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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

STEEL SYMP.1963/
Technical Paper/B.1
17 October 1963

ENGLISH
Original: FRENCH

D04789

OXYGEN - LIME STEELMAKING PROCESSES

OLP, LD-AC, LDP, LDK

by

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SUMMARY

In the basic pure oxygen steelmaking processes, using tilting converters, use of lime of a small size and especially of lime powder in suspension in the oxygen jet itself, assures a higher flexibility during the refining.

The principle of these processes is briefly summarized and various examples of industrial realizations are presented.

These results, completed with a heat balance study allow, in each special case, to work out an economical comparison.

Finally, the importance of research now in progress in the field of the automation of these processes is underlined.

1. INTRODUCTION

Possibilities of producing large tonnages of pure oxygen at a low cost explain the spectacular development observed since a few years on the new basic oxygen steelmaking processes and especially of those of the LD type.

The LD process which has been for the first time applied in Austria, twelve years ago, on an industrial scale, has been mainly used for hot metal with low phosphorus content, easy to refine. Experience gained in many steelworks all over the world has moreover confirmed that the "ideal" hot metal for the refining itself in an LD converter corresponds to a maximum phosphorus content of 0.2% and to a silicon content of about 0.6%, if we consider only these two elements.

However, for different reasons (for instance proximity of important ore fields, commercial balance with foreign countries ..) a new steel plant may be led to use raw materials (ore, coal, coke ...) of such compositions and such qualities that the produced hot metal deviates more or less from the ideal conditions for the LD process quoted above.

This is especially the case of the phosphorus iron ore fields in Europe; steelmakers were therefore led to look for possibilities of refining the resulting phosphorus hot metal of the Thomas type by means of pure oxygen.

Thus, different solutions were found, either in tilting converters of the LD type or in rotary furnaces (Kaldo, Rotor) or in modified open hearth furnaces (Ajax). Considering the scope of the topic, we will limit ourselves to discuss the solution given by the tilting converters.

The LD type processes developed in this way may be of two main kinds:

- on the one hand, the OLP[(1)] and LD-AC[(1)] processes using lime powder in suspension in oxygen;
- on the other hand, the LDP[(1)] and the LDK[(1)] processes, using progressive addition of lime by means of a spout.

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(1) OLP (Oxygen-Lime-Powder) - developed by IRSID, in France
LD-AC (LD ARBED-CNRM) developed by these Societies in Luxemburg and Belgium
LDP (LD Pompey) developed by the French Société des Aciéries de Pompey
LDK (LD Krupp) developed by the Krupp Society in Western Germany.

These processes have been now satisfactorily tested on an industrial scale. Several million tons of steel were produced through them. They will be described briefly and it will be shown how they can solve some of the problems which may arise for new steelworks in developing countries.

2. PRINCIPLE OF THE PROCESSES AND INDUSTRIAL REALIZATIONS

The OLP, LD-AC, LDP, LDK processes use tilting converters with a full bottom, a basic lining and an emerged vertical lance for refining.

They are, however, of two kinds, according to the way the lime is introduced:

(a) In the case of the OLP and LD-AC processes, lime as a powder is put in suspension in pure oxygen and injected directly through the refining lance.

Fig. 1 shows the principle of these processes.

First, lime powder is prepared in crushing plant which gives a product of a size lower than 2 mm. Then, the powder is pneumatically transported to the steel-shop where it is put into a powder dispenser. This apparatus which works at high pressure in oxygen, delivers a regular and controlled lime flow. The mixture oxygen-lime powder is led to a vertical water-cooled lance and injected into the metallic bath.

Many technological details have been fully worked out through several years of research and industrial experiences in the field of lime powder injection in pure oxygen. It is therefore essential to adapt, in a new steel shop, a delivery and regulation equipment which has already been industrially tested.

The LD-AC and OLP processes differ, of course, in some respects, such as powder dispensers, regulation of the lime flow in oxygen, movable connexions of the lime line, recommended lance types, but as they are based upon the same principle, we shall avoid to distinguish them below and we shall name them as "lime powder processes".

(b) For the LDP as well as for the LDK process, lime is previously crushed to a size lower than 40 mm, even 20 mm. It is then discharged by successive additions at different stages of the blowing, by means of a feeding spout arranged through the gas captation hood, with a suitable orientation.

Weighing systems permit to control in an accurate way the quantity added.

Although a few differences exist between the LDP and LDK processes, especially as far as the heat operation is concerned, we shall not distinguish them and shall name them both as "small lumps lime processes".

During the last years, many industrial realizations of the processes have been made in western Europe. The range of unit capacity of the corresponding converters is extremely large, since it includes vessels of 2, 5, 16, 20, 30, 40, 50, 60, 120 and 140 t.

Fig. 2 presents the cross section of a 30 t. converter designed for intermediate deslagging: this deslagging which takes place by tilting on the side opposite to the tapping hole is made easier by the funnel-shaped upper part of the lining.

Fig. 3 shows a group of two 50 t. converters using lime powder injection for refining high phosphorus pig iron.

Fig. 4 is a picture of the control room common to two 30 t. converters using also lime powder injection. It shows obviously the simplicity of the control of the whole operation, which is done by one man.

3. METALLURGICAL DISCUSSION

During the refining with pure oxygen, low phosphorus pig iron (0.2%) which has a silicon content of about 0.6 to 1% raises no particular problem, even when lime is added at the beginning of the heat: in fact, silicon is oxidized in the first minutes of refining practically in any conditions of slag formation.

This is clearly shown by the chemical evolution curves in fig. 5.

On the contrary, difficulties occur when the phosphorus content of the hot metal increases and goes beyond 0.5%.

As distinct from silicon, phosphorus can be removed only in presence of a liquid slag, basic and sufficiently oxidizing. During the relatively short time of a heat, a slag amount more important than in the case of hematite pig iron with normal silicon content should be formed and that in a controlled way. In order to assure this quick and controlled formation of a basic slag for Thomas pig iron with a phosphorus content of 1.8%, lime is added in small lumps during the blow, in successive steps well determined according to the progress of the heat.

This can also be achieved in a still more rational way through lime powder injected in suspension with pure oxygen: lime powder is extremely reactive and arrives into the bath with the oxygen itself of the jet, and speeds up the slag formation. Finally, the instantaneous flow rate, easily controlled, can be [illegible] to the desired value according to the period of the heat.

An important conclusion is that the lime powder processes are very much less dependent on the lime quality than the lime lumps processes.

While the lime lumps may present very different physical and chemical properties, which has a great influence on their dissolution process, consequently on the conditions of slag formation, the very small size of the lime powder gives on the contrary a reactivity always high, whatever the nature of the initial lumps.

These advantages appeared sufficient to justify industrial trials now in progress with lime powder processes for refining hematite pig iron.

Whatever the process used, as soon as the phosphorus content becomes too high, for instance higher than 0.6%, it becomes advantageous to eliminate a part of the formed slag during the operation, while it is not rich in iron oxide, and to finish the heat with a limited amount of oxidized final slag. It follows that the Fe yield of the heat increases, which can still be improved by the recovery of the final slag for the following heat. This technique is now classical for refining high phosphorus pig iron of the Thomas type (with a phosphorus content of about 1.8%) and the graph of fig. 6 gives an example of the evolution of the refining of such a pig iron. Blowing is stopped at a carbon content of about 0.7%, which allows the elimination of a slag with low iron content (only 5%) and high phosphorus content, which is used as a fertilizer.

Generally, the refining method should be adapted to each type of pig iron. Therefore, trials in a pilot converter of a few tons capacity give very useful information before the starting of a plant and permit to determine a refining technique suitable to the pig iron which will be produced. Several firms and research centres in Europe are now well equipped for these preliminary studies which facilitate the design of a new steel plant, and the starting of its installations.

As an example, we shall mention the trials done with lime powder injection in the 5 t. pilot converter of IRSID in France, at the request of a foreign firm. The iron for this new plant was complex and rich in silicon (more than 2%), rich in phosphorus (1.4%) but poor in carbon (2.5%).

For such a pig iron, the deslagging of one intermediate slag is not sufficient since too large amount of silicon gives a too acid slag, which does not permit, later on, a sufficient dephosphorization.

The total lime consumption is about 150 kg per ton of pig iron and the advantage of injecting in situ lime powder in suspension in oxygen is the possibility of forming a slag in a controlled way during a very short time and at the desired moment. That would be impossible with additions of lime lumps.

4. HEAT BALANCE AND NATURE OF THE COOLING AGENTS

(a) Heat balance

Although many factors are involved, such as composition and temperature of the pig iron, lime composition, convertor shape, production rate ... , it is possible to know with a good approximation the heat excess which will be available during the refining of a given metal in a top blown converter and to compare this value with known industrial results.

Among the factors on which the steelmakers can act, the silicon content comes first.

Calculations show that an increase of 0.1% of the silicon content gives a supplement of 5.6 thermies available in the converter, which corresponds to a supplementary melting of 17 kg of scrap per ton of pig iron.

This calculated value is confirmed by the results obtained in different LD steelshops, as it may be deduced from fig. 8 representing the percentage of scrap in the metallic charge as a function of the pig iron silicon.

Thus, while as far as the refining itself is concerned, the most favourable hematite pig iron has a silicon content of 0.6%, some works prefer to increase this content up to 1% in order to be able to melt 70 kg of supplementary scrap and reach 330 kg of scrap per ton of pig iron.

It is also possible to determine the influence of the physical temperature of the pig iron when charged into the vessel; calculations, confirmed by experience, show that an increase of 20°C of the pig iron temperature increases the molted scrap weight per ton of pig iron by 11 kg.

Thus, the interest of reducing as much as possible heat losses between the pig iron casting and its charging into the vessel is seen. Use of torpedo ladles, which avoid the mixer, leads to a noticeable increase of the melted scrap weight, but this is at the expense of the regularity of the charging.

Fig. 9 is one of the possible representations of the heat balance of the refining operation. This example refers to a Thomas pig iron (C = 3.7%, P = 1.9%, Si = 0.6%) refined with lime powder with an intermediate deslagging and recuperation of the final slag.

The establishment of similar balances enables to determine in each particular case the amount of scrap which may be melted.

It should be finally noted that it is possible to increase this amount with some artifices such as scrap preheating, coal or oil addition, but these processes have not yet received sufficient confirmation on an industrial scale in order to judge their advantages.

(b) Nature of the cooling agents

The heat excess resulting from the previous balance is generally called "scrap equivalent", indicating that cooling may be achieved through the addition of different cooling agents:

- scrap:

Their charging should be quick and they should not occupy an excessive volume inside the vessel in order to avoid difficulties in starting the heat. Especially, it is not possible to charge the same scrap as in an open hearth oven and a previous preparation is often necessary. One should be careful too with the oxidization ratio, the humidity and, in some cases, with the residual elements content.

- iron ores:

Rich ores should be exclusively used; otherwise refining is more complicated as a result of the gangue. Charging cannot be done in only one time at the beginning of the heat, because violent reactions with pig iron and even explosions can occur.

Pellets of iron ore, with a diameter of less than 20 mm are quite well suitable, because of the lack of fines and their uniform size allows a regular and controlled charging during the blow. For ore with a 33% content of Fe (as Fe_2O_3 the thermal equivalence is very close to 4) i.e. a kg of ore is equivalent to 4 kg of scrap.

By taking a preceding example of an addition of 330 kg of scrap per ton of hot metal, one obtains 83 kg of pellets, corresponding to a weight of 52 kg of Fe. So that the consumption of gaseous oxygen is lowered from 50 to 33 Nm3.

- Prereduced ores:

The possibilities of producing prereduced ores with costs close to those of scrap must be carefully considered for use in oxygen steelplants. The advantages

- easy handling;
- controlled additions during the blow;
- quick and regular melting down;
- no residual elements other than those in the ore itself.

These ores can be only partially reduced, resulting in a more advantageous cost; however, an adjustment of the thermal efficiency must be introduced (for example 1 kg of prereduced ore with 20% FeO is equivalent to 1.4 kg scrap). It is then necessary that the oxidization level does not vary inside a given bath, if one wants to avoid a large scatter in the final temperatures of the heats.

These additions as pellets, prereduced or not, are especially well adapted to the automation problems which will be discussed later.

4. <u>CONSIDERATIONS ABOUT COSTS - IMPORTANCE OF AUTOMATION</u>

It is not within the scope of this conference to discuss the investment costs of steelmaking plants using the LD process or similar processes, since the figures strongly depend on the local conditions, specific to each plant, and also on the technical solution chosen. For example, one knows the important cost elements related to the hood and gas cleaning equipment. The new processes of gas collecting without combustion which has been lately developed may thus lead to a decrease in the investment cost of an oxygen steelplant.

(a) <u>Comparison between lime powder and small lime lumps processes</u>

As far as investments are concerned, one has to compare:

- on the one hand, a plant for crushing lime into powder, a pneumatic transportation to the steelplant, lime dispensers with their regulation;
- on the other hand, a plant for crushing lime into small lumps (40 or 20 mm) with screening, lumps transportation to the steelplant and the removing of fines, the storage in bins at the steelshop, and the distribution of lime generally by belt.

The fact that lime powder behaves like a fluid makes easier to draw up lime flow circuits, and allows a greater flexibility as far as the location of the dispensers is concerned. This is not the case of bins and belts which must be above the converter when lime lumps are used.

Investments costs are practically alike in both cases, when compared to the total cost of the whole steelplant.

Considering the comparison of costs of operation, different points must be mentioned:

- energy consumption:

Crushing of lime into powder and its transportation requires a small amount of energy: for example, for an addition of 100 kg of lime per ton of steel, this consumption is 1 kwh per ton of steel, i.e. of about the same order as for the crushing, screening and transport to the plant of lime in small lumps.

- abrasion:

If lime is not too high in silica, lime powder is not abrasive and costs due to wear of pipes are low when the lime flow has been adequately designed.

- maintenance:

Lime dispensers with their regulation need a periodic maintenance by a specialized technician.

- oxygen consumption:

It is higher by 1 or 2 m^3 per ton of steel in the case of lime powder compared to lime lumps, because the dispensers are under an oxygen pressure which has to be released when the convertor is filled up again.

- lime consumption:

Crushing of lime into small lumps makes fines, the proportion of which reaches 10 to 15% of the lime weight. It is not recommended to add these fine particles into the converter through the nose during the blow, at least as far as converters bigger than about 20 t. are concerned, because a large part of these fines are blown out and carried over in the fumes stream. To take the earlier example of a consumption of 100 kg of lime per ton of steel, 10 to 15 kg may thus be lost when using lime in small lumps.

This last element is sufficient to counterbalance most of the other items mentioned, so that from the point of view of operating costs, the two types of processes are practically equivalent.

(b) Influence of the type of hot metal to be refined

LD steelplants refining hot metal low in phosphorus can reach high outputs, as is seen from graph 10, drawn from actual plant results.

This graph shows, as a function of the tonnage of the converter, the annual output of a steelplant composed of 2 convertors, one in operation, the other in refining or in reserve. One can see, for example, that such a steelplant with 2 converters of 50 tons is sufficient to produce annually a little more than half a million ton of steel.

This astonishing result cannot, however, be obtained without given conditions, i.e.

- use of hot metal of favourable composition (low phosphorus content of 0.2% max. and silicon content of about 0.6%);
- fitting of all auxiliary equipment so as to reduce to a minimum the operation sequences between blows;
- continuous fight against dead times.

The refining of hot metal of not so favourable composition or of an irregular nature can lead to a sharp decrease in productivity: thus in the case of a high quantity of slag per blow, requiring an intermediate deslagging, one can estimate at 30% the drop in the capacity of the plant, compared with the figures of graph 9.

As a consequence, depreciation as well as operating costs increase in the same proportion inasmuch as they are proportional to output (part of labour, energy ...).

More important slags lead in general to an increase in consumption of refractories, but it appears difficult to provide accurate data in that field which changes rapidly, for in the case of low phosphorus hot metal, lining consumption may already vary from 5 to 10 kg per ton of steel. Moreover, the way lime is added and slag is [illegible] play an essential role which it has not yet been possible to determine quantitatively.

The operating results of an oxygen steelshop depend in large part on the control measures, especially during the blow. With a process which is 20 to 30 times faster than the open hearth process, and which does not give the possibility of sampling the bath directly, the blower can follow only approximately the evolution of the refining, and is often helpless when the blow does not behave normally.

This explains the importance of research on automation or more precisely on the extensive control of the blow by an electronic computer.

[illegible] . 11 shows the principles of the different elements to be considered: the use of powdered lime, behaving as a fluid, appears as a favourable factor for automation.

[illegible], these studies on automation would be a failure, if they were not [illegible] by extensive research on the different measurements whose data [illegible] computer: only the quality of these measurements can provide the [illegible] controlling [illegible] by the computer.

Fig. 12 shows different means of continuous control of the refining process: may it be mentioned for instance that from measurements of the fumes from the converter, it is now possible to know at any time during the blow the carbon content of the bath without sampling it.

The measurements are fed into the electronic computer which instantaneously makes the necessary calculations, and thus provides the blower with data allowing it to react methodically during the blow.

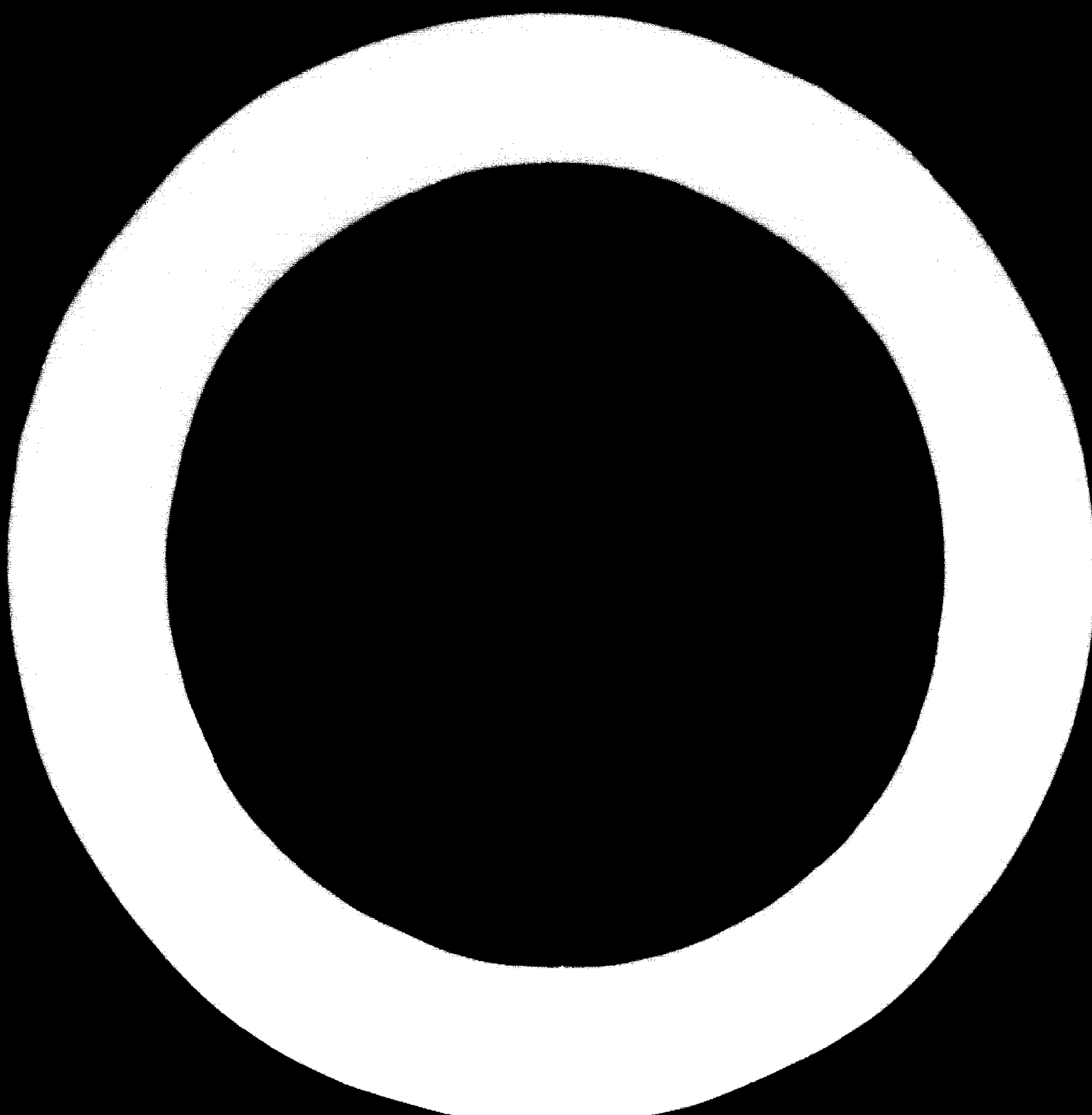
The problem of recruiting and training steelmaker foremen was formerly of utmost importance: it is thus much simplified although men of above average will always be needed for this job.

CONCLUSION

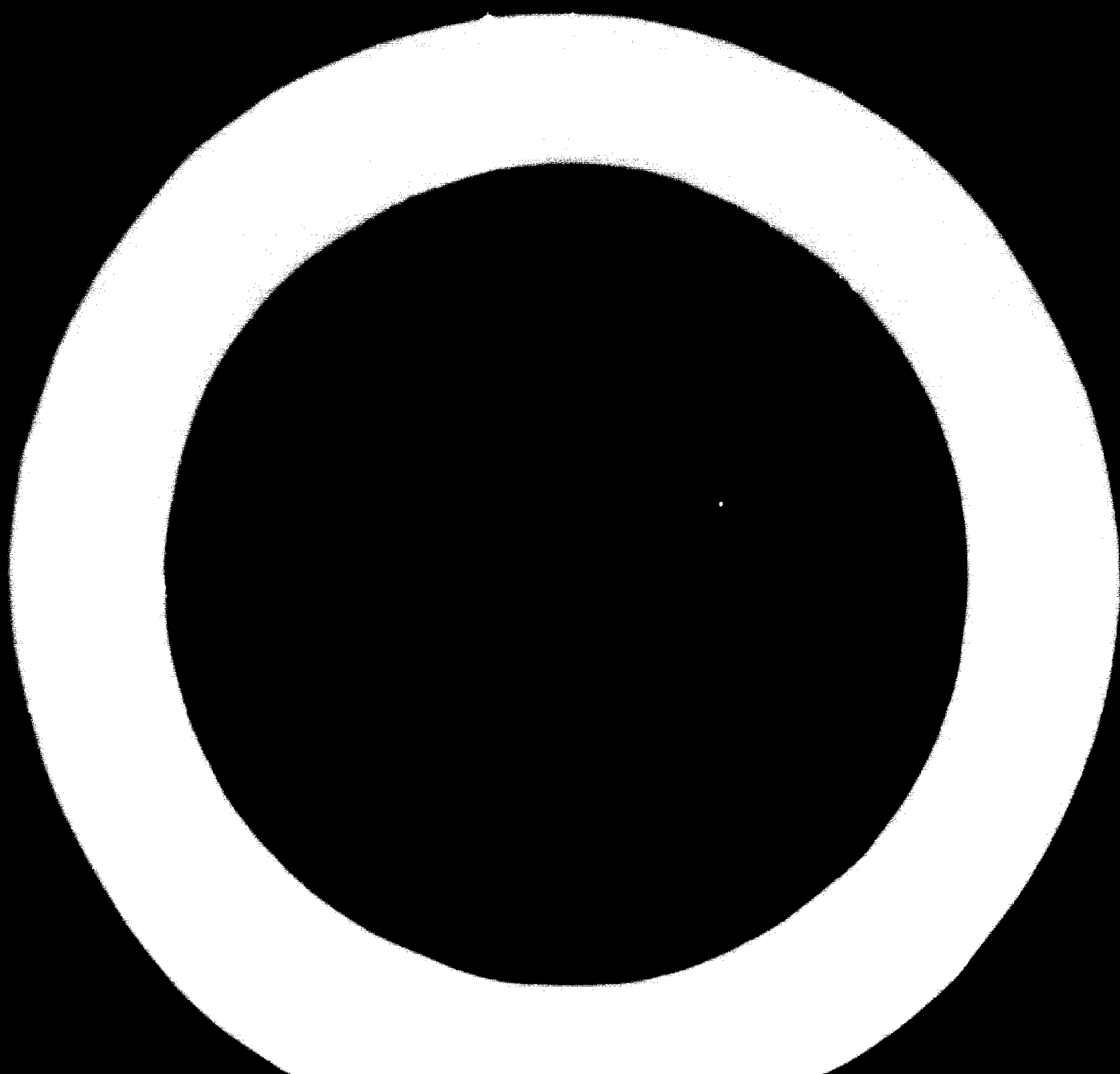
Due to the large field covered by this conference, it was impossible to go into the details of its different parts. We have tried above all to show the great flexibility deriving from the use of small grain sized lime, and mainly from lime powder blown with the oxygen stream.

The knowledge acquired in that field makes it possible, for every individual case of a new plant, to make a detailed metallurgical study, possibly completed by some pilot plant trials, thereby paving the ground for a more accurate corresponding economic study.

Finally, we have underlined the great interest attaching to the present studies on process control with the help of electronic computers, connected with measurement apparatus specially designed to this end.



Figures



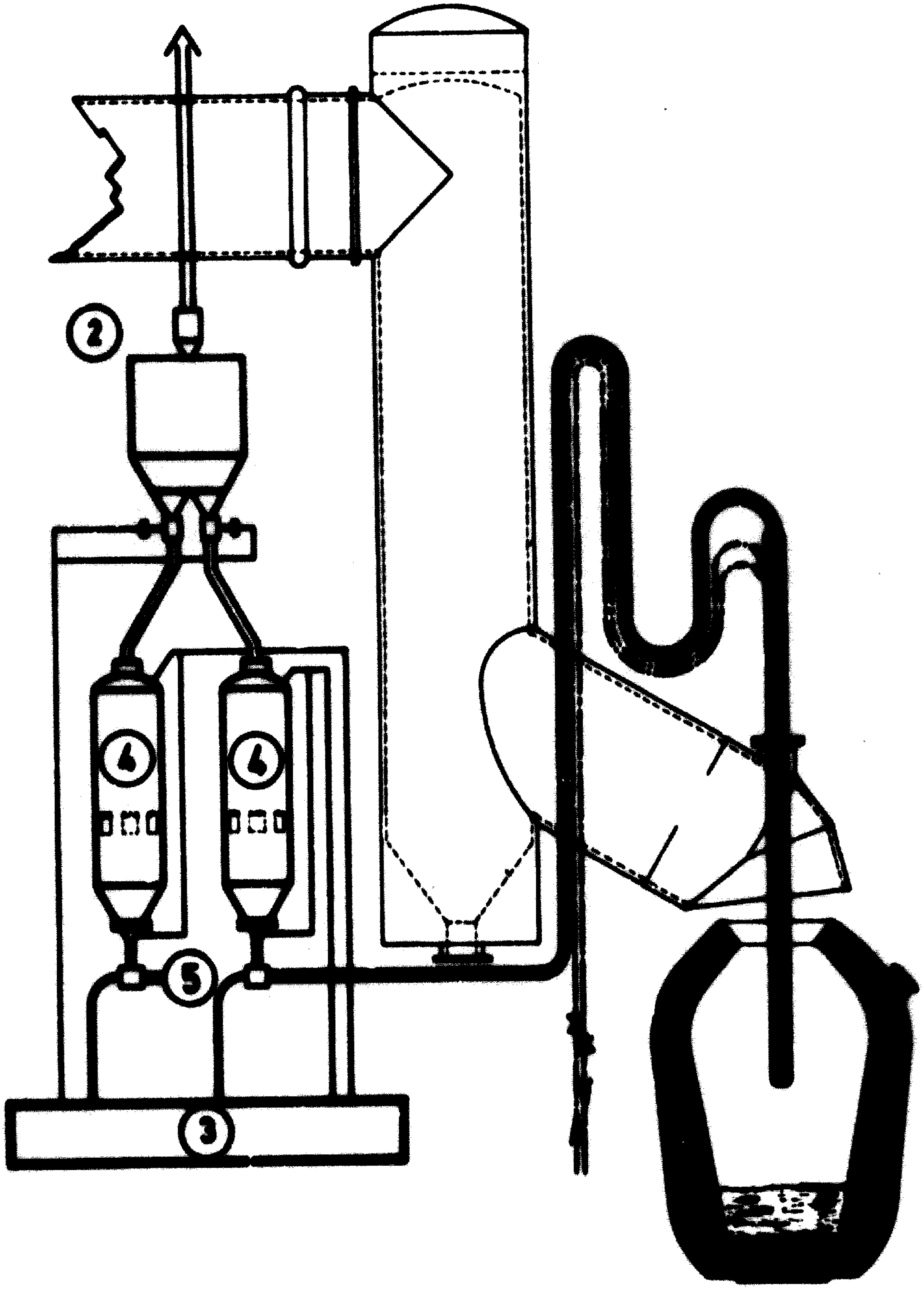
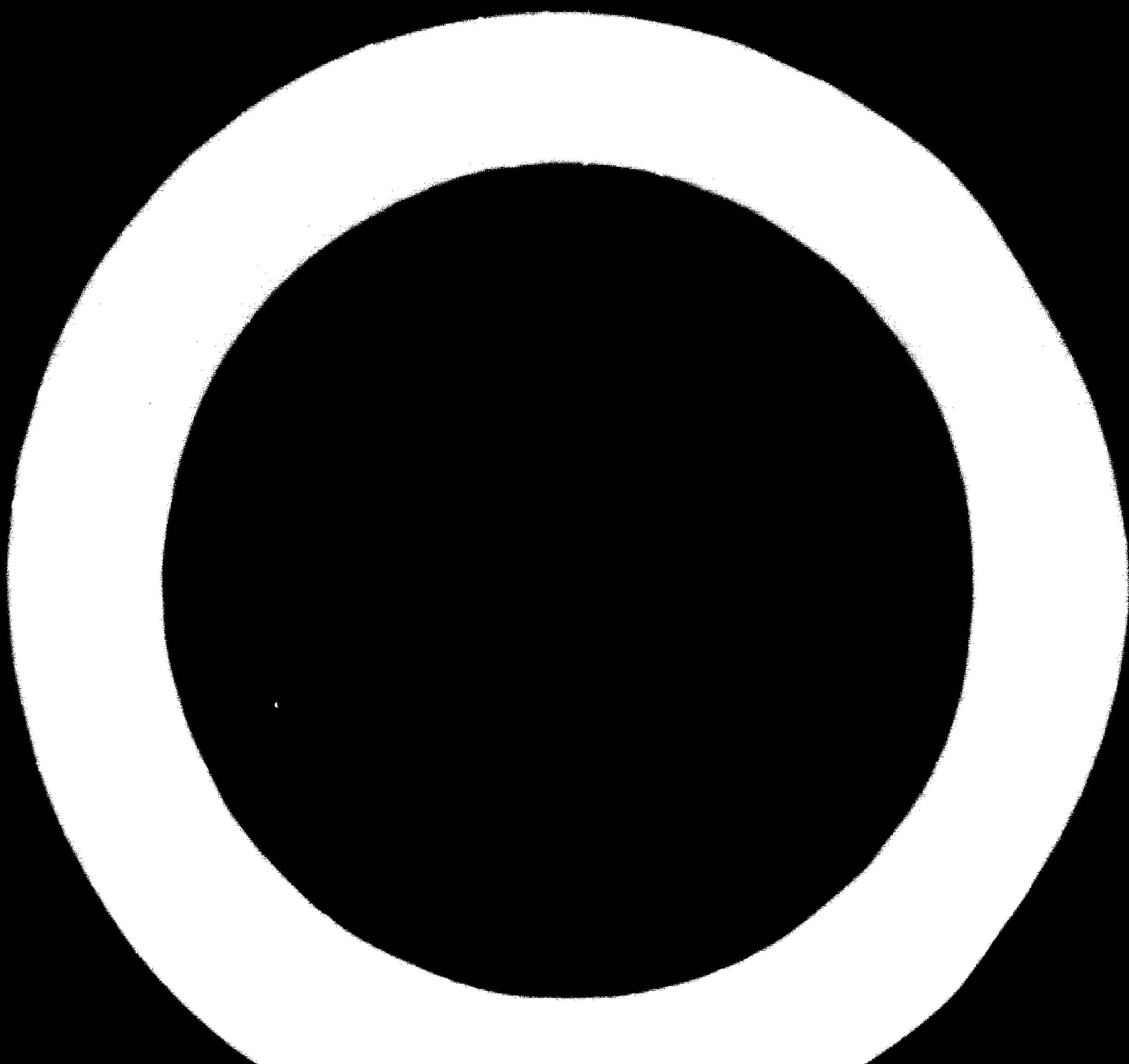


FIG. 1



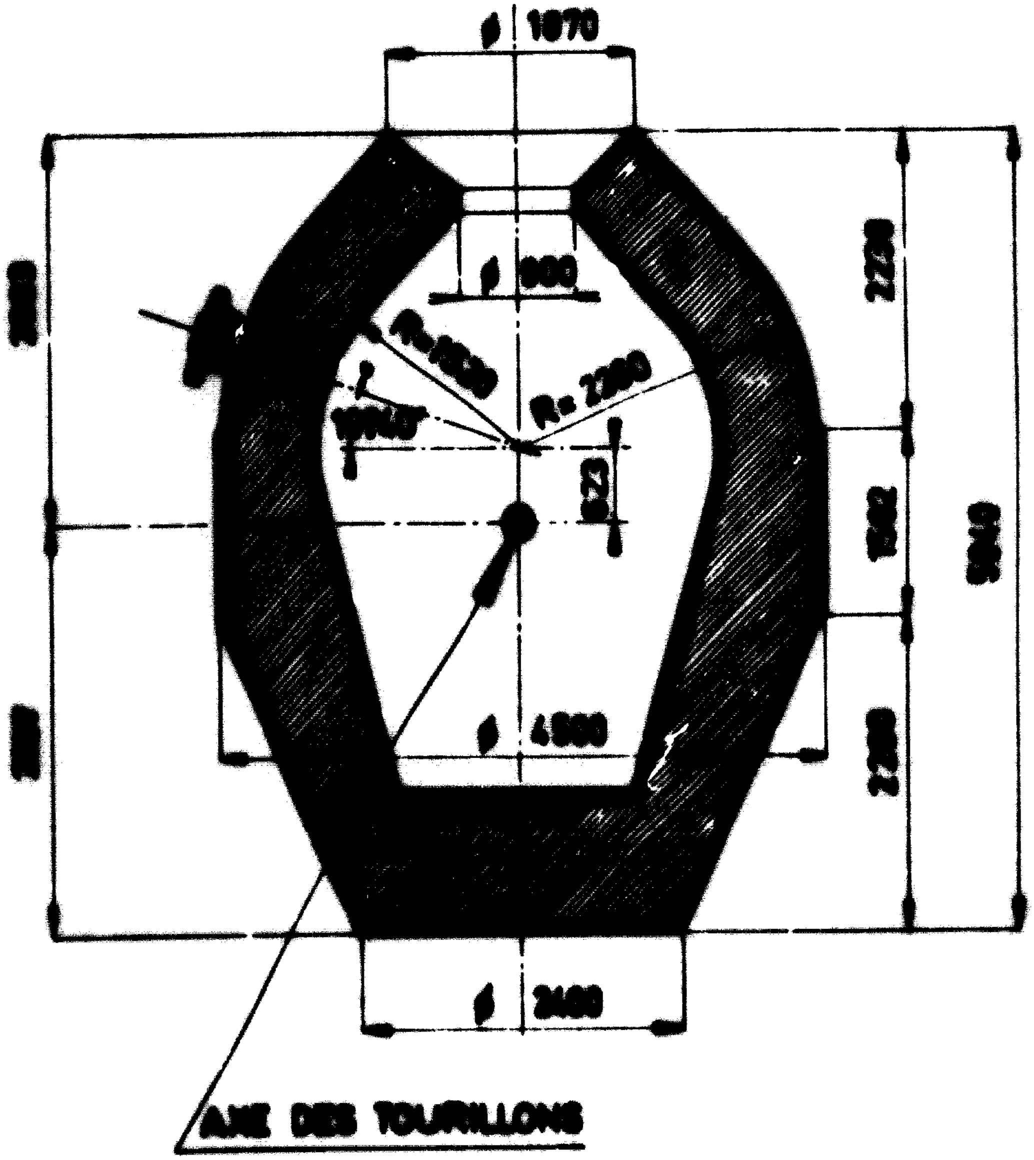


FIG. 2

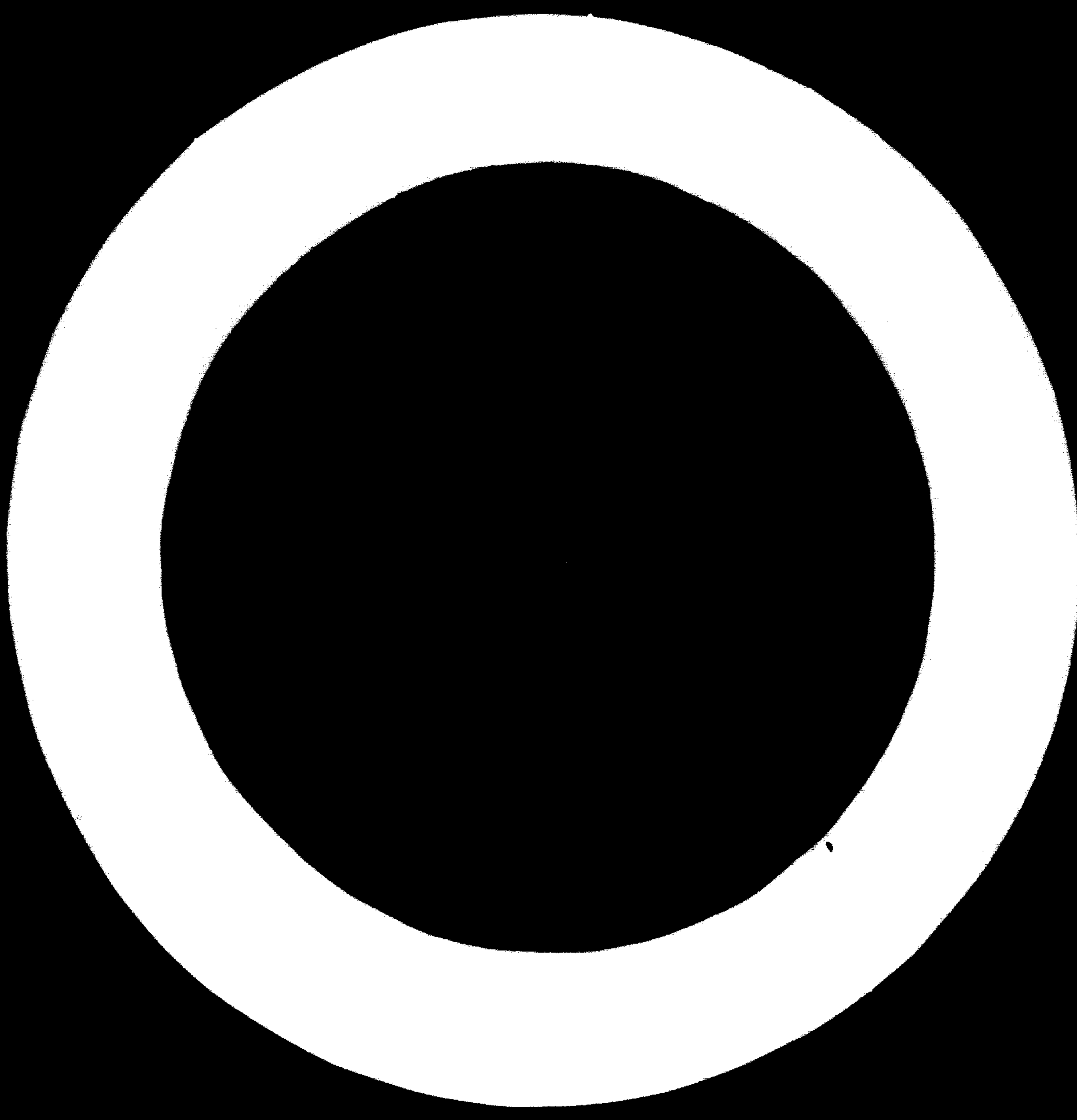
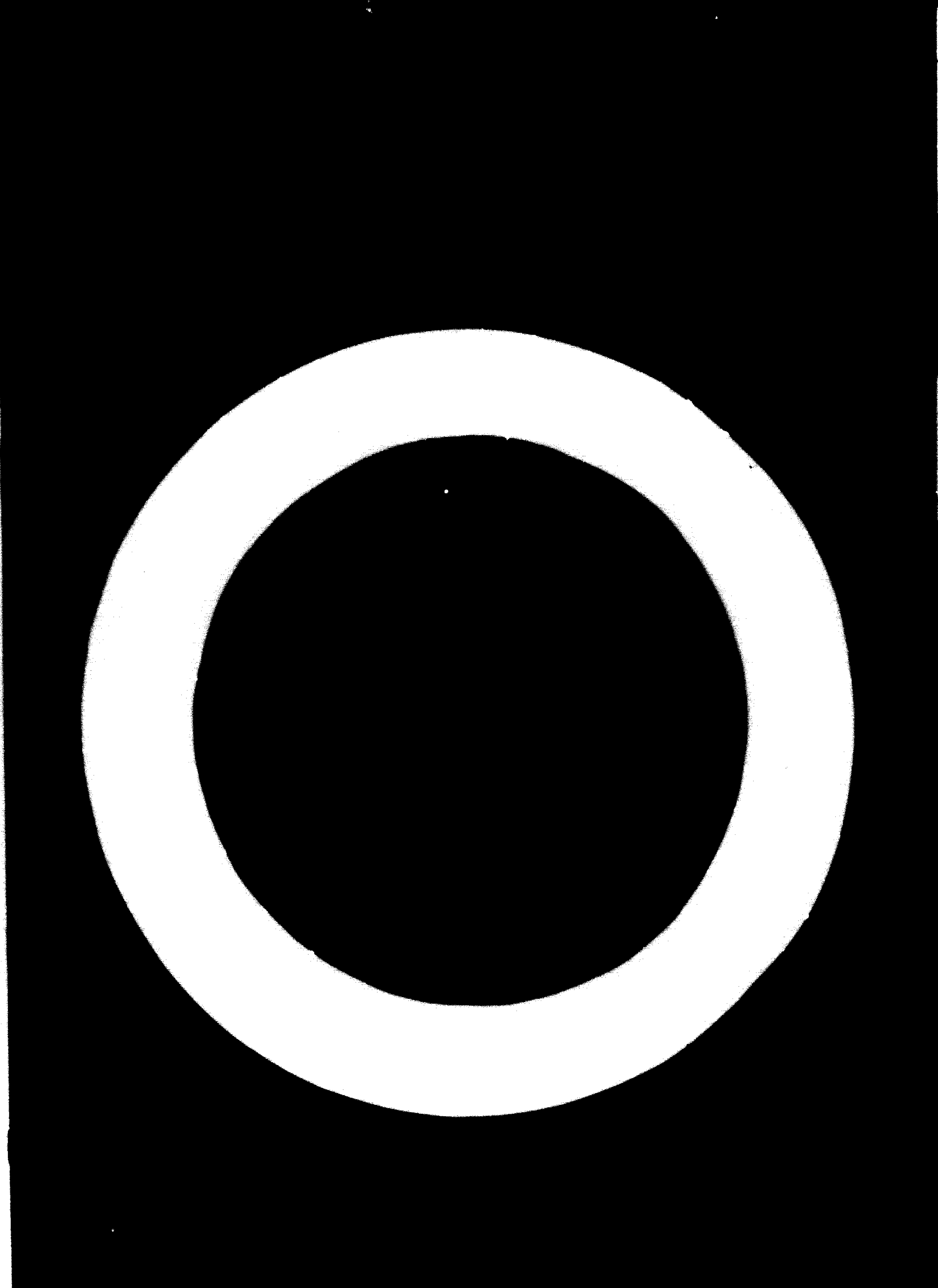
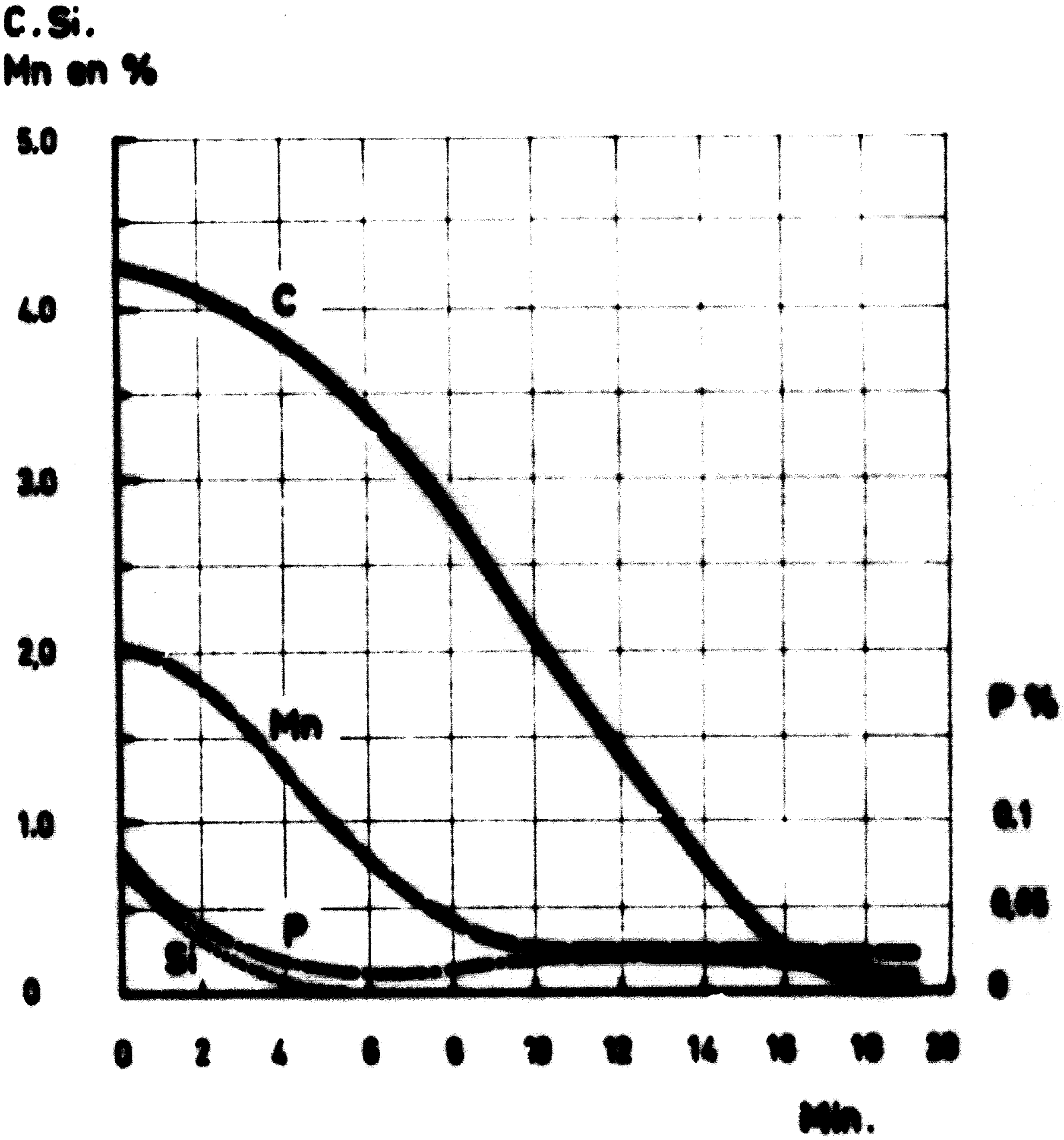


Figure 3

Figure 4




C.Si.
Mn en %
5.0
4.0
3.0
2,0
1.0
0
C
Mn
P
Si
P %
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2
4
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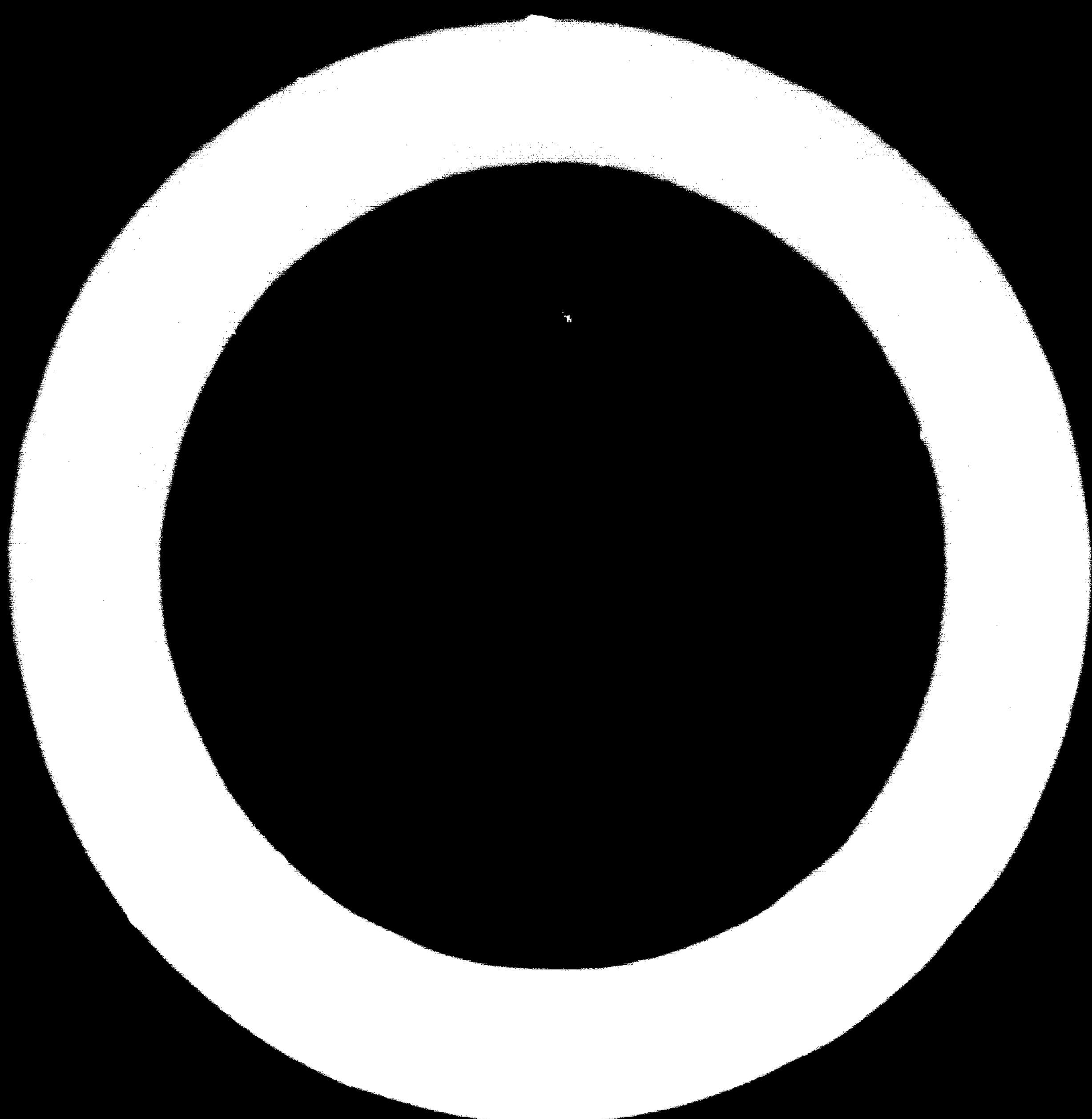
16
18
20
Min.

FIG. 5



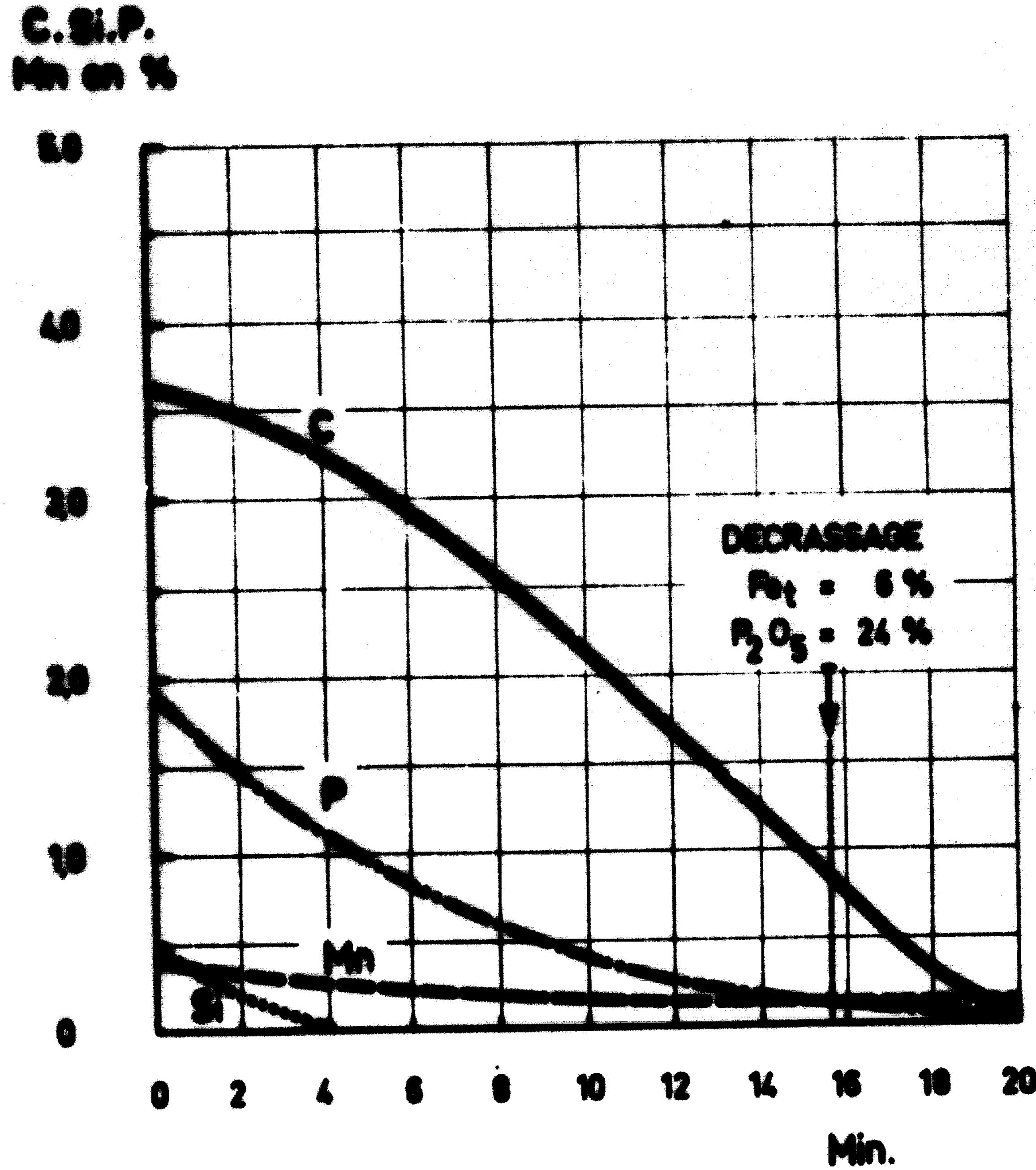
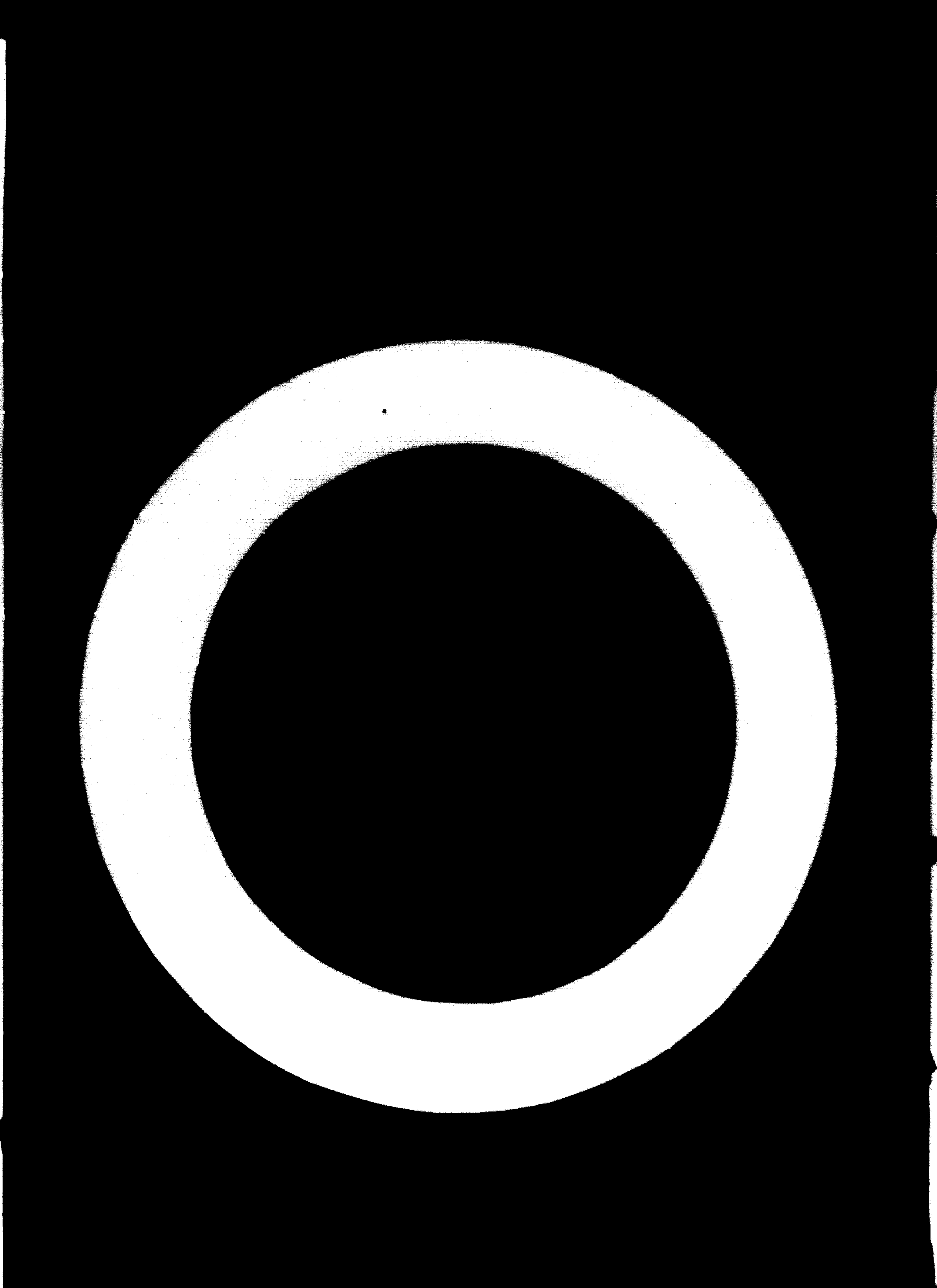

C.Si.P.
Mn en %
5,0
4,0
3,0
2,0
1,0
0
C
P
Mn
Si
DECRASSAGE
Fe_t = 6 %
P_2O_5 = 24 %
0
2
4
6
8
10
12
14
16
18
20
Min.

FIG. 6



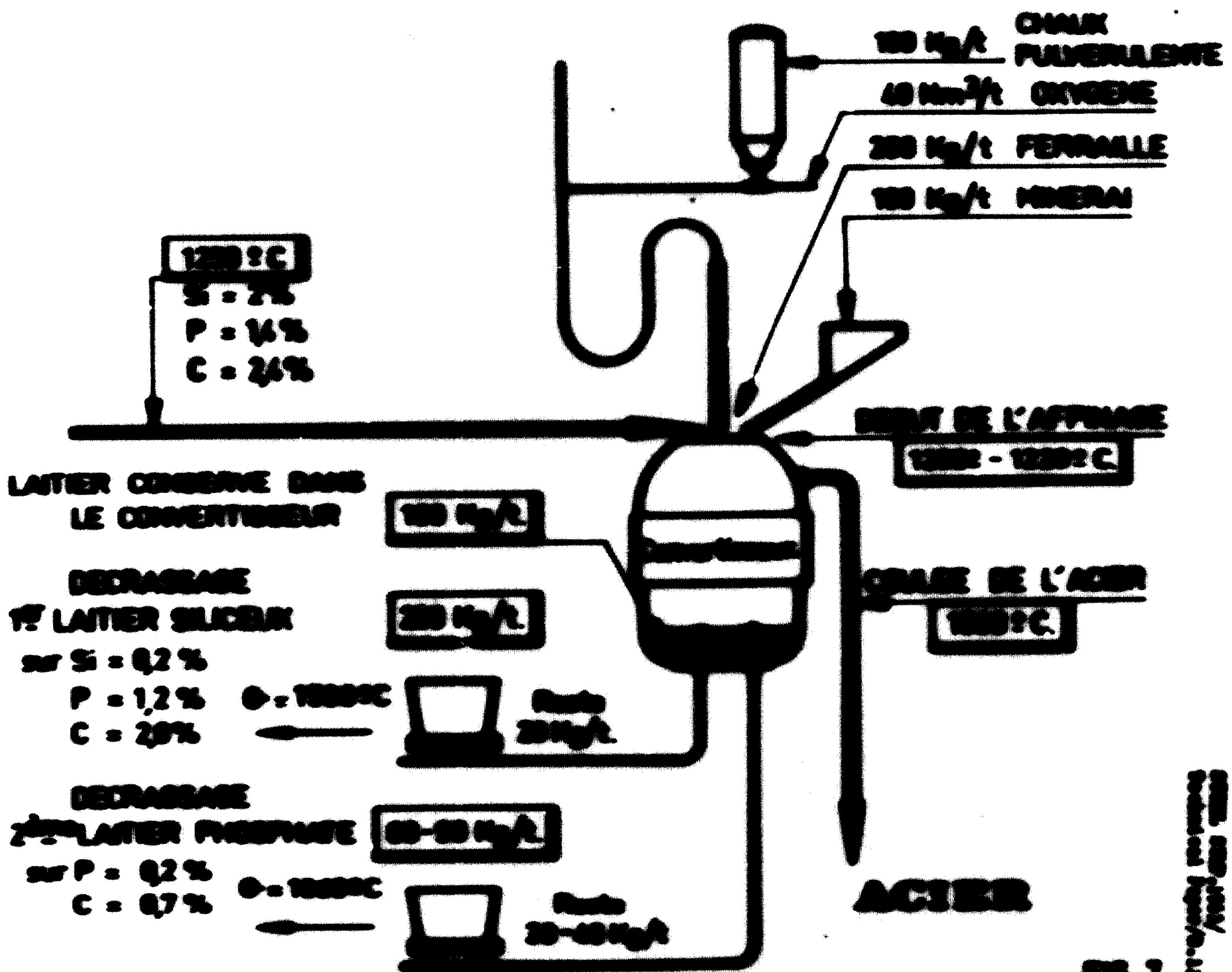
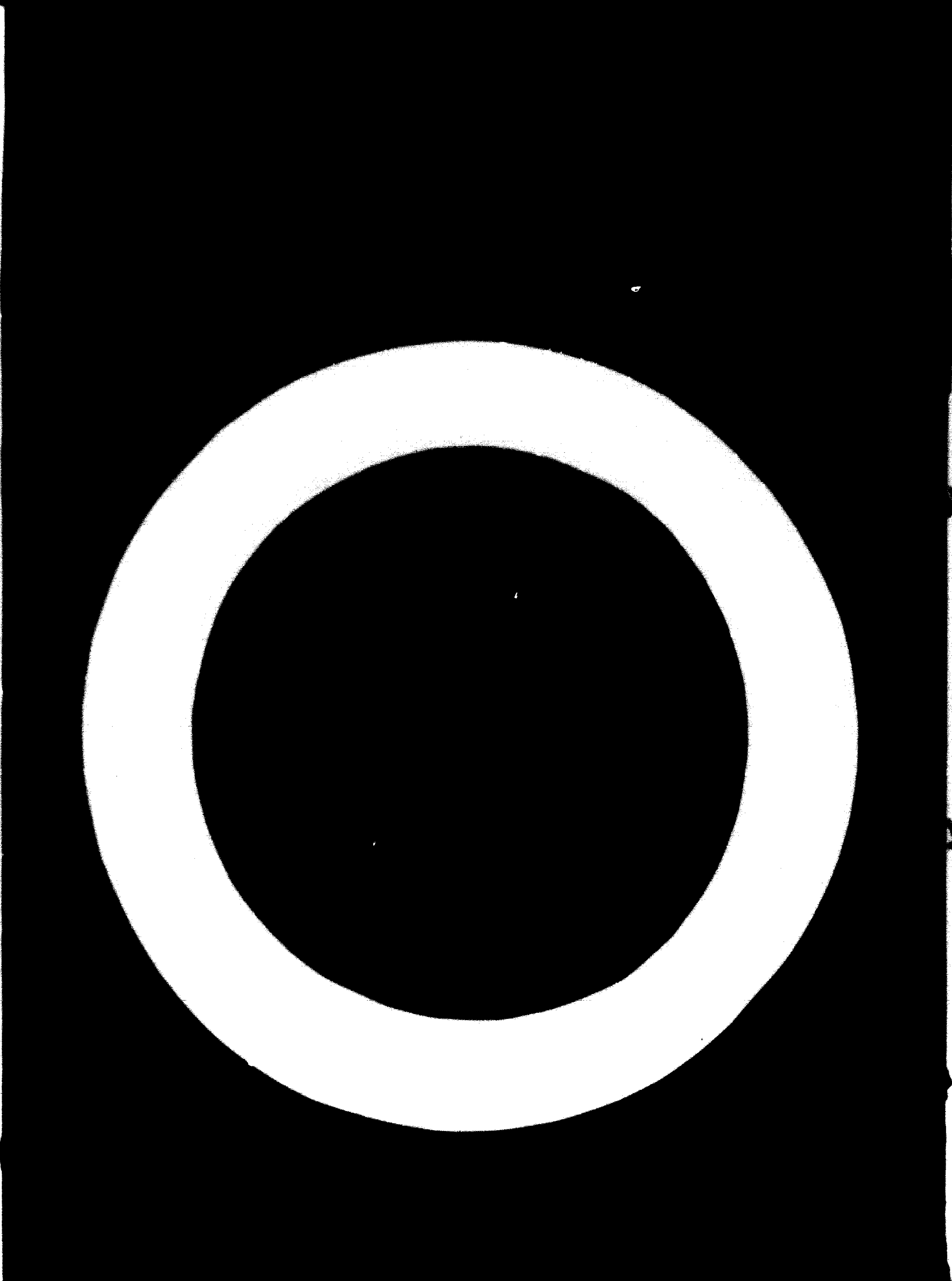
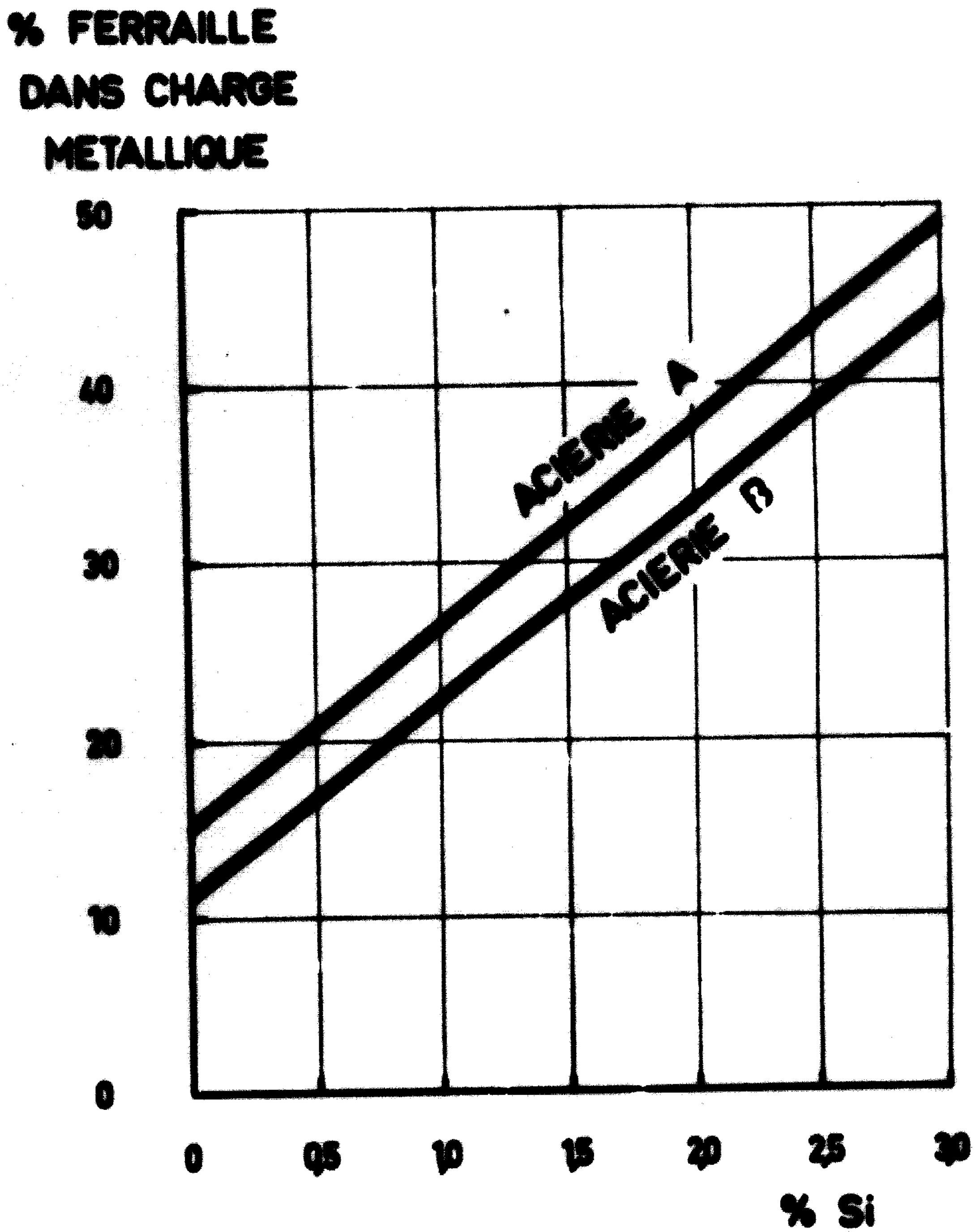

CHAUX PULVERULENTE
OXYGENE
FERRAILLE
MINERAI
DEBUT DE L'AFFINAGE
COULEE DE L'ACIER
ACIER
P = 1,6 %
C = 2,6 %
LAITIER CONSERVE DANS LE CONVERTISSEUR
DECRASSAGE
1er LAITIER SILICEUX
sur Si = 0,2 %
P = 1,2 %
C = 2,0 %
DECRASSAGE
LAITIER PHOSPHATE
sur P = 0,2 %
C = 0,7 %

FIG. 7




% FERRAILLE
DANS CHARGE
METALLIQUE
50
40
30
20
10
0
ACIERIE A
ACIERIE B
0
0,5
1,0
1,5
2,0
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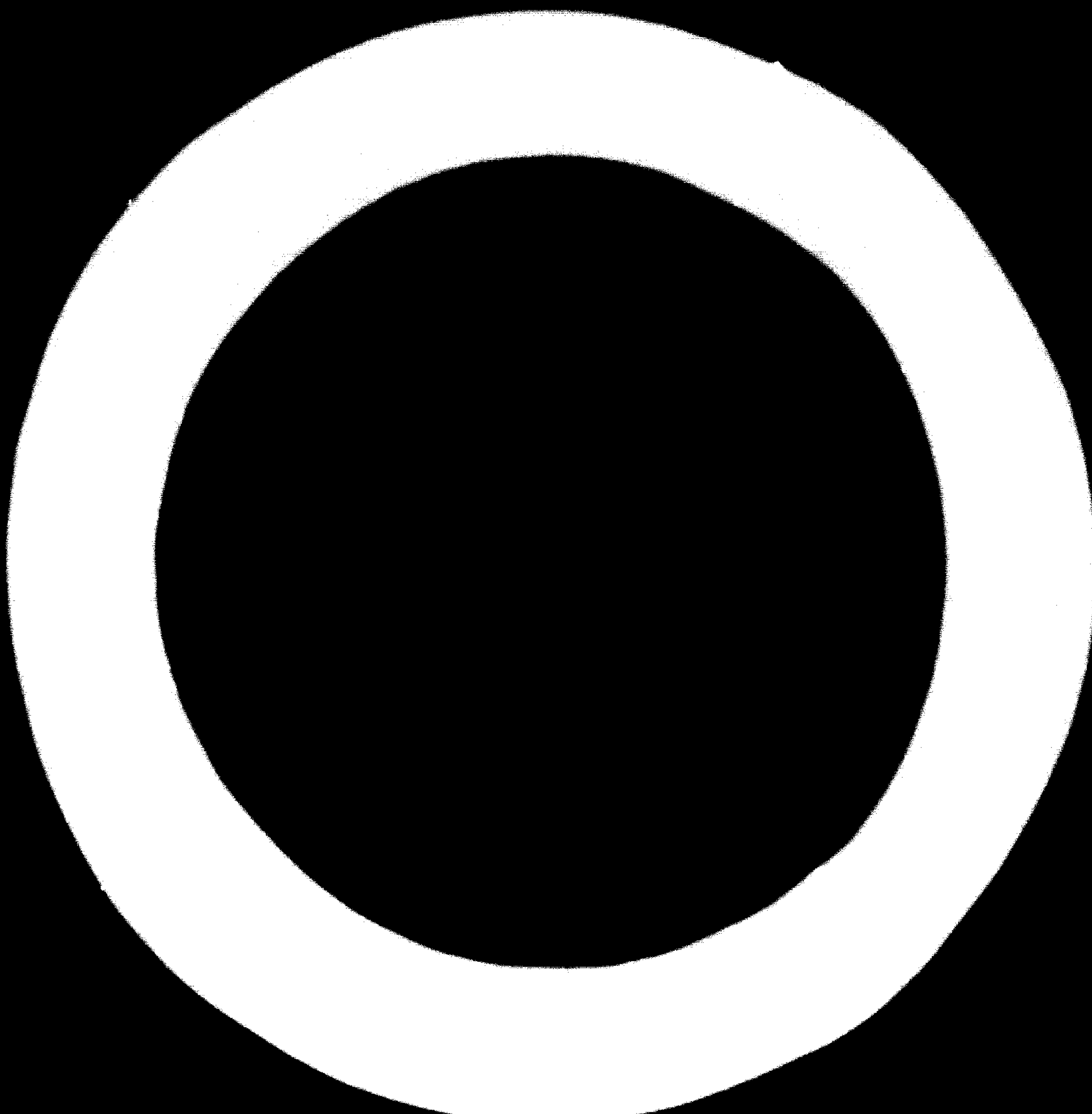
3,0
% Si

FIG. 8



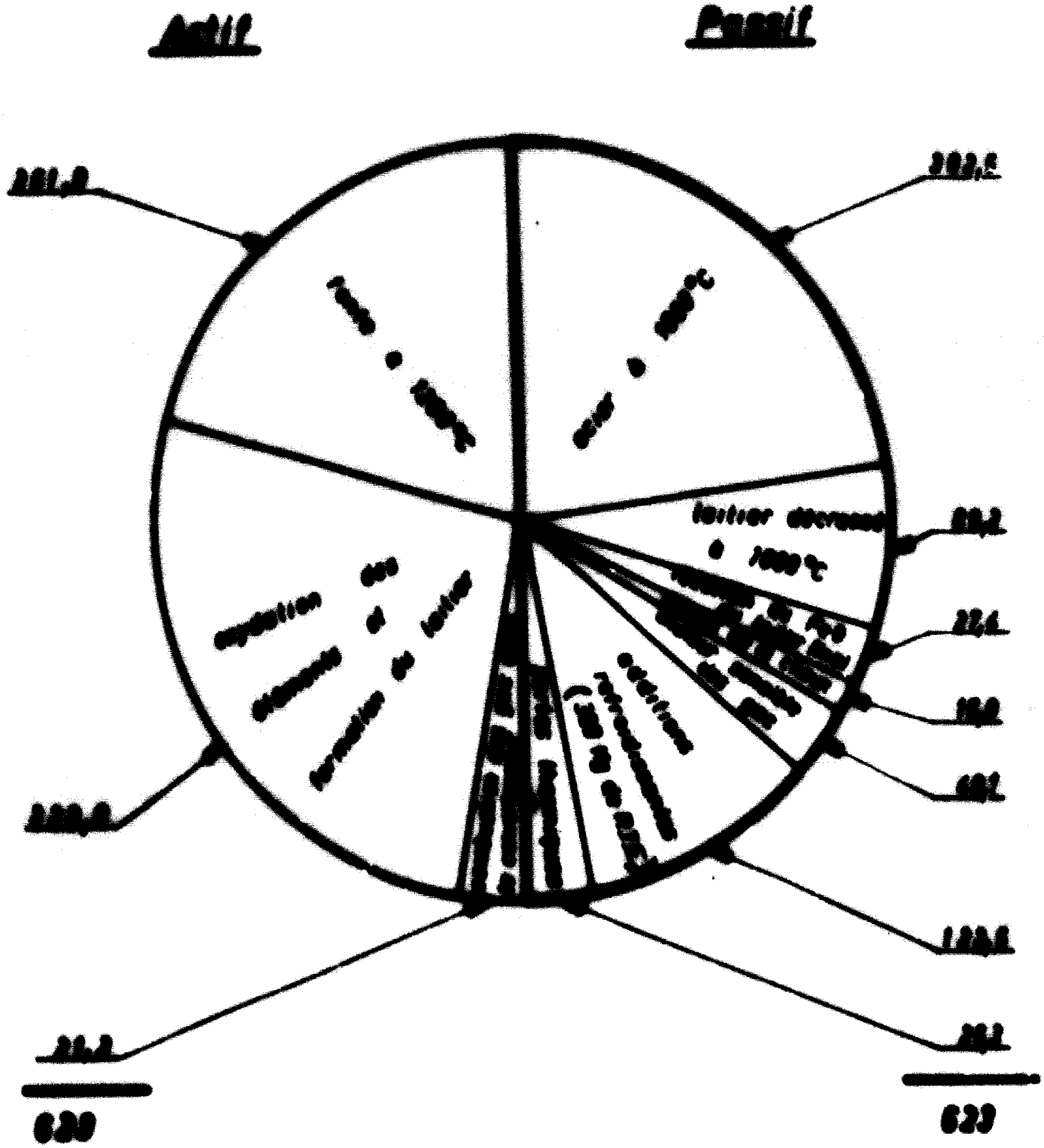
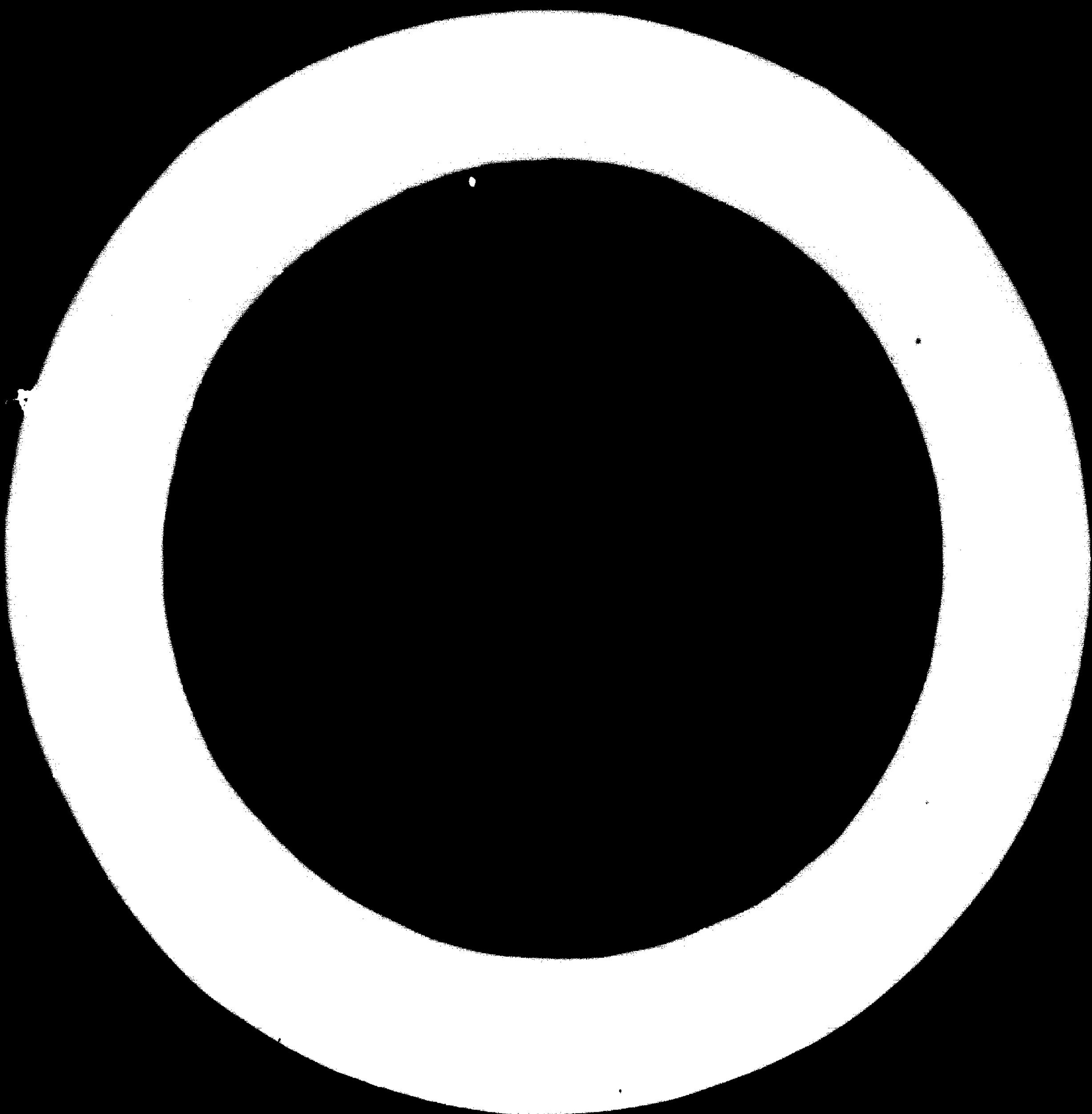
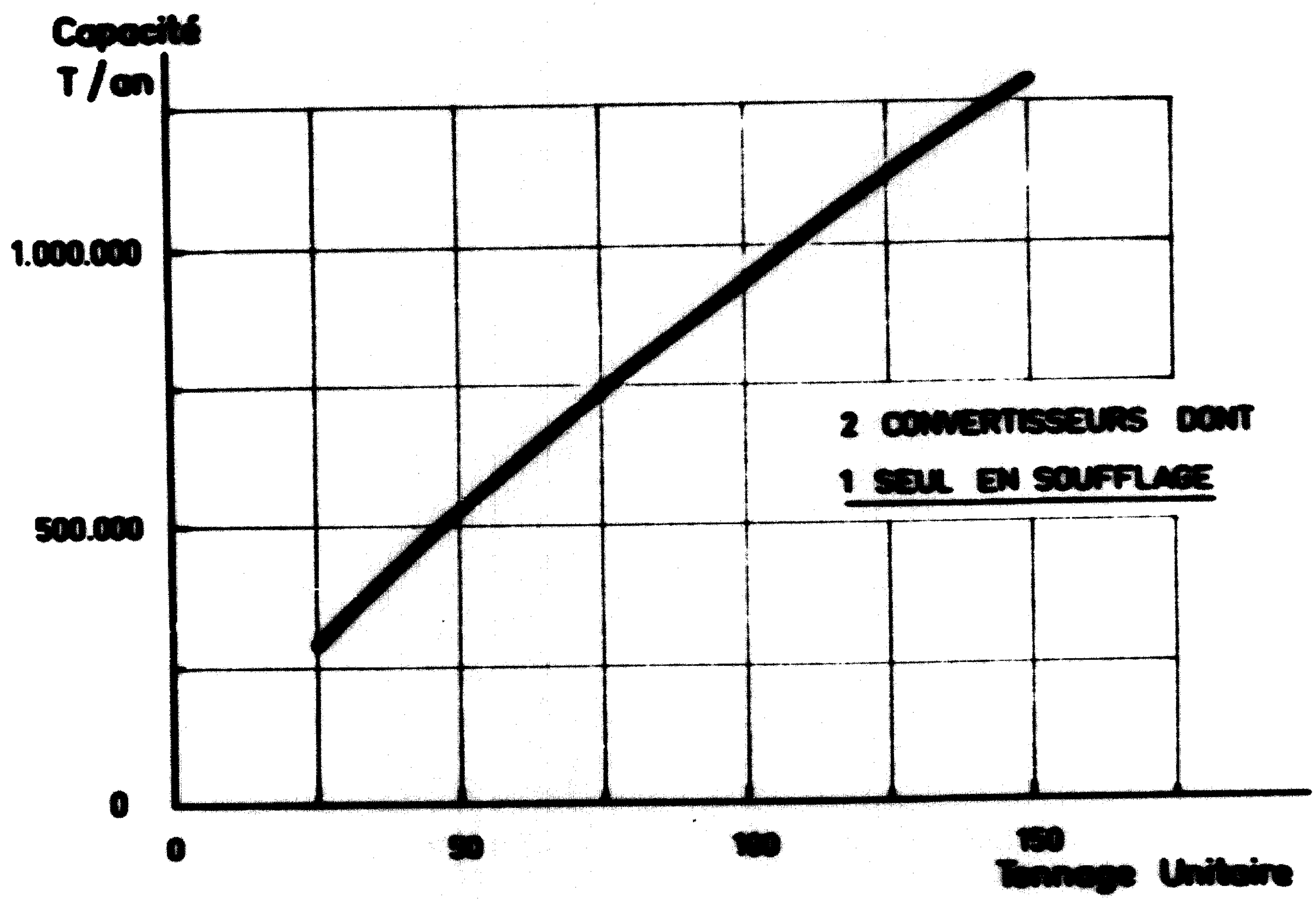

Actif
Passif
laitier décrassé
oxydation des
éléments et
formation du laitier
additions
620
623

FIG.9




Capacité
T/an
1.000.000
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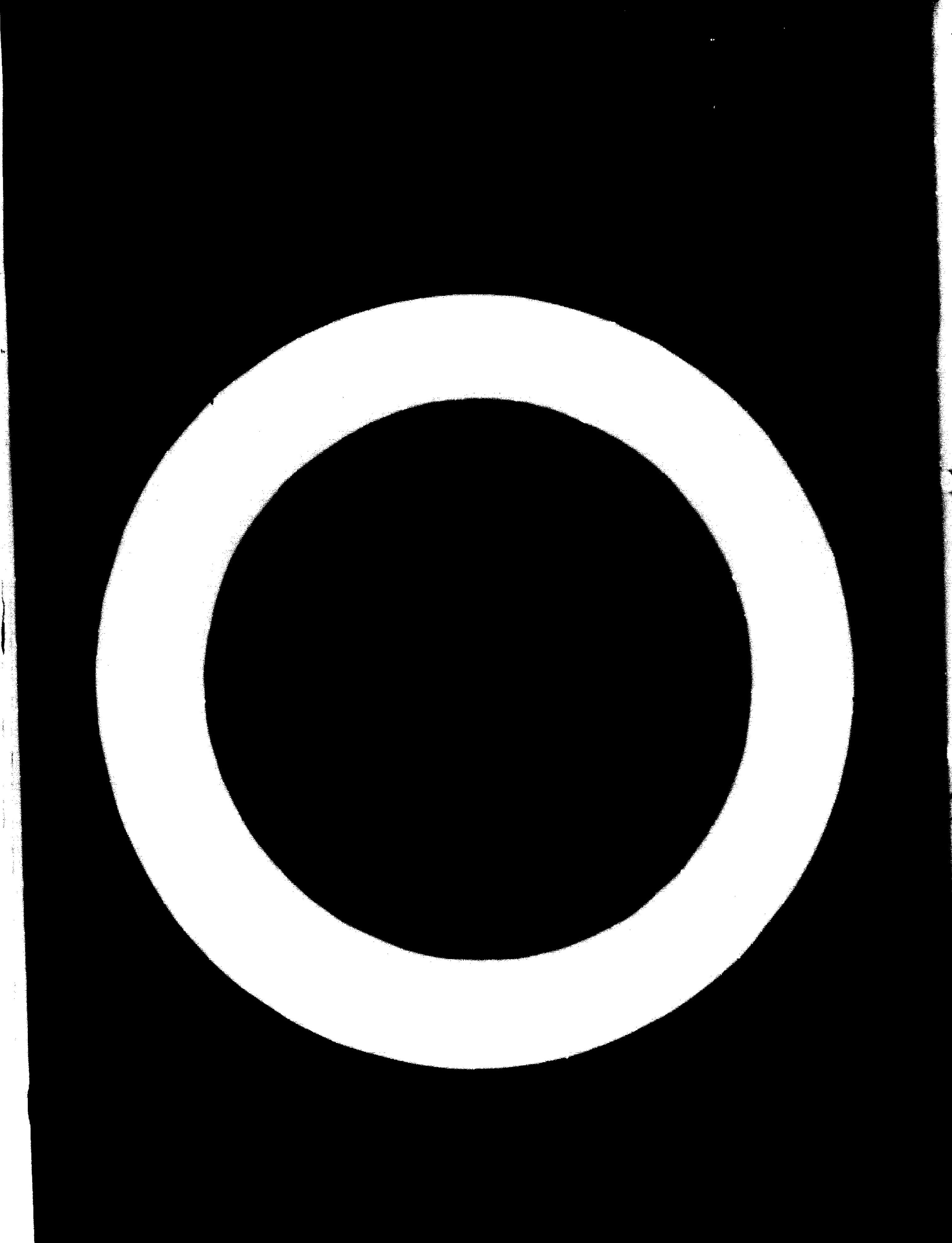
0
50
100
150
Tonnage Unitaire
2 CONVERTISSEURS DONT
1 SEUL EN SOUFFLAGE

FIG. 10



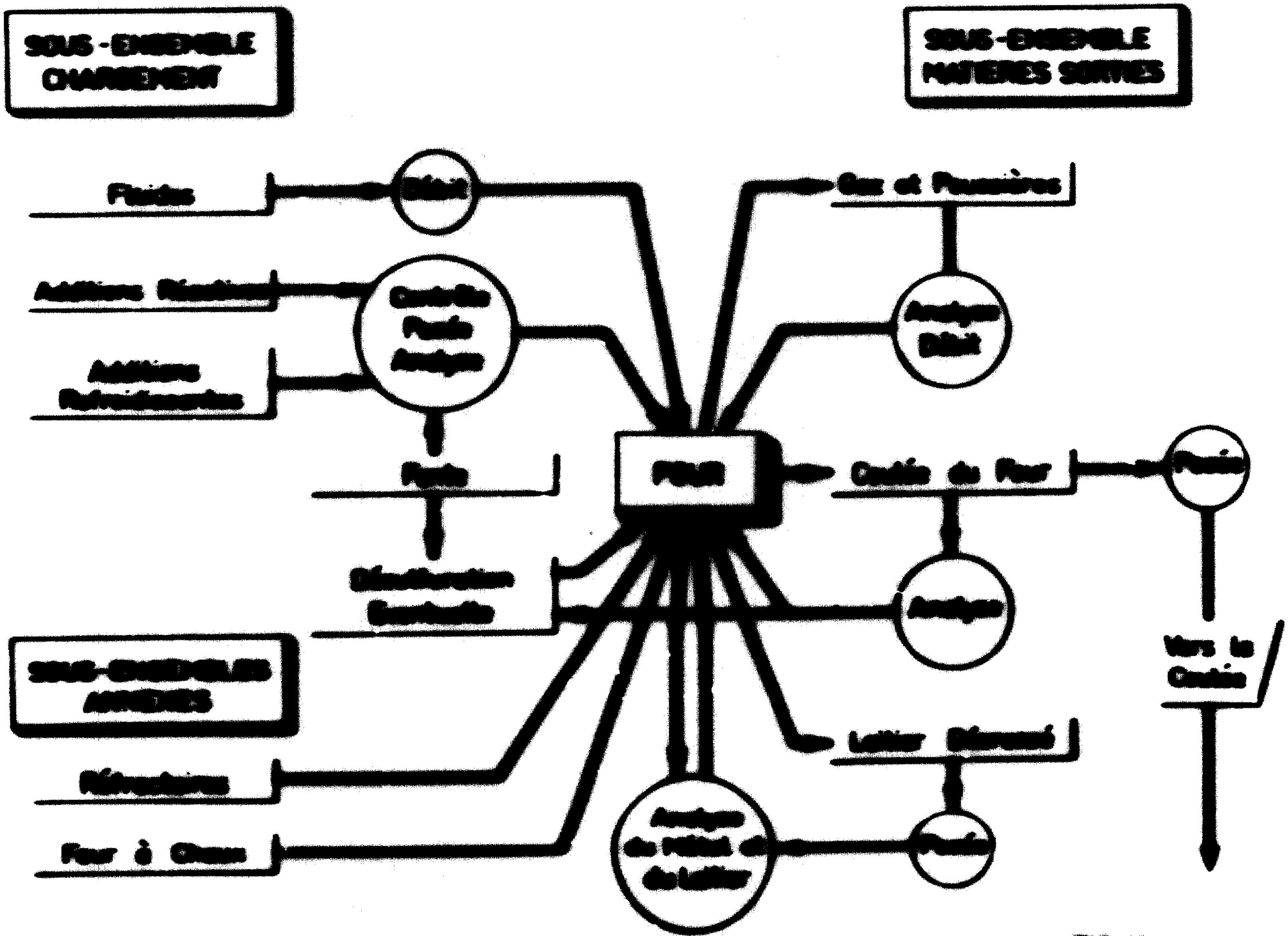

SOUS-ENSEMBLE CHARGEMENT
SOUS-ENSEMBLE MATIERES SORTIES
Fluides
Gaz et Poussières
Coulée du Four
Vers la Coulée
SOUS-ENSEMBLES ANNEXES
Four à Chaux

FIG. 11

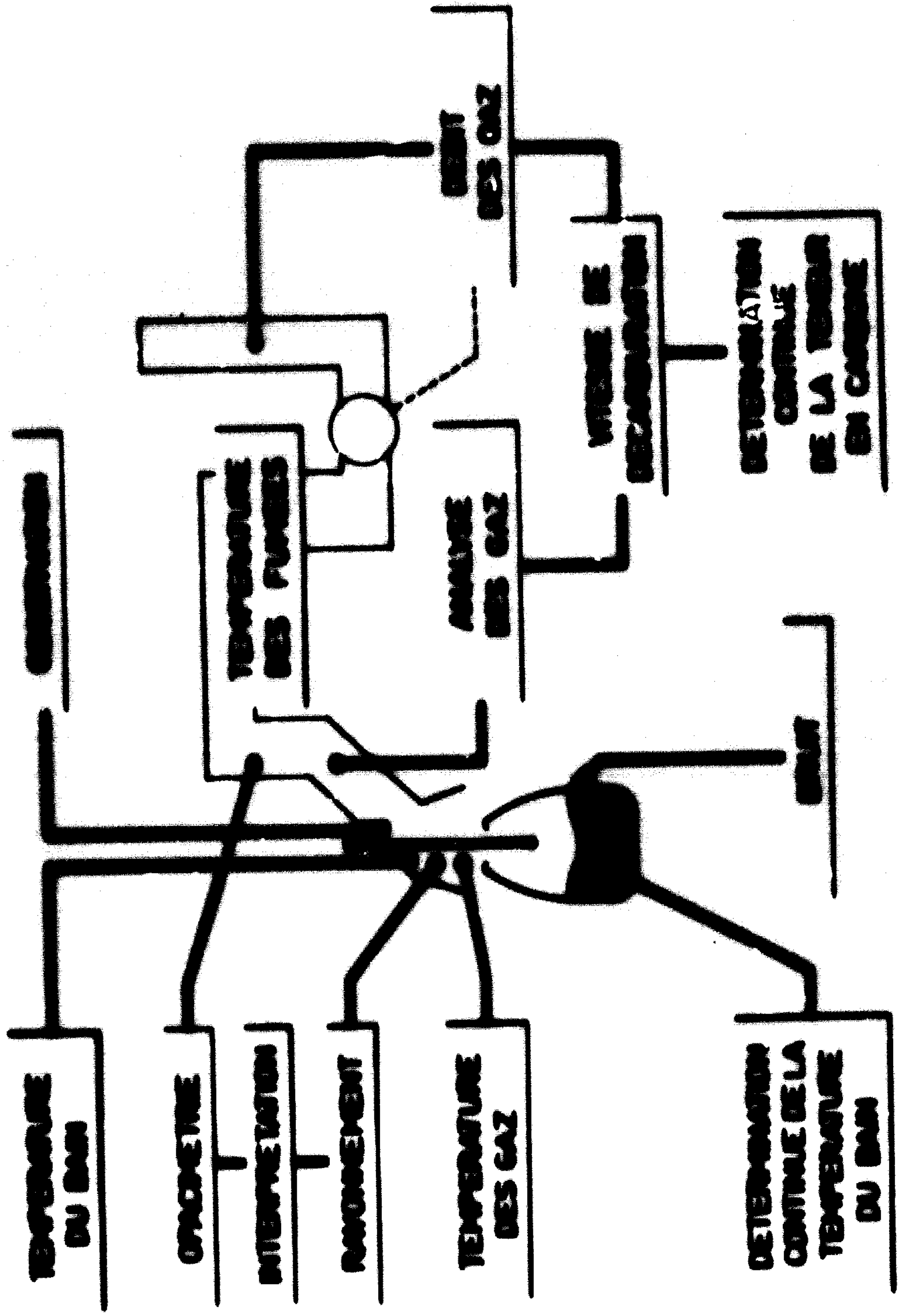

DEBIT DES GAZ
VITESSE DE DECARBURATION
DETERMINATION CONTINUE DE LA TENEUR EN CARBONE
TEMPERATURE DES FUMEES
ANALYSE DES GAZ
DEBIT
TEMPERATURE DU BAIN
OPACIMETRE
INTERPRETATION
RAYONNEMENT
TEMPERATURE DES GAZ
DETERMINATION CONTINUE DE LA TEMPERATURE DU BAIN

FIG. 12

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