton of ore reduced) and availability of high quality iron ore.

The cost of transformation of the ore, reduced by direct process into steel, is higher than scrap transformation as a consequence of the increase of power, fluxes, slagging materials and refractories consumption as well as a consequence of tap to tap time increase.

As far as we know, the most interesting adoption of a direct reduction process is to be found in a steel plant in a Latin American country. The steel plant with a capacity of about 300,000 tons/year works together with a direct reduction plant producing daily 700 tons of sponge iron (the plant is operating on two lines, one with a 200 tons/day and the other with 500 tons/day production).

As a consequence the steel plant is constantly fed by 70% sponge iron and about 30% scrap, most of which is home scrap.

Besides these integrating processes upstream medium and small steel plants, also downstream integrating processes have been successfully and largely employed as of late. We refer in particular to the continuous casting process which has proved to be suitable for productions on a reduced scale of semifinished products, in substitution of blooming mills, slabbing mills, and continuous billets mills.

The continuous casting is economically advantageous for yearly productions falling between 50,000 and 300,000 tons, depending on the number of columns and the product section, and eliminate the use of the above mentioned mills, which are costly and whose installation is economically justified only for large productions.

All these integration possibilities for small and medium steel plants have played a decisive rôle in favour of the electric furnace, not only because they have allowed the realization of small and medium steel working units with a more and more complete and integrated cycle, but also because a plant so conceived has all the possibilities, starting from the initial nucleus to reach considerable production rates through successive expansions.

V. <u>Two examples of modern electric steel works installed in Latin American countries</u>

Before ending these notes about the adoption of the electric furnace in developing countries, we would like to shortly illustrate two examples of modern electric steel works erected and successfully operating in Latin America. These are TAMSA, Veracruz (Mexico) and SIDERCA, Campana (Argentine). The production of both these steel works is mainly absorbed by the plants producing seamless pipes. The general layout (Figures 6 and 7) foresees the final installation of four electric furnaces of 50 tons each covering a yearly ingot production of from 200,000 to 260,000 tons.

Although the two designs are quite similar we would refer in particular to the TAMSA steel-shop, since this latter has been operating for a longer period. TAMSA started its activity 5 years ago, in March 195?, while SIDERCA went into operation about one year ago.

TAMSA started with one electric furnace. In October 195[illegible] a second electric furnace started operating, and a third one in October 1961. Everything is ready for the installation of a fourth unit, whenever necessary. The furnaces have a nominal capacity of 35 tons but in practice the charges reach up to 53 ÷ 54 tons and each heat yields from 48 to 49 tons of ingots. The shell's diameter is 15', that of the electrodes is 18" and the transformer capacity is 12,000 KVA. The plant is provided with a 150 cu.m./hour oxygen installation. Oxygen is being blown during the refining phase. Without the use of oxygen the production has been of about 4 heats in the 24 hours, i.e. slightly more than 8 tons/hour each furnace; whereas by using oxygen in a 3 to 4 cu.m./ton ratio, it has been possible to obtain more than 5 heats in the same period, which makes about 10.5 tons/hours each furnace.

With two furnaces and a forced running it has been possible to obtain yearly outputs of more than 160,000 tons. By operating 3 furnaces it should be possible to easily obtain yearly outputs of 200,000 ÷ 210,000 tons.

Whereas the use of oxygen is normal practice in the TAMSA steel shop, various experiments have been carried out to analyse and identify the best ways to increase the furnaces productivity, to diminish the conversion costs and to reach a clearer view as to the most convenient integrating systems. We refer here to the use of oxygen-gas burners and to the partial substitution of scrap with hot metal and sponge iron. The results obtained were really interesting and have confirmed the noticeable adaptability of the electric furnace to new technological systems to increase it productivity, to the modification of its traditional consumption rate in view of a more economical operation related to different ambient conditions, and to the integration with various iron ore reducing process.

The plan of the two steel works has been studied bearing in mind in particular the dimensional characteristics of the ingots. TAMSA manufactures ingots with an average weight of 800 ÷ 900 Kg., the average number of ingots resulting from each heat being 60. The minimum unit weight per ingot is 400 Kg. and the maximum number of ingots per heat is about 120.

As regard SIDERCA, the minimum and average weight are still lower and as a consequence the average and maximum number of ingots manufactured is higher.

TAMSA's production covers all the range of steel qualities in conformity with A.P.I. Standards (grade A, grade B, X-42, X-46, X-52, X-56, J-55, N-80, P-105, P-110, grade D and grade E) as well as steel for the mass production of high quality products such as tool-joints, rock-bits, drill collars, and high pressure gas bottles. The steel produced has always a limited tolerance on the specifications because of the successive processing and also because of the severe working conditions the finished product has to undergo. The impurity content rates are clearly specified by the various Standards (A.P.I., A.S.T.M., S.A.E.) and are kept within rather low values.

We would like to add that the higher the characteristics of the steel, the higher the bearing of the quality of the raw material charged, hence the necessity to buy high quality scrap and to carefully select the scrap coming from outside and the home scrap, in this latter case to make a better use of the alloying elements contained.

As regard the power supply, TAMSA is fed by an hydroelectric plant of four 45,000 kVA each units, with the possibility of expansion up to 6 units. The granted capacity is 34,000 kW of which 8,000 ÷ 10,000 kW are absorbed by the rolling mills and by the general and auxiliary services. The total monthly consumption is about 14 ÷ 15 million kWh, more than 10 million of which are absorbed by the steel works.

As regards SIDERCA, working at present with two furnaces (12,500 kVA each), the necessary power is supplied by a thermoelectric plant with a 37,500 kW and the possibility to double it. The thermoelectric plant feeds the steel plant, the rolling mill, the general and auxiliary services as well as some nearby transforming plants pertaining to the same group.

It is interesting to note that all of TAMSA's installations can be fed through one single transformer's set thanks to the parameters stability of the electric power produced by an overdimensioned hydroelectric plant. With SIDERCA, on the contrary, it is necessary to separate the steel shop transformers from those feeding the other installations, in order to deaden the effects of sudden load variations of the furnaces on the other processes.

Milano, 11th September 1963
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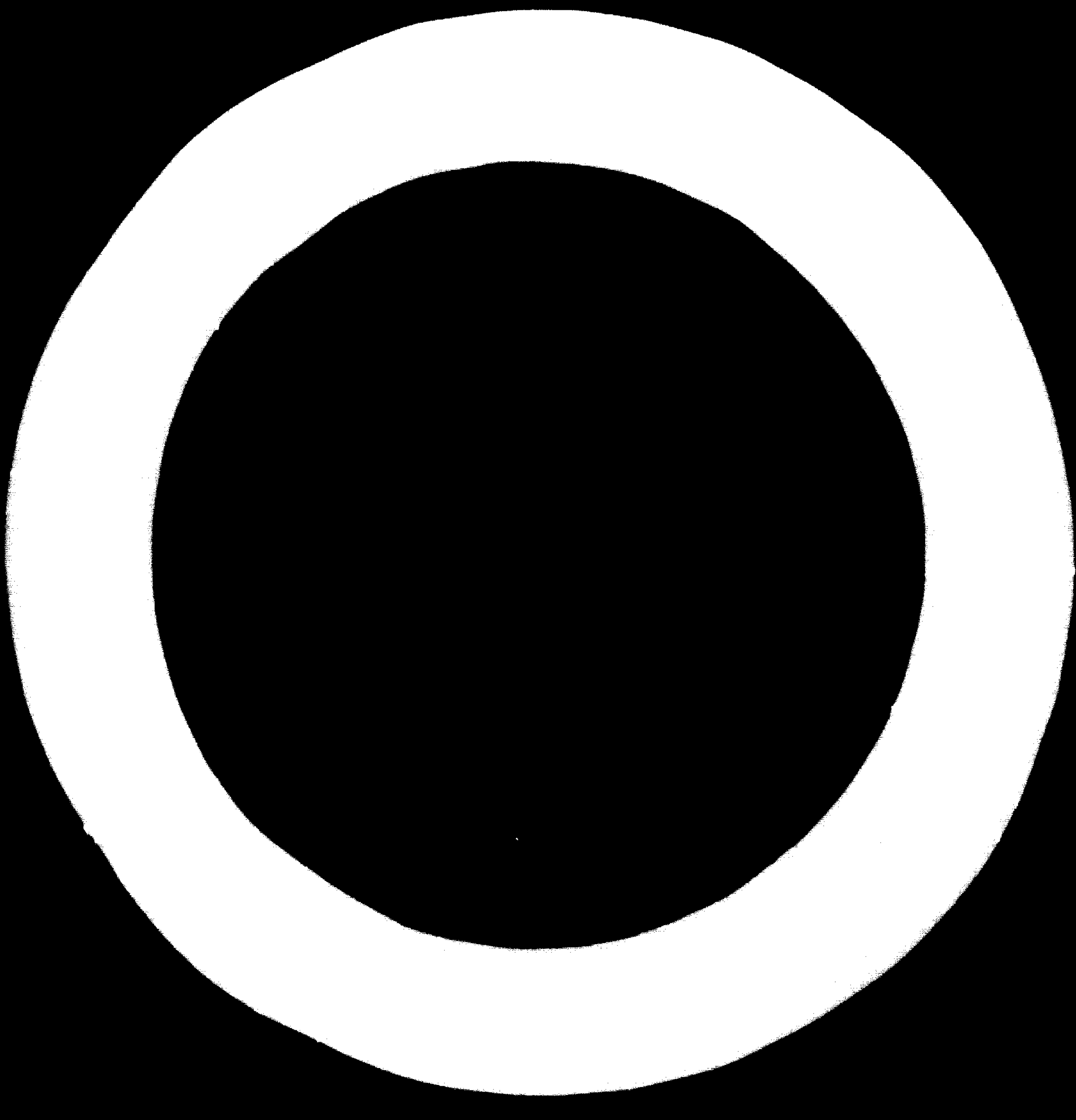

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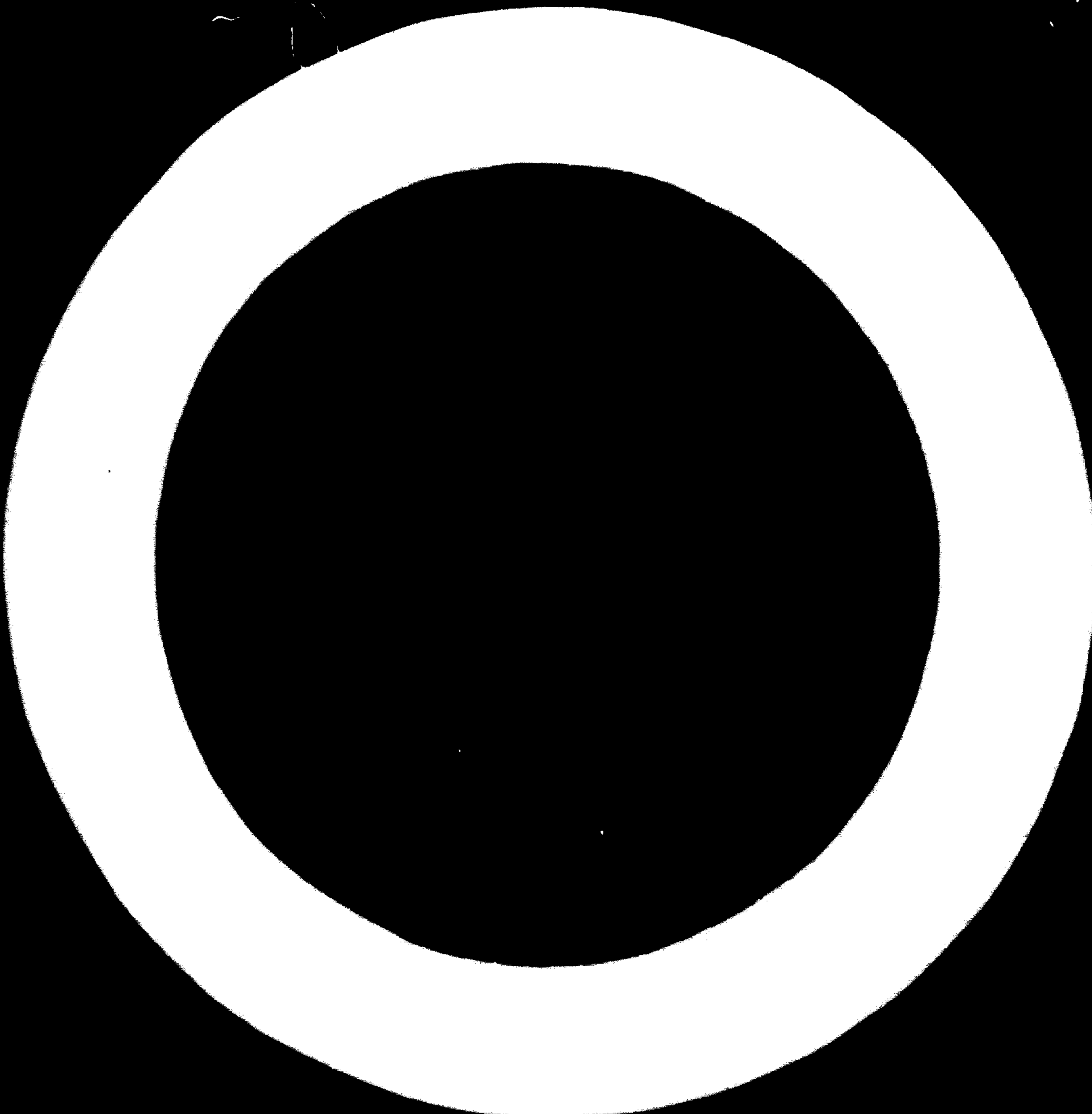


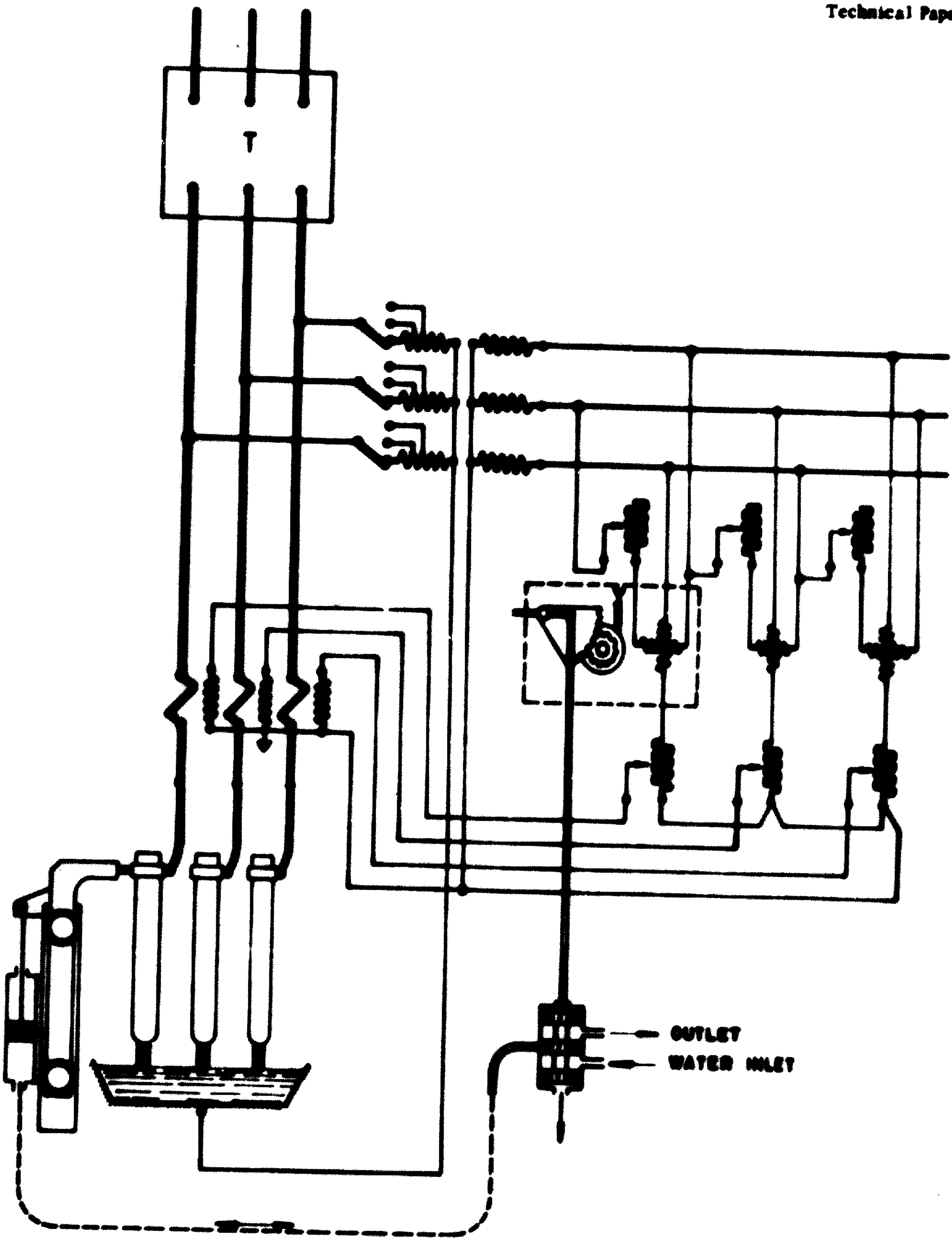


Fig.1 — BASIC SCHEME OF THE HYDRAULIC REGULATION

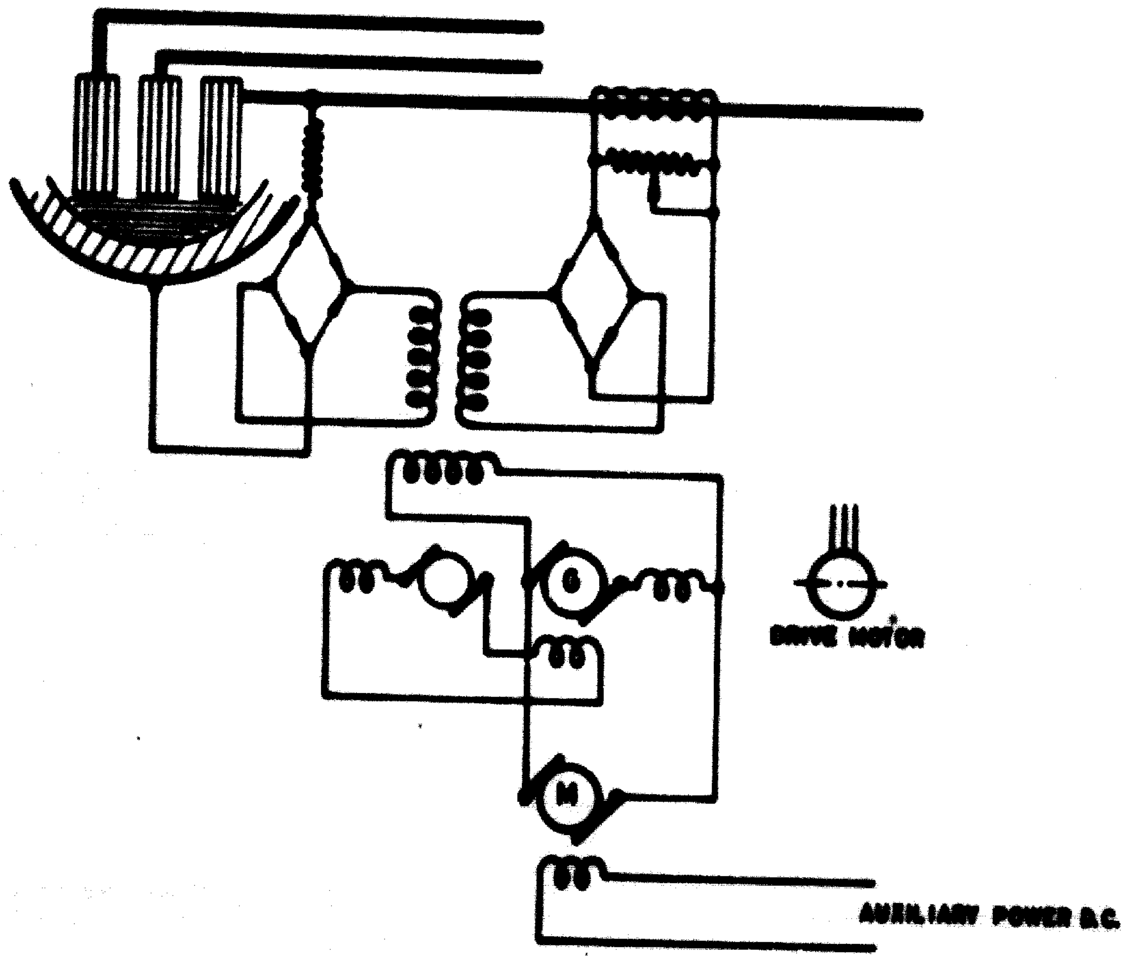
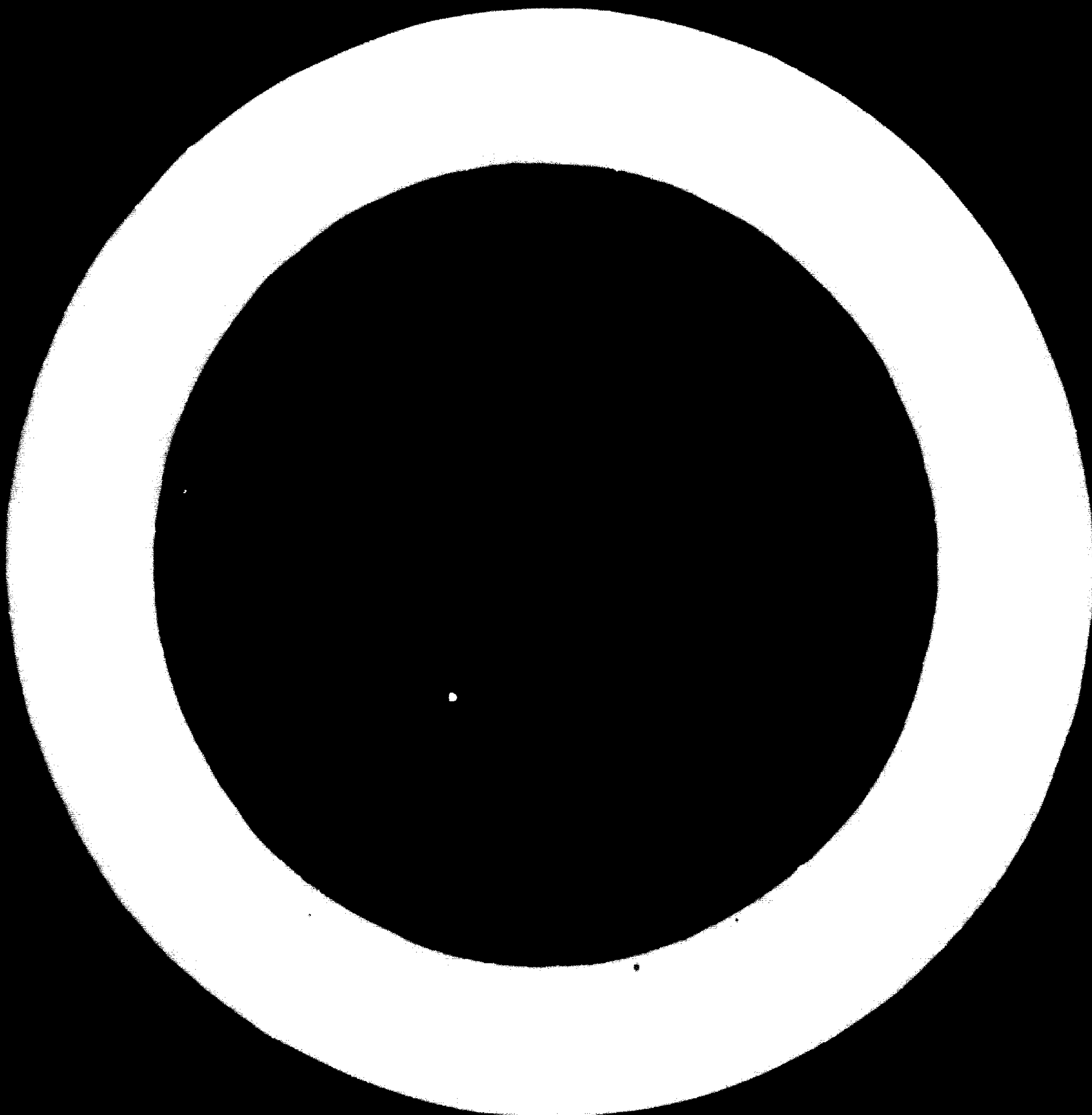


Fig. 2 - ROTOTROL REGULATION. BASIC SCHEME. THREE MACHINES SET FOR PHASE



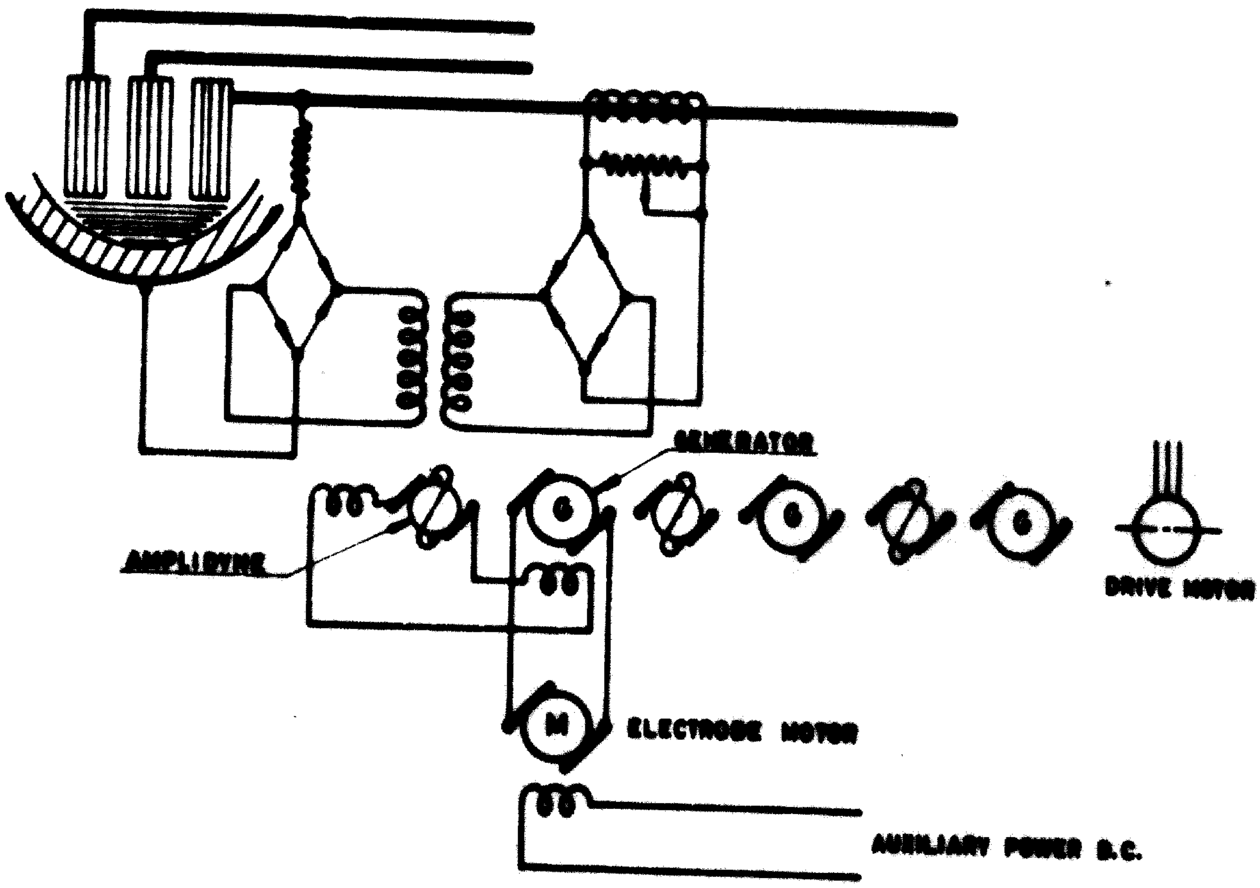
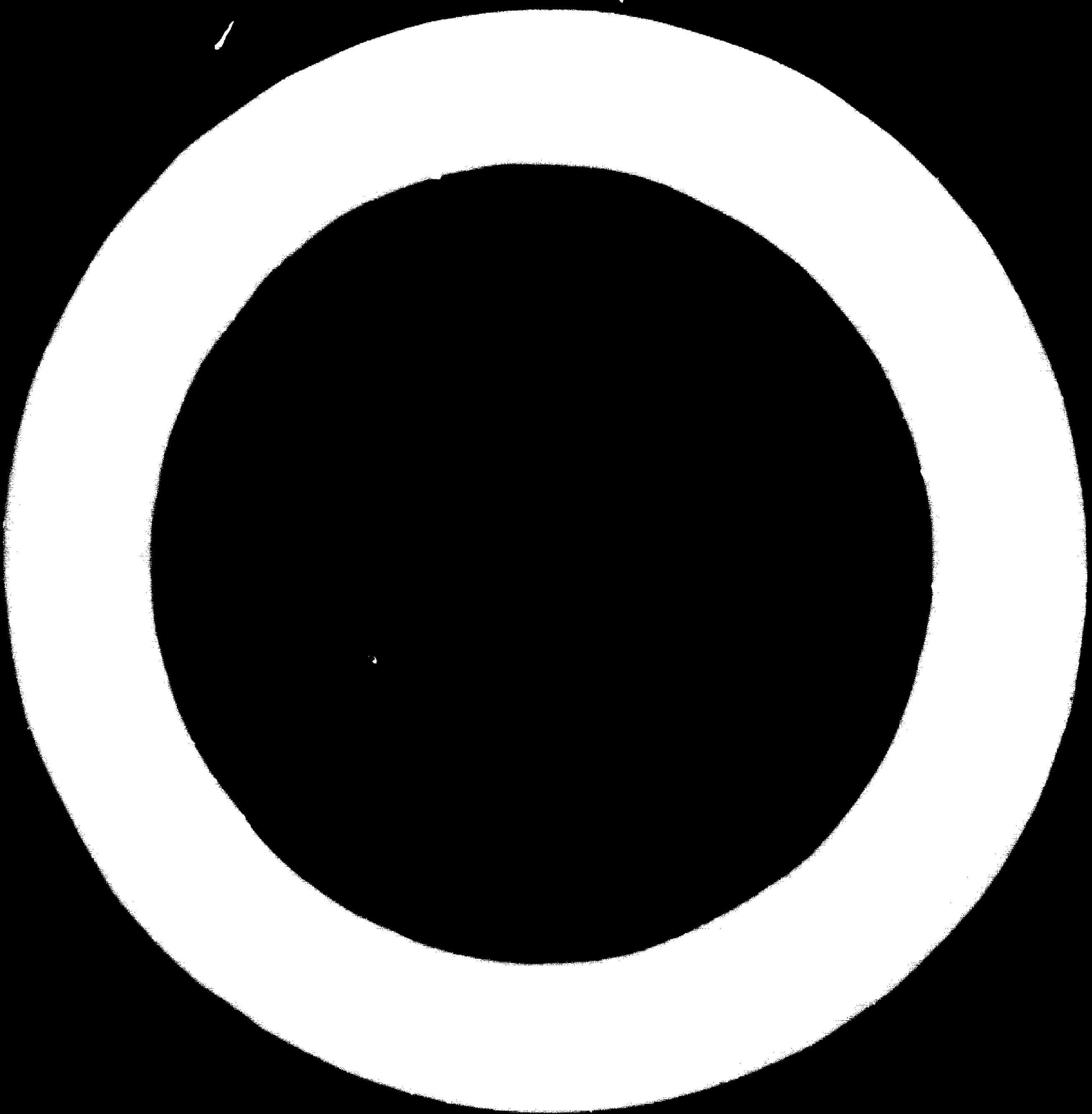


Fig. 3 AMPLIDYNE REGULATION. BASIC SCHEME. SINGLE SET OF 7 MACHINES FOR THREE PHASES



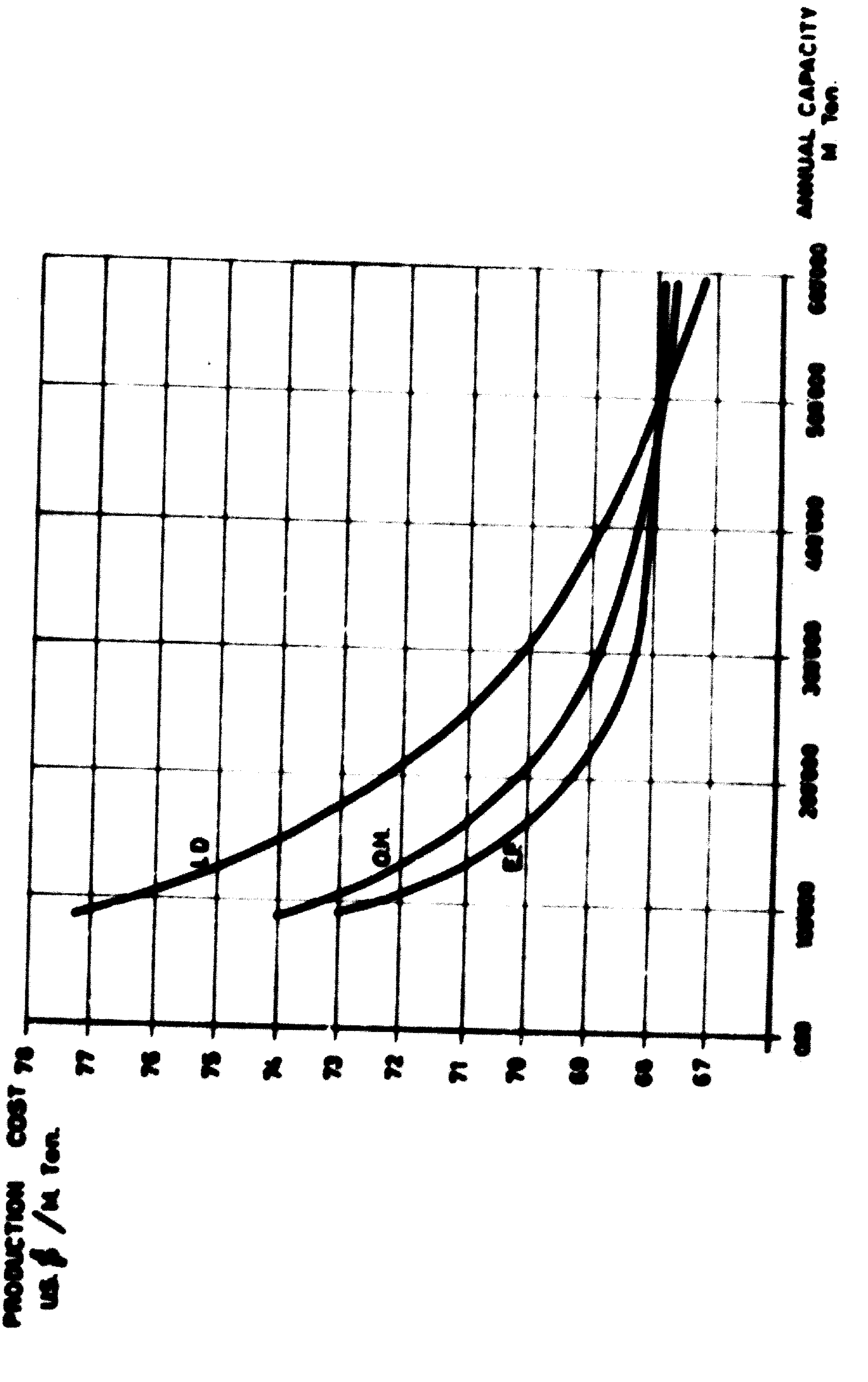
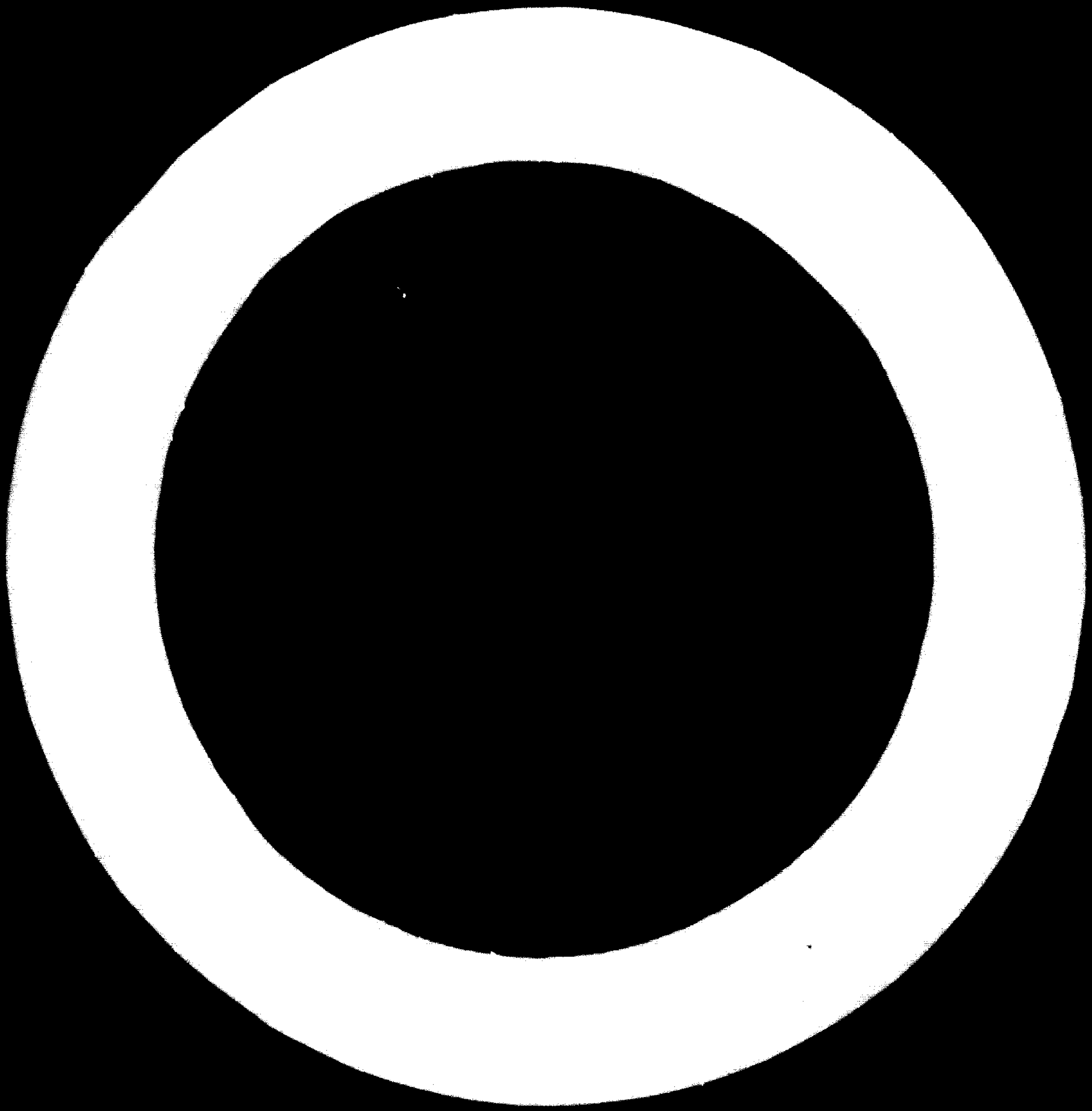


Fig. 4 - PRODUCTION COST IN RELATION TO THE CAPACITY OF THE PLANT



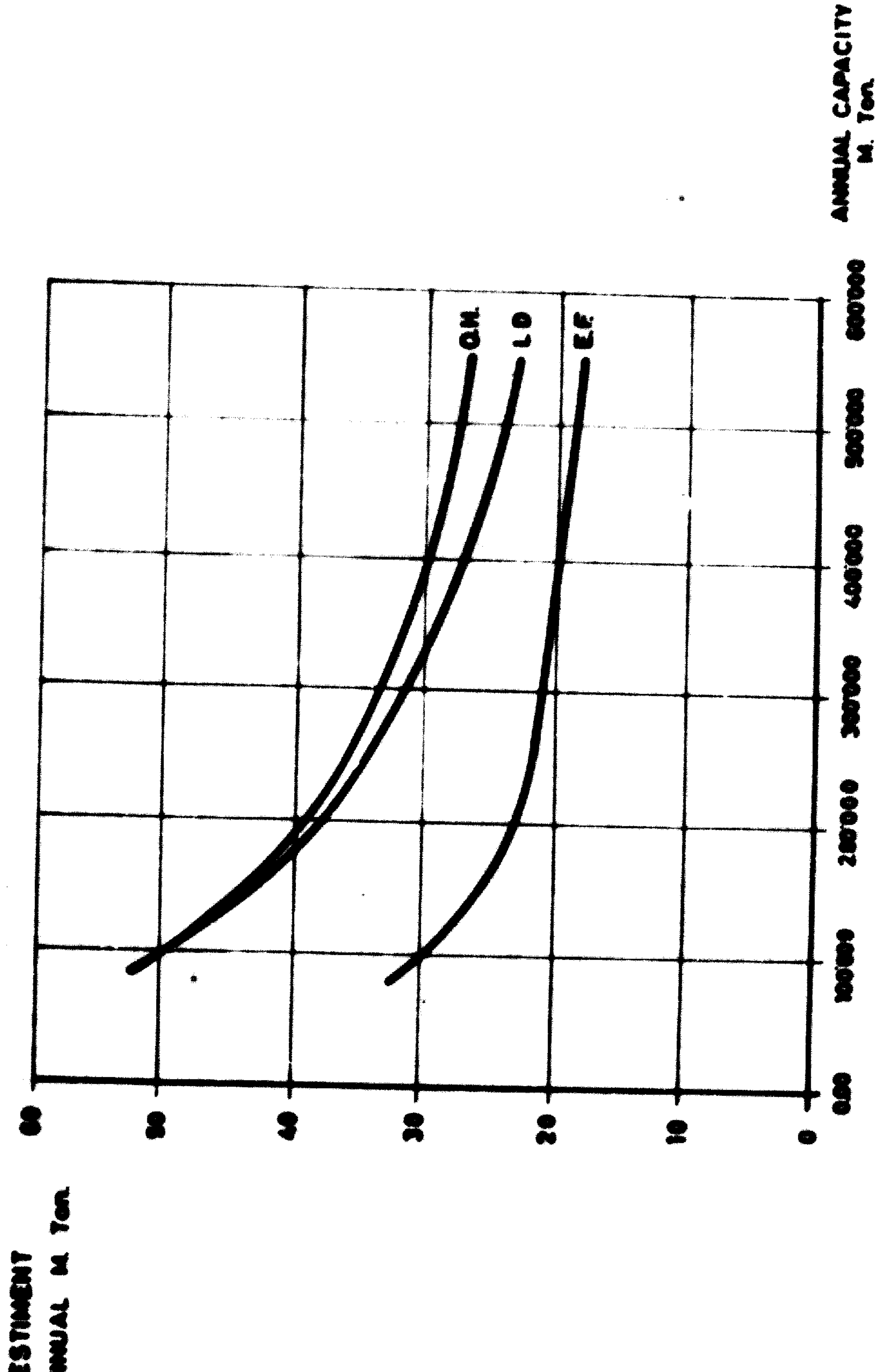
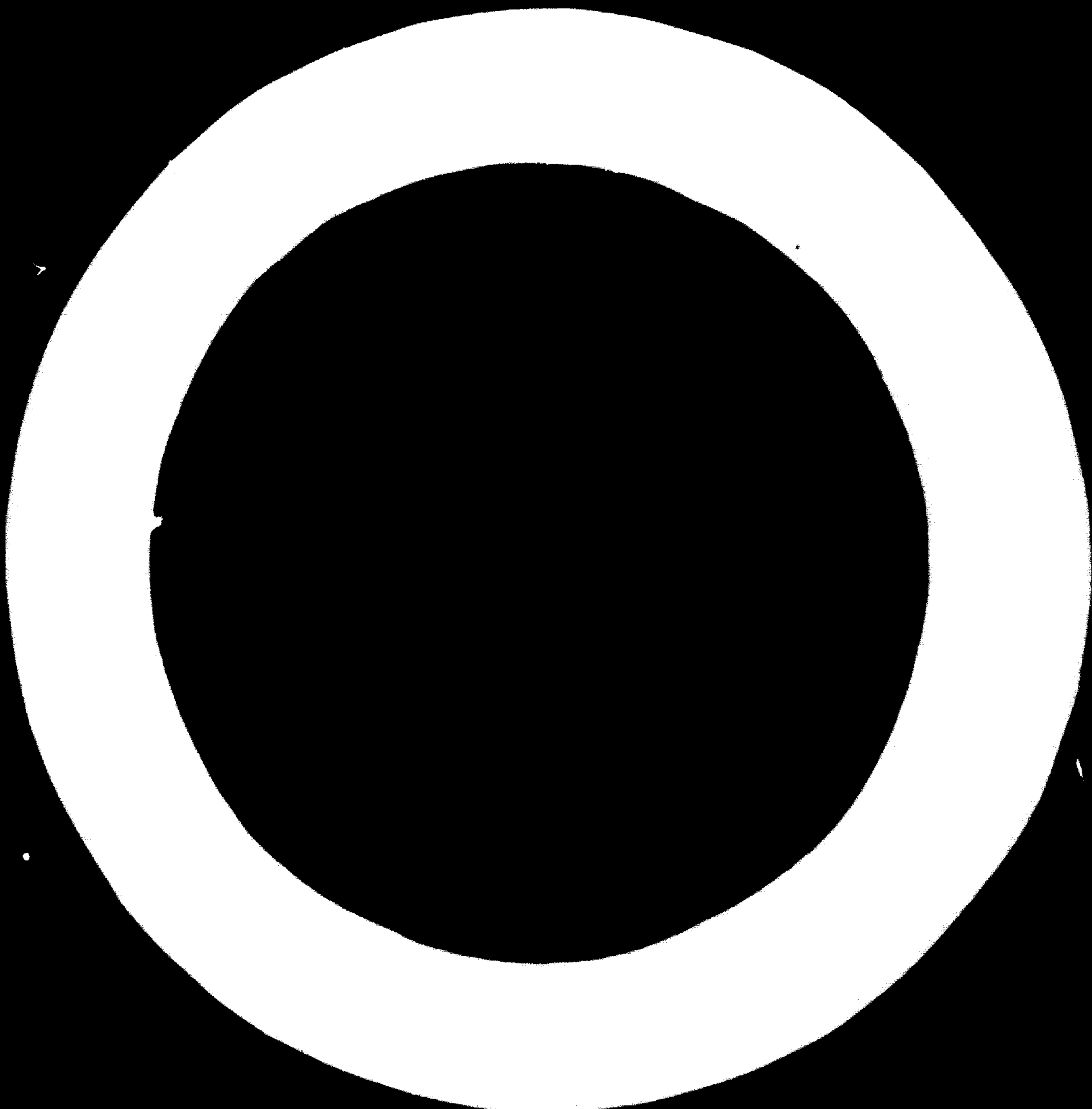


Fig.5 - INVESTMENT IN RELATION TO THE CAPACITY OF THE PLANT



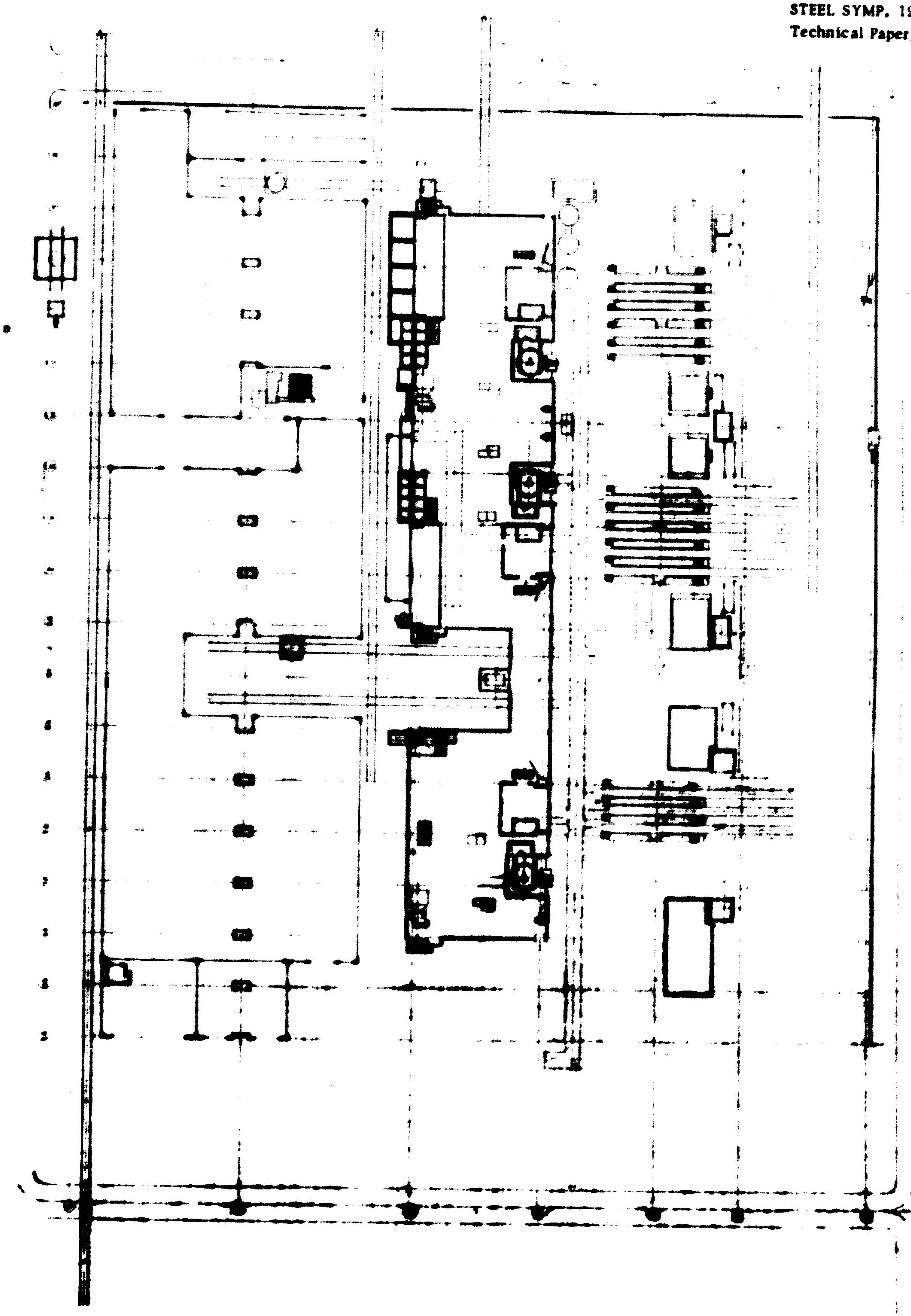
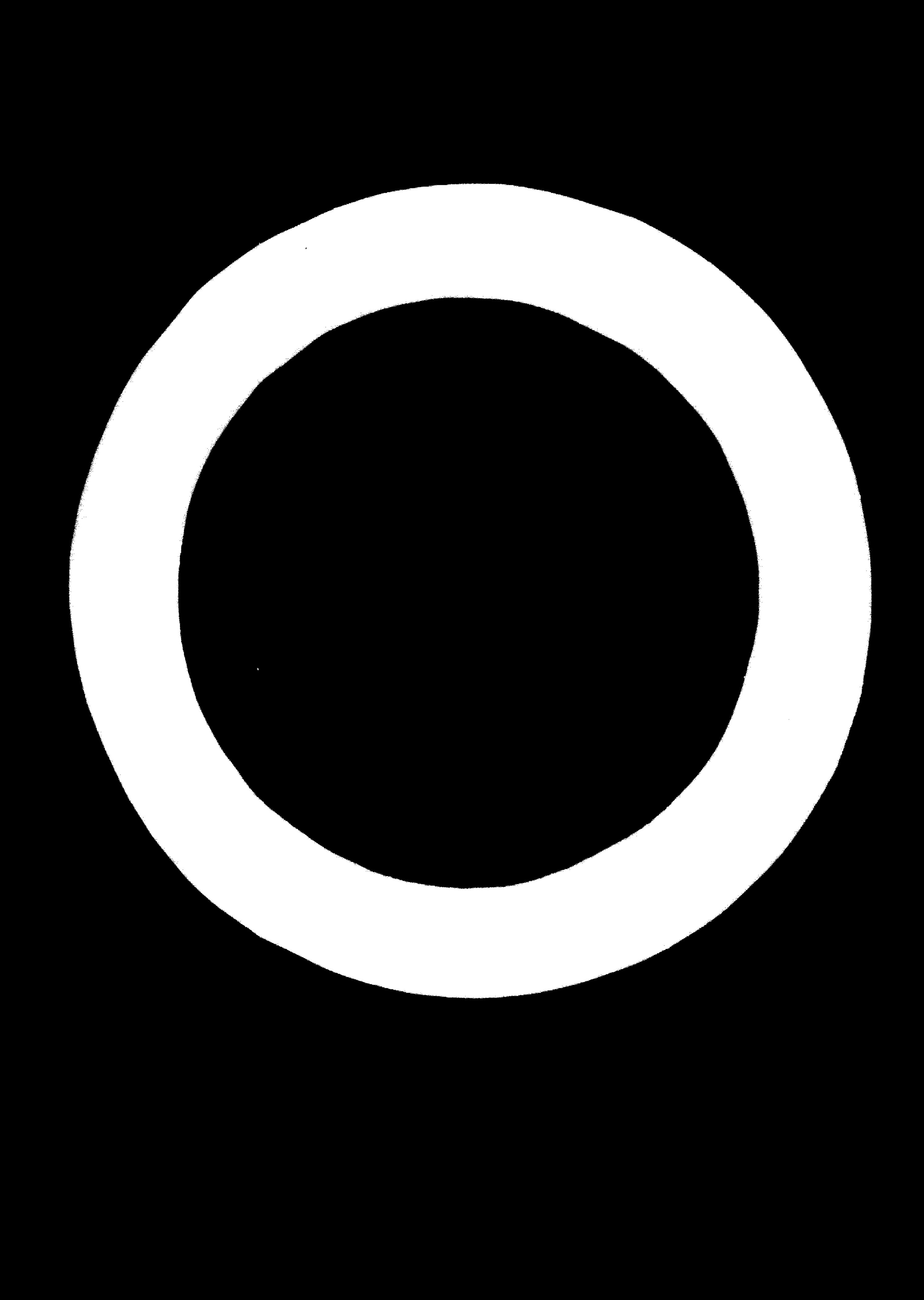


Fig. 6 — TAMSA MELT SHOP — PLAN



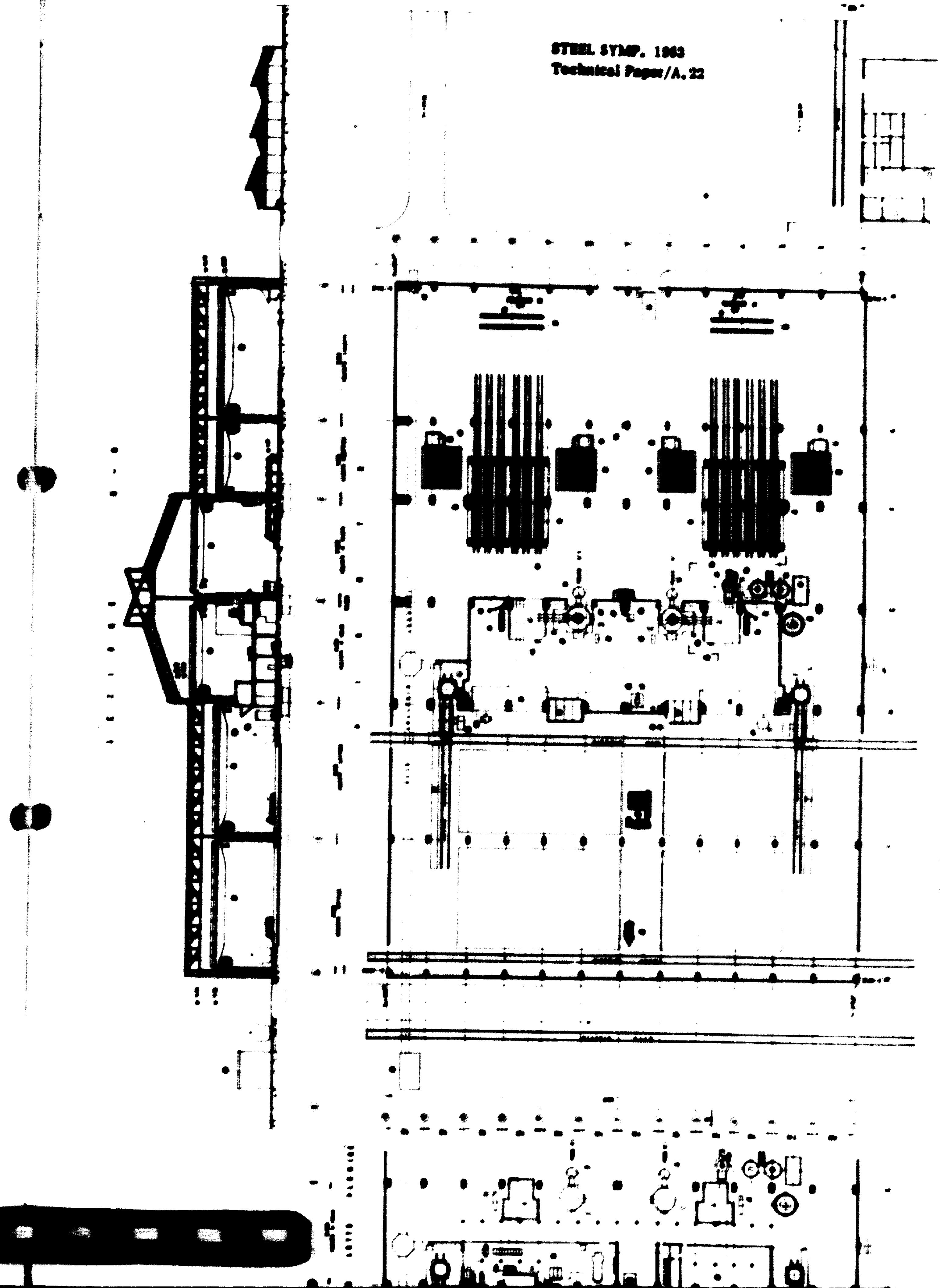


Fig.7- SIDERCA MELT SHOP-PLAN AND SECTION

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