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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.11
11 October 1963

Original: ENGLISH

D04788

OPEN HEARTH STEEL-MAKING WITH OXYGEN

by

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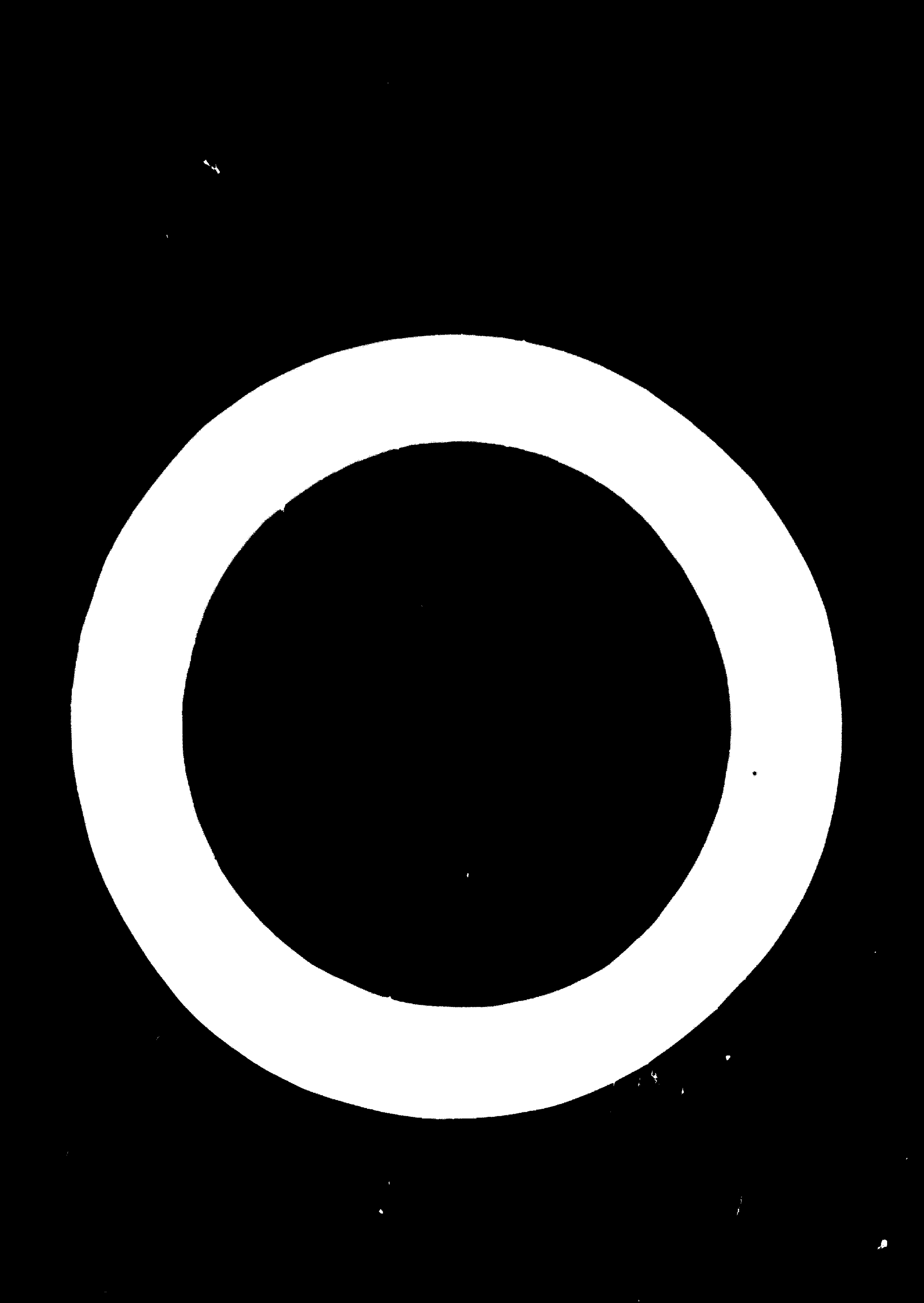
GE.63-14610

Prague 11/16 November 1963



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OPEN HEARTH STEEL-MAKING WITH OXYGEN

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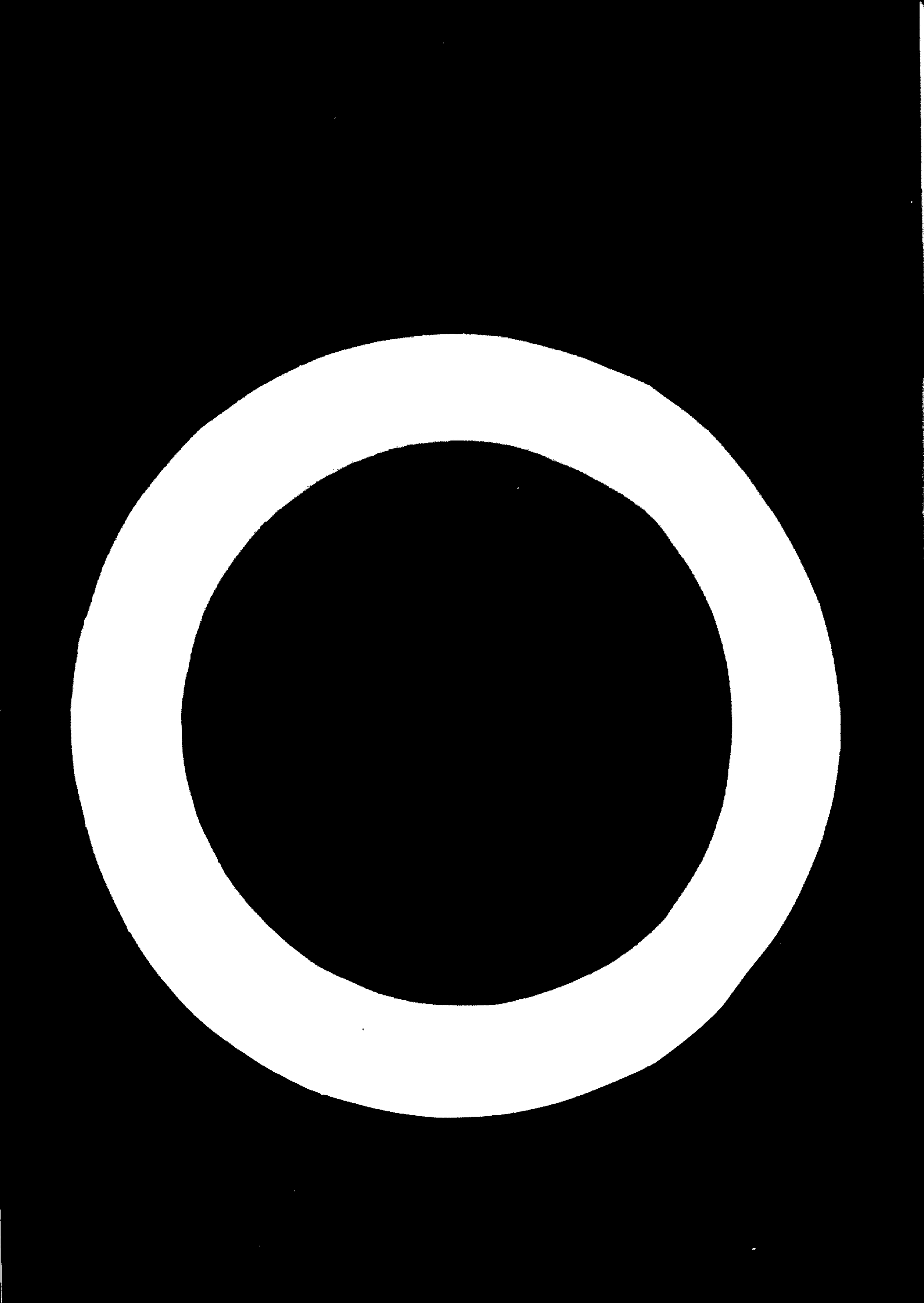

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Symposium on application of modern technical
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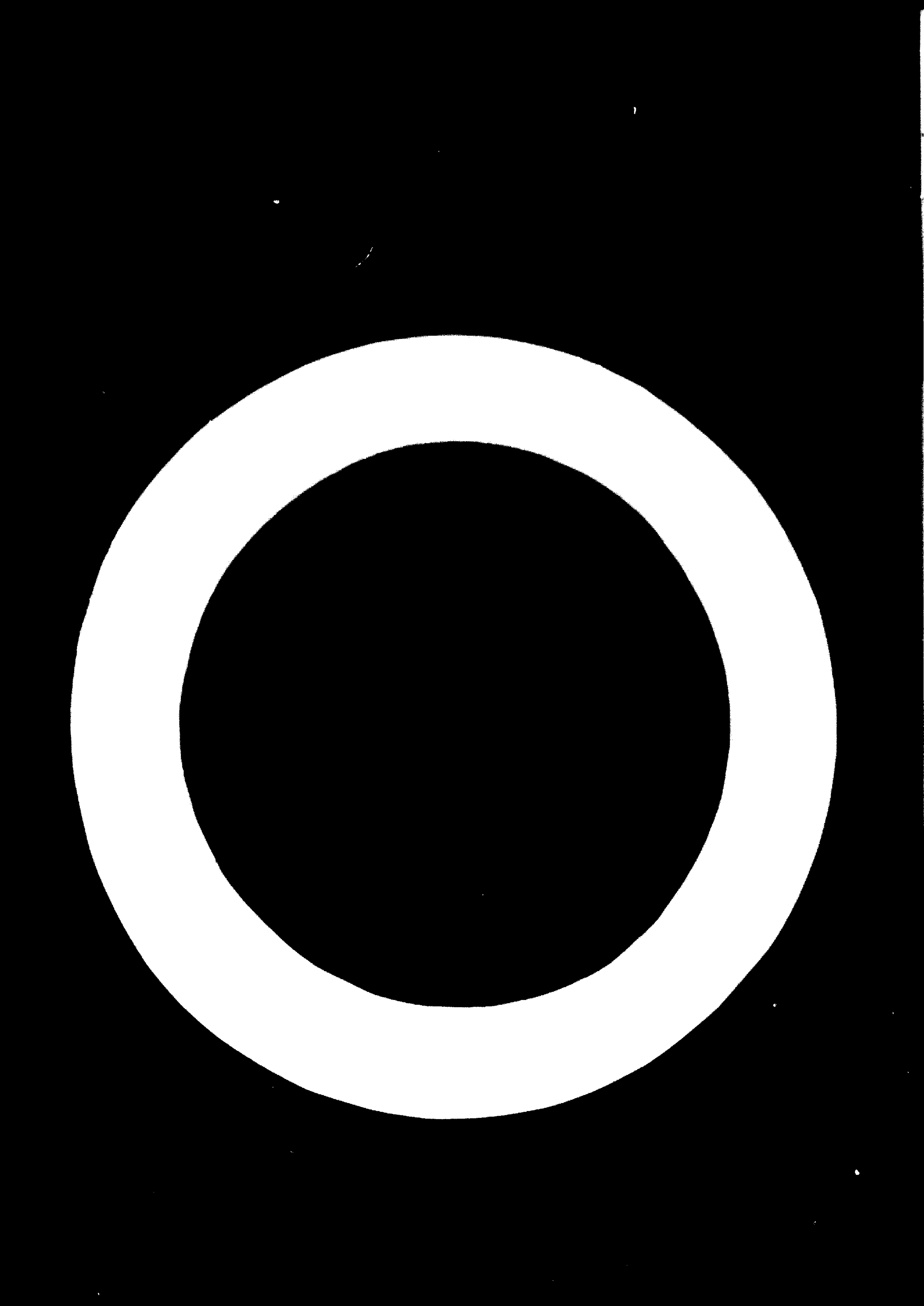

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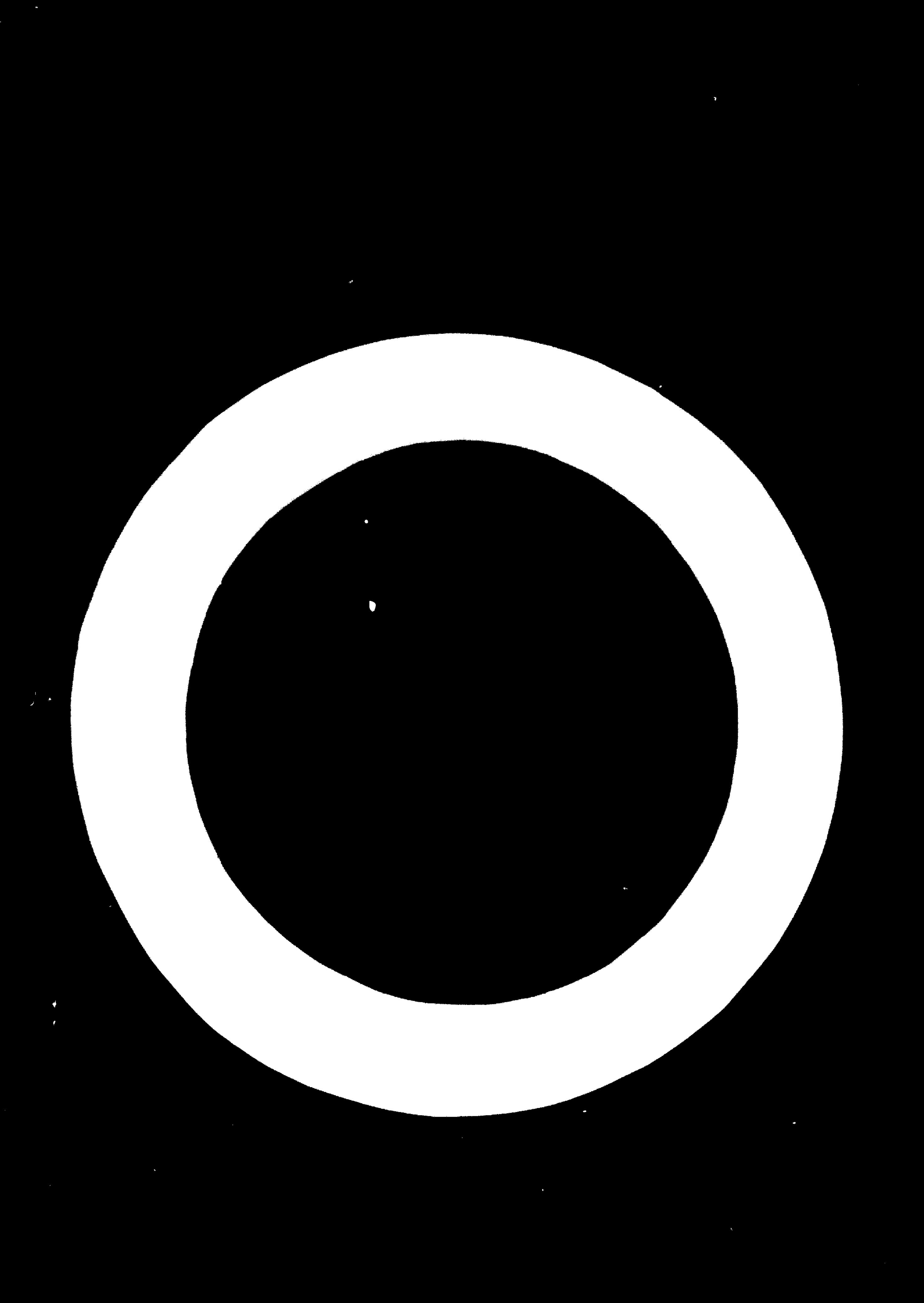


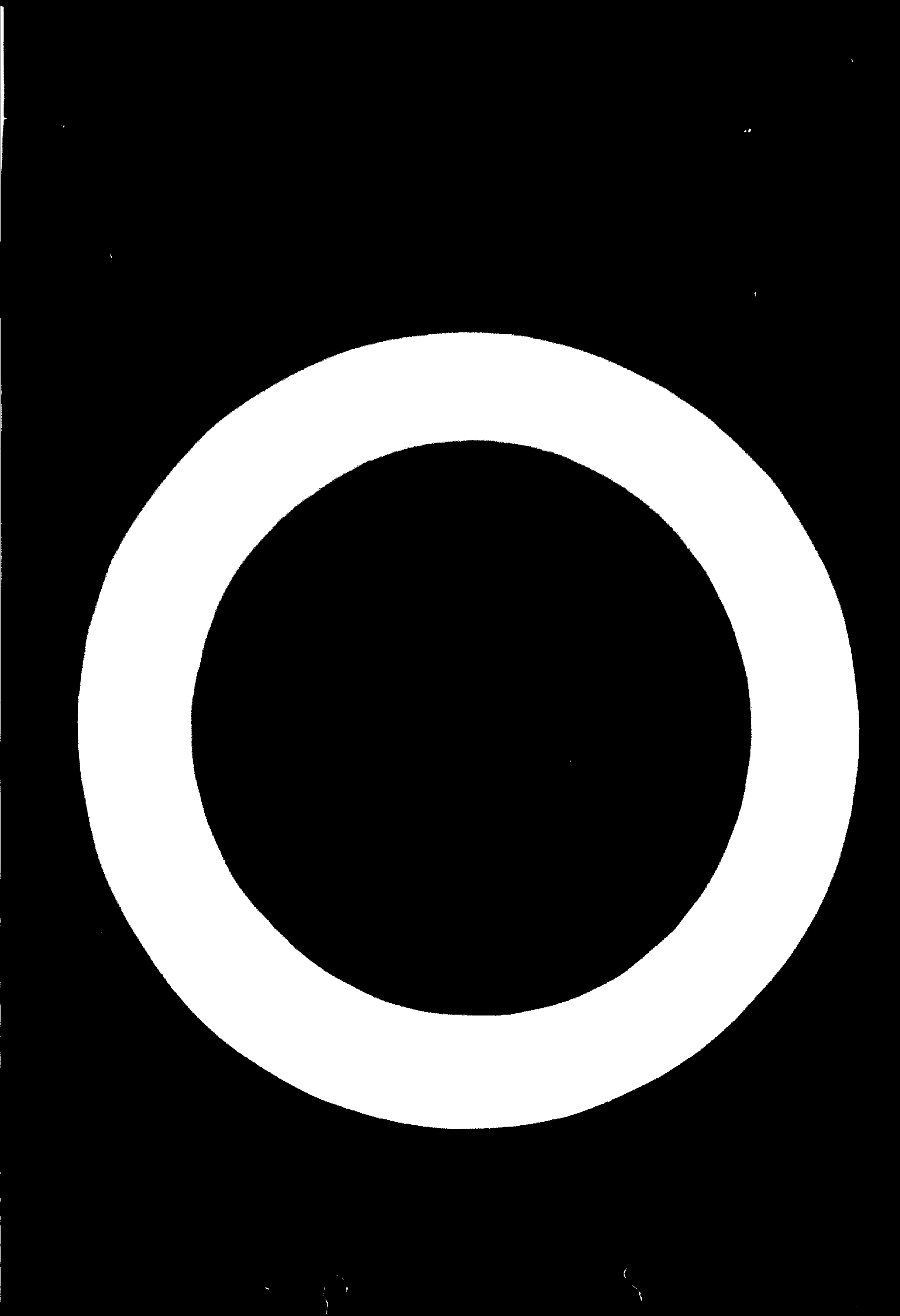
INTRODUCTION

The increasing demand for steel and the development of new converter processes have made it necessary for the Martin-Siemens steel concern to modify rapidly their production system, installing equipment suitable for the new processes involving considerable financial burdens, to increase to the maximum possible the output at the lowest possible cost.

To this necessity is mainly due the progressive evolution of the Martin-Siemens furnace, avoiding the building of new and costly plants.

This evolution has involved to same extent all sides of steel processing.

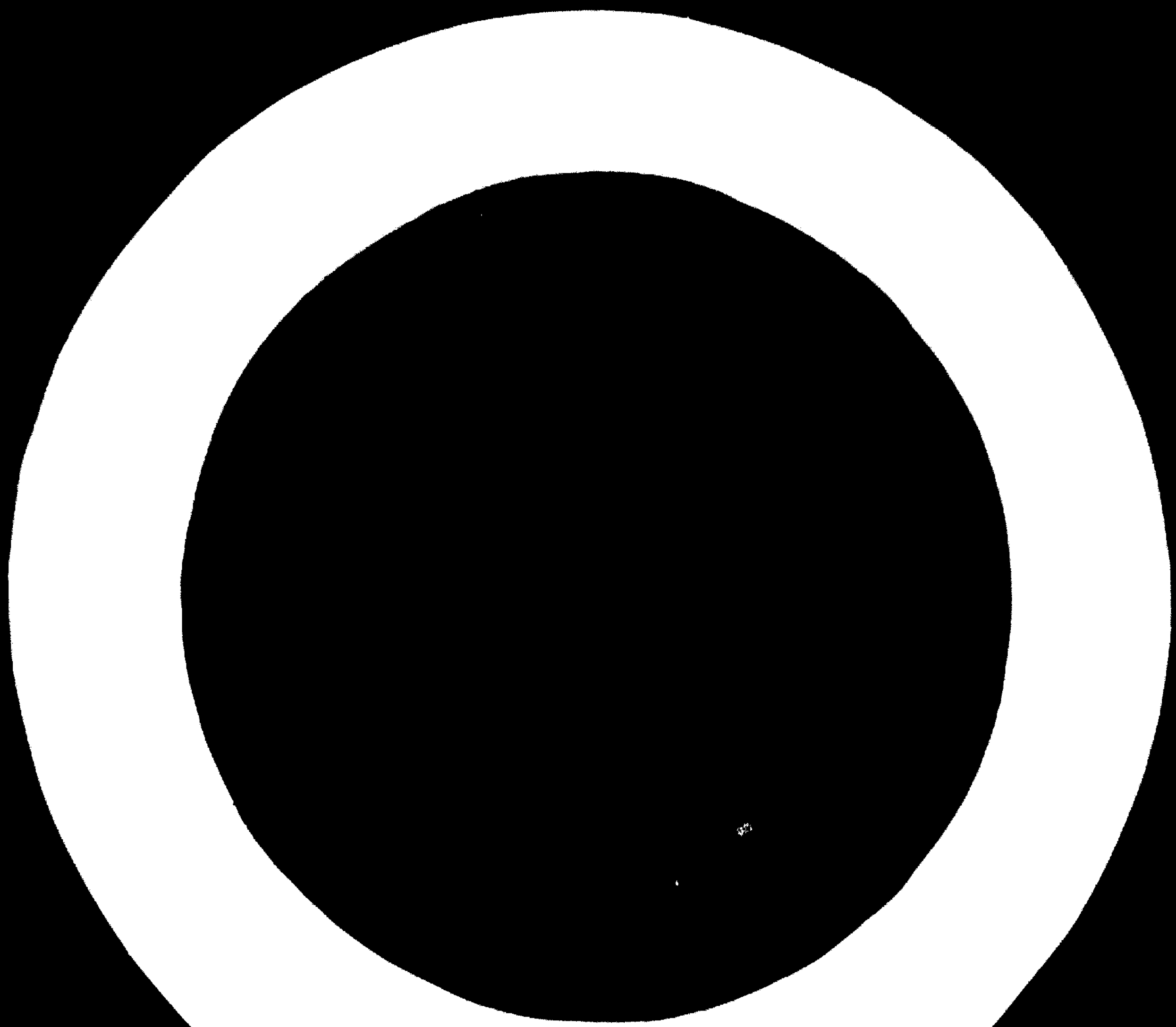
Thus, one has studied alterations in the design of the furnace to increase its capacity, lower repair time and lenghthen its life. Basic refractories have gradually taken the place of silicon bricks and silicon-alluminium bricks, so as to enable the furnace to run at higher temperatures. One has also made an accurate study of the factors of importance in operation and production (vol. of liquid iron, time from beginning of charge to molten metal, etc.). A gradual improvement has been introduced as regards auxiliary services, regulation and control systems.



In the general picture of this evolution, the principal factor increasing production has been the introduction of the intensive use of oxygen in melting and refining, which has produced a considerable shortening of the heat time.

The use of oxygen in the burners, modifying the flame and rendering it hotter, has accelerated melting considerably. The blowing with lances through the roof in refining, has deeply altered the kinetics of the oxidation reactions, in the past greatly tied to the slowness of the diffusion through gas-slag and slag-metal surfaces, by intensifiying the working of the bath and bringing about a good convection-mixing of the bath. The gradual evolution of the Martin-Siemens furnace and especially its improvement through the intensive use of O_2 have considerably strengthened its position, putting it once more on a competitive basis as regards other types of converters.

We do not intend to describe in the following pages in its general form the oxygen and output problem in Martin-Siemens furnace, also because this would not be practicable on an absolute basis, as the result of the use of O_2 depend strictly upon the different working conditions in the various Steel-works. We shall limit ourselves to a description of what has been recently achieved in our plants and of the results which have been obtained.



BRIEF OUTLINE OF PAST DEVELOPMENTS

The "Oscar Sinigaglia" Steelwork belonging to the Italsider Group is equipped with 6 basic Martin furnaces, designed by Maerz, of 250 M.T. capacity each.

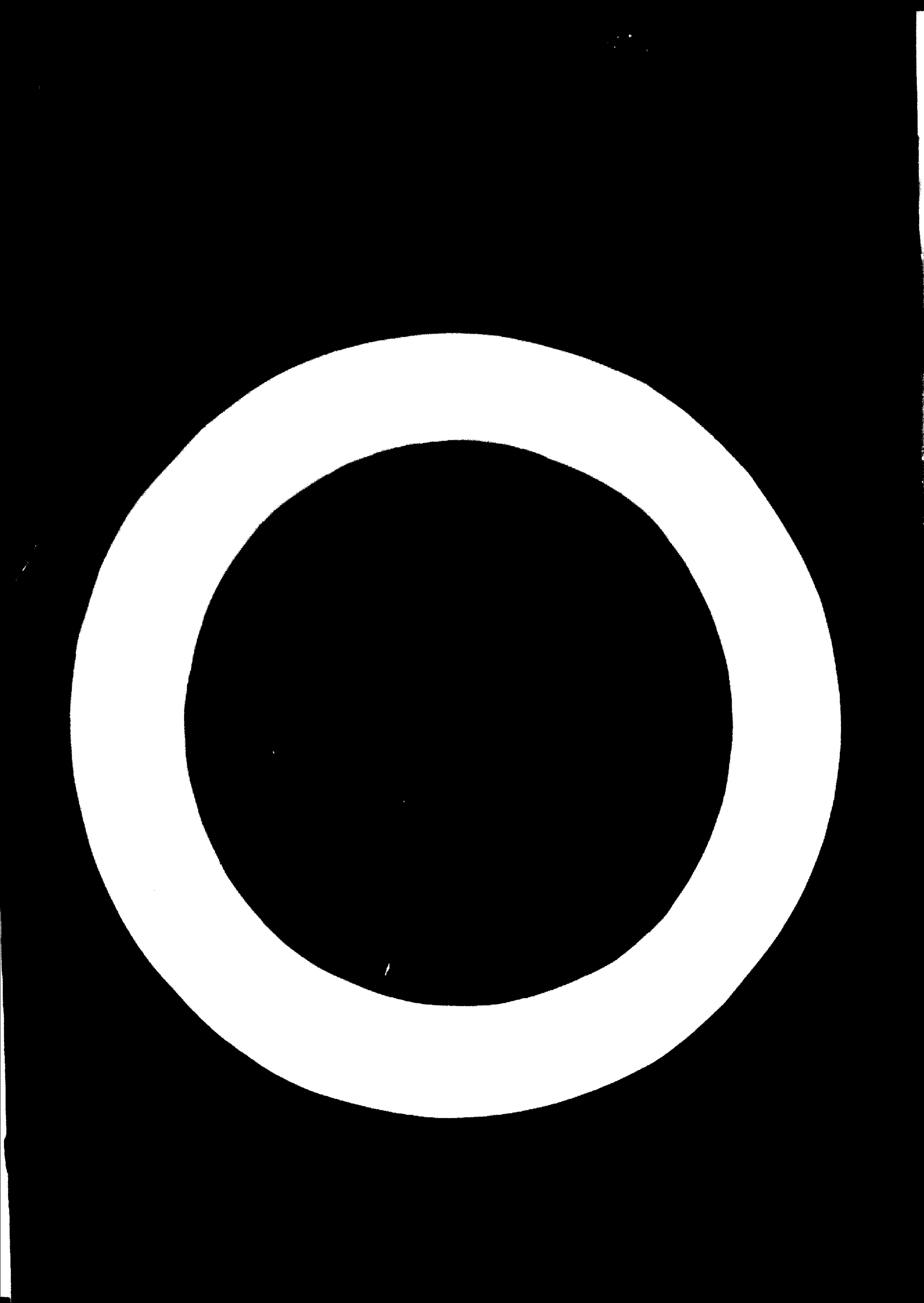
The present output volume is of around 140,000 M.T. monthly, which corresponds to a yearly output of 1.7 million M.T.

Plans for the near future foresee a rise in the yearly output up to 2 million M.T. of steel , later on to 2.2 million M.T., the capacity of the furnaces being eventually increased to 300 M.T.

The output consists mainly of low carbon content rimming steel for drawing sheets.

The use of oxygen in Martin furnaces was first tried out in these works in 1956, when the need to obtain a greater steel output from the existing plants produced research on new operating procedures capable of increasing production.

At first, the use of oxygen was limited to the decarburization phase. It would be introduced by means of iron tubes through the holes in the charge doors. This system, althouth technically efficient, was later given up due to several disadvantages which only recently have been mainly overcome in Japanese steelworks, where actually



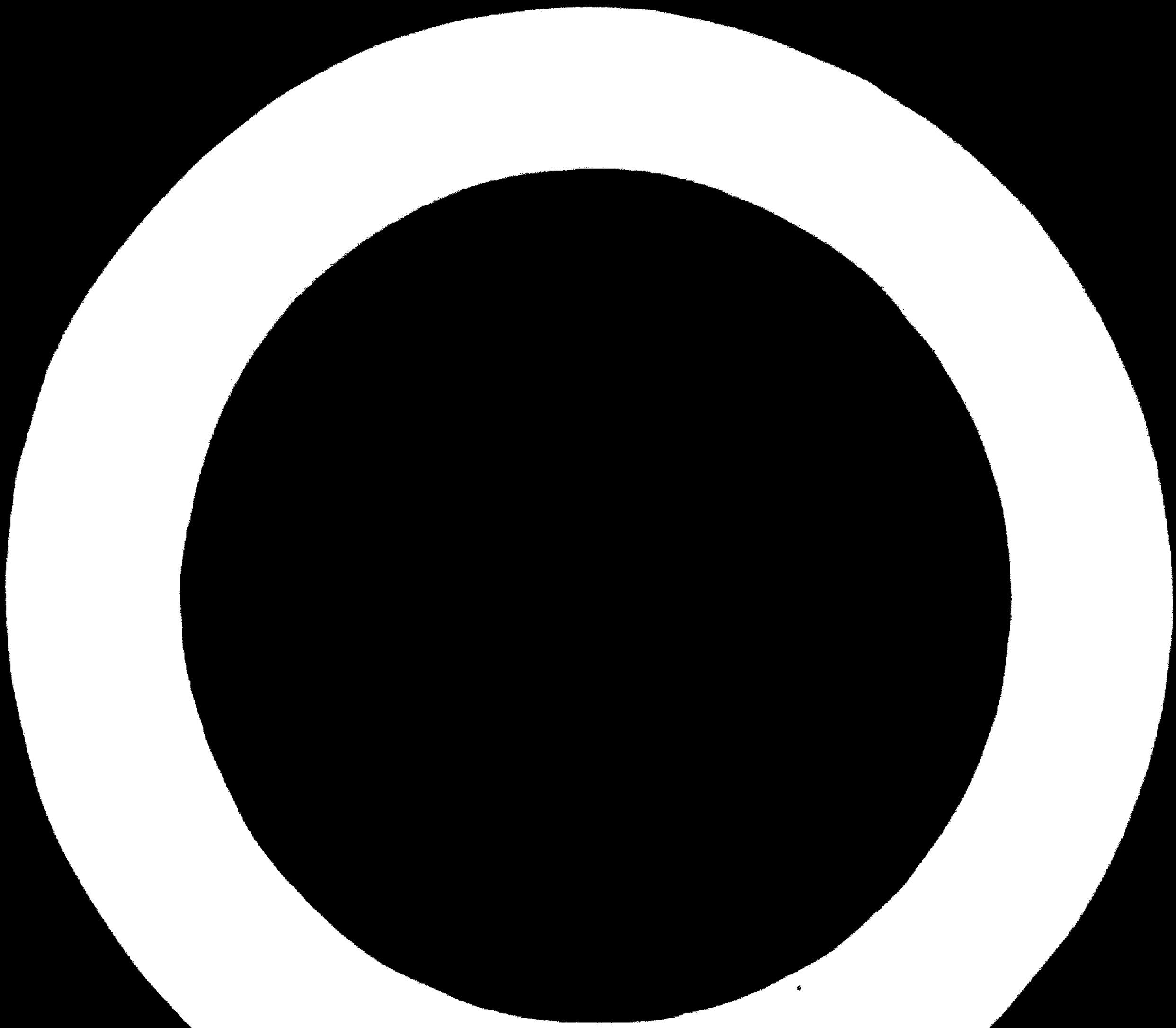
this type of procedure has been increasingly adopted giving excellent output results.

The following step was taken with the introduction of water-cooled lances passing through the roof (at first one lance per furnace, then two, and at present three). With the adoption of the basic roof, the length of the oxygen blowing was increased to the point of starting it from the completion of the molten metal charge.

At the same time, we also developed the method of using oxygen in combustion, from the start of the solid charge till the introduction of the molten metal, or until the taking of the first sample, reaching an enrichment of the air corresponding to about 25% of oxygen.

The combined use of these two procedures (enrichment of combustion air during the initial phase of melting, and later use of lancing oxygen into the bath) produced the results outlined in Table 1, which refer to a test furnace. These results brought about the following development at the "Oscar Sinigaglia" steelwork:

- a new Ø 28' blast furnace to increase liquid iron production;
- two oxygen production plants, with an output capacity of 5600 cu.m./hr. each;
- extension of the steelworks auxiliary services (enlarged liquid pig iron bay, charge and pouring cranes, and accessories etc.),



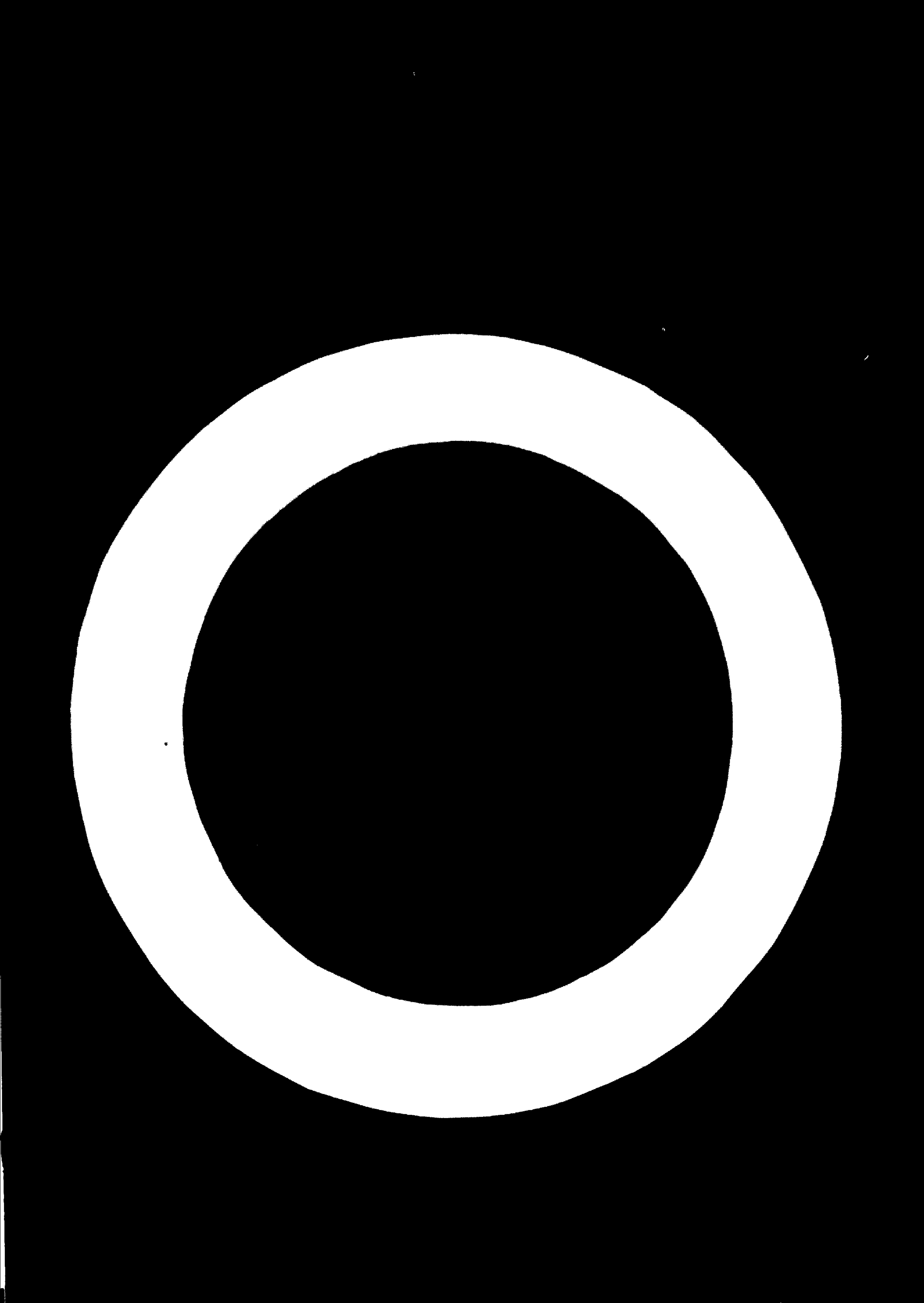
These new installations have been gradually put into operation as from 1962, and thus since then the oxygen method has been adopted intensively.

While greater quantities of liquid iron and of oxygen are making possible a gradual increase in the overall output of the steelworks, plans have been made for new tests to be carried out to complete and develop the studies carried out in 1958.

TESTS COMPARING THE USE OF THE OXY FUEL LANCE TO THE USE OF O_2 TO ENRICH THE COMBUSTION AIR

From the results of the preceding years' tests, we had seen that the use of O_2 to enrich the combustion air produced considerable increases in output, even in the case of charges with a high percentage of liquid pig iron. Later, in the U.S.A., oxygen fuel lances were developed and tested, these being auxiliary oxygen burners passing through the roof of the furnace, to spread and increase over the solid charge the high temperature zones given by oxygen combustion. This method can be considered a development from the lancing of oxygen from head burners.

In order to see if the greater output described in technical literature in connection with the use of "oxy-fuel" were feasible in our present installations, and would thus justify the minor adjustments needed, we carried out test

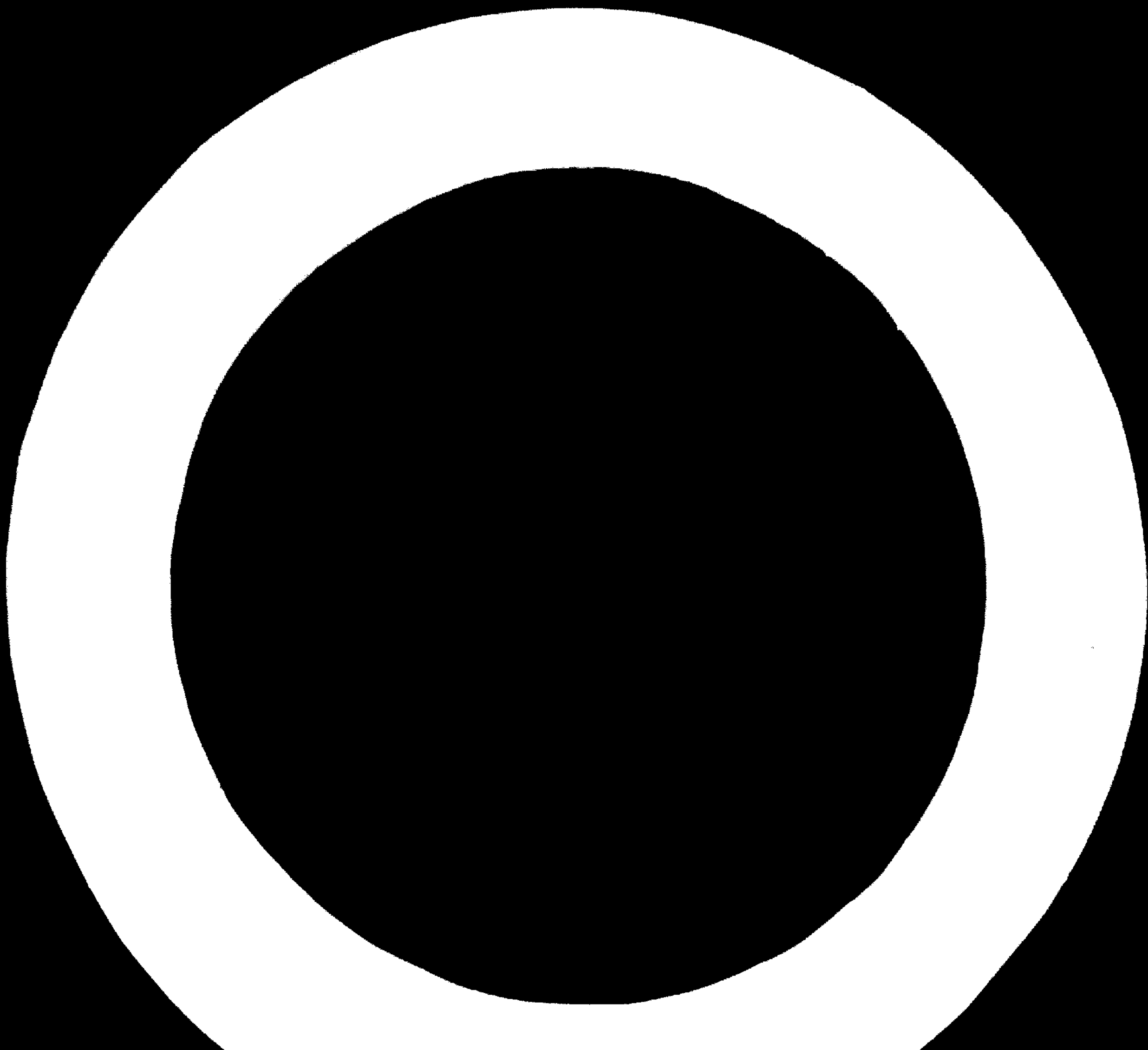


furnace heats to compare the "oxy-fuel" method with the usual method of using O_2 through head burners. For this purpose, the central three-nozzle lance was replaced with a specially designed lance,which allowed the simultaneous introduction of oxygen and methane. From first charge to the introduction of liquid iron, the method of combustion consisted in the use of oxygen through the head burners to a capacity of 2000 cu.m./hr., and from the "oxy-fuel" lance to a capacity of 1800 cu.m./hr. The combustion air volume was fixed at 50 x 10^6 Cal. equivalents per hr. The CH_4 supply from the central lance was at 9 x 10^6 Cal./hr., while the entire fuel supply from the head burner was automatically controlled by a continuous analyzer of O_2 in the fumes, adjusted for the desired 3% value.

The heats in this comparison had an indentical combustion operation, except for the oxy-fuel lance which was not in use.

After the introduction of the liquid iron, in both cases, two O_2 lances were used having a total capacity of 3000 cu.m./hr.; the supply of oxygen from the burners and of oxygen and methane from the central lance was of course cut off.

The heats in the two series were duly planned in the statistical sense, to reduce to a minimum the effect of other variables in heat times and consumption. The results of the tests are shown in Table 2.

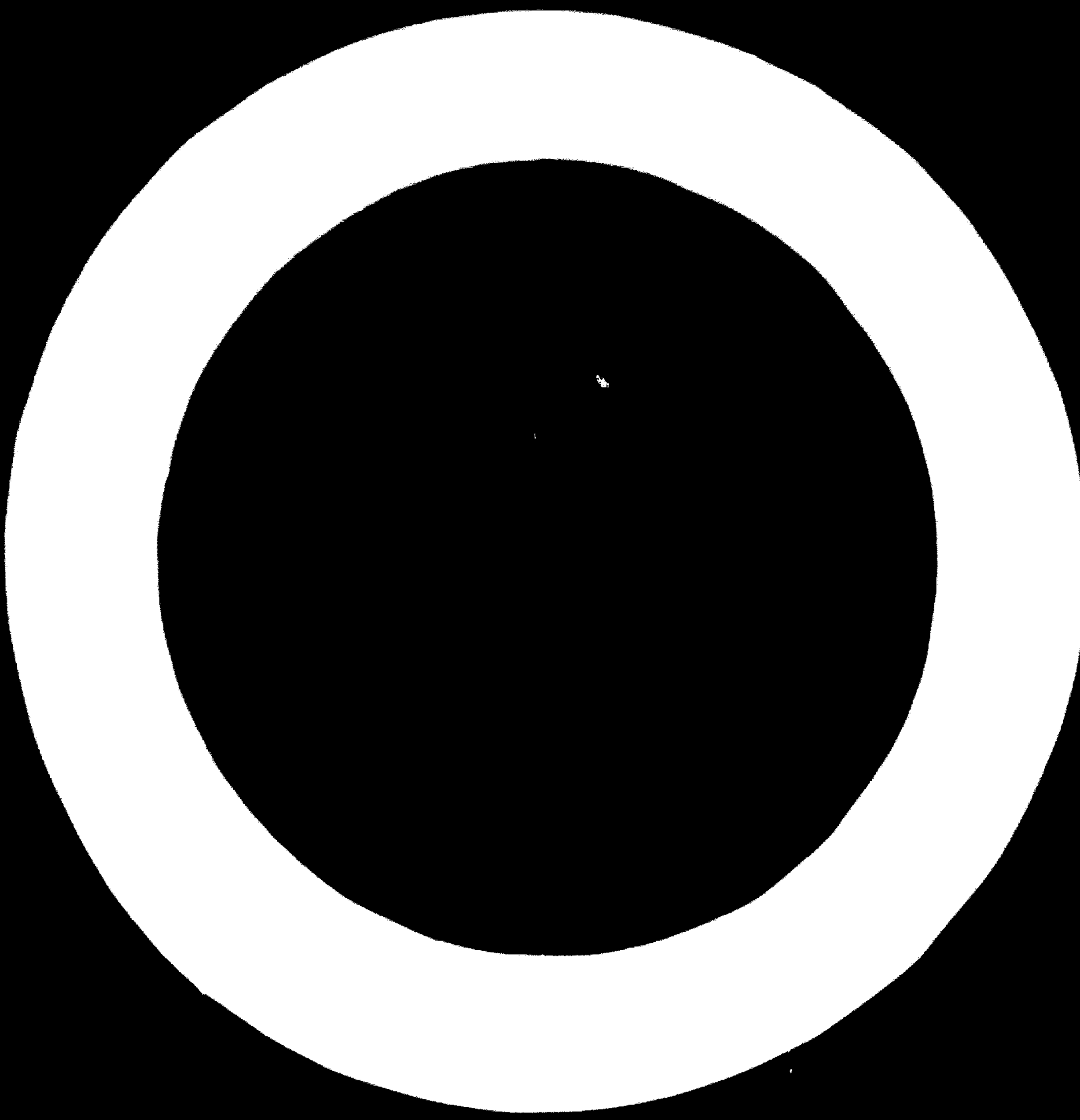


From these results one can see that the oxy-fuel did not actually produce increased output, but rather only a heavier consumption of oxygen and fuels.

The main reason for this negative result lies in the type of installation in our steelworks. In Fig. 1 one can see the statistical correlation, between the time from charge to pouring and the time from first charge to introduction of first liquid iron, produced for the heats with the use of oxy-fuel. In the statistical examination of the influence of the various factors on the heat time, the time of introduction of the liquid iron is shown to be the most important, as can be seen from the steep slope of the regression line.

It therefore appears that to obtain the maximum advantage in production from the oxy-fuel method, one should concentrate upon having a very rapid introduction of the liquid iron into the furnace. In order to achieve this, it is essential that the utmost speed be applied to the solid charge: this, for a 250 M.T. capacity furnace, should in our opinion be at least of 200 to 250 M.T. for hour. Such a charge speed is not feasible continuously for all a steelworks' furnaces, unless one has an especially good installation for the preparation of scrap and sorting of charges, or unless one adopts new charging systems which still need to be tested.

As in our case we did not feel we could garantee on a continuous basis charge speeds of over 100÷120 M.T./hr.



of scrap, we have abandoned the oxy-fuel method for the time being.

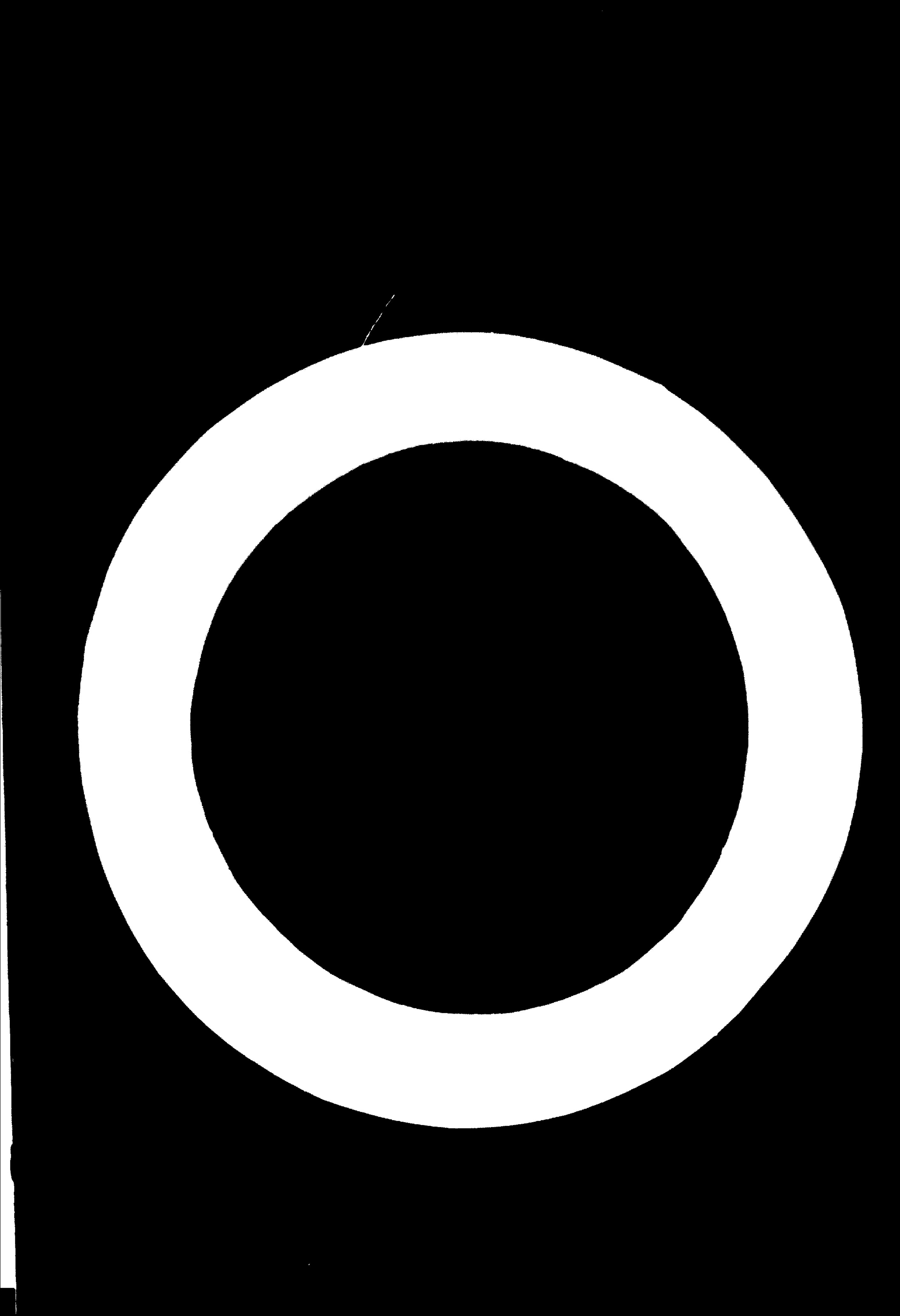
Another result of these tests is that one should consider a single oxy-fuel lance to be probably insufficient for a furnace of 90 sq.m. hearth, not producing fully a suitable distribution of high temperature combustion zones over the charge. Moreover, research upon the optimum oxygen-methane ratio might produce definite improvements in consumption.

TESTS COMPARING THE USE OF OXYGEN IN COMBUSTION AND BLOWING ONLY WITH LANCES

The above remarks upon the introduction into furnace of the liquid iron, and the consequent need for a rapid charge, actually hold true for any method which involves a sufficiently high intensity of combustion during the first phase of the heat. Even with the simple use of oxygen from head burners, an insufficient charge speed hinders the full exploitation of the potential advantages of high temperature combustion.

We thus consider it advisable to concentrate the use of all the available O_2 (35 cu.m./M.T. approx.) on the period following the introduction of the liquid iron.

In this way, possible delay in the charge or liquid iron, though obviously unfavourable to productivity, do not



cause a higher consumption of oxygen and, in part, of fuel.

To cross-check these conclusions, we have carried out a series of tests comparing heats with oxygen in combustion and with oxygen from lances only.

The first method involved:

- injection of O_2 from the burners up to the introduction of the liquid iron, with a supply of 2000 cu.m./hr.
- injection of combustion air constant for the entire heat and equal to 45×10^6 Cals.equiv./hr.
- injection of O_2 through 3 lances, during the period from liquid iron to pouring, with a supply of 2250 cu.m./hr.

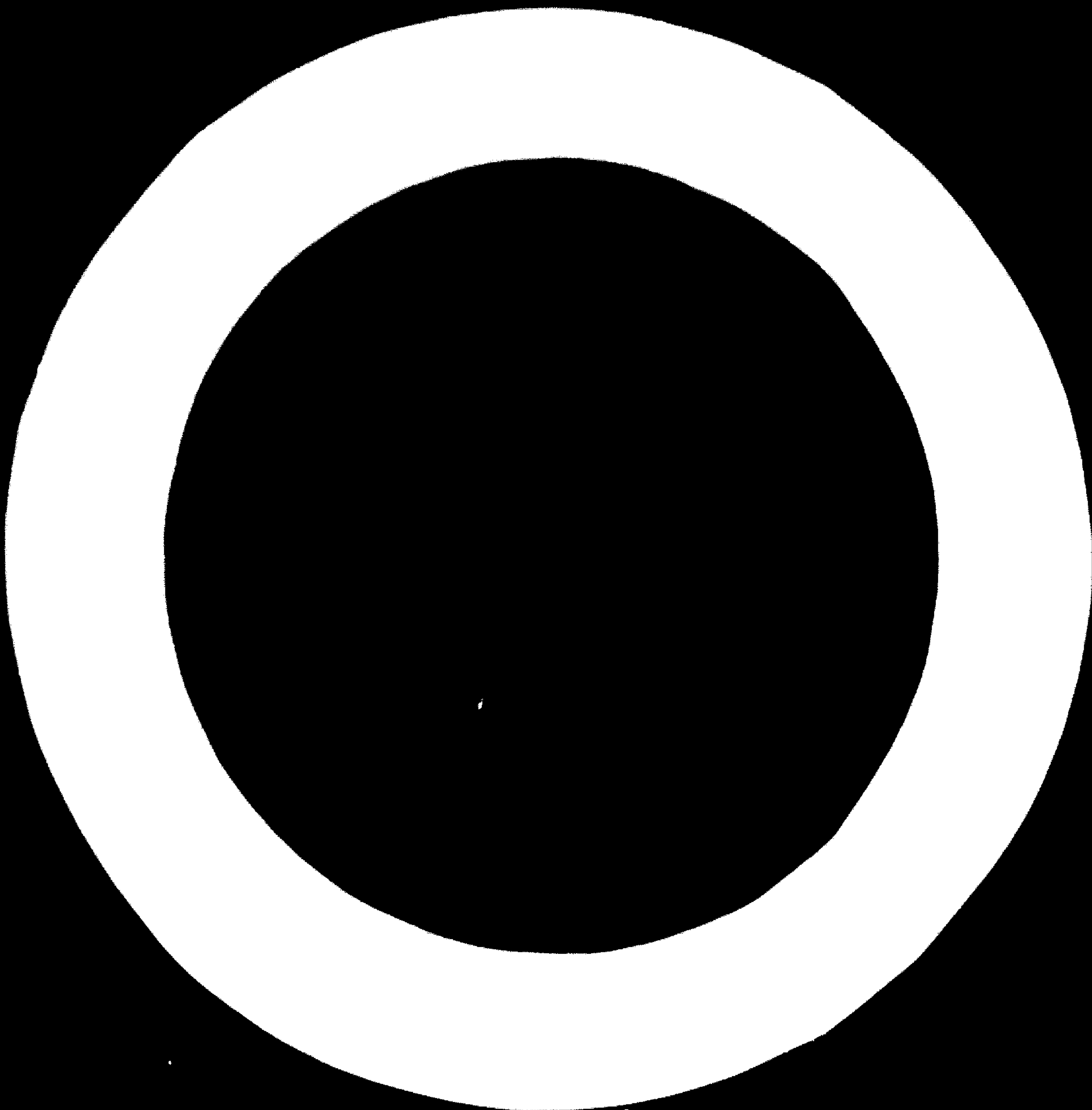
The second method involved:

- injection of air constant for the entire heat, equal to 45×10^6 Cals.equiv./hr.
- injection of O_2 through the 3 lances, from liquid iron to pouring, with a supply of 3000 cu.m./hr.

In both cases, the supply of fuel was automatically controlled by the fumes analyzer, adjusted for the desired 3% oxygen value during charge, and 4.5% after the liquid iron.

The results of these tests are shown in Table 3.

From these one can see that practically the same production per hour can be obtained using O_2 through the lances only instead of through the burners, achieving however a reduction in oxygen and fuel consumption.

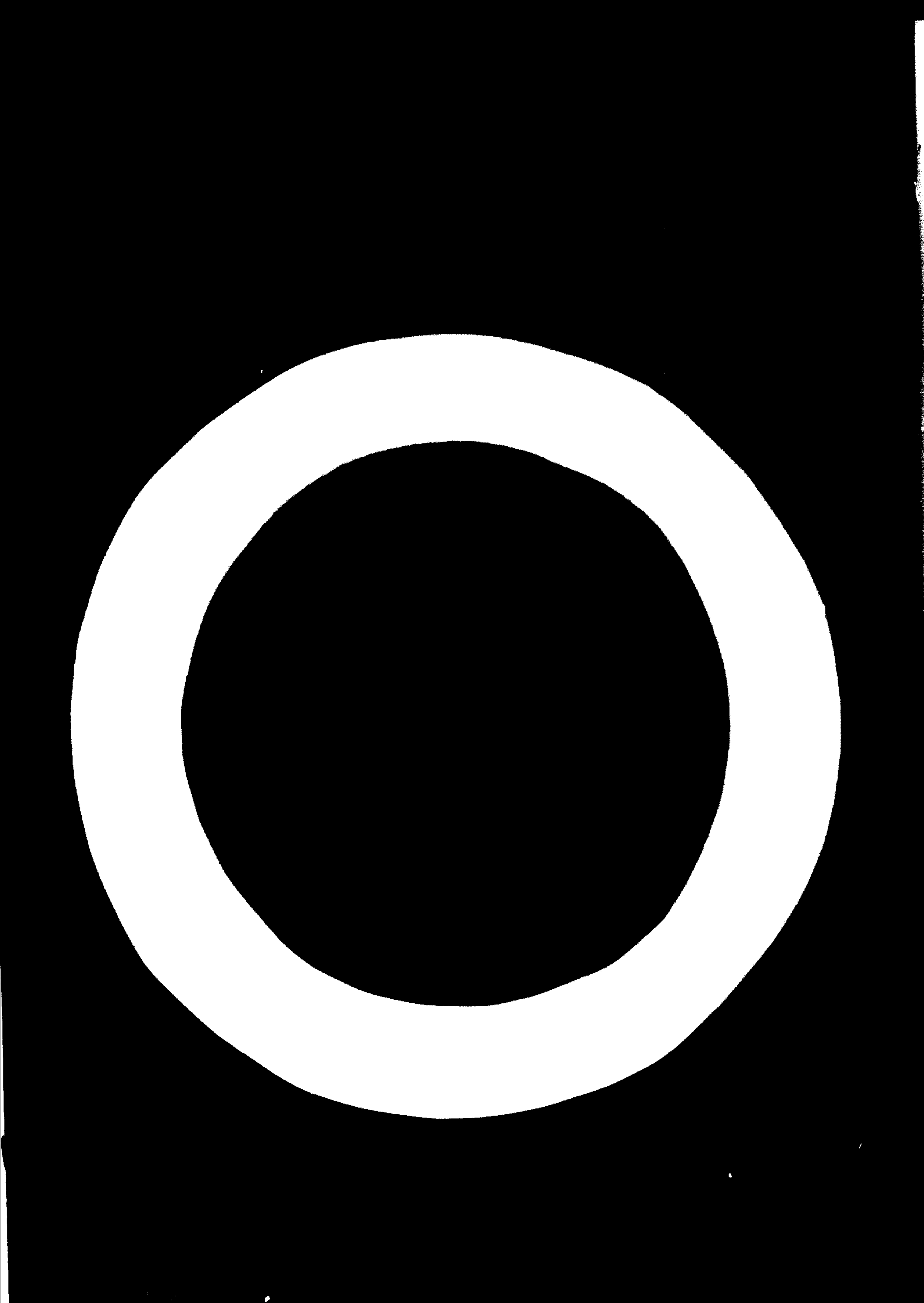


The results shown are of course valid for charges having over 60% liquid iron. For lower liquid iron percentage charges, it may be advisable, from the production point of view, to raise the intensity of combustion before introducing the liquid iron, and this, depend over a certain limit as it is from the regeneration capacity of the checkers, is advisable only with the use of oxygen in combustion.

One should note however that the use of oxygen injected at high speed through the head burners, apart from enriching the combustion air and thus raising the temperature of the flame, also causes a greater amount of movement in the flame itself. But by this sight, the oxygen could be quite suitable be replaced by more economical steam.

Tests carried out over a long period have shown that the injection of high speed steam through the burner, with a supply of 2500 Kil/hr., compared to the usual method of atomization of fuel oil with 700 Kil./hr. of steam. produced a shortening of the heat time of approx. 7%. This has been proved to be due to both the greater movement of the flame and a certain increase in the capacity for oxidization of the furnace. The interruption of the intense injection of steam at the rate of about 1% of C in the bath gave protection against the steel absorbing hydrogen.

Negative factors in this method were the rapid wear of the refractory lining of the front and head walls, and a quicker filling of the slag pockets.



INTENSIFIED USE OF O_2 BY MEANS OF LANCES

The results of the tests mentioned up to now cause us to conclude that the use of O_2 is advisable only during the heat period after the introduction of the liquid iron, due to the difficulty of carrying out charges at sufficient speed.

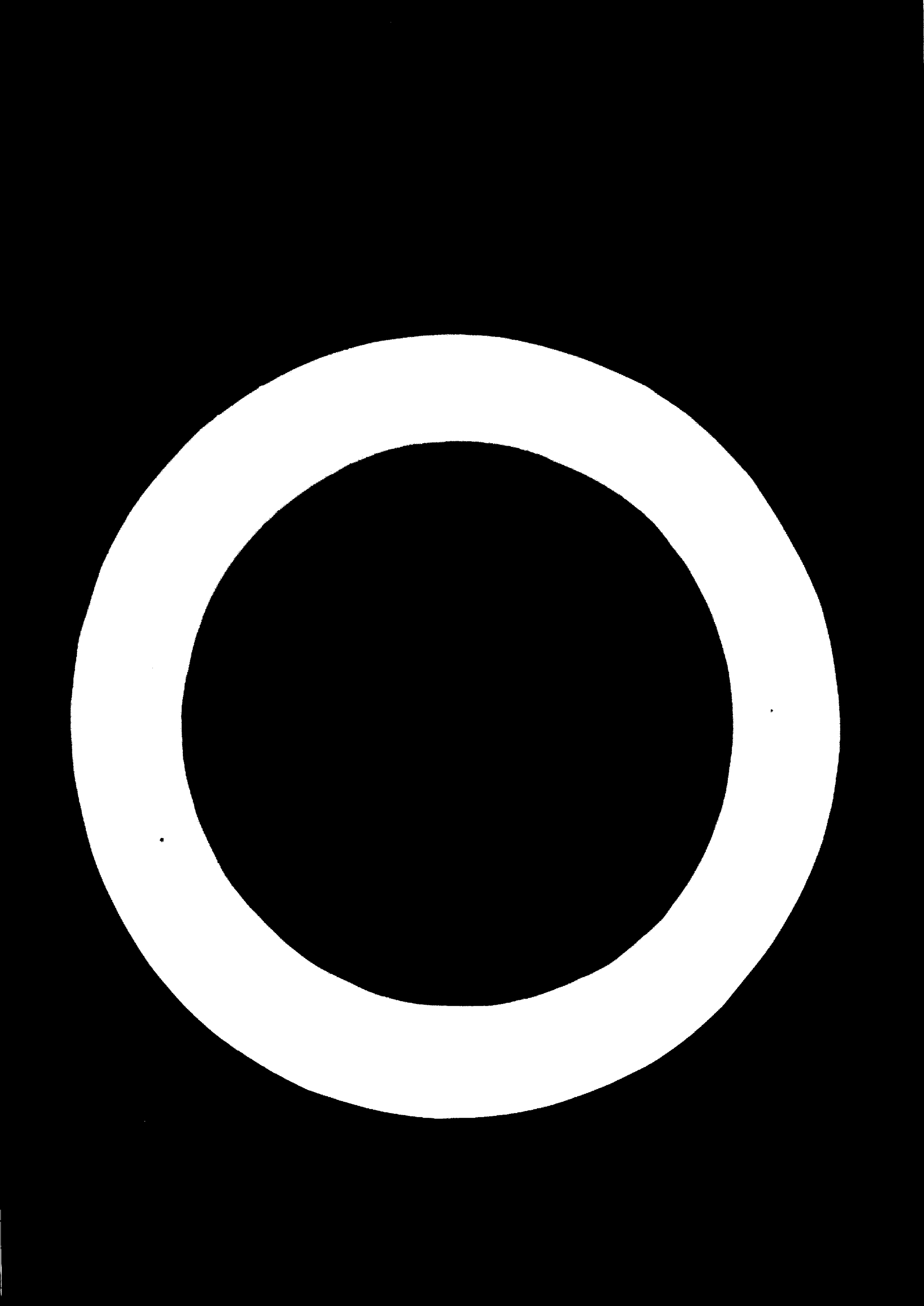
As we were considering a rather intense O_2 lancing during the rifining phase only, we proceeded to test over a period in order to determine the main factors in the thus modified method.

The results of this period of testing are:

a) The need for certain basic factors to be constant, such as the quality and quantity of the liquid iron, the quality of the raw material in general and of the times of the various operations.
   Such a need is generally inherent in any development from one method to another.

b) The need for frequent controls of the temperature and the C during the heat, connected to the considerable speed of the process and thus to the shortening of its various phases.

c) The need for an accurate control of the height of the lances above the slag. This is obvious, considering that it regulates the efficiency of the working of the bath by the oxygen and the kinetics of the oxidizing reactions, as well the distribution of iron oxide between slag and metal.



d) The need for a final slowing down in the carrying out of the heats so as to give the bath the utmost uniformity. This means one should avoid the adding of ore and cutting off the O_2 lancing during the last phase of refining, and at the same time gives a guarantee against an overoxidization of the bath.

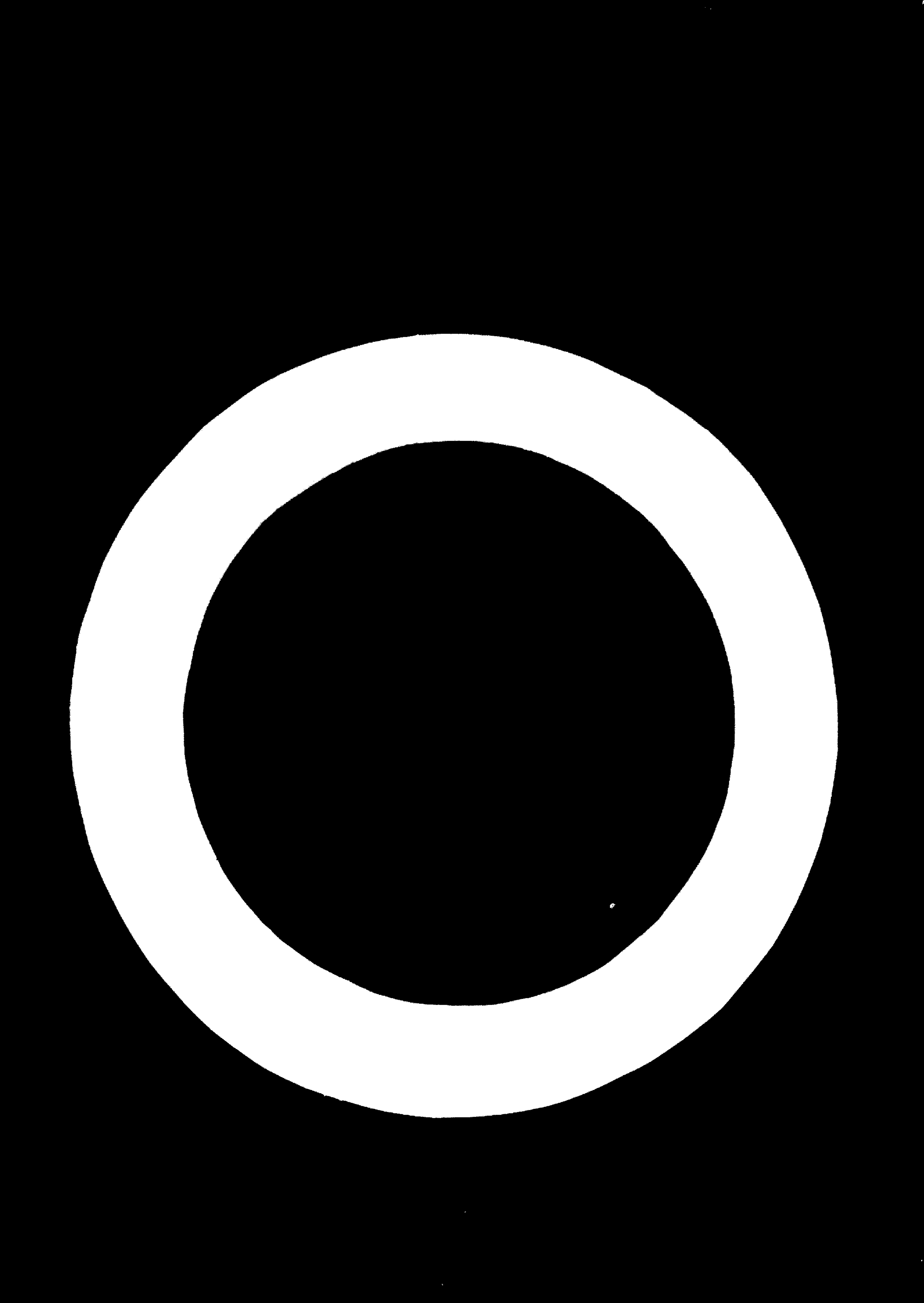
Bearing in mind these factors, we succeeded in achieving the results shown in Table 4.

One need hardly add that these results, which refer to only one furnace, cannot be immediately extended to the entire steelworks, due to the number of factors which contribute to their wear in normal operating conditions.

The test heats were carried out with charges of between 60 and 65% of liquid iron. The combustion program involved a constant air injection of 45×10^6 equivalent Cal./hr.

Some of the data in this Table are repeated in Fig. 2.

It is particulary interesting to note the ratio of ore consumption to oxygen injection. The reduction of the quantity of ore in the charge, or its wearing away due to sufficiently high injections of oxygen, allows more rapid melting and working at higher temperatures, while the lessened need for net heat in the charge allows a lower consumption of calories. A method that does without ore in the charge has already been in use for some time in a modern Canadian steelworks, givin excellent output results.



One should not however understimate the economic aspect of the charge, as it cost worsens due to the reduction or abolition of its most economic component.

From a first summary evaluation, examining the cost of the charge, fuel and oxygen in the test heats, one finds that an intensified use of oxygen corresponds to a certain increase in the cost of the steel.

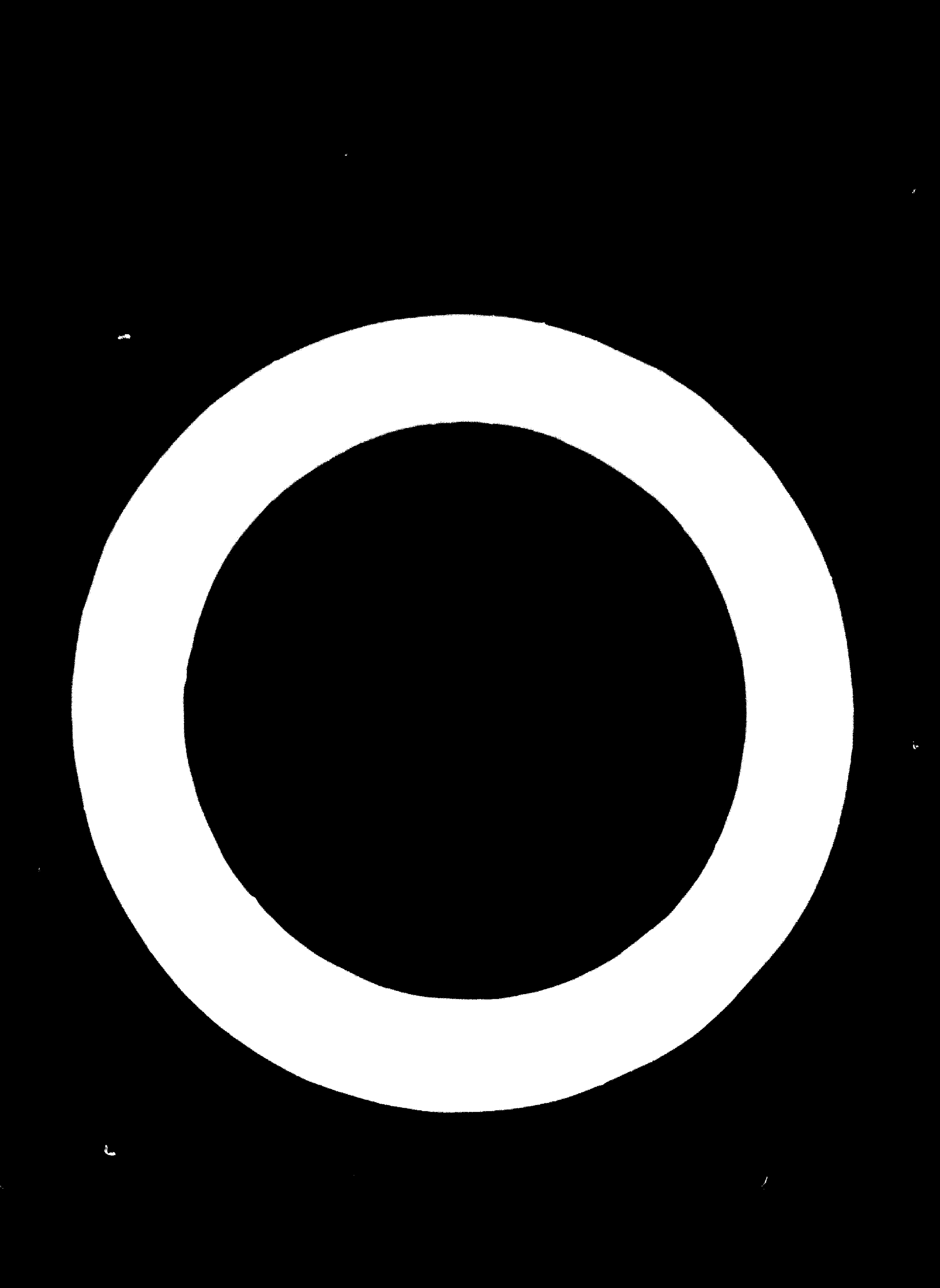
This holds if one ignores the variations in yield of the charge and the wear of the refractory (to determine which accurately would necessitate tests over long periods), variations which in any case contribute to worsen further the cost due to methods with an intense use of oxygen.

OUTPUT QUALITY

With reference to the results we obtained, we agree in general with other writers on the point that an intensive use of oxygen does not involve a lowering in the quality of the production.

We should however mention some points in connection with the use of oxygenn such as: a slight average fall in the % of Mn from the first to the last ingot poured, and a slight increase in surface defects in the rolled products.

It is however difficult to distinguish between the direct effect of the use of oxygen and the derived increase in output which is of considerable importance especially



for plants having a high coefficient of saturation of their own productive capacity.

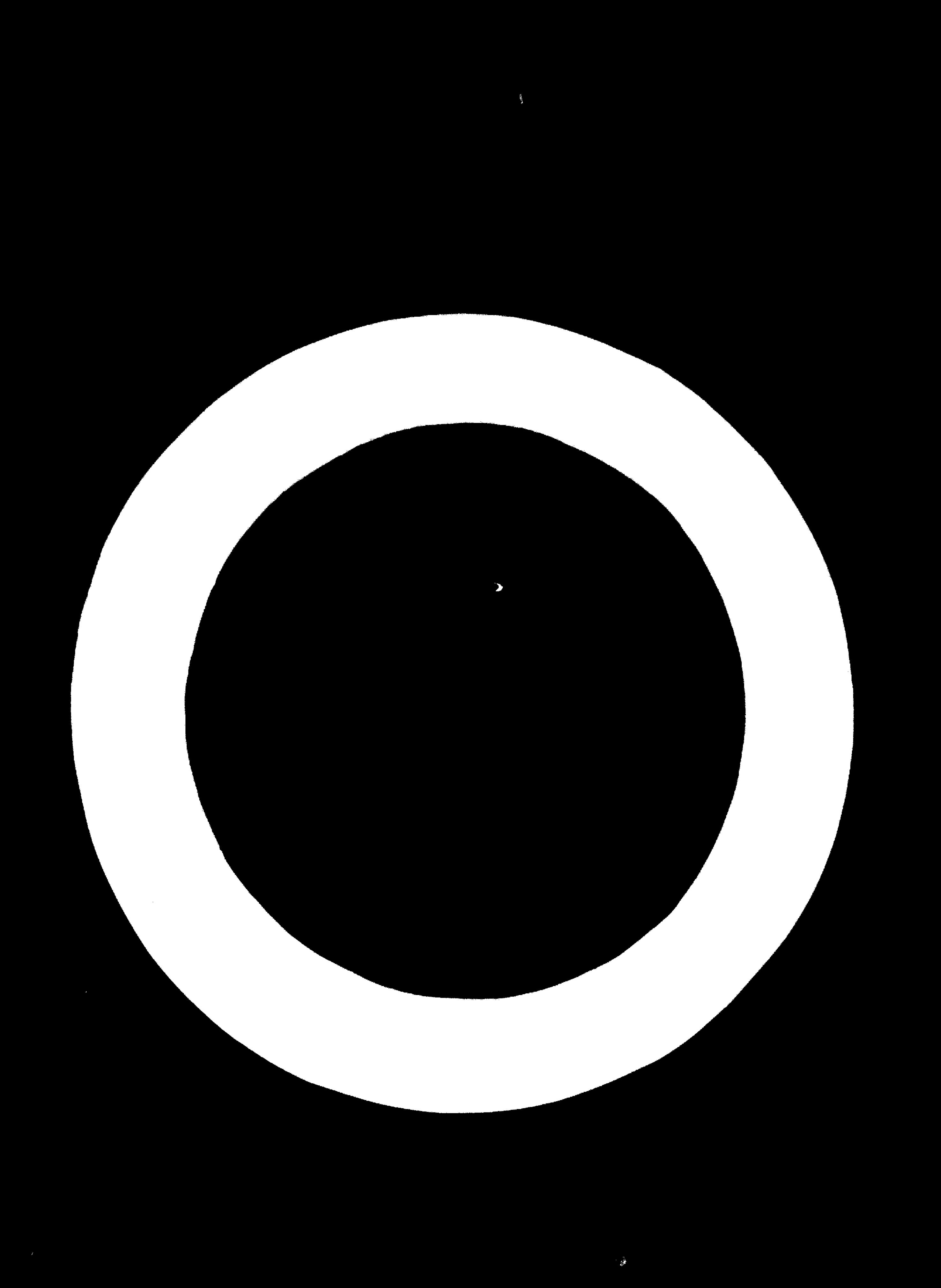
Another factor noticed, due to the use of O_2, is a slight tendency to a higher pouring temperature. This was held within certain limits and was not such as to produce serious disadvantages regarding phenomena such as the return of the phosphorous or the action in the ingot mould due to rimming steel, nor any definitive advantages regarding desulphurization.

On the whole, to say it once more, the outlook is good as regards quality.

This is obviously referred to the working in steelworks in accordance with practice acquired after preliminary testing. As a general guide, to show the sort of troubles one can encounter using oxygen working methods insufficiently studied and checked, we will mention as follows our findings during the early part of the tests.

For the same reason, we also give some comparisons with our results in the past or, not in any great way different, with our present results, ignoring the minor faults we have already mentioned:

- oxidization out of control with a high FeO % in the slag (around 42-44% as against our usual 35-36%) and low C % at pouring (0.035-0.040% as against our usual 0.050-0.055%);
- difficulty in ascertaining the temperature, with frequent ladle bottoms of a certain consistency being left even at high pouring temperatures;



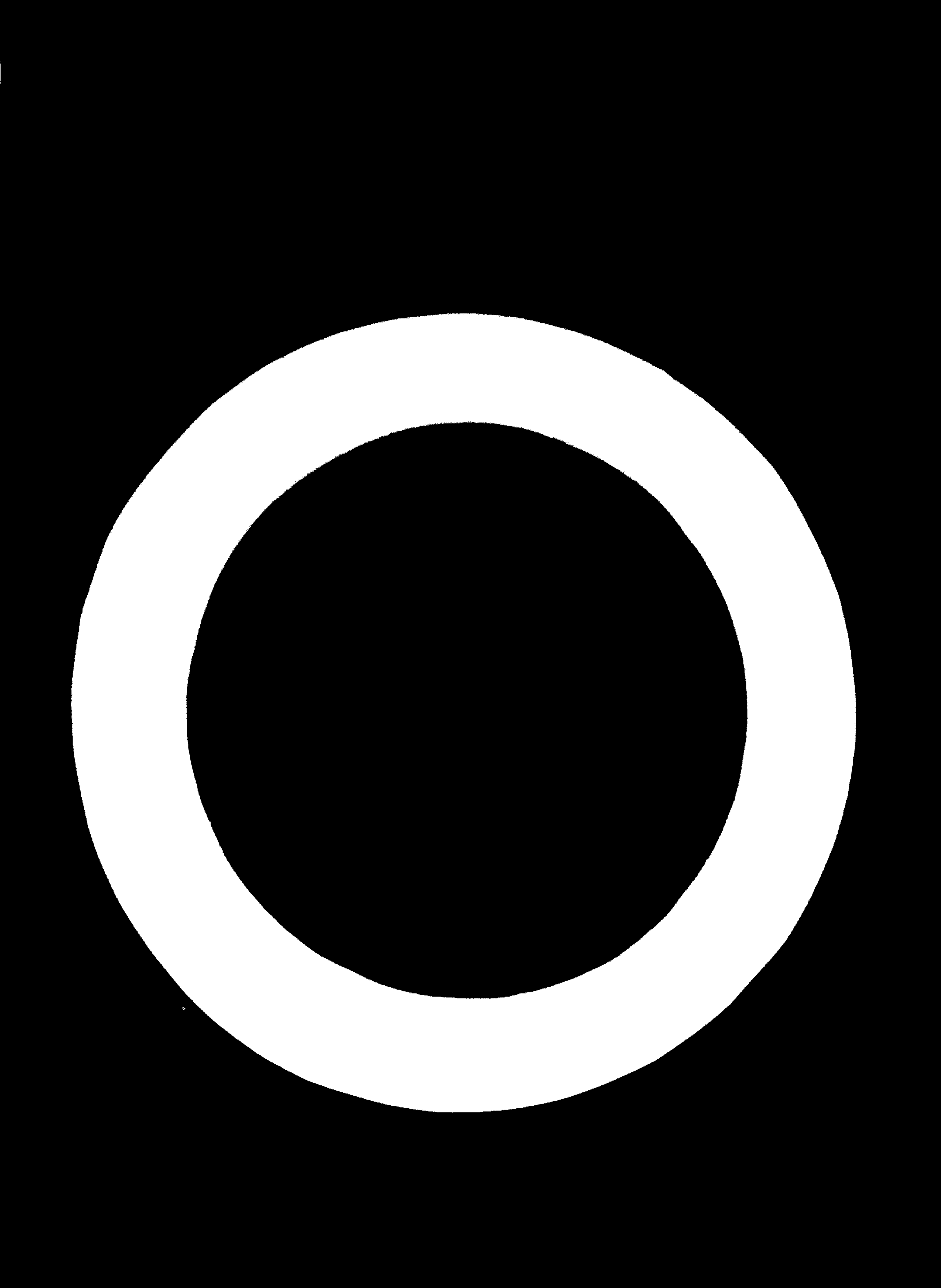
- pronounced fall in Mn % from the first to the last ingot poured. This fall was on the average 0.06-0.07% (usual values: 0.02-0.03%);
- considerable increase (from 10 to 20%) of % of downgraded or discarded ingots.

The above drawbacks show clearly the need for those who adopt the intensive use of O_2 in Martin-Siemens furnaces to prepare things adequately, as this method, though relatively simple, requires special care and the assistance of a suitable control system, due to the high speed at which it is carried out.

CONSUMPTION OF REFRACTORY MATERIALS

Although we did not carry out specific tests on the subject, one can see how, over a period of little more than a year, the total refractory consumption in the furnaces went from 10 to 14 Kilos per M.T.

The first consumption figure refers to working conditions where the supply of oxygen was approx. 10 cu.m. per M.T., and of liquid iron in the charge approx. 50%. Under present working conditions one has instead a use of oxygen of approx. 30 cu.m./M.T. and liquid iron charges of approx. 60%. At the same time, the refractory consumption by lancing for the maintenance of the roof went from 1 to 1.5 Kilos/M.T.



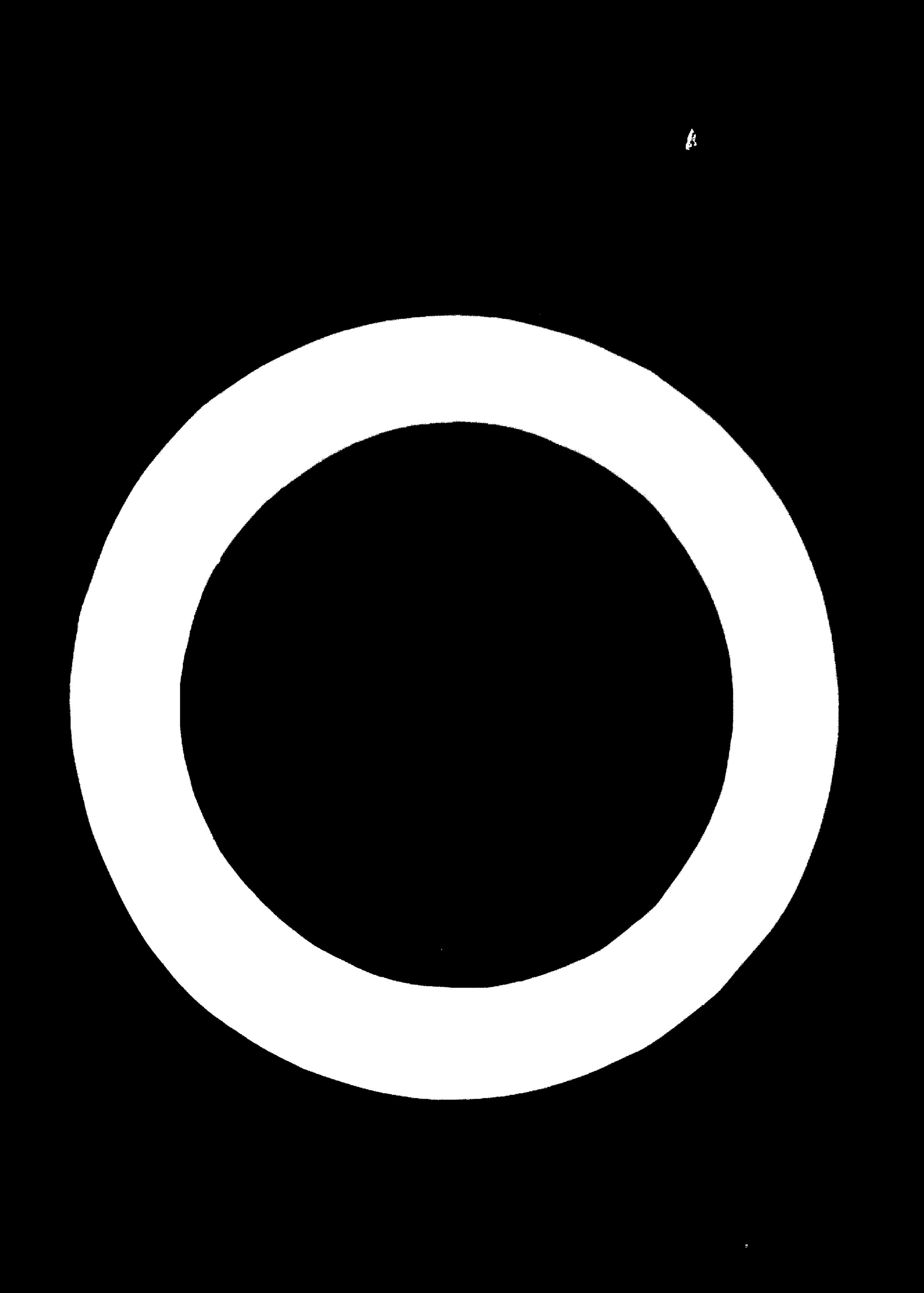
A peculiar characteristic of the intensive use of oxygen in lancing is the rapid wear of the centre of the furnace roof, in the lancing area, contrary to what had been noticed when working with a lower oxygen injection (10 cu.m./M.T.), in wich case wear of the roof took place mainly in the front area.

The main causes of the above mentioned greater wear of the roof are the huge volume of fumes rich in CO and iron oxide developing from the bath, the value of the laboratory pressure no controllable during the periods of intense reaction, the splashes of slag and metal caused by oxygen lancing.

In order to reduce the destructive effect of the use of oxygen on the roof refractory, one must study the suitable ratios for the oxygen supply and the diameter of the lancing holes, the reduction of the curvature radius of the roof, the intensified use of plastic refractory material for relining, the increase in the diameter of the uptakes and in the free cross-section of the checker, and the increase in the surplus of combustion air.

YIELD

As regards the yields one should also refer to a rough comparison between the present method and working conditions before the intensive use of oxygen.



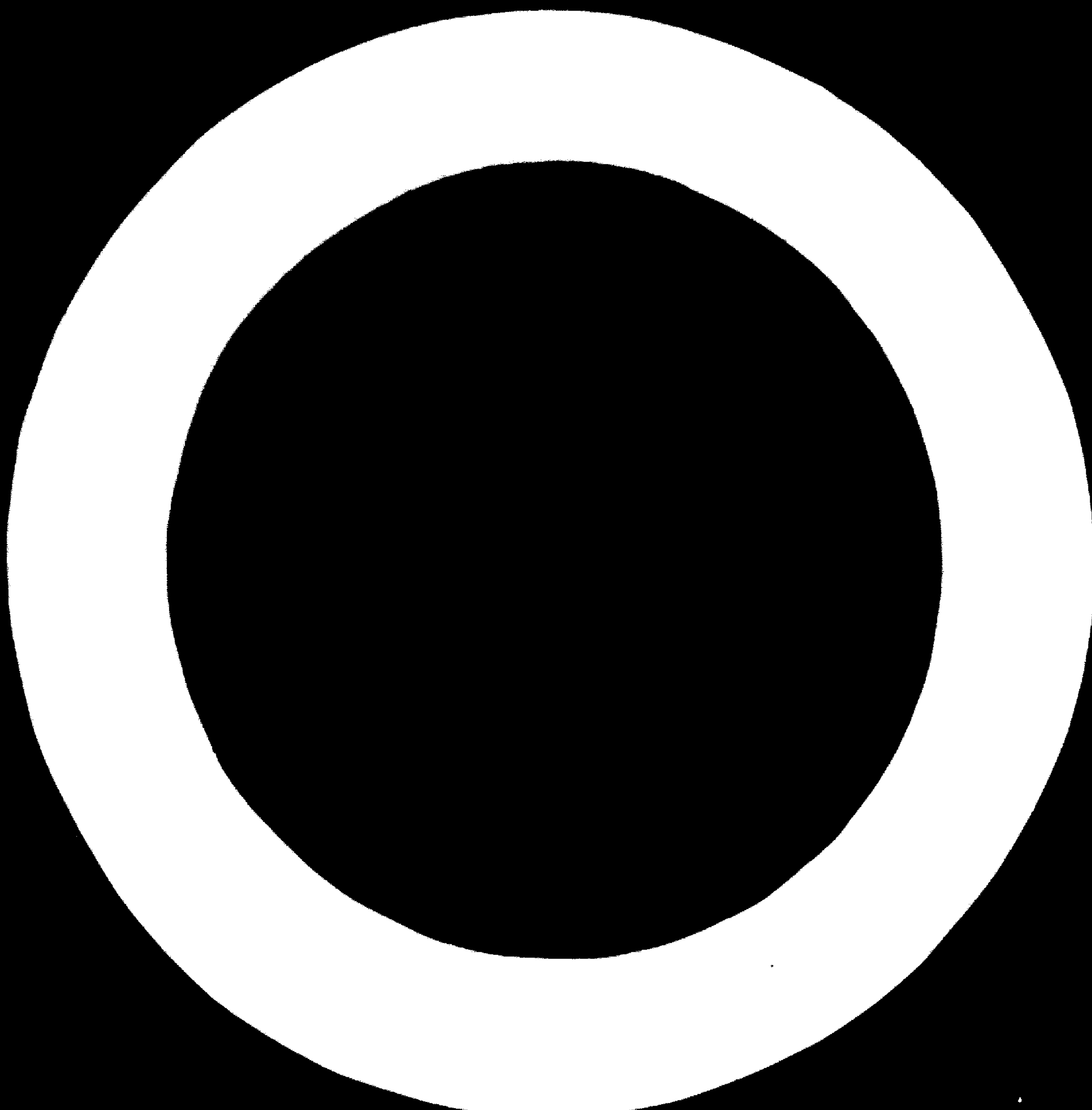
With a 10% increase in the liquid iron in charge, and an oxygen consumption stepped up from 10 to 30 cu.m. per M.T., correspond to a drop in the metal charge yield of 2.5% approx.

This is due to the larger quantities of slag, the greater loss of Fe in the slag (especially in the flushing slag), and to the increased release of red smokes.

FUTURE DEVELOPEMENTS

Regarding an increase in production, the plans for the immediate future are for the time being limited to an even moré intensive use of oxygen in lancing.

Our long term plans and aims, provided the quality and quantity of the charge remain constant, consist in the adoption of new methods for a practically continuous control of the analysis and the temperature of the bath, and the application of systems for the injection of solid material into the bath, so as to achieve a repetition of the method that could be a first step towards the "optimum stage" of the process.



ENCLOSURES

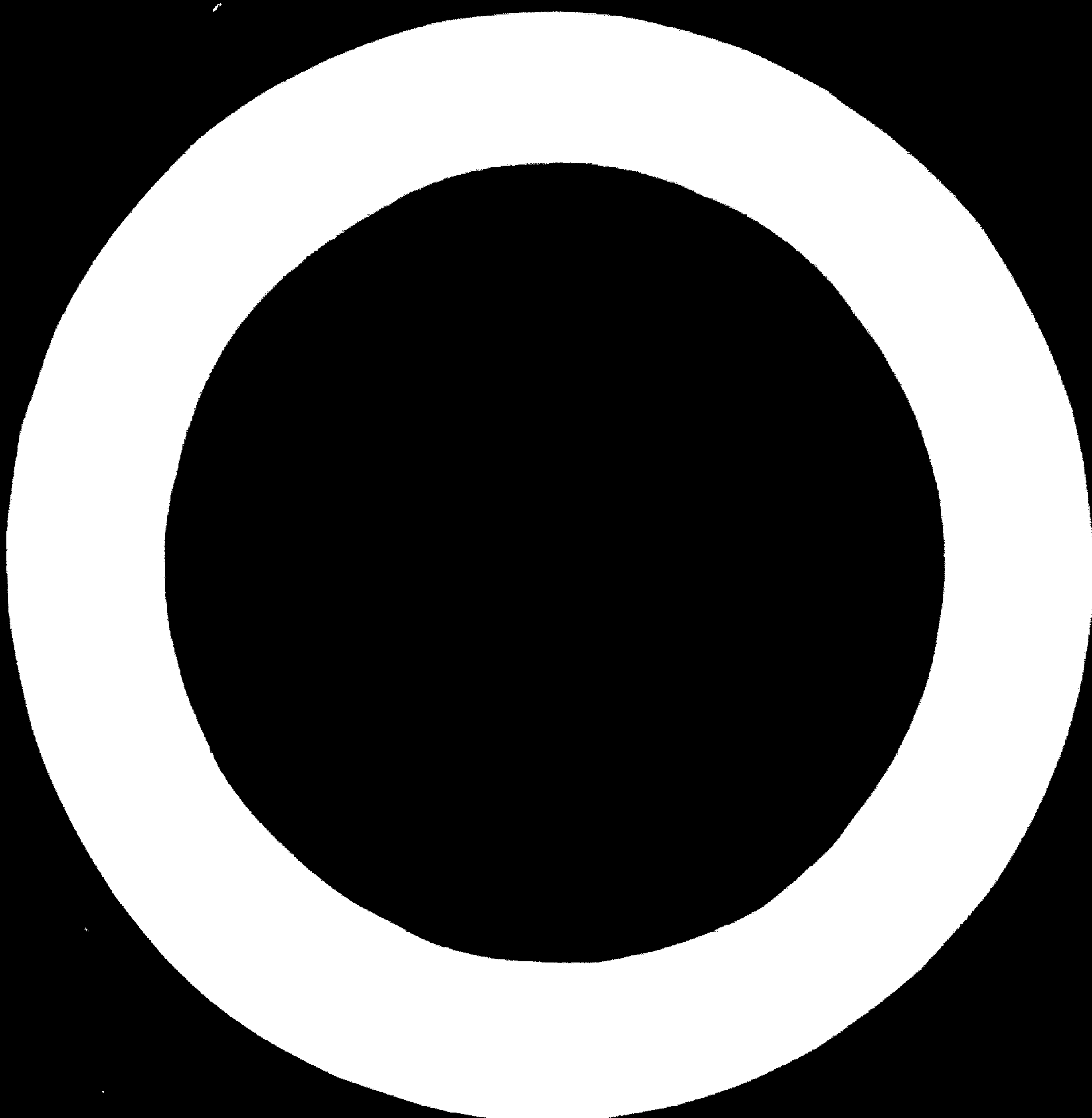


Table 1

Liquid iron in charge	%	60 ÷ 65
Hourly output from tap to tap	M.T./hr.	44.19
Specific thermic consumption	Cals./M.T.	557,000
Specific oxygen consumption	cu.m./M.T.	31.27

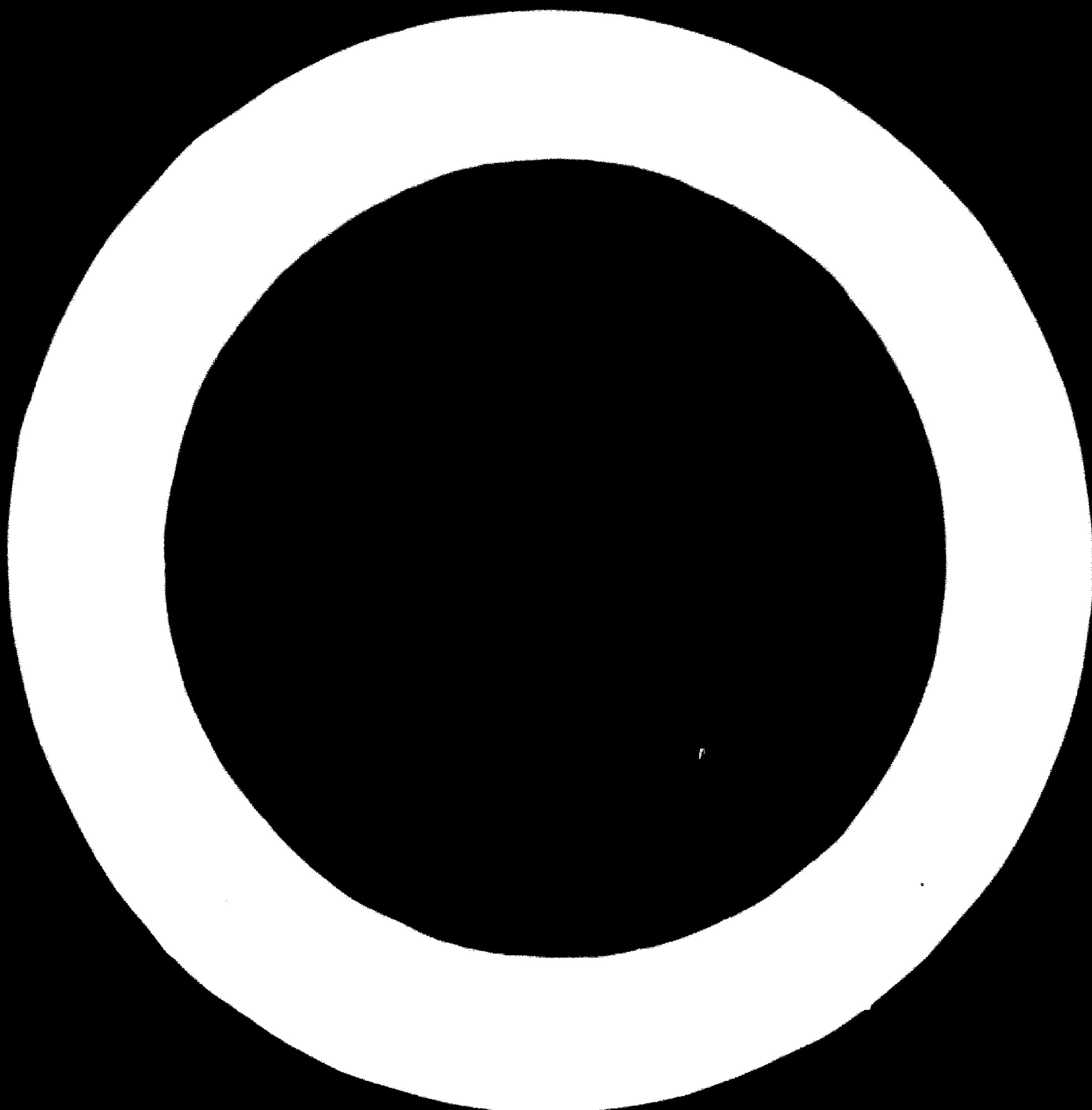


Table 2

	Use of oxygen through the head burners	Use of oxygen through head burners and oxyfuel lances	Percentage differences %
Heats n°	28	28	-
Liquid pig iron %	64	64	-
Time from tap to tap hr./min.	4,53'	4,49'	-
Hourly output M.T./hr.	50.57	51.77	2
Specific thermic consumption Cals./M.T.	475,972	525,056	9
Specific oxygen consumption cu.m./M.T.	39.07	46.17	15

- The difference in the specific consumption of oxygen of the two groups is statistically significant to 99%.

- The difference in the specific thermic consumption of the two groups is statistically semisignificant to 95%.

- The difference in the output of the two groups is not statistically significant.

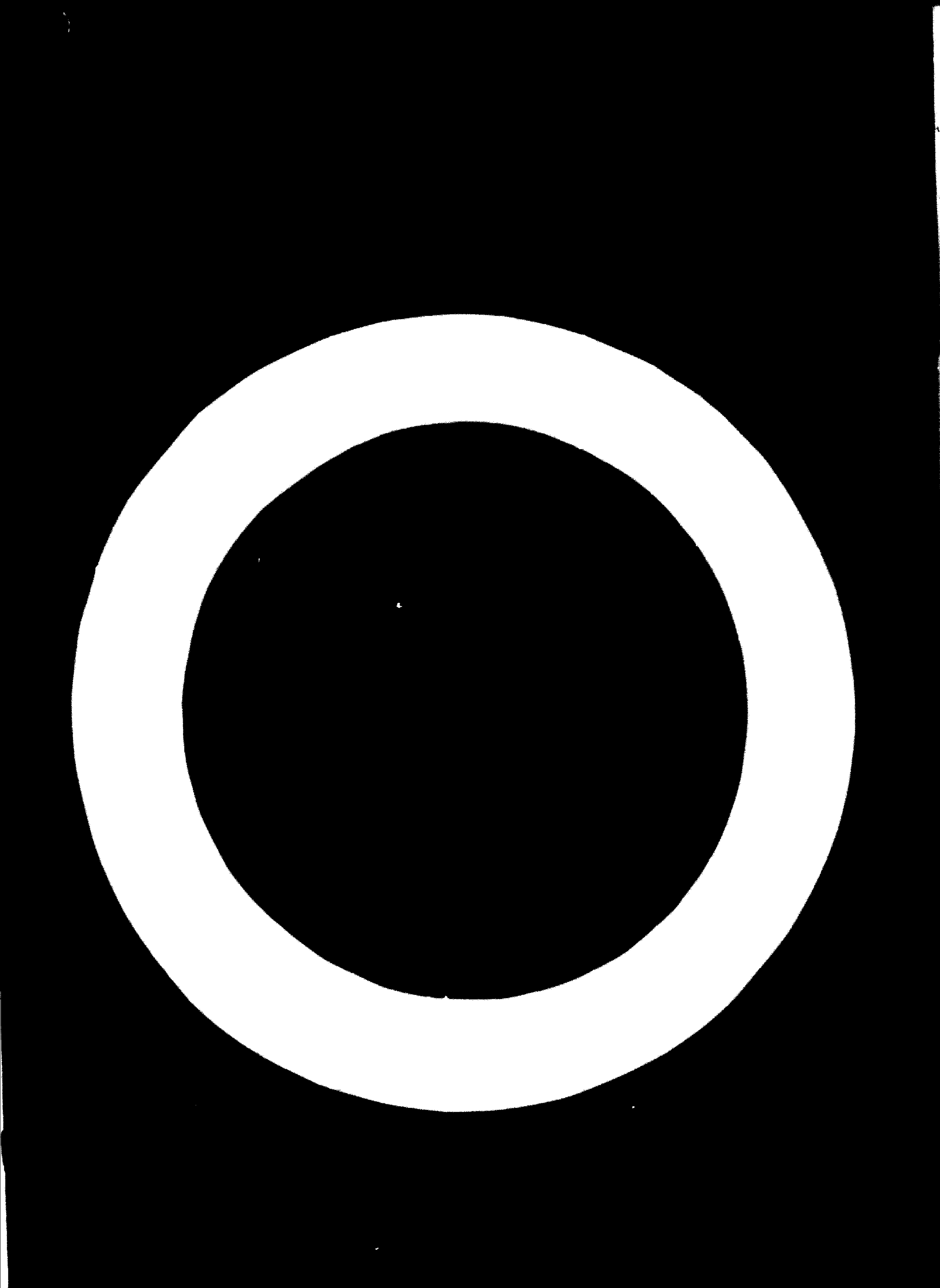


Table 3

		Heats with injection of O_2 through lances	Heats with injection of O_2 through burners, later through lances	Percentage differences %
Heats	n°	51	56	-
Liquid pig iron	%	65	65	-
Output of oxygen through burners	cu.m./hr.	-	2,000	-
Output of oxygen through lances	cu.m./hr.	3,000	2,250	
Solid charge time	min.	51'	53'	-
Pig iron charge time	hr./min.	1,34'	1,31'	-
Time from tap to tap	hr./min.	5,34'	5,43'	-
Hourly production	M.T./hr.	44.85	43.67	2.7
Specific thermic consumption	Cals./M.T.	546,738	587,589	7
Specific oxigen consumption	cu.m./M.T.	32.58	37.86	14

- The differences in calories and oxygen consumption of the two groups are statistically significant to 99%.

- The difference in production of the two groups is statistically semisignificant to 95%.

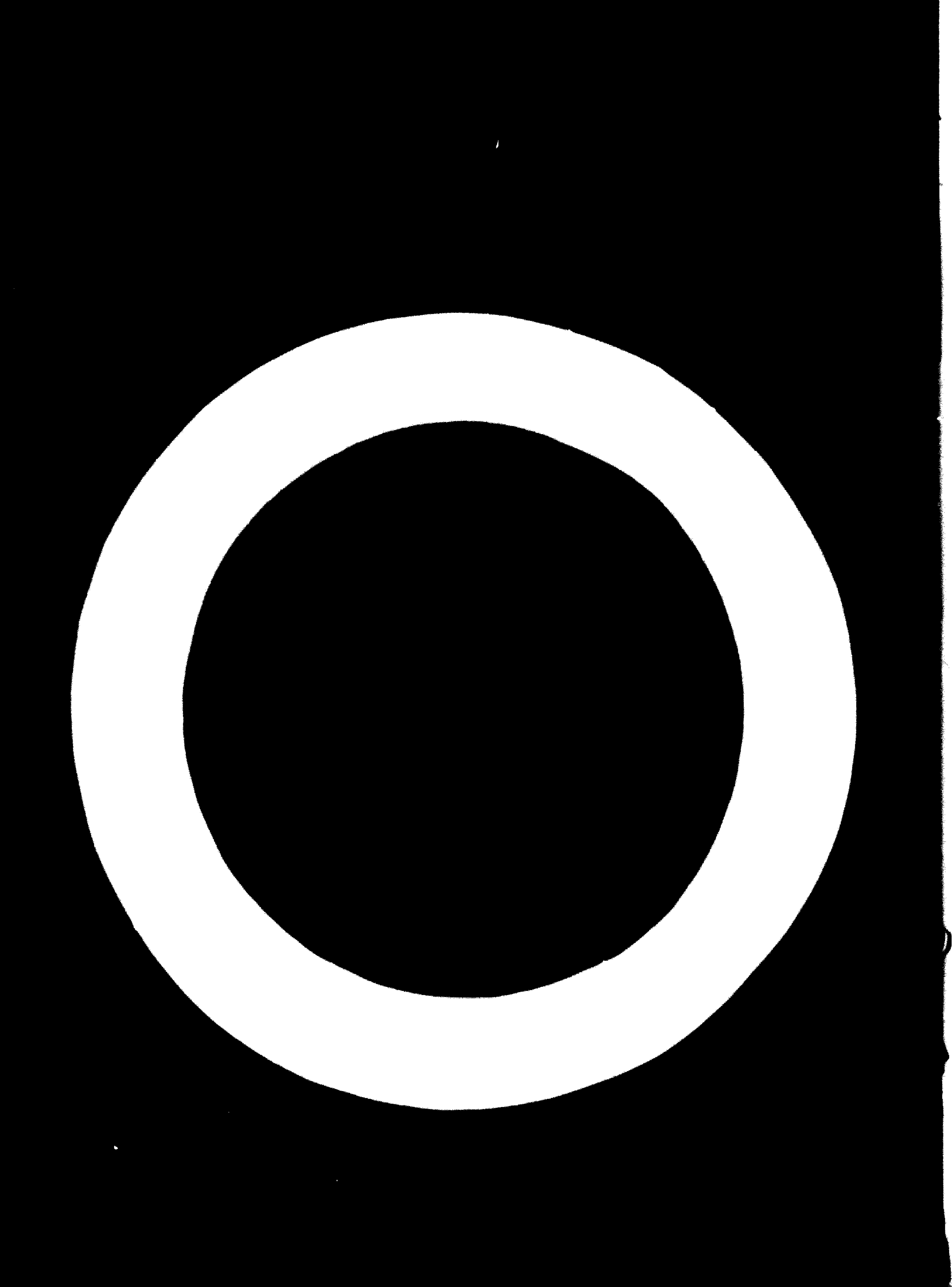


Table 4

	Heats with an oxygen output of 2,100 cu.m. per hr.	Heats with an oxygen output of 3,100 cu.m. per hr.	Heats with an oxygen output of 4,200 cu.m. per hr.
heats n°	40	40	75
Time from tap to tap hr./min.	6,20'	5,36'	5,05'
Hourly production M.T./hr.	39.50	44.72	49.02
Specific thermic consumption Cals/M.T.	571,789	520,750	430,445
Specific oxygen consumption cu.m/M.T.	23.69	26.70	35.36
Ore consumption Kil./M.T.	73.88	70.19	38.47

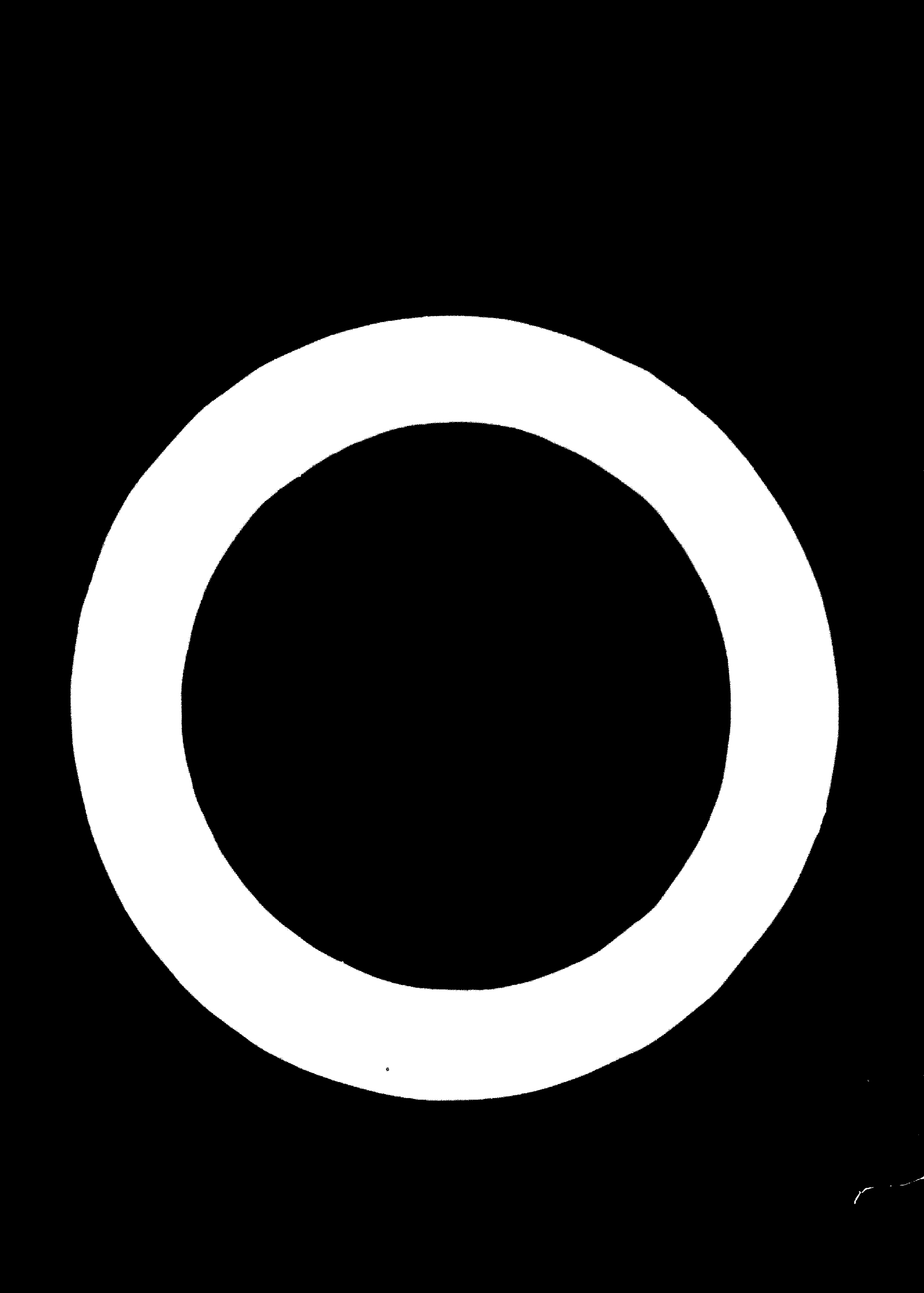
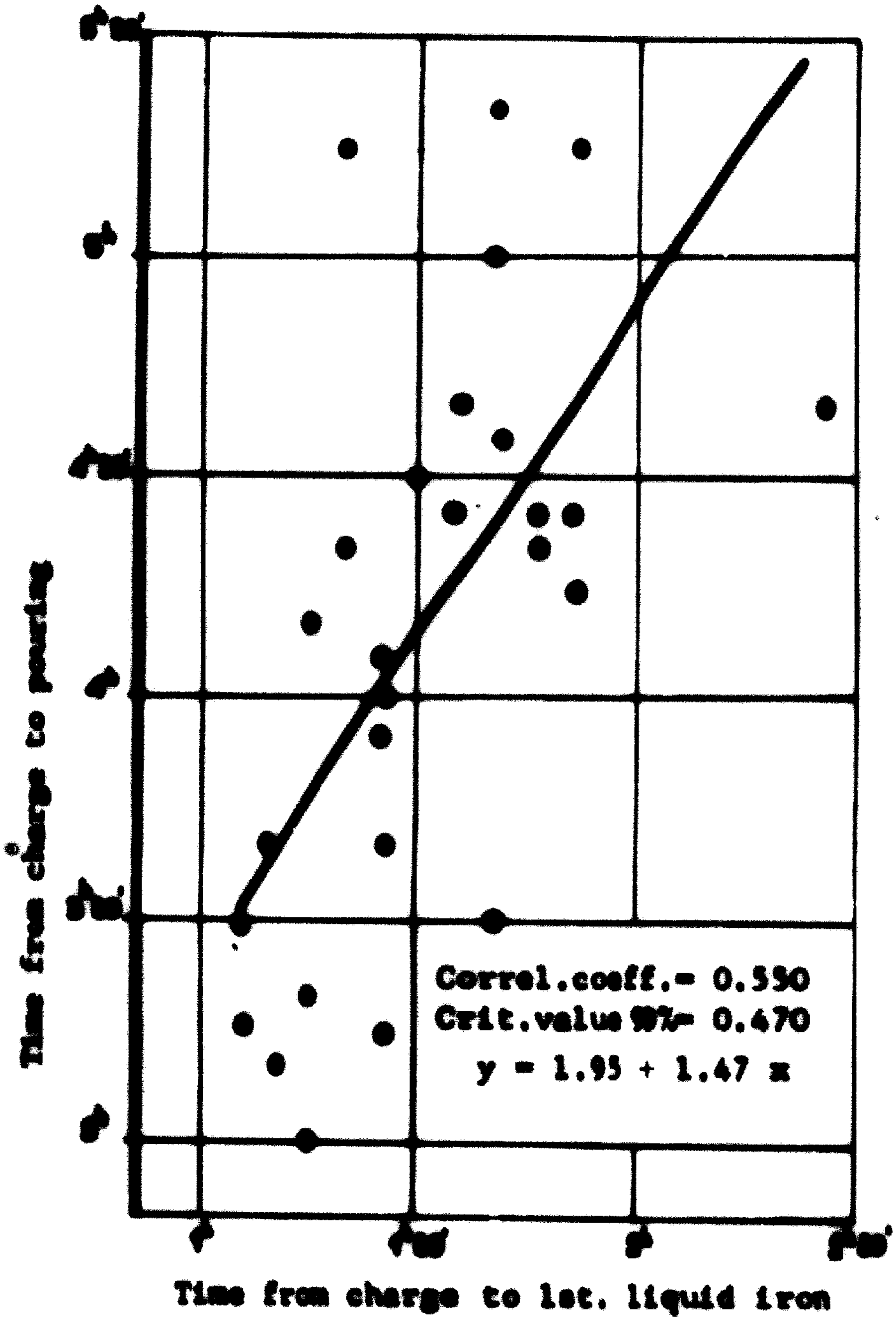


Figure 1



Relation between heat-time and time of introduction of liquid iron (for heats with use of oxy-fuel)

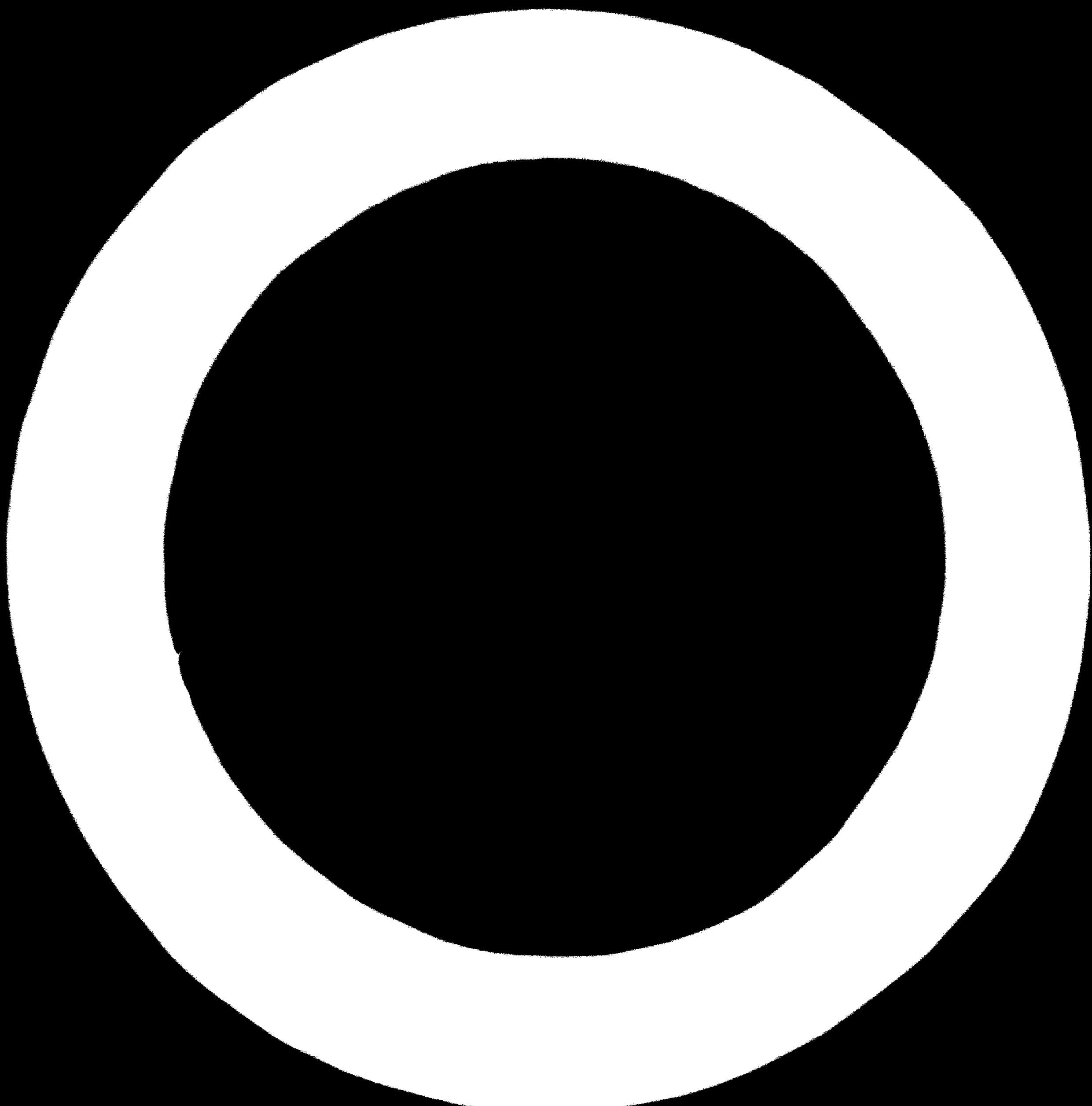
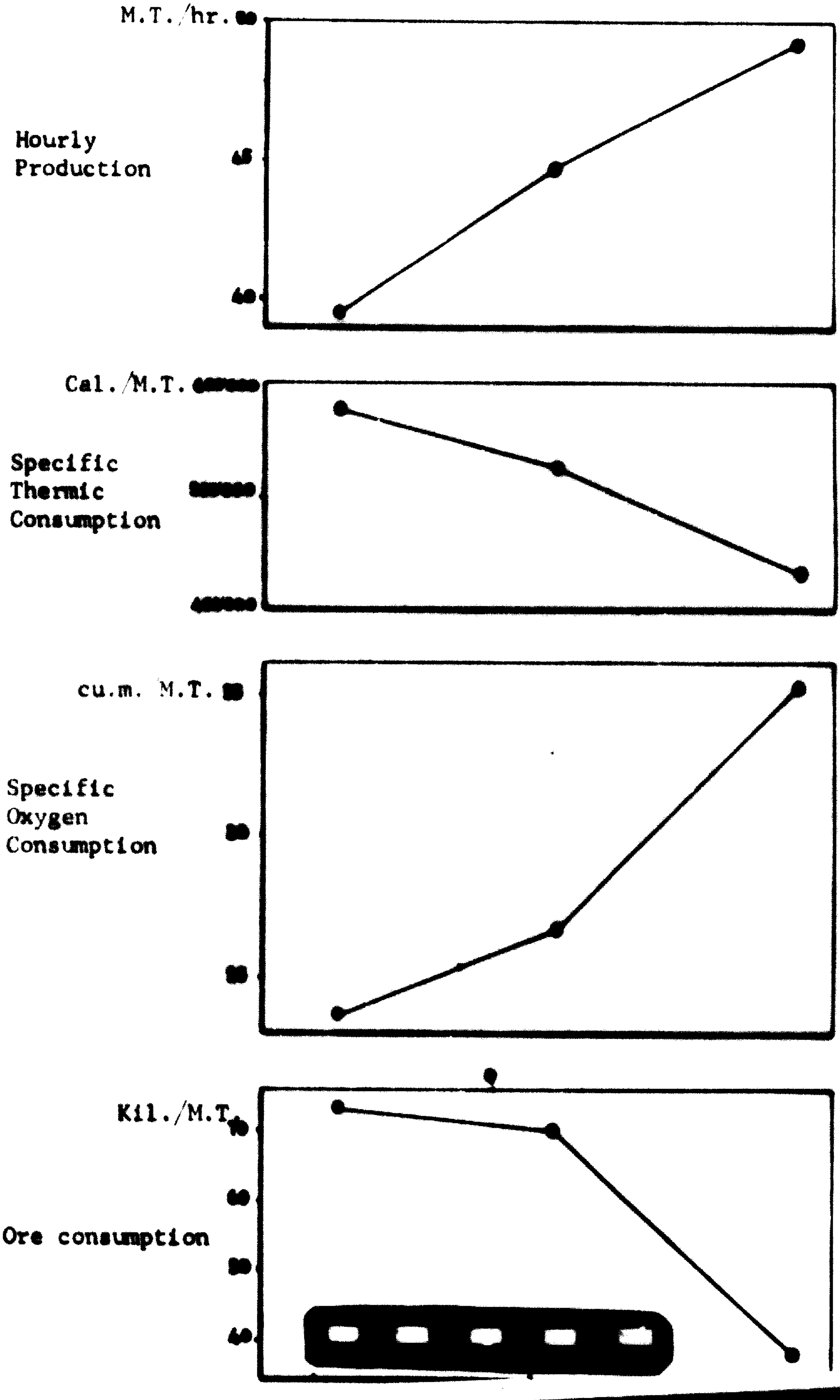


Figure 2


M.T./hr.
Hourly Production
Cal./M.T.
Specific Thermic Consumption
cu.m. M.T.
Specific Oxygen Consumption
Kil./M.T.
Ore consumption

4. 4. 74