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DEVELOPMENT IN ELECTRIC STEELMAKING[1/]

by

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SUMMARY

The continuous expansion of electric arc steelmaking in the world is very well known .

It must be remembered that electric steelmaking on the one hand and oxygen steelmaking on the other hand are the only processes which are developing in the same time as more ancient processes such as air converter (Thomas, Bessemer) or open-hearth are gradually disappearing .

This paper will be divided in four parts, devoted respectively to :

- the increasing application of electric arc steelmaking to the production of many different types of steel;
- the use of a wider range of raw materials in electric arc steelmaking ;
- the energy aspect of electrical steelmaking, either with scrap or with prereduced iron ores ;
- the evolution of construction and operation of electric arc furnaces .

This survey will be based on recent papers, publications and communications, specially to the Electric Arc Conference, organised by I R S I D , in CANNES (France) in 1971.

I. WIDENING APPLICATION OF ELECTRIC ARC FURNACES TO DIFFERENT KINDS OF STEEL

It is very well known that the electric arc furnace has been specially used since the beginning with the invention of this furnace by HEROULT (2) for alloyed and special steels. As an example, in France, the production of all the electric arc furnaces was, up to now, mainly alloyed and special steels (4). In 1971, France produced 2,314 Millions tons special steel, among which 1,526 Million tons (i.e. 66 %) in electric arc furnace on the other hand, these special steels were 64 % of the total production of French electric arc furnaces (i.e. 2,379 Millions tons steel). A brand new electric arc steelmaking shop, such as the one at ISBERGUES (5), is a good example of such a classical trend around the world where the arc furnaces are used, in all the countries, for a large proportion of special and alloyed steel.

However, in the same time, electric arc furnaces are used for the production of common steel, either in large steelmaking shops or in mini-steel plants.

Fig. 1 gives an illustration of the expansion of electric arc steelmaking in the world.

I.1. Mini-steel plants

The continuous growing of mini-steel plants is very well known and table I gives some estimate capacities, at least for the most important countries (6). This leads to a probable world capacity around 30 Mt steel/year, i.e. about 5 % of the world steelmaking capacity. It must be remembered that mini plants are covering a rather wide range of capacities, starting from around 50 000 t a year and sometimes even less, to plants with capacities over 500 000 t per year.

The classical flowsheet of a mini-steel plant is the following :

- electric arc steelmaking using scrap ;
- casting which was made formerly in small ingots or billets, and which is now, more and more, continuous casting in billets ;
- rolling mills, mainly for bars, wire, rods or merchant profiles.

For such plants, electric arc furnaces are usually in the range of 10 to 60 tons and fig. 2 gives, as an example, the distribution of all the electric arc furnaces in Italy. The statistical data published in Warsaw (7) refers, of course, to all Italian electric arc furnaces, i.e. including those producing alloyed steels. However, the production of all these furnaces can be divided approximately as follows :

- 2 Mt of special and alloyed steels,
- 6 Mt of common steel, produced in mini steel plants.

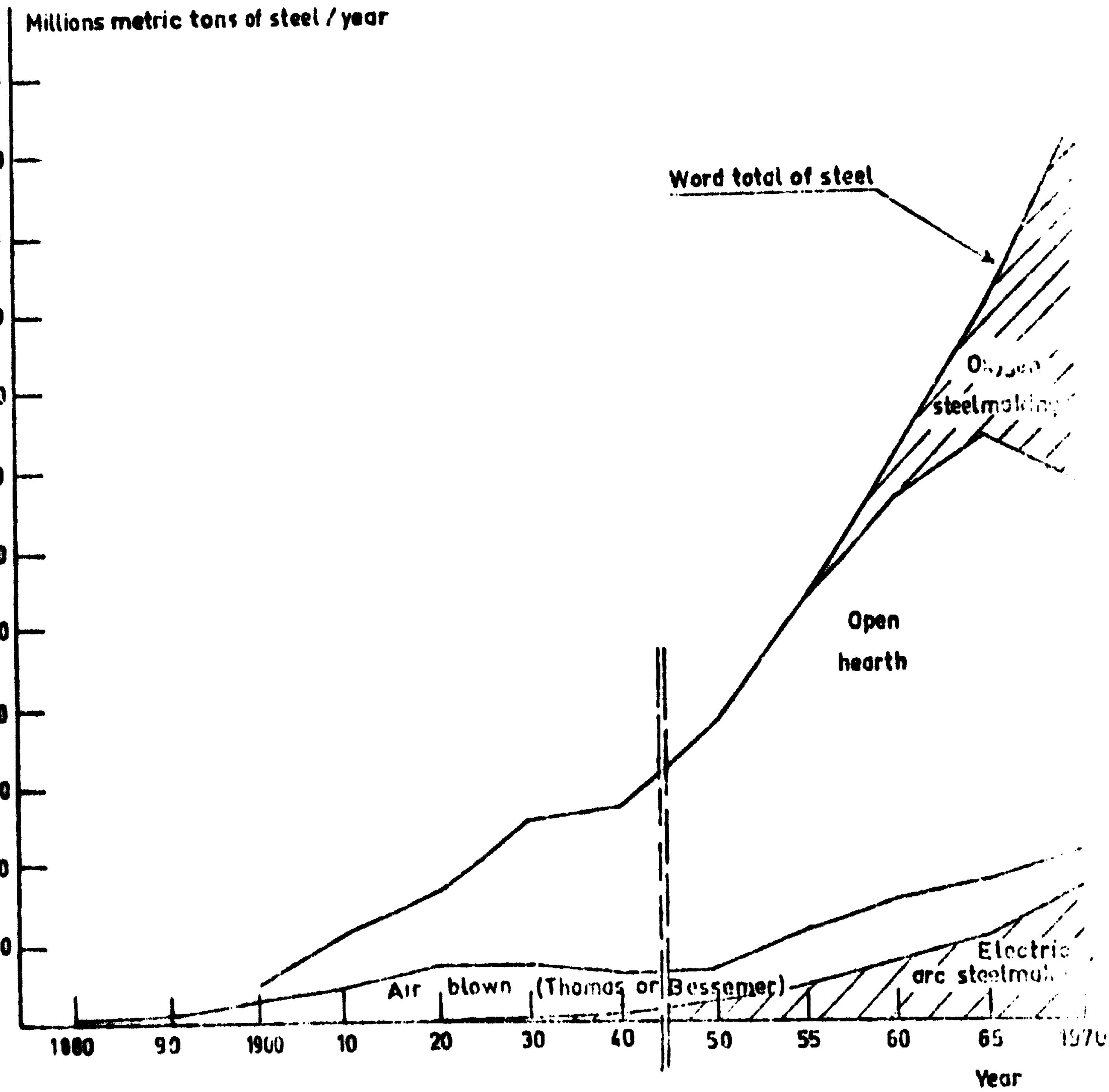


Fig. 1 - Growth of world electric arc steelmaking

TABLE 1 - Estimated world capacity of mini steel plants (from Luth (5) and additional data).

Country	Capacity Mt steel per year in mini steel plants	Remarks
USA	6	5 % of total steel of this country
Italy	4 to 5	25 % "
Spain	3	40 % "
Switzerland	0.2	36 % "
Federal Republic of Germany	1.2	2.6 % "
Brazil	2	38 % "
Japan	8 to 12	10 % "
Mexico	1	25 % "
Approximate world total	30	around 5 % of world total production of steel

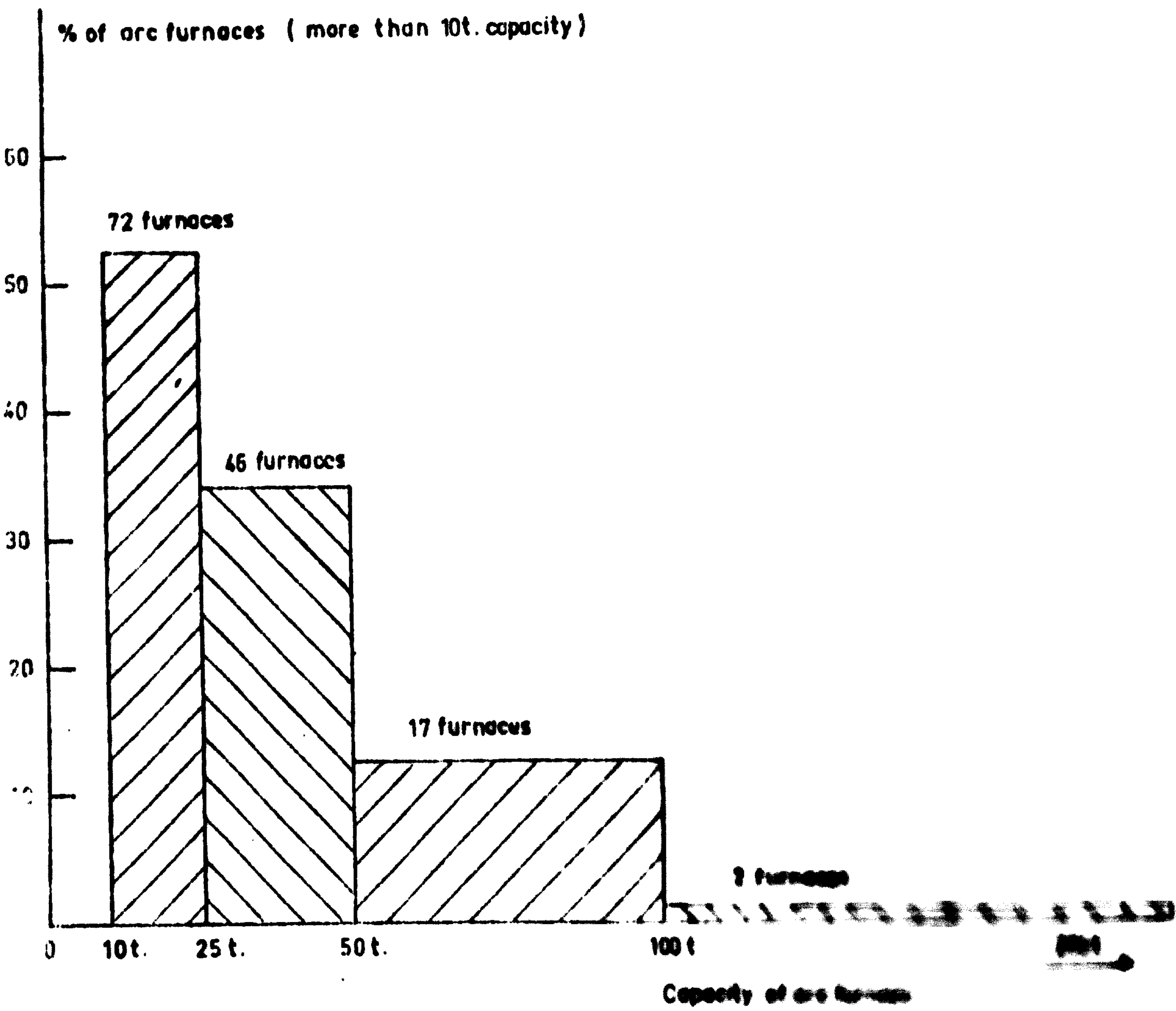


Fig. 2 – Distribution of electr

Figure 2 show clearly that in around 60 mini-steel plants in Italy, there are about 1[illegible]0 furnaces, practically all of them with capacities between 10 and [illegible]0 tons. The situation is, practically, exactly the same in Japan as illustrated by figure 3. On the other hand, the newest mini-steel plants in Italy and Japan but also in Germany, United Kingdom, U.S.A., France, etc. have furnaces slightly bigger, say around 60 t up to 50 t for some of them.

I.2. Development of large electric arc steelmaking shops

On the other and, compared to the mini-steel plants, a number of large electric arc steelmaking shops have been built in recent years. We mean electric arc steelmaking shops in the range of 0.[illegible] to 2 Mt per year. Tables II and III give some ideas of the number of such plants in the United Kingdom and the United States. This situation is reflected in figure [illegible], where it can be, clearly, seen that distribution of arc furnaces in United Kingdom, according to sizes, is different from Italy (see figure 2) and Japan (see figure 3). A number of them have been described in the technical literature during recent years and it is interesting to know that some of them have been built not only for sections, such as bars, profiles, etc., but also for flat products, specially plates (8).

II. WIDER RANGE OF RAW MATERIAL FOR ELECTRIC ARC STEELMAKING

As it is very well known, the electric arc furnace is generally using solid cold raw material, and mainly scrap. In a review from United Nations (9), it is shown that scrap makes up to 97 or 98 % of the metallic charge of electric arc furnace. On the other hand, the electric arc furnace can consume a more or less important part of the scrap, depending on several factors and, specially, the relative part of the different steelmaking processes (see table IV).

With the rapid disappearance of open-hearth furnaces, electric arc furnaces are the main users of growing tonnages of scrap which are existing in industrialized countries. The case of the U.S.A. is specially illuminating in this respect and it has been several times published that in the long range, up to 40 to 45 % of the steel production of the U.S.A. could be made in electric arc furnaces by melting scrap.

However, scrap can be :

- of insufficient quality to produce quality steel specially carbon steel [illegible]
- insufficient in quantity, specially in underdeveloped or developing countries where the evolution of local scrap is slow.

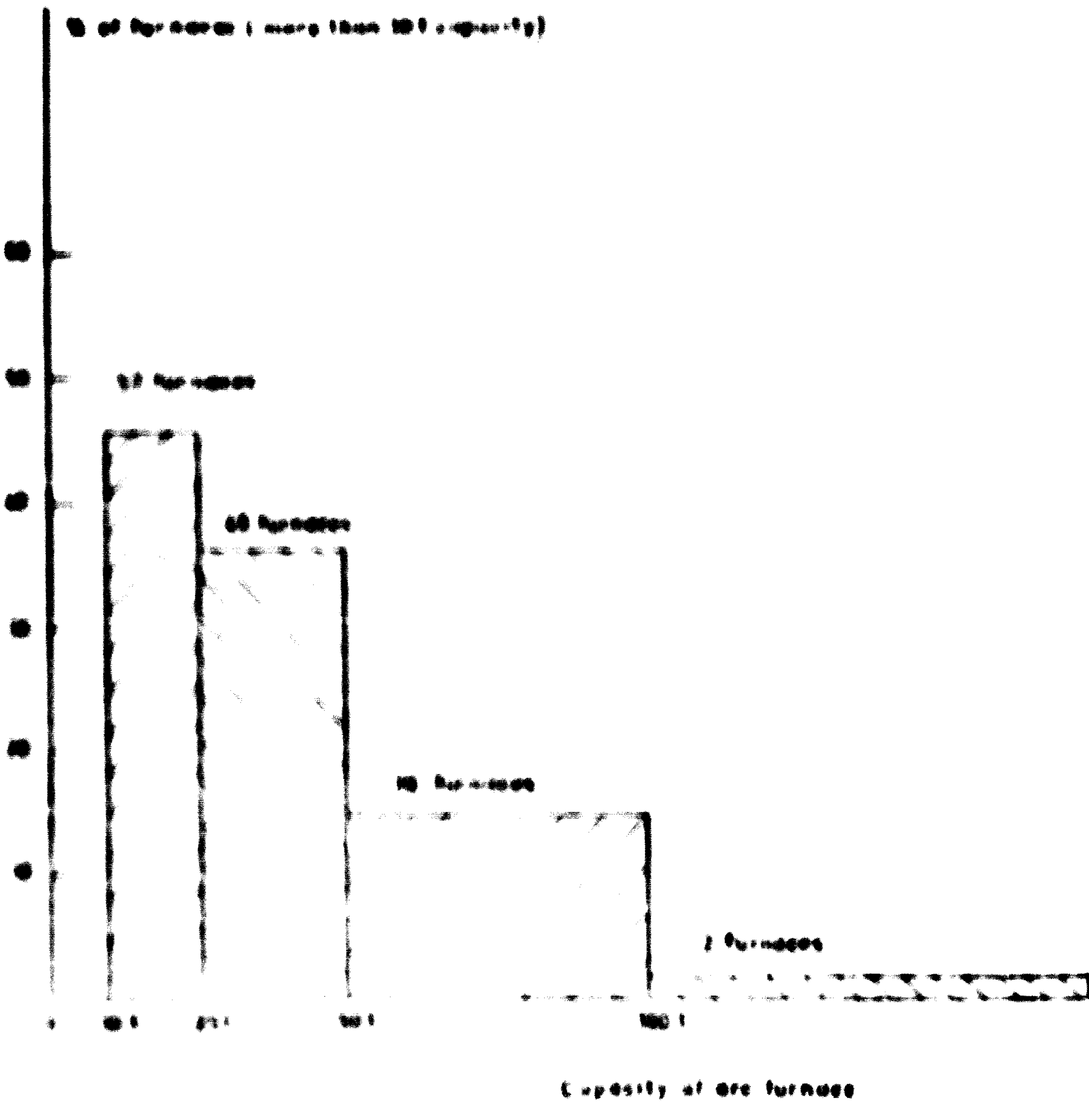

Capacity of arc furnace

TABLE 11 - Number of plants in United Kingdom using only electric arc furnaces to produce steel (at end of [illegible])

Capacity	Number of plants
From [illegible] to 100 000 t steel/year	[illegible]
From 101 000 to 500 000 t "	[illegible]
From 501 000 to 1 000 000 "	[illegible]
Above 1 000 000 "	1
Total	10

[illegible] large electric arc steelmaking plants in the [illegible] (15) in 1972).

[illegible]	Furnaces capacity in short tons	Production 1970 short tons
[illegible] STEEL [illegible]		
[illegible]	6 x 175 t	957 000
LACLEDE STEEL		
Alton, Illinois	2 x 225 t	763 000
LUKENS STEEL		
Coatesville, Pennsylvania	2 x 100 t 1 x 150 t	600 000
NORTHWESTERN STEEL AND WIRE	2 x 150 t	
Sterling, Illinois	1 x 250 t 1 x 400 t	
REPUBLIC STEEL		
Canton, Ohio	7 x 200 t	
UNITED STATES STEEL		
Texas Works, Baytown, Texas	2 x 200 t	
Fairless Works, Pennsylvania	2 x 200 t	

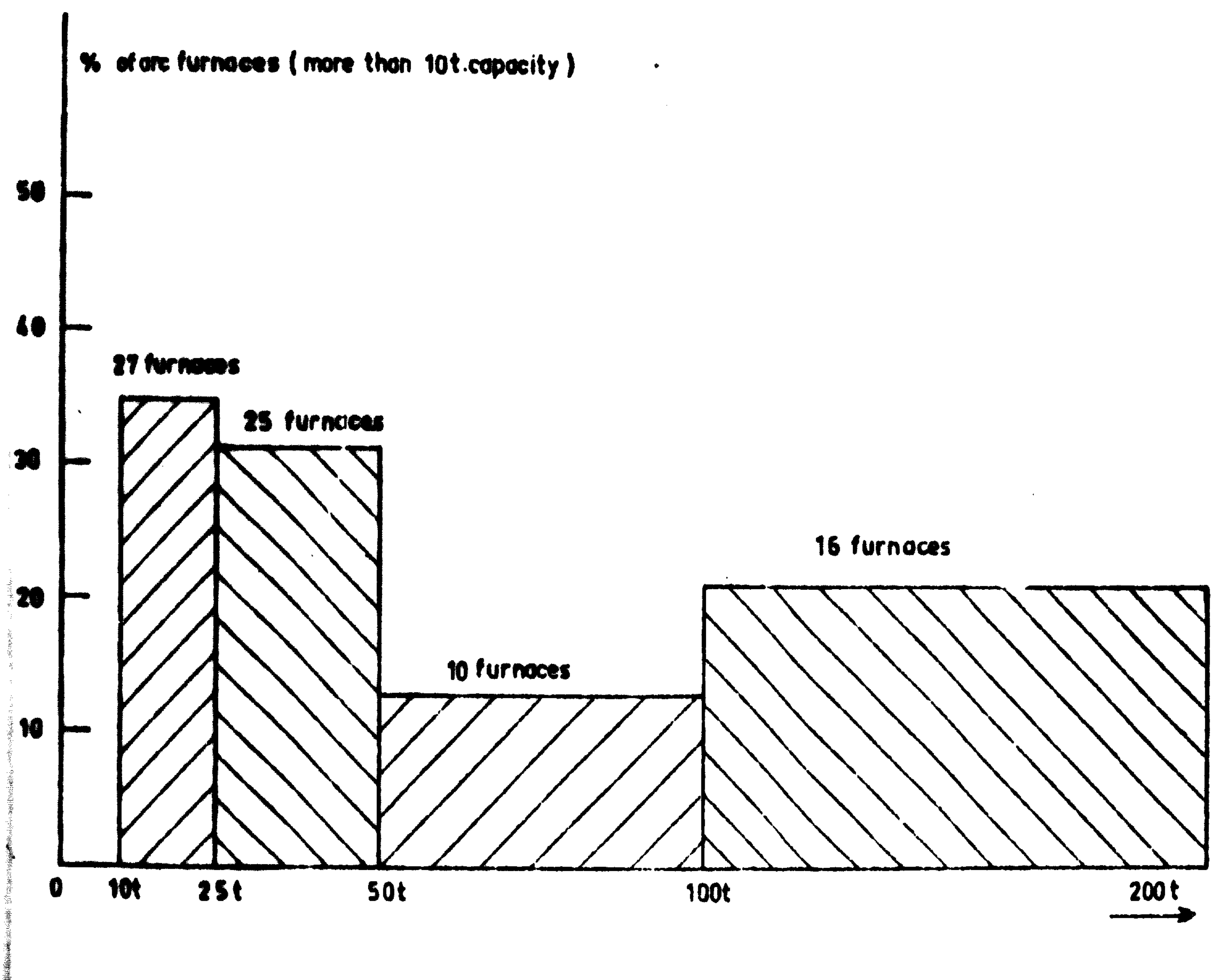


Fig. 4 - Distribution of electric arc furnaces in the UK

TABLE IV - Utilization of scrap in different steelmaking processes for three selected countries in 1969

Country	USA		Italy		Japan	
Use of scrap	Mt/year	%	Mt/year	%	Mt/year	%
in open-hearth (Mt / %)	28	43	2.6	25	3	10
in oxygen converters (Mt / %)	18	27	1.0	9	14	45
in electric furnaces (Mt / %)	20	30	6.9	66	14	45
Total Mt scrap / %	66	100	10.5	100	31	100

About this last point, several studies, such as the one made by Mr ROCA (10) show clearly that, if a given country or a given area is developing very fast, specially as regards iron and steel utilization, the quantity of arising scrap will be insufficient to sustain the production of electric arc furnaces.

In this context, a number of tests and practices have been developed to use :

- either hot metal or pig iron. In this respect, we must mention the interesting work done some times ago in CHIMBOTE (Peru) and, more recently, at ARMCO STEEL Corp. in HOUSTON (Texas) (11) ;

- prereduced iron ores. This is an important subject to which we will devote more consideration.

II.1. Prereduction of iron ores

During recent years, there has been a gradual increase in production of prereduced iron ores. Figure 5 shows the development of production of prereduced iron ores, considering only prereduced materials that are used in electric arc furnaces. In this respect, a number of interesting developments have been made, specially to charge continuously such granulated material as prereduced iron. It must be noted that such developments can also be applied to fragmentized scrap such as shredded scrap.

Figures 6, 7, and 8 show three typical designs and layouts of continuous charging equipment used in electric arc furnaces. They are leading to interesting development in the way of charging and melting continuously the charge of electric arc furnace and open the door to automation (12) (see figure 9).

II.2. Scrap prices

Another advantage in the development of prereduction processes could be a stabilization of the cost of the metallic charge of electric arc furnaces.

Scrap prices are, as it is well known, fluctuating in a very wild way (see figure 10) (9). More recently, scrap prices have, in Japan, as an example, increased from the range of 40-50 U.S. dollars/t delivered to plant, up to more than 80 U.S. dollars/t within two months !

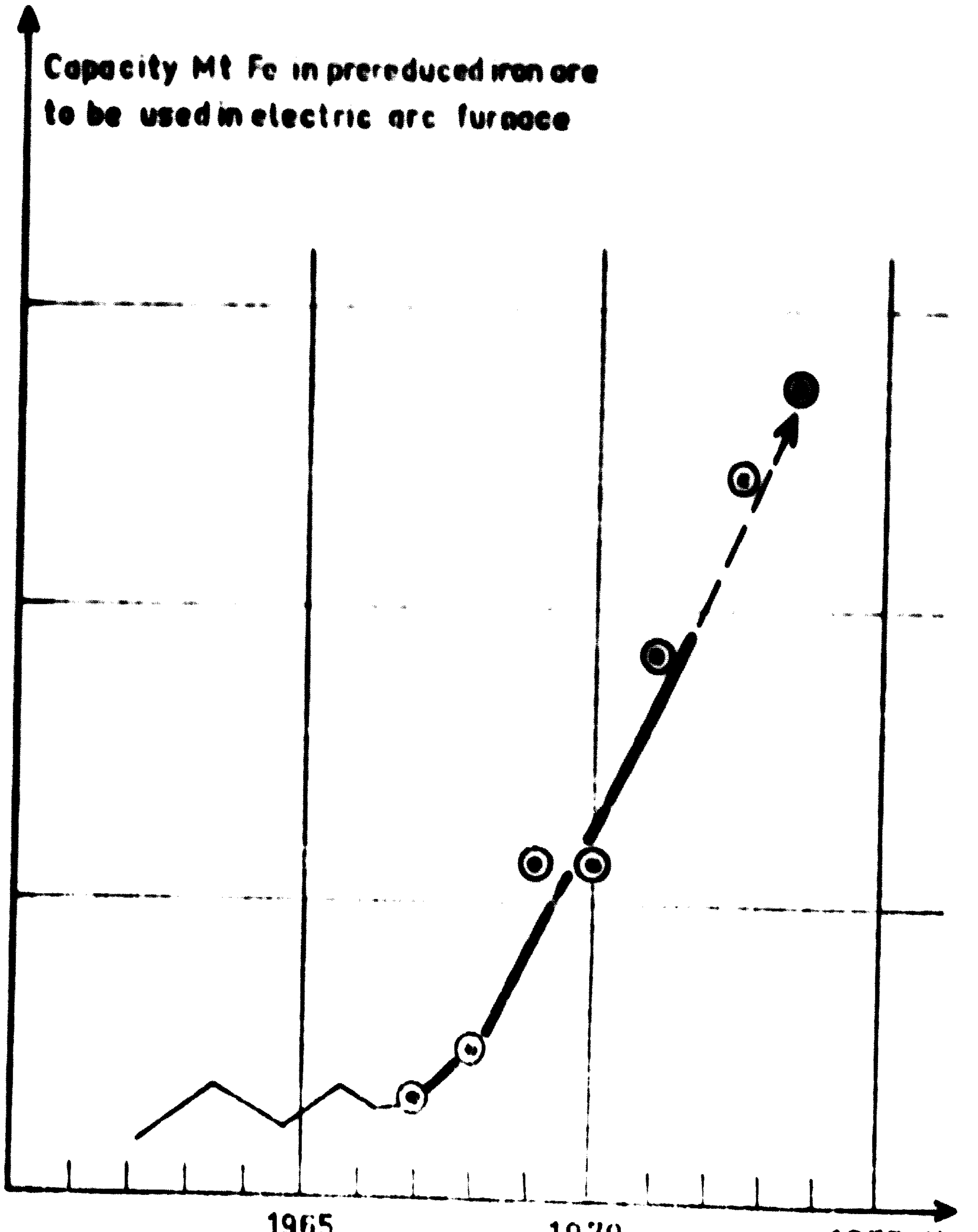


Fig. 5 – Approximate [illegible] from prereduced iron ore

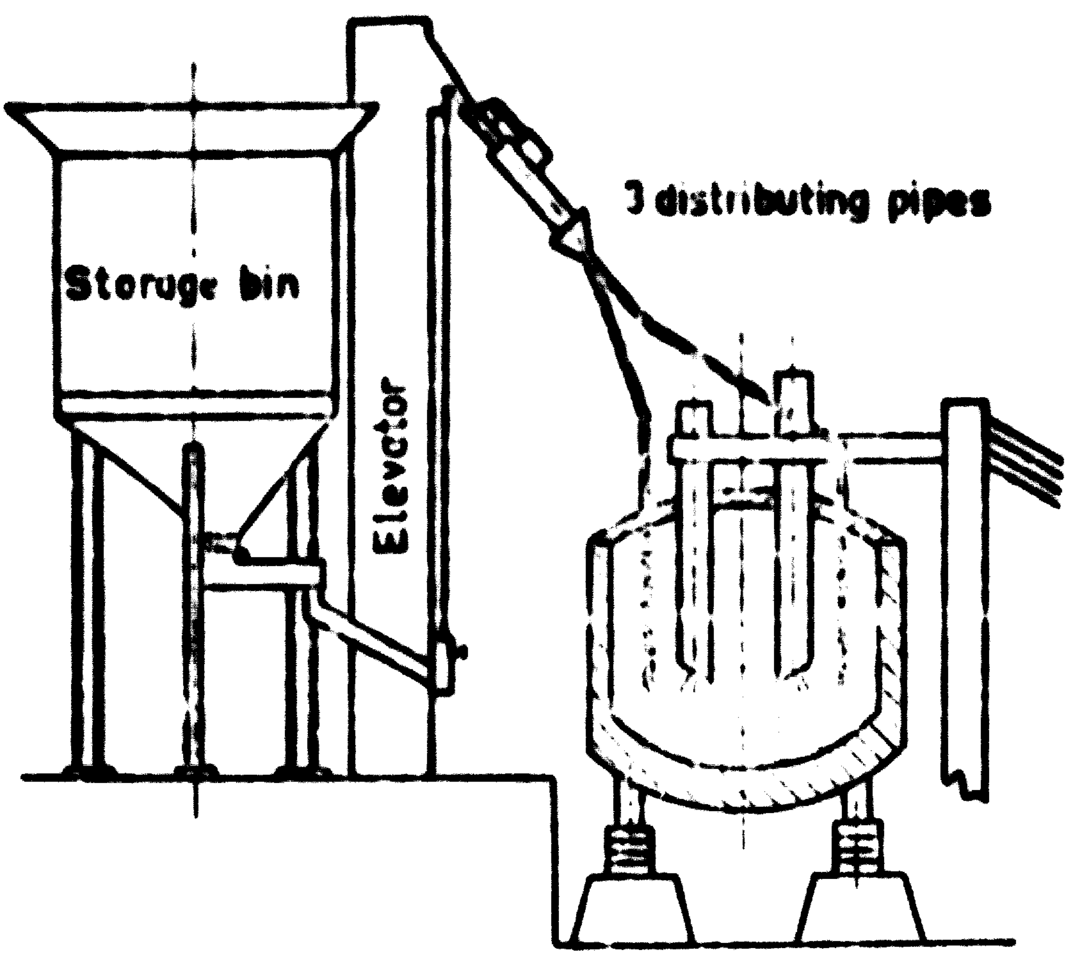


Fig. 6 - The Contimelt continuous charging system

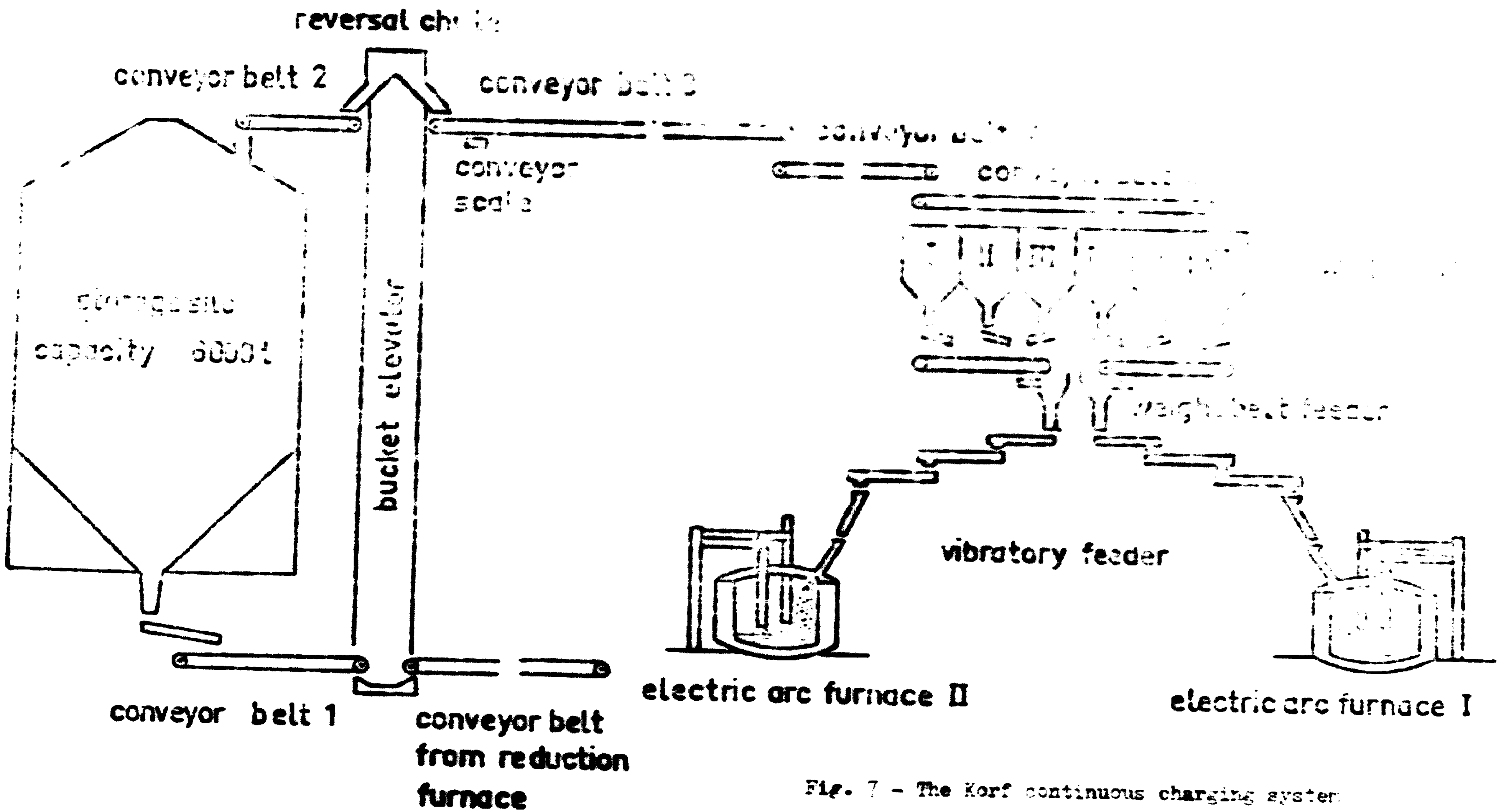


Fig. 7 - The Korf continuous charging system

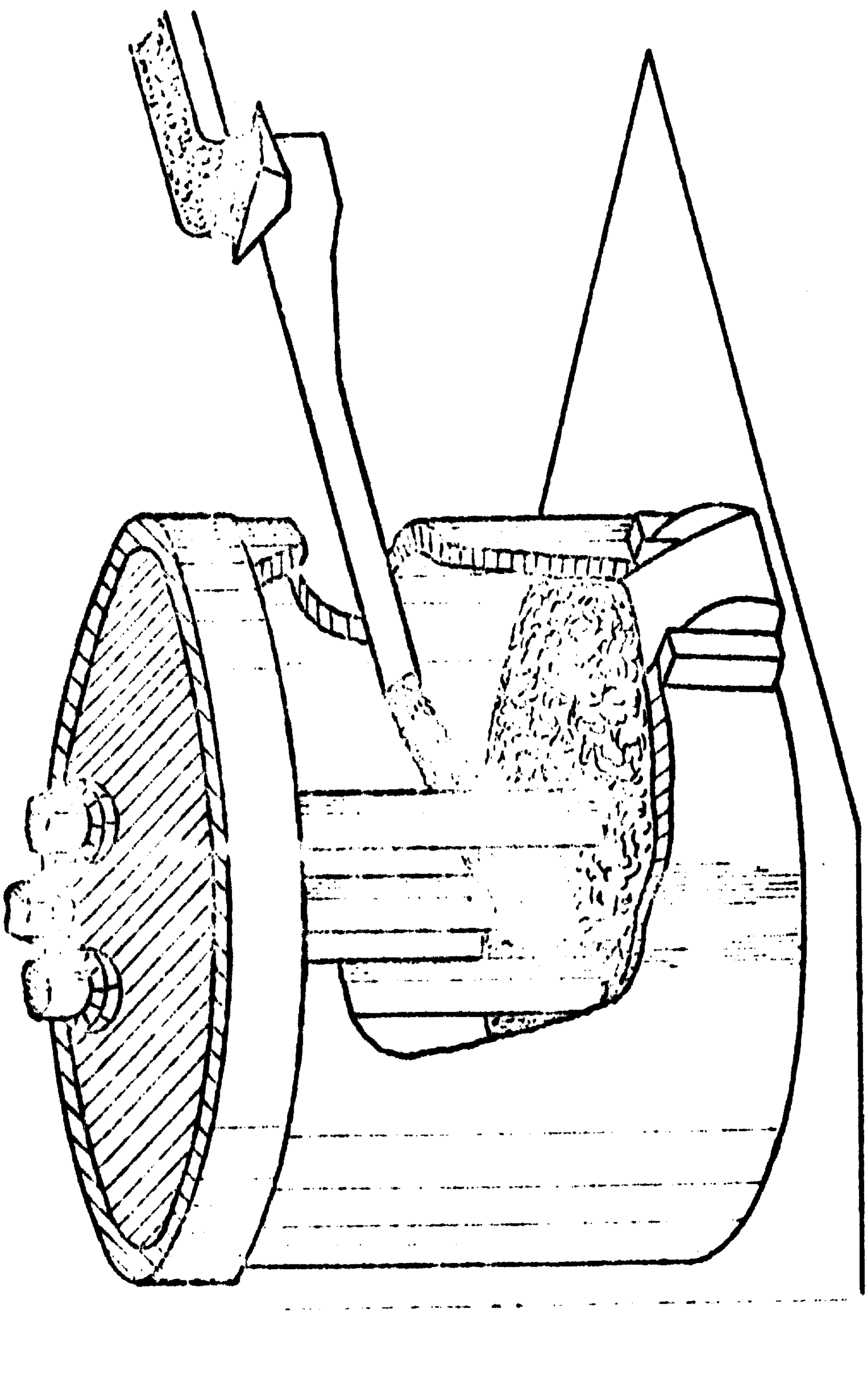
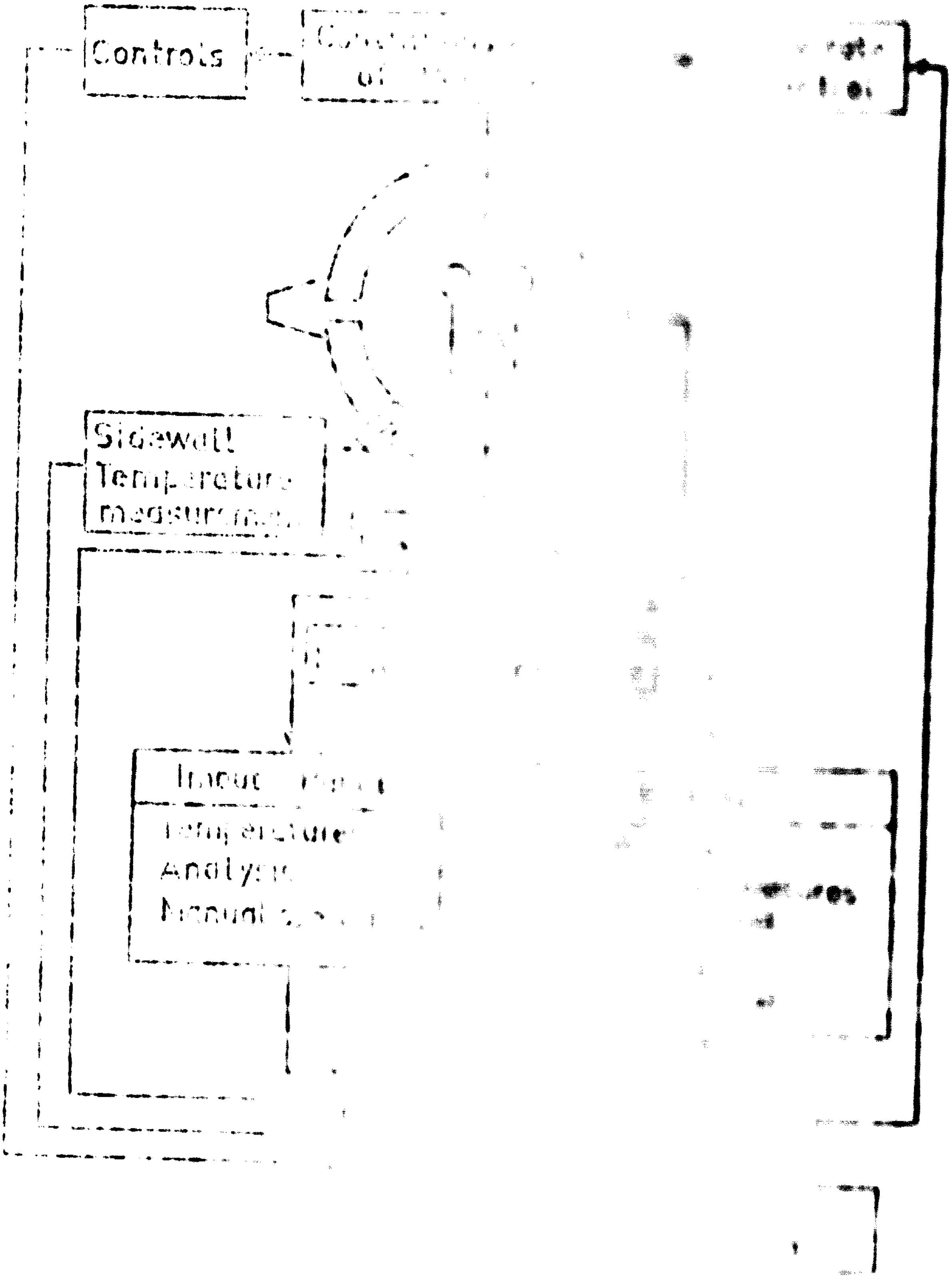
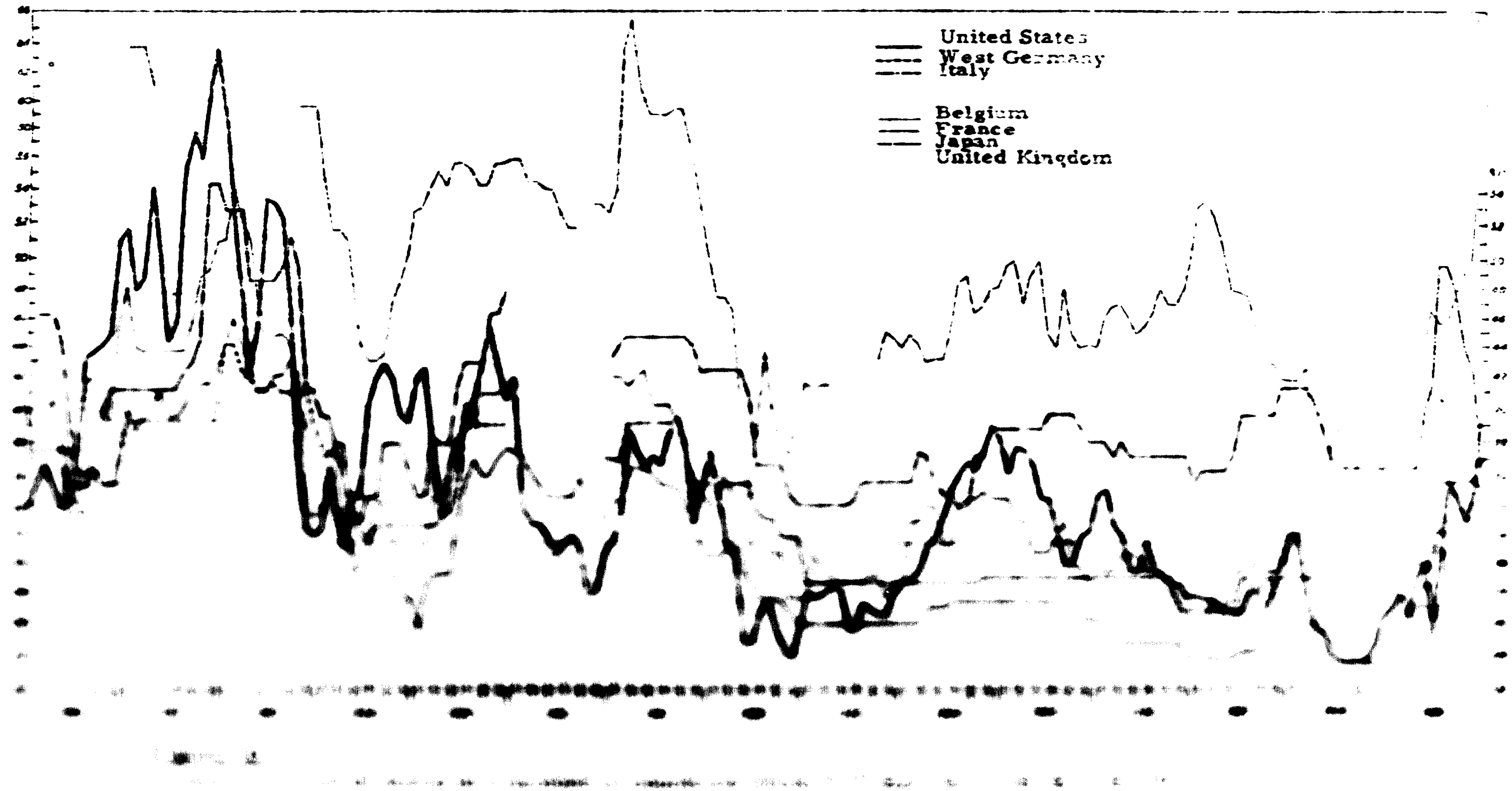


Fig. 8 - The Tamsa continuous charging system


Controls
Sidewall


United States
West Germany
Italy
Belgium
France
Japan
United Kingdom

[illegible]

Compared [illegible] flowsheet, i.e.

- [illegible] of hot metal in [illegible] furnace,
- conversion of iron into steel in oxygen converter,

electric [illegible] melting has several advantages :

- low cost investment, which is in the range of 20 dollars per ton of steel (excluding rolling mills) compared to more than 100 dollars ([illegible] excluding rolling mills) for the combination blast furnace + oxygen steelmaking ;

- utilisation of electrical energy, which can be produced from many different kinds of primary fuels, compared to the classical flowsheet, which is using still a rather large quantity of high-cost coke.

In fact, starting from scrap, electric arc melting needs only about [illegible] kWh per metric ton of liquid steel, i.e. :

- about 0,[illegible] M kcal equivalent per metric ton of liquid steel, (i.e. [illegible] BTU) ,

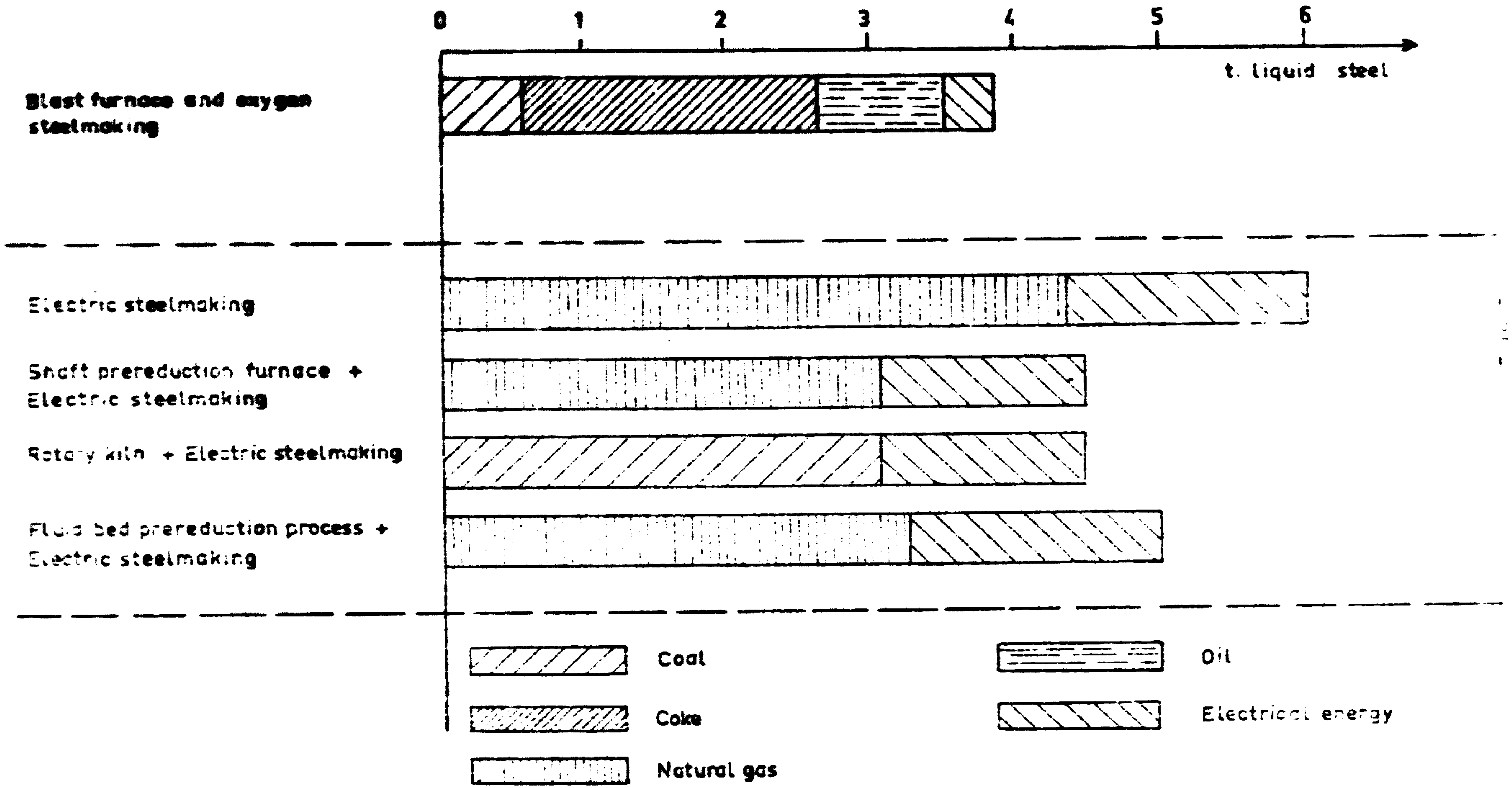
- about 1,[illegible] M kcal to produce this electrical energy in a conventional power plant (i.e. 5.4 MM BTU).

This comparison, of course, is not fair in that the electric arc furnace, in such conditions, is starting from scrap. If we want to use iron ore, [illegible] to a possible flowsheet incorporating prereduction, as we mentioned previously. In such case, we can produce steel from iron ore with total energy consumption, which can be quite attractive compared to the classical flowsheet. Figure [illegible] gives, in this respect, comparison of the energy balance for all these [illegible] ([illegible]). It can be seen that total energy consumption for such flowsheets is comparable to the best "classical scheme" operations and if gas or oil is cheaper than solid fuel, such new concepts for iron and steel production [illegible] quite attractive.

[illegible] [illegible] AND OPERATION OF ELECTRIC ARC FURNACES

[illegible]

[illegible] electric arc furnaces are built [illegible] to a maximum of 360 metric tons [illegible] operating in [illegible] Western Steel [illegible] large number [illegible] heat size)



[illegible] per metric ton of steel for different [illegible]

TABLE V - Large arc furnaces in operation or under construction from Schwabe and Robinson (16)

Shell Diameter ft	m	Capacity Hot Metal Metric Tons	No.	Country	Approximate Maximum Power, MW
20	6.1	100-105	2	Canada	30-39
			1	Japan	35-41
			1	Sweden	30-35
			4	Total	
21	6.4	125-135	3	Italy	45-48
			(+1 U.C. France)		
22	6.7	140-160	19	USA	45-55
			2	W. Germany	
			2	S. Africa	50
			23	Total	
			(+1 U.C. Italy)		
24	7.3	180-225	4	USA	40-57
			[illegible]	U.K.	
			20	Total	
			(+2 U.C. Canada)		
25	7.6	170	1	Japan	
26	7.9	230-240	4	USA	35-40
32	9.8	365-400	1	USA	95-105
TOTAL			56		

used in "mini-steel plants". Regarding large electric arc furnaces, table V (from Schwabe and Robinson (16)) clearly shows the trend towards larger and larger capacity. At the same time, there was an important development in electric supply which [illegible] "[illegible] Power" ([illegible]).

IV.2. Ultra High Power

As has been published many times during the recent years, one of the main development of the electric arc furnace has been the use of large power inputs. The classical flowsheet published by Dr SCHWABE (14)(16) shows what is the difference between conventional electric arc furnaces as they were built ten or twenty years ago, and the new UHP (Ultra High Power) furnaces being built at the present time (figure 12).

IV.3. Productivity of electric arc furnaces

With what we have said about size of furnaces and power of transformer, it is clear that the productivity or the daily production of electric arc furnaces has been increasing tremendously. Coming again to a recent paper of Schwabe and Robinson (14), figure 13 shows it is now possible to build arc furnaces producing 1 Mt steel/year.

Regarding operating time, from the normal 4 to 5 hours tap to tap for common steel ten years, ago a number of recent furnaces are in the range of 2 to 2 1/2 hours, i.e. 10 to 12 heats a day ! (1)

IV.4. Batch vs continuous electric arc steelmaking

The electric arc furnace as described in our paper is the usual batch furnace. It is usually charged with scrap or any other raw material in buckets and, of course, it is tapped when melting and refining is completed. In recent years, there has been a number of attempts to get a better utilization of the electric arc furnace as a melting unit, the refining operation being made either in ladle or in another furnace.

In recent years, there have been a number of attempts to modify the simple flowsheet and to operate more efficiently. It is, of course, very difficult to mention all the proposed processes but we want to mention the main trend in this field :

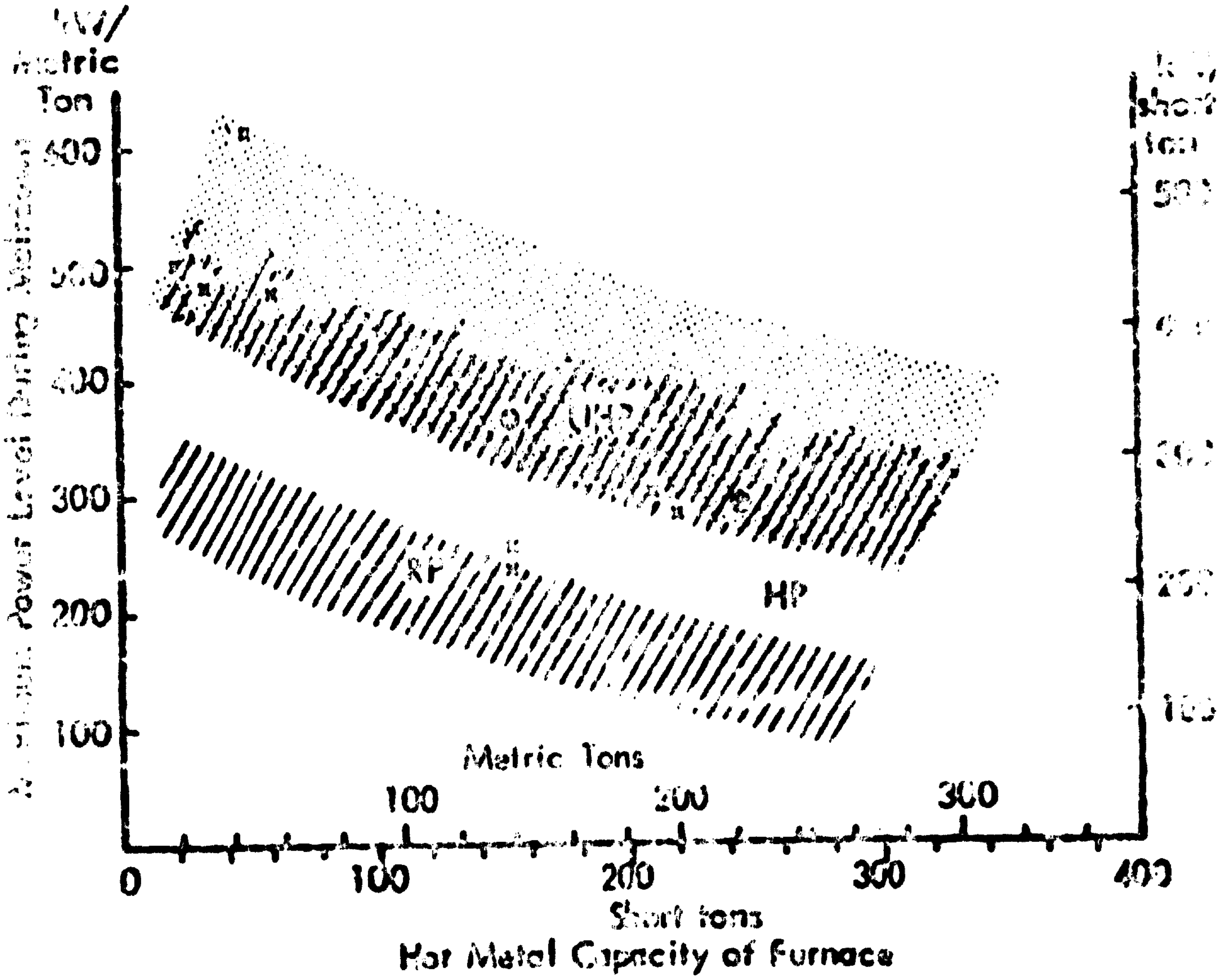


Figure 12
Range of specific power levels of arc furnace
(from SCHWABE and ROBINSON (14))

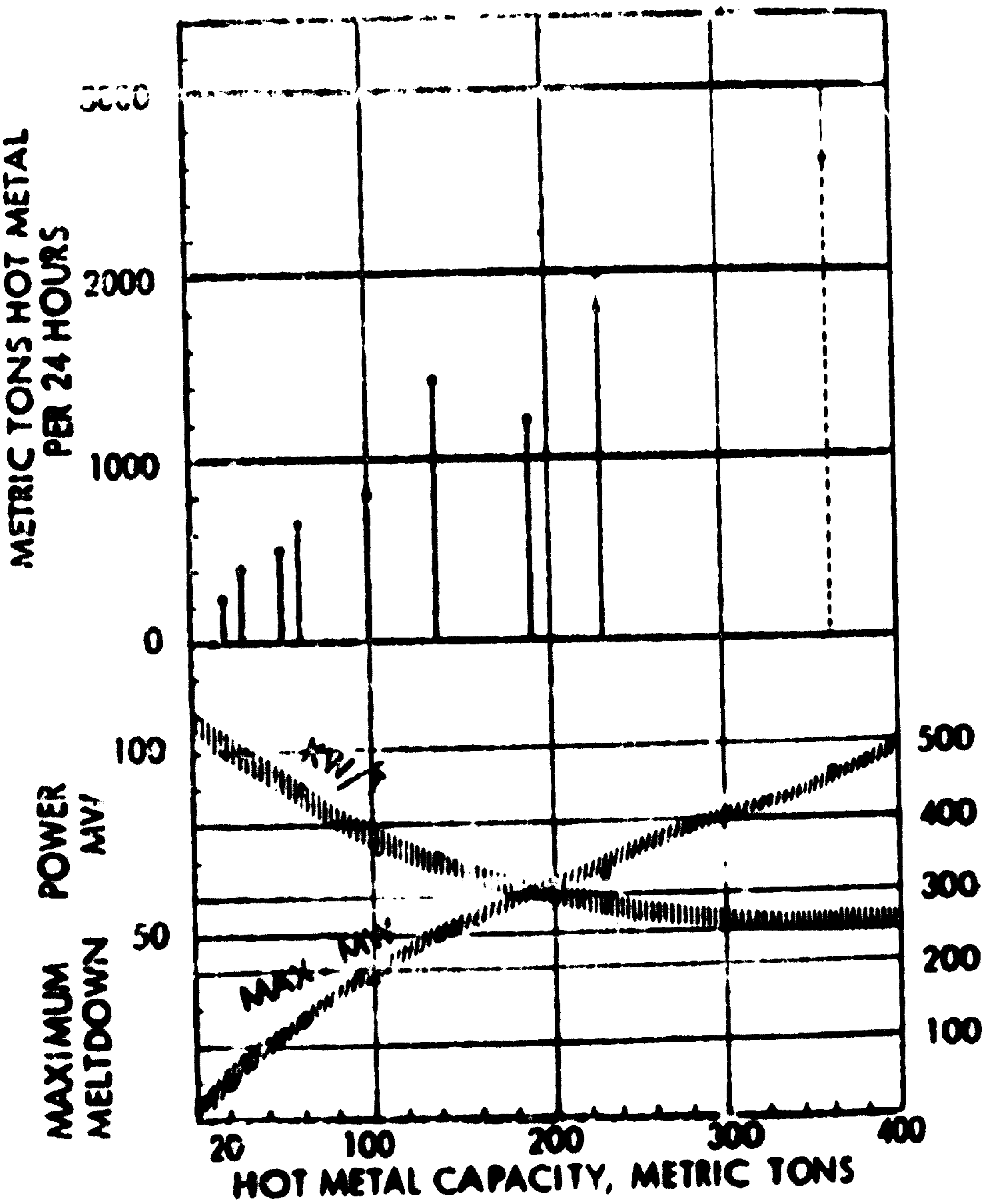


Figure 13

Daily production figures of typical UHP furnaces producing single slag, low-carbon steels ; bottom : maximum meltdown power (MW) and specific power levels as functions of furnace size

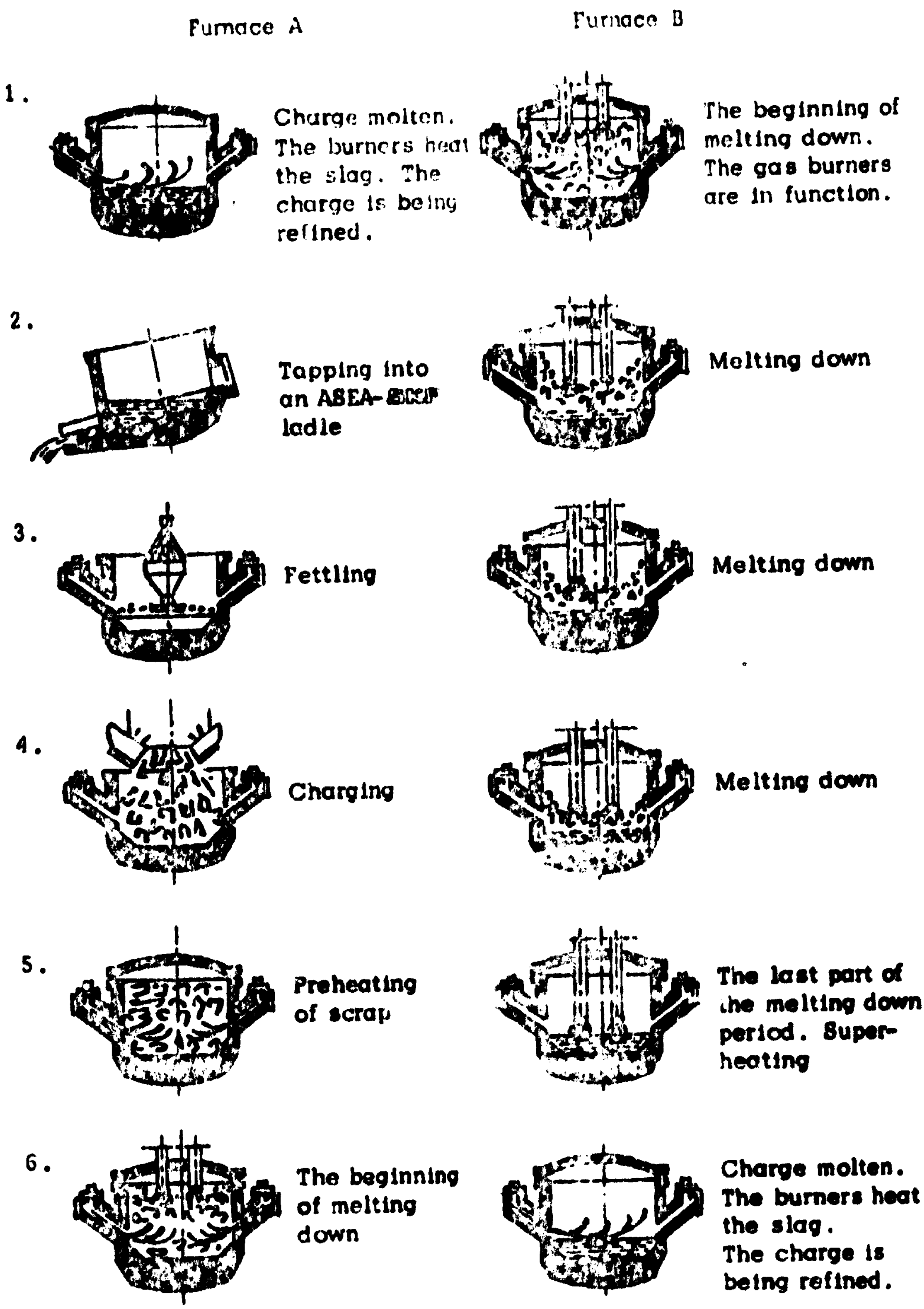


Figure 14
The S K F double furnace (from TIBERG (13))

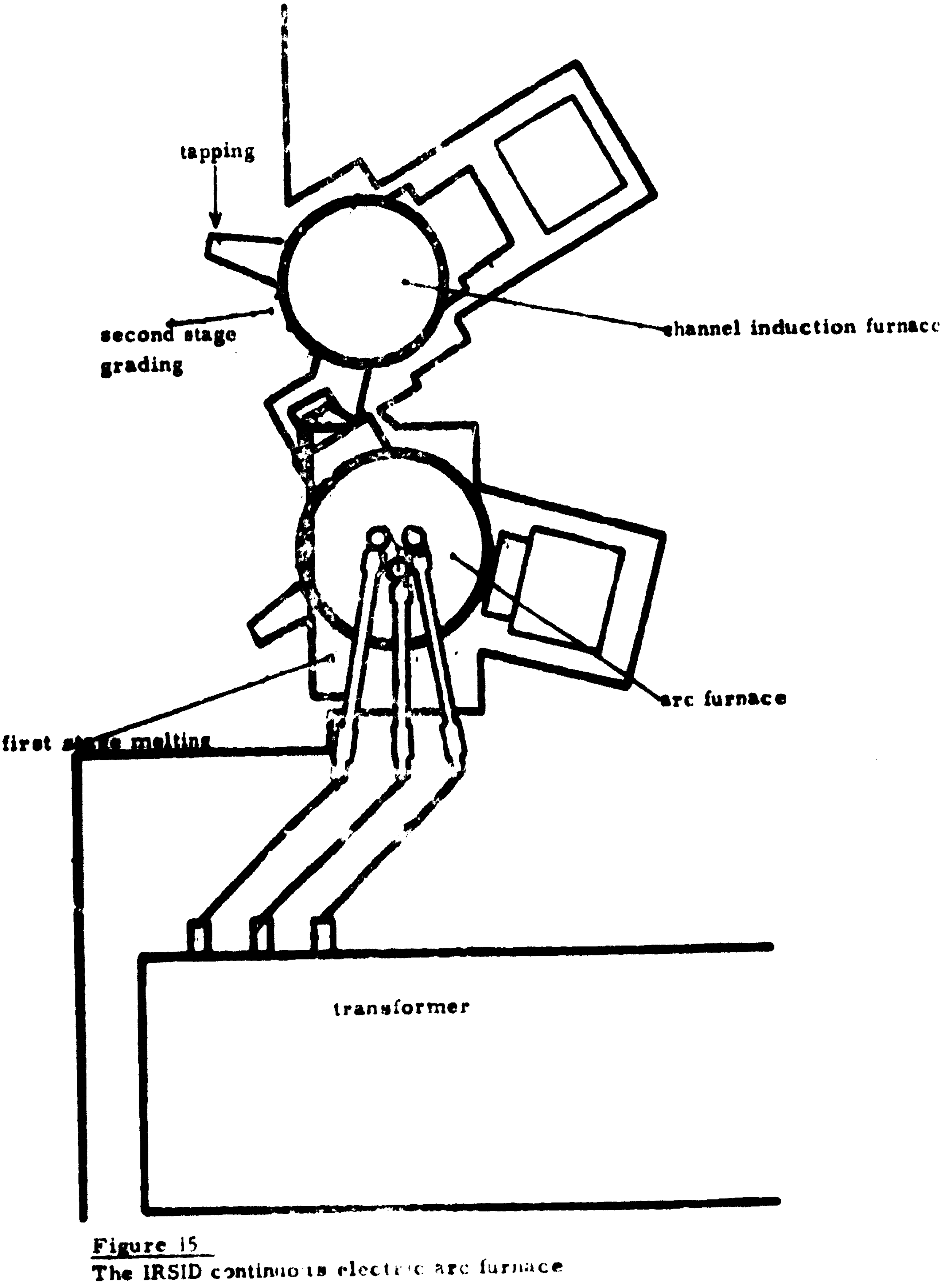


Figure 15
The IRSID continuous electric arc furnace

- a first line of approach was the continuous charging of prereduced material or shredded scrap, as mentioned previously in parag. II.1. and figures 6, 7, 8 and 9 ;

- a second way of operation is the use of the electric furnace just to melt the charge, the refining operation being transferred to a ladle (17) ;

- a possible further step would be the use of two furnaces, one being used for melting, the second one for refining, or even with more complex division of work between the two furnaces. In this class, we can find the SKF process (see figure 14) (18);

- a further trend could be the development of a continuous electric arc furnace incorporating continous charging and continuous tapping in a "nuanceur" or grading furnace, such as was developed by IRSID, both for continous oxygen steelmaking and also for continuous arc steelmaking furnaces.

Figure 15 show the basic design of such a furnace which started at the end of 1972, at the rate of 100 t steel/day (4 t/h) in the IRSID experimental station of MAIZIERES-lès-METZ (France).

CONCLUSIONS

This survey shows clearly the growing role of the electric arc furnace in the Iron and Steel Industry. This is due to its relatively low investment cost and to the use of a energy source which is becoming increasingly plentiful and is relatively not very expensive.

The basic feed of such electric arc furnaces will remain the increasing amount of scrap generated in the industrialized as well as in the developing countries. At the same time, the anticipated development of the prereduction processes will give a new feed material, enhanced perhaps by a more stable price than the usual scrap. Furthermore, the use of such a prepared burden can change design and practice of the conventional arc furnace by taking opportunity of continuous charging devices and improved automation schemes.

It must be noted that the same techniques apply to the use of shredded scrap and, more generally, sized raw materials.

For the future, we think the electric arc furnace will be more and more devoted to melting, refining being transferred to another apparatus. This could, ultimately, lead to continuous electric arc steelmaking.

(1) International Confere[illegible] [illegible]making.
Cannes (France) [illegible]

(2) Symposium d'Electro[illegible] [illegible] 19.10.63

(3) VII International Con[illegible] [illegible] Pologne - 18-22
Sept. 1972

(4) DEMARTEAU (M). [illegible]
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France - paper n° [illegible]

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p. 650-661 -

(6) LUTH (F)
Uberblic [illegible] Stahl und Eisen [illegible]

(7) BRUZZONE (G)
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l'U.I.E. - [illegible]

(8) (anonyme) [illegible] U.S. STEEL)
33 Magazine [illegible]

(9) C.E.E. de [illegible] la ferraille de fonte
et d'acier [illegible]

(10) ROCCA (R)
Evaluacion de la [illegible] en america latina
XI Congreso de [illegible]

(11) RANKIN (W. M.)
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(12) ASTIER (J) [illegible]
The increasing [illegible] arc furnaces
Conference [illegible] technology of sponge
iron and [illegible]
Jamshedpur [illegible]

(13) ASTIER (J), DELLA CASA [illegible]
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filières d'élaboration [illegible]
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(14) SCHWABE (W.E.) and [illegible]
New development in [illegible]

(15) Electric furnace round up
" 33 " Magazine - July and [illegible]

(16) SCHWABE (W.E.) and [illegible]
Development of large [illegible]
Paper n° 105 at (1) -

(17) ANTOINE (J.)
at (1) -

(18) TIBERG
at (1) -

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