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SINTERING - A GENERAL REVIEW:

A COMPARATIVE CONSIDERATION OF SMALL AND LARGE SINTER PLANTS WITH SPECIAL ATTENTION GIVEN TO THE PLANNING OF NEW INSTALLATIONS IN DEVELOPING COUNTRIES

by

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1. Synopsis

The development of the sinter process after World War II. The great advantages offered by high-percentages of sinter with regard to the output of blast furnaces. The preparation and beneficiation of ore as an important factor in the modern practice of blast furnace. Ore tests with view to the aptitude of sintering and best suited processes. The most essential factors for producing sinter of good consistency and high porosity. The treatment of finished sinter and determination of its quality. Example given for ascertaining the best suited fuels (i.e gases, cokes, or coal), and moisture required. The expected output and possibility of increasing the output by admixtures of lime or dolomite. Results of such tests in a pilot plant with view to sintering plants. Determination of the project size to be chosen on the basis of sintering qualities of a single ore type and of a mixture consisting of various ore types. Recommendations to developing countries to start with small plants after the pan system which can be extended to a certain size by joining further machinery units. The advantage of sintering each pan individually, thereby avoiding to a great extent a loss of production.

The project's size and limit of output. The Greenawalt system as intermediate phase for belt sintering. The importance of sintering by belts for countries intending to increase their pig iron production or to build large plants. Consideration from the economical view-point of sintering plants operating after the belt system with highest output. Advantages and disadvantages of the different sintering systems.

2. Introduction

In the years after World War II the development of the sinter process has made such rapid strides in comparison with previous times that in the modern blast-furnace plants of today all over the world an average of 40-50% of the ore burden consists of agglomerates while formerly the maximum rate was 10-20%. It was not the fault of the sintering process that this development was first a slow one; the rapid increase in the burden was caused by new metallurgical knowledge about the reduction of ores, especially of sinter, in the blast furnace. The beneficial effect of a high sinter rate on coke consumption and efficiency was the reason for using a maximum amount of agglomerates. Another factor was the enormous expansion of the iron and steel industry throughout the world and the necessity for developing new ore deposits. This in turn resulted in larger quantities of lump ores appearing on the market with a corresponding amount of fine ores.

The great successes achieved in the blast-furnace practice could be enhanced further when the importance of reducing the slag volume in the blast furnace was realized, because the use of richer ores resulted in a further saving of coke. Ore preparation and concentration are therefore necessary, especially where the distance between producing point (ore mine) and consuming point (blast furnace) is great and thus involves high freight costs. In the reverse case, ore concentration or ore grading can be dispensed with, when the ore is smelted in the immediate neighbourhood of the ore mine. This requires careful metallurgical and economic deliberations, as any process preceding the blast furnace calls for capital and increases the ore costs.

The question whether an ore is to be "prepared" or "agglomerated" has to be decided in the sense that "preparation", that means crushing, screening, and concentration, should take place at the mine, whereas "agglomeration" or "sintering" should be carried out at the blast-furnace plant. The concentration by physical means only makes sense where one can expect cost advantages on the ore markets. The necessity for sintering the fines in the immediate neighbourhood of the blast-furnace plant is due to the low strength of the material. Sinter is not an article for export.

3. <u>Selection of the ores</u>

The choice of the sintering process is determined by the chemical and mineralogical composition of the ores, as hematites (Fe_2O_3) have poorer sintering properties than magnetites (Fe_3O_4). As a result of the coarser lattice structure the first-mentioned ore types only yield a sinter of low strength, because the formation of fayalite (2 $FeO.SiO_2$) and of hedenbergite ($CaO.FeO.2\ SiO_2$) when adding lime is impeded. For ores of this type, which are to be sintered without any admixture of magnetite ores, the aptitude for sintering has to be determined by sintering tests. If the results are poor, it will be better to pelletize the ores so as to make them suitable for the blast furnace. Pure hematite concentrates can only be sintered, if so-called "green pellets" are produced with the addition of binders and then burnt on the sintering belt or in kilns. The suitability of an ore for the sintering process must be determined in a pilot plant or in the big laboratories of the firms constructing sinter plants. Other speakers on the subject of "sintering" will describe the importance of such investigations in their papers.

4. <u>Metallurgical aspects</u>

Sintering is by no means a simple process of combustion, but a complicated chemical process which depends upon a number of factors. Three components of the feed must always be in balance to achieve a good sinter quality. These are: ore, fuel and water. If these materials are properly controlled, a uniform rate of ignition and a high efficiency will be assured. The speed with which the flame front surges through the sinter cake is the criterion of the sintering process. When this speed is slow on account of the composition of the mix and its density, efficiency decreases. When the speed is increased beyond an optimum value, the quality of the sinter deteriorates and the circulating load increases. Fuel and water additions, which are predetermined by tests, are kept constant and are only altered when there occur changes in the quality or moisture of the ore. The only variable is the speed with which the flame front passes through the feed till the maximum waste-gas temperature has been reached which marks the end of the sintering and thus the sintering time (Fig. 1).

In modern sinter practice the whole sintering process is automatically controlled by the maximum temperature of the waste gases.

To make this possible, the characteristics of the mix must be closely controlled:

(a) The moisture of the mix may only vary within narrow limits.

(b) A constant ore size composition must be ensured by screening.

(c) A uniform composition of the feed must be guaranteed.

It is advisable to mix the material by ore bedding to smooth out the non-uniformity in the composition of the run-of-mine ore.

The importance of keeping these factors constant has induced many experts in this field to investigate the effect of the physical properties of the feed on the permeability of the sinter bed to the air flow. All investigators have confirmed that the moisture of the mix has the greatest influence on permeability. This is due to the fact that the water content causes a film formation both on the ore and the fuel, which, as a result of surface tension, leads to the formation of small balls in the rotating drum. The volume is increased and the air gets a freer passage. The mix is made more permeable and combustion takes place at a faster speed. German research workers have investigated the relationship between the resistance to the air flow and the water content (Fig. 2).

They have found that the influence of the water content is greater with a fine-grained material than with a coarse-grained one. All ores and even their various fractions have, as has been confirmed by British investigators, an optimum moisture content, which should, if possible, not be undercut or exceeded (Fig. 3).

This important discovery has led to the installation of special rotating drums before the mix is fed on to the sintering belt, so as to increase the effect of the ball formation. In many cases the coagulation is also assisted by the use of lime in which case lime hydrate is being formed. The larger volume gained from the loosening of the mix must be maintained after this has been fed to the grate. Therefore, the drop between feed hopper and grate should be kept as low as possible. Too high a drop can cause the balls to disintegrate and thus reduce the permeability to the air flow by 50 %.

5. Control of the sinter quality

I have only outlined those points which are most important for the preparation of the mix: the other speakers will give further details on this subject. However, I should like to say a few words about the treatment of the finished sinter. In many countries methods for testing the quality of sinter have been developed, which enable us to compare sinter qualities. The shatter test, the tumbler test, and also the sieve test showing the size distribution of fines, are all used to determine the quality. There is as yet no internationally accepted standard value for the sinter.

A factor determining the sinter strength is the percentage of fuel in the mix. If it is too low, a friable sinter results, too high a percentage on the other hand causes slagging on the grate. The ash content of the fuel, which should be as low as possible, is incorporated into the sinter and reduces the iron content. Within certain limits, however, the fuel increases the strength. High-ash fuel should, therefore, not be used. On the basis of the fixed carbon content, low-volatile coal and low-temperature coke from lignite are equivalent to high-temperature coke. The more finely ground the fuel, the lower the fuel consumption. The optimum size is 1 - 3 mm.

The finished sinter is, even if a maximum strength has been obtained, an extremely brittle material, which must be transported to the blast furnace with great care. This brittleness, particularly in hot condition, implies that the sinter can only be cooled by air. Quenching with water must in any case be avoided, as this would lead to a complete disintegration and make fun of the sintering process. In plant practice circular coolers or, where local conditions permit their application, pan conveyors have rendered good service as air coolers. Because of the low strength of the sinter, the shortest transport route and as little handling as possible should be chosen. Where the sinter cannot be handled with the required care, it will be advisable to sieve it again at the top of the blast furnace before it is charged into the furnace, so that the permeability of the burden to the blast will not be reduced by the fines.

6. <u>Determination of the sinter strength of an ore grade on a test pan</u>

I should like to illustrate the important prerequisites for a good preparation of the mix described by me before, by way of an example for the sintering aptitude of a single ore grade, a Swedish ore: so as to show how the fuel rate, the optimum moisture content and the sinter output can be predicted from the results of the preliminary tests.

For the test a Swedish ore concentrate with an iron content of 64.4% was available. The very fine-grained ore with a high proportion of fines of about 70% minus 0.2 mm can according to <u>Figs. 4a and 4b</u> be readily sintered with the low fuel rate of 3% C, but the sintering time is such that the output would be too low.

The increase of the fuel rate to 4% C resulted in a decrease of the sintering time and an increase of the output. A further increase to 5% C gave even better values; but the sintering time became longer and the output declined because of a high slagging rate. The moisture content of the mix determined at the same time was roughly 8%. Moisture contents below this figure resulted in inadequate coagulation. Above this figure the excessive moisture caused a disintegration of the fine balls. At an addition of 4% C and 8% H_2O the determined optimum sinter output of 16 t/m^2 suction area every 24 hours is not very high. This is due to the high fineness of the ore. The sintering time was 22 minutes, as is shown by Fig. 5. The unsatisfactory output can, however, be improved by adding burnt lime or dolomite to the mix, so as to increase the permeability to the air flow. The addition of 4% CaO decreased the sintering time to 10 minutes (Fig. 6).

The temperature in the mix rises faster, the waste gas volume increases and the power requirements for the suction draft become lower as a result of the loosening caused by the addition of lime. The better permeability accelerated the sintering process, and the production of finished sinter increased to 38.4 t/m^2 in 24 hours. By the addition of dolomite (Fig. 7)an increase to 26.7 t/m^2 in 24 hours was obtained, because the hydration is lower with dolomite than with lime. All output figures are based on the test pan, so that, as is known from experience, for large-scale production a deduction of 10 - 15% must be made. This example shall serve as an illustration of how the sintering characteristics of an ore are determined by tests with a view to avoiding miscalculations in production.

These tests also furnish the basic data for the construction of new plant, as the sinter output of a full-scale producing plant can in this way be determined for a specific ore. However, if a plant is to be constructed for ores of different physical properties, it must be designed in such a way as to meet all operational requirements. This implies a large range of adjustment and a maximum fan power. Davies and Mitchell give the following maximum and minimum values for the planning.

Suction	20-70 inches water gauge
Total air consumption	14,000-80,000 cu.ft. per ton of feed
Flame front speed	0.25-1.50 inches per min.
Bed height	10-17 inches
Circulating load	5-45% of feed.

This table indicates that the suction of the fan is determined by the ore with the highest degree of fineness and that the range of adjustment is extremely wide. The power requirements for the fan are determined by the properties of the ore. A poor aptitude for sintering may therefore cause a progressive rise of the costs, which will be all the steeper the smaller the plant is planned. The influence of the conversion costs on the total sintering costs as a function of the belt length has been determined by VOICE for the conditions prevailing at Appleby-Frodingham (Fig. 8).

According to this diagram plants with a small grate area or a short belt length have higher costs than bigger plants where the conversion costs show a falling trend, especially as a result of the lower power requirements.

7. Selection of the sintering system

This relationship is of importance for the planning of a new plant. The well-known fact that the specific costs in industrial plants will only decrease at high outputs also applies to sintering plants. But the discovery that the costs of a plant depend upon the size of a machine, in this case the fan, makes it worth considering whether this unit should with smaller plants not be divided up into a number of single units. You are going to hear details about this point in the following papers. In this symposium it appears important to me to think of those countries which have no iron industry of their own and want to start with a sintering plant of small capacity.

I would recommend to build units which can systematically be extended in accordance with the sinter needs without any interference with the production. In this case pan plants ought to be chosen the number and size of which can then be adapted to the desired pig-iron production. Each pan would need a fan for generating the suction, or two pans could be served by one fan. They form a unit. The size of the pans can be fixed in accordance with the prevailing conditions. With the pan systems that are known today in the world, the Greenawalt pan system or the Swedish A.I.B. system, which is built by a German firm under a licence, it is possible to install pans in sizes of between 5 and 30 m^2. By installing several such units with the necessary grate surface it will theoretically be possible to achieve any desired output.

Practice has, however, shown that for reasons connected with the mechanical side of the process there is an output limit to the pan process. According to the experience gained with pan plants all over the world this limit is of the order of 1500 - 1800 tons per day on the annual average. These are maximum outputs. On the whole not more than 1200 tons per day are attained on the annual average, expecially with plants working after the Swedish system. For plants with a sintering surface, which consists for example of 12 pans, each of 5 m^2, an efficiency of

$$\eta = \frac{\text{Standing time}}{\text{Cycle time}} \times 100$$

results,

or, as the cycle time from output to output consists of standing time + changing time, of

$$\eta = \frac{\text{Standing time}}{\text{Standing time + changing time}} \times 100$$

At 20 minutes standing time and 1.5 minutes changing time an efficiency of

$$\eta = \frac{20}{20 + 1.5} \times 100 = 93\%$$

results.

It can be seen from this example that the efficiency of the plant is too high. A margin of 7% will not be sufficient to compensate other disturbances. With this plant with a pan type of 5 m^2 and 12 pans, equal to 60 m^2 grate surface, and a specific output of 20 t/m^2 and day, the output of 1200 t/day would be too high. In this case a smaller number of pans with a larger grate surface ought to be chosen; but the sintering properties of the ore are determining for the correct rating.

The great advantage of the pan sinter lies in the metallurgical field; for each sintering cycle is an individual one, which means that it is only typical for the mix resting on the grate. By observing the rise of the waste-gas temperature till it has reached its maximum, the end of the sintering can clearly be discerned. Any irregularity of the mix, which is due to differences in grain size, moisture or fuel, can be compensated by varying the sintering time accordingly. It has however been observed, and this is a disadvantage, that, when an individual pan with a poor mix has a long sintering time, the rhythm of the pan changes is disturbed, so that the working cycle as a whole is always determined by the pan with the longest sintering time. The size of the pans should therefore be so chosen as to include a sufficient reserve in the changing time, so that a smooth operation will be assured. A plant with 6 - 8 pans and an output of up to 1000 tons of sinter per day appears to be the most economic unit for a plant working after the Swedish system.

With the much bigger pans working after the Greenawalt system higher outputs can be achieved, as the grate surface is, as a rule, at least 25 m^2. It will however not be advisable to install more than 6 pans. The disadvantage with this plant is that the size of the pan makes it necessary to install two suction stations and that the sintering cannot always be uniform throughout the whole grate area. For this reason it will be more difficult to control the sintering time for people who are not so skilled. With the increasing size of the pans the sintering process becomes more difficult. The difference in the suction in the case of 2 suction stations may adversely affect the sinter quality as the concentrical surface sintering becomes irregular.

In highly industrialized countries where people have had technical training for generations the belt system is today preferred unless the ores must be pelletized on account of their specific properties. It is true that also a belt system will after a certain period of running-in yield good results. But with the pan process it will always be simpler to make a completely untrained crew familiar with a new technical process. With a Swedish pan a miscarried sintering process means a loss of 2 - 3 tons of material. When the required sintering temperature is not observed with a belt plant the loss of production will be ten times as high. Figs. 9 and 10 show a pan plant working after the Swedish system.

They show the furnace bay of the plant. Fig 11 illustrates the sintering process on a 12 m^2 pan.

Both with the pan and the belt system the ouput per area depends solely upon the ore mix. It can be the same with or without the addition of lime or dolomite. The smaller the plant, the better the pan process and the higher the required sinter production, the more advantageous the belt systems.

8. Conclusion and summary

A modern blast-furnace plant consists, irrespective of its size, of two divisions, if the furnace is worked on modern metallurgical principles. One division is the burden preparation with grading and sintering plant, while the furnace operation proper with its pertinent machinery forms the main part. The burden preparation is again divided into an ore crushing and screening plant and a sintering plant. The ore grading plant can be erected on the mine, because it must not necessarily be at the site of the blast-furnace plant. The sintering plant, on the other hand, must be erected in the immediate neighbourhood of the blast furnace. This question of site is important.

The size of a blast furnace depends upon the planned production. The ultimate expansion of the blast-furnace plant must be taken into consideration, which means that one starts with one or two blast furnaces and adds further furnaces later on. The construction of a sintering plant should be started on similar lines, so that larger sinter quantities will become available when the pig-iron production is increased. This means that the future development must be taken into account for the sintering plant. When a sintering plant is planned, the ultimate size of the buildings, belts and bins must already be fixed, because the cost of extending these facilities at a later stage would be much higher. This concerns the preparation of the mix.

Pan plants can be extended step by step, as the extension can take place without interruption of the production, when the plant has the necessary capacity for the preparation of the mix. Belt plants, on the other hand, must be shut down for a longer period of time to be able to lengthen the belt. This is a disadvantage. If a new belt was erected instead of the extension, there would be no interruption of the production, but the output will be doubled.

A pan plant can be extended gradually, and it offers the possibility of individual sintering, which is advantageous for the sinter quality. But the advantage of a pan plant only exists up to an annual production of 300,000 tons. When the desired sinter output is higher, sintering practice all over the world has shown that the belt process is superior both in terms of output and costs.

The costs for a new plant depend upon its size and location. They are independent of the system chosen. The capital costs, related to the annual ton of sinter produced, are higher with small plants than with big ones. According to cost calculations of German sintering plants the capital costs for small plants amount to 13 - 14 US-$ per ton of agglomerate produced per year. With larger plants this amount decreases to 11.5 - 12.5 US-$. The high investment costs require a high capital service, which is the main cost factor in the conversion costs. In Germany it amounts to 38%, while 23% are accounted for by the maintenance costs of the plant, 22% by energy costs and 15% by personnel costs. The general overhead costs have been disregarded because of the different structure of the various iron and steelworks.

This figure shall only serve as an indication. I do not want to speak for or against a specific sintering system nor to set forth all advantages and disadvantages. In the following papers my ideas will be dealt with in greater detail.

It has been my task to give an introduction into the problem and to outline the great importance of sinter for the modern blast-furnace practice.

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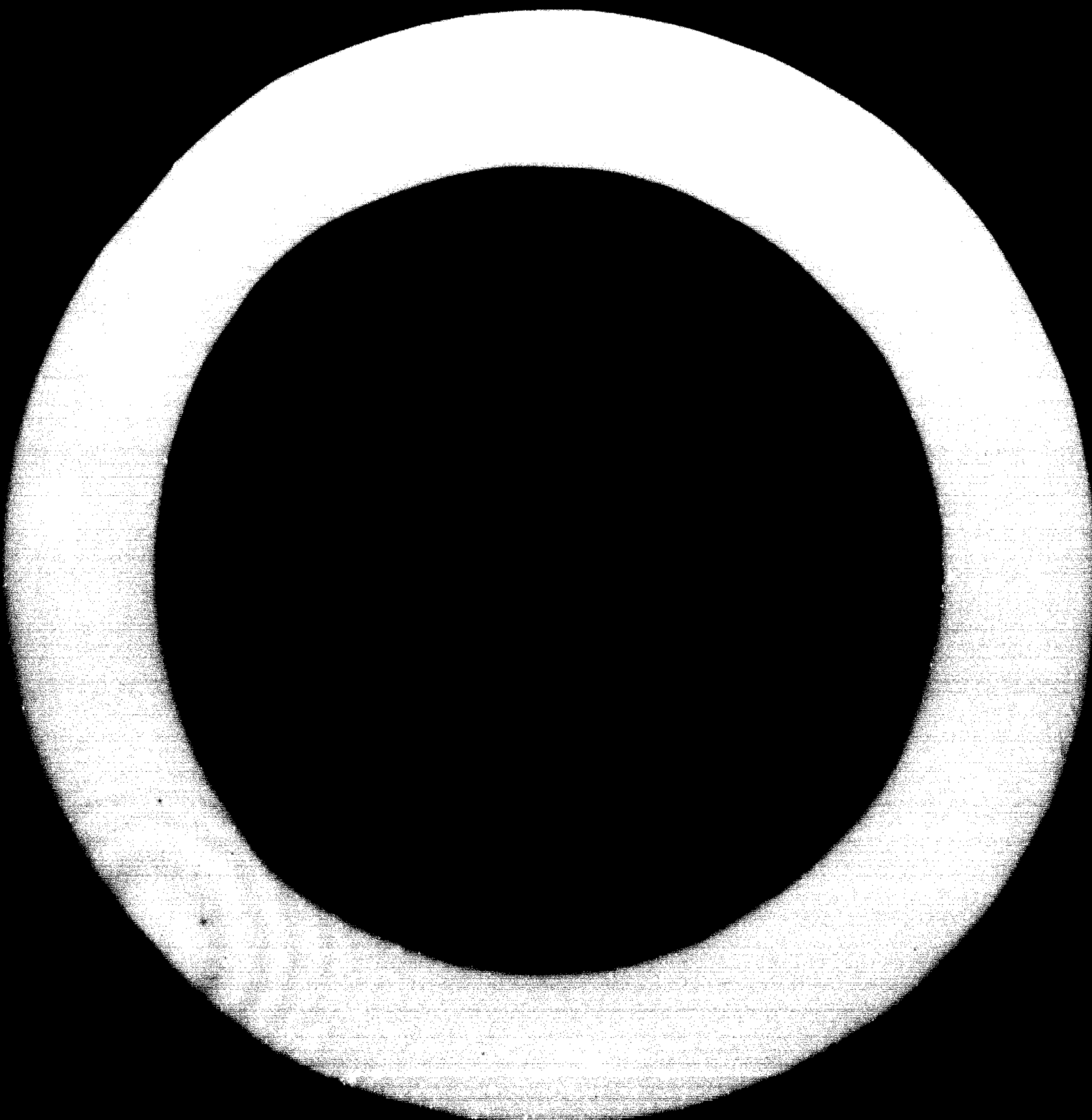
FIGURES



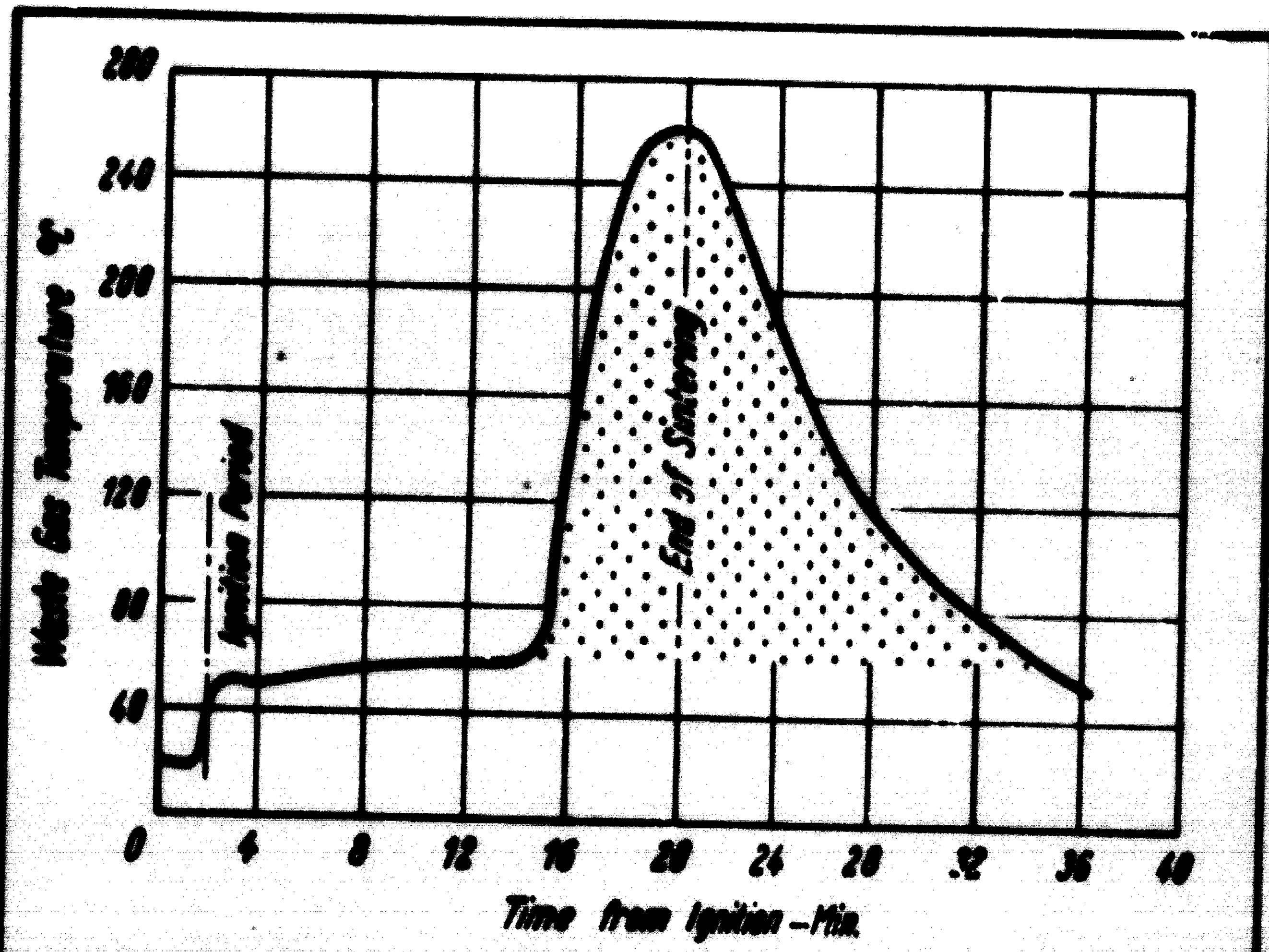
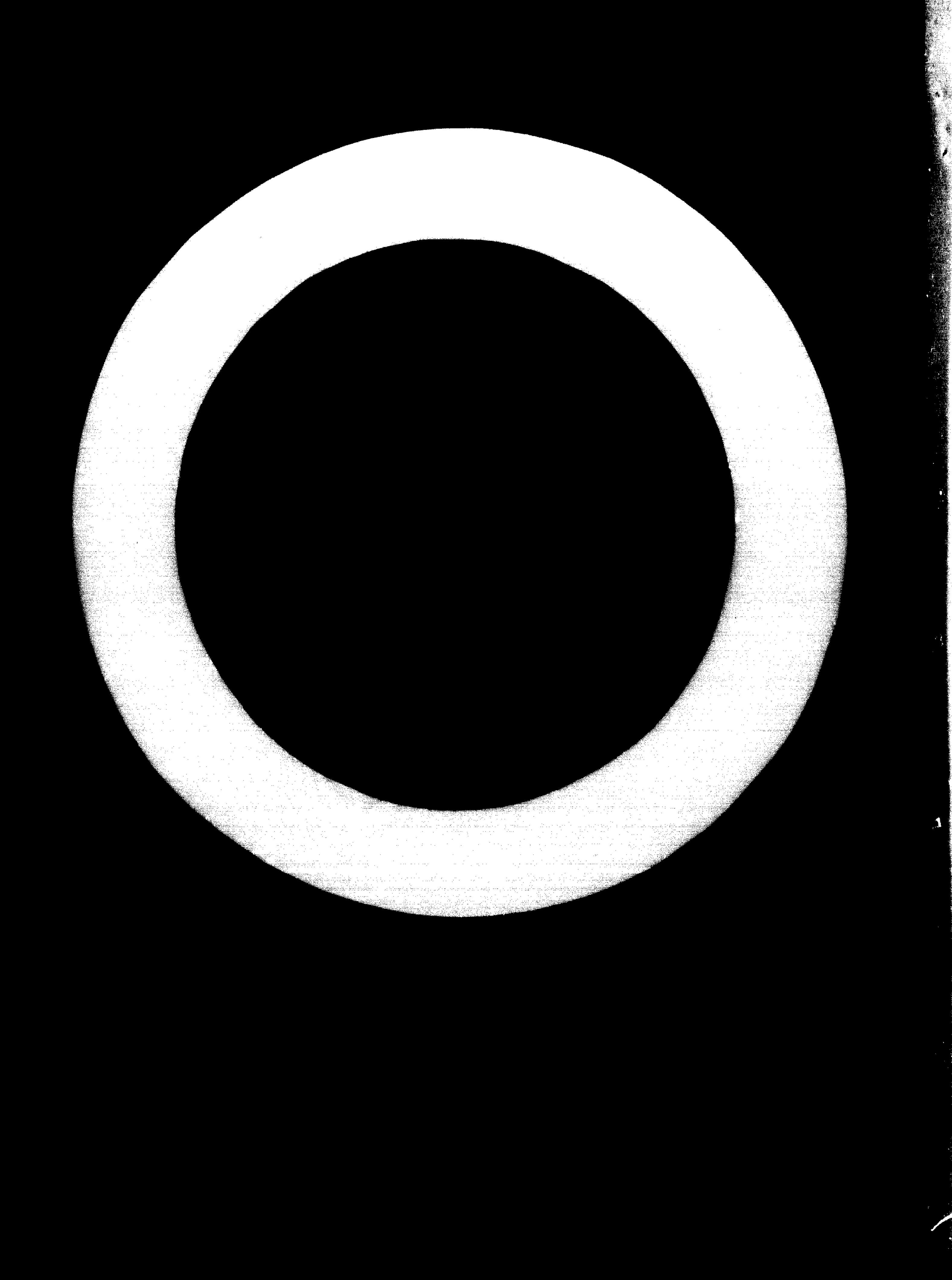


Figure 1 | Typical Waste Gas Temperature Curve for Rich Ore Feed. According to W.Davies and W.Mitchell | RUHR-CONSULT [illegible]



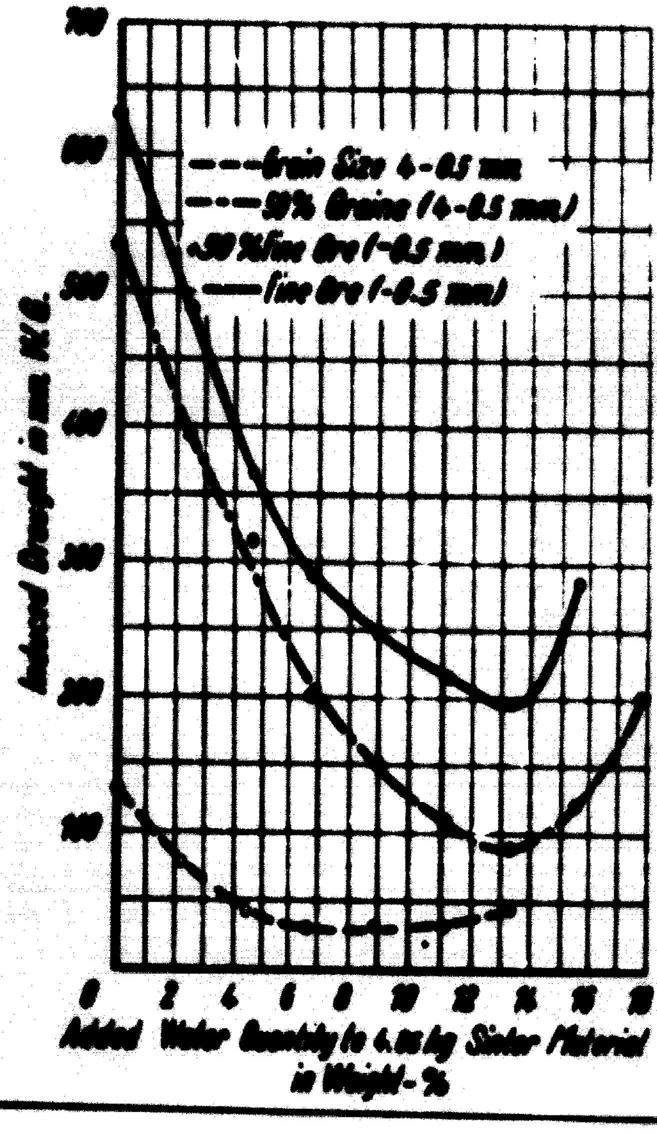


Figure 2

Influence of the added Water Quantity on the Air Resistance of a Sintering Mixture

According to Luyken and Kraemer

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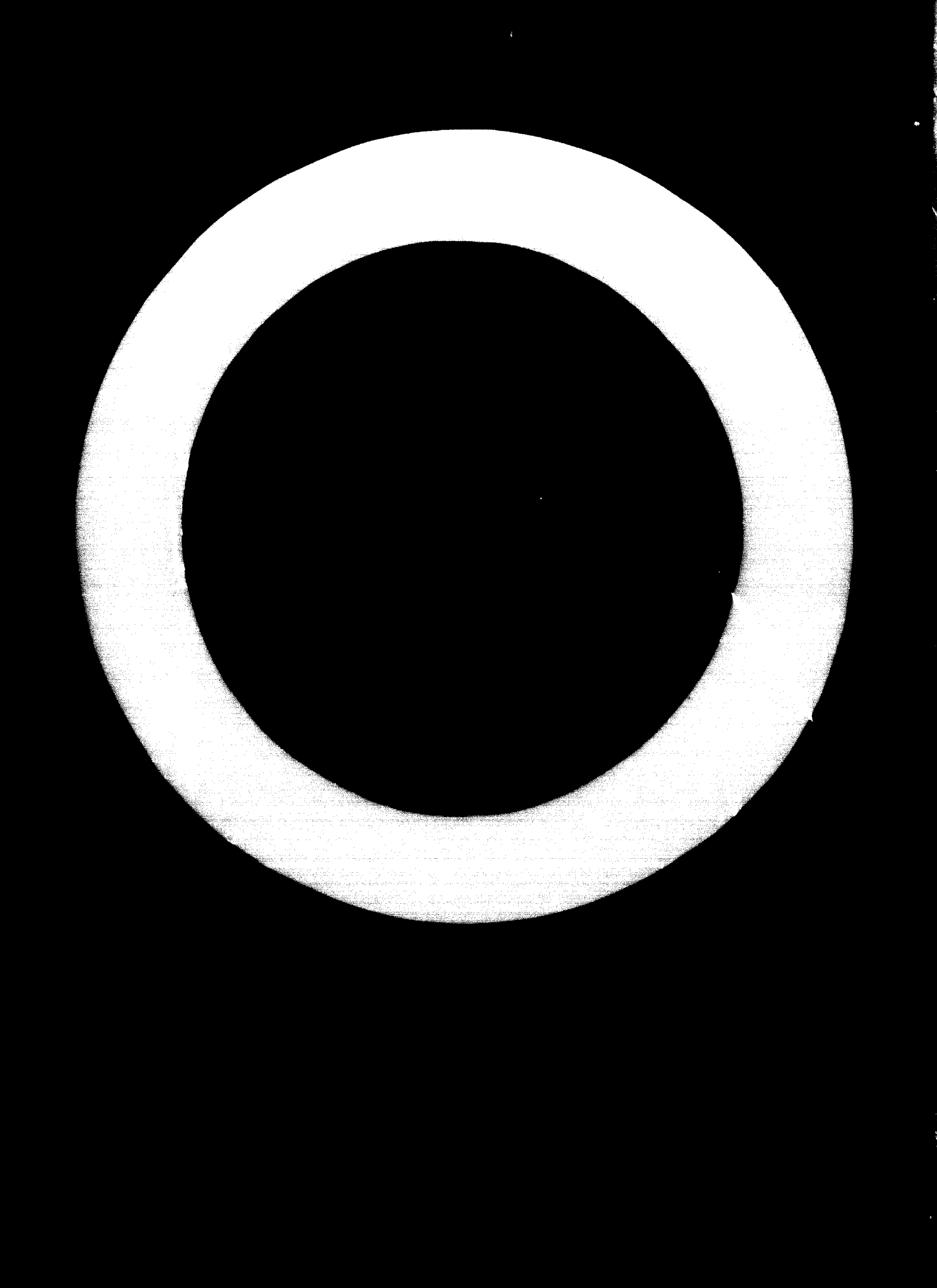

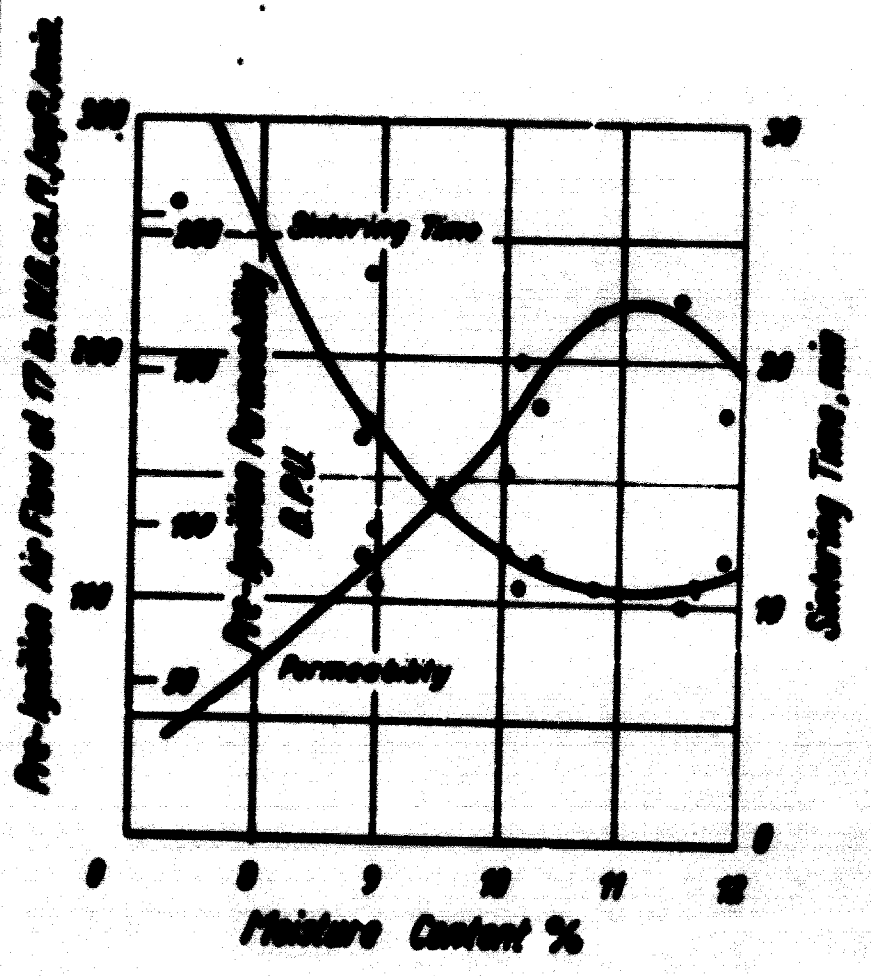

Figure 3

Influence of Moisture Content on Sintering Time and Permeability

According to E.W. Voice and Assistants

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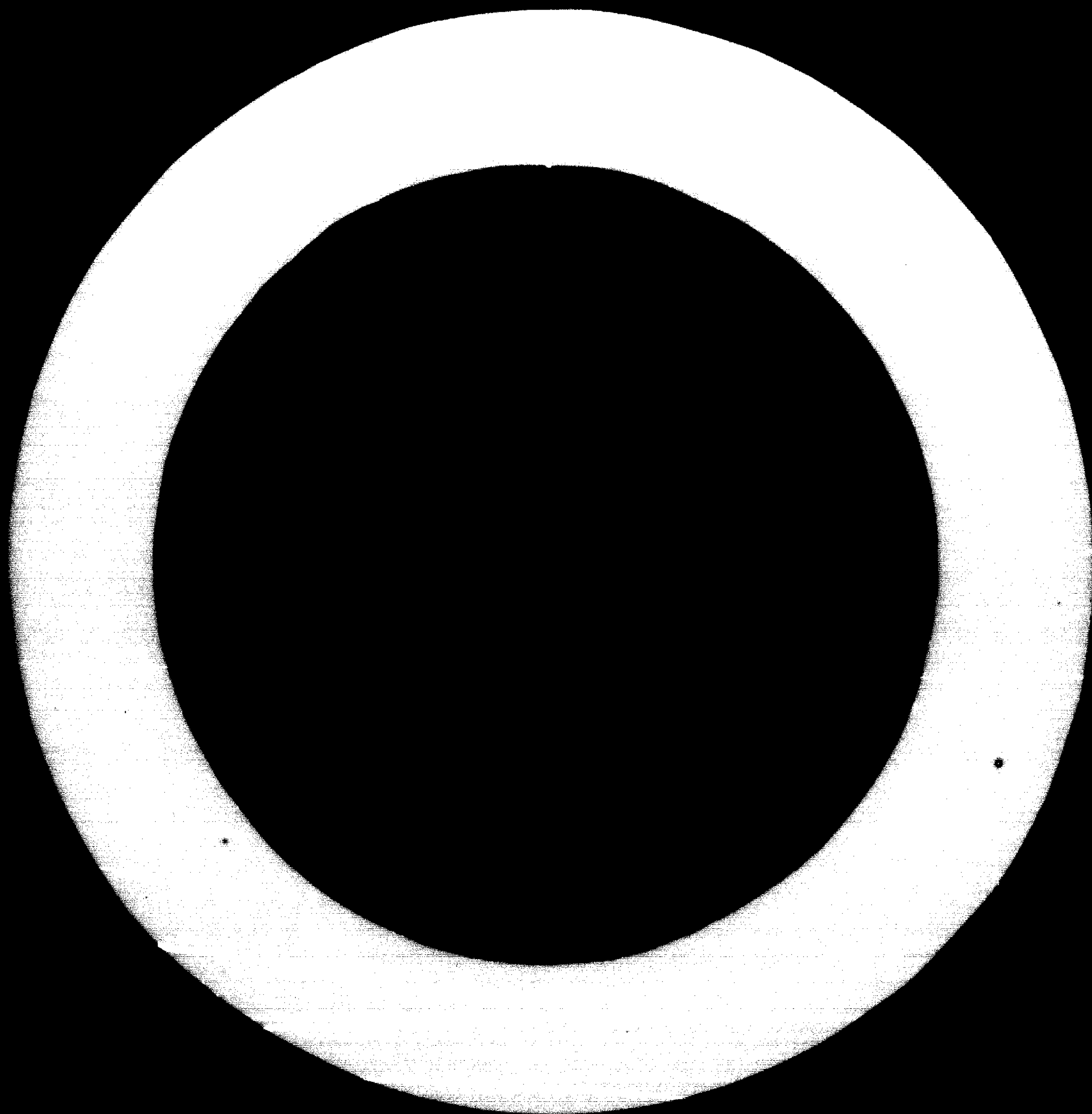


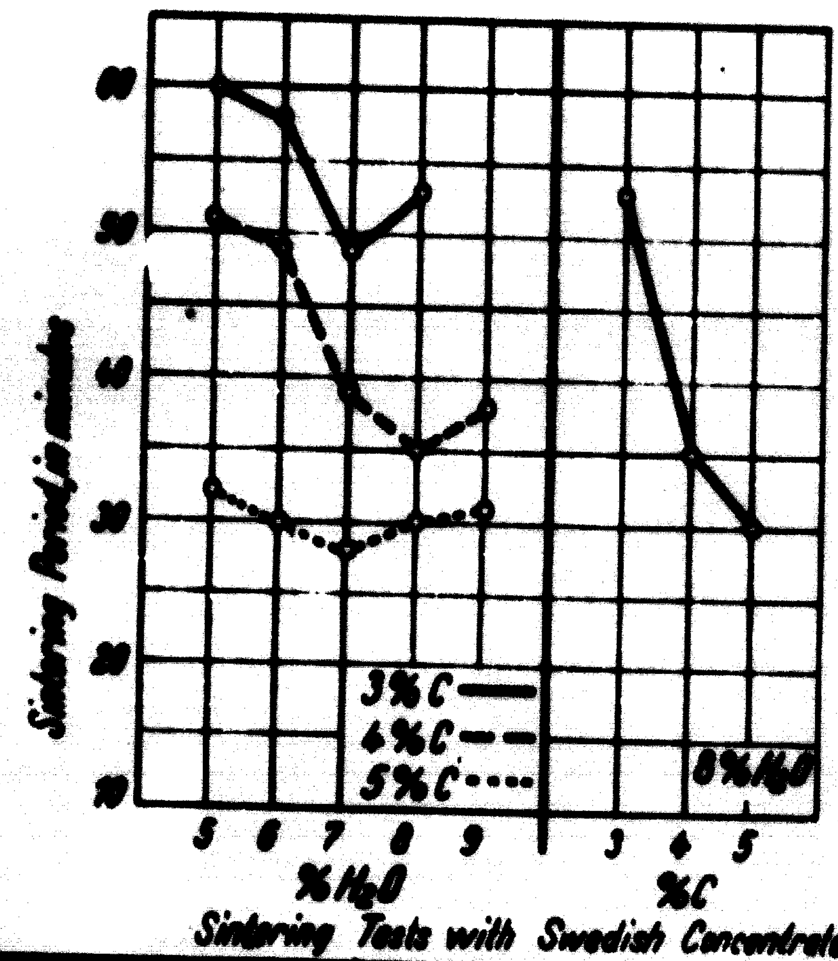
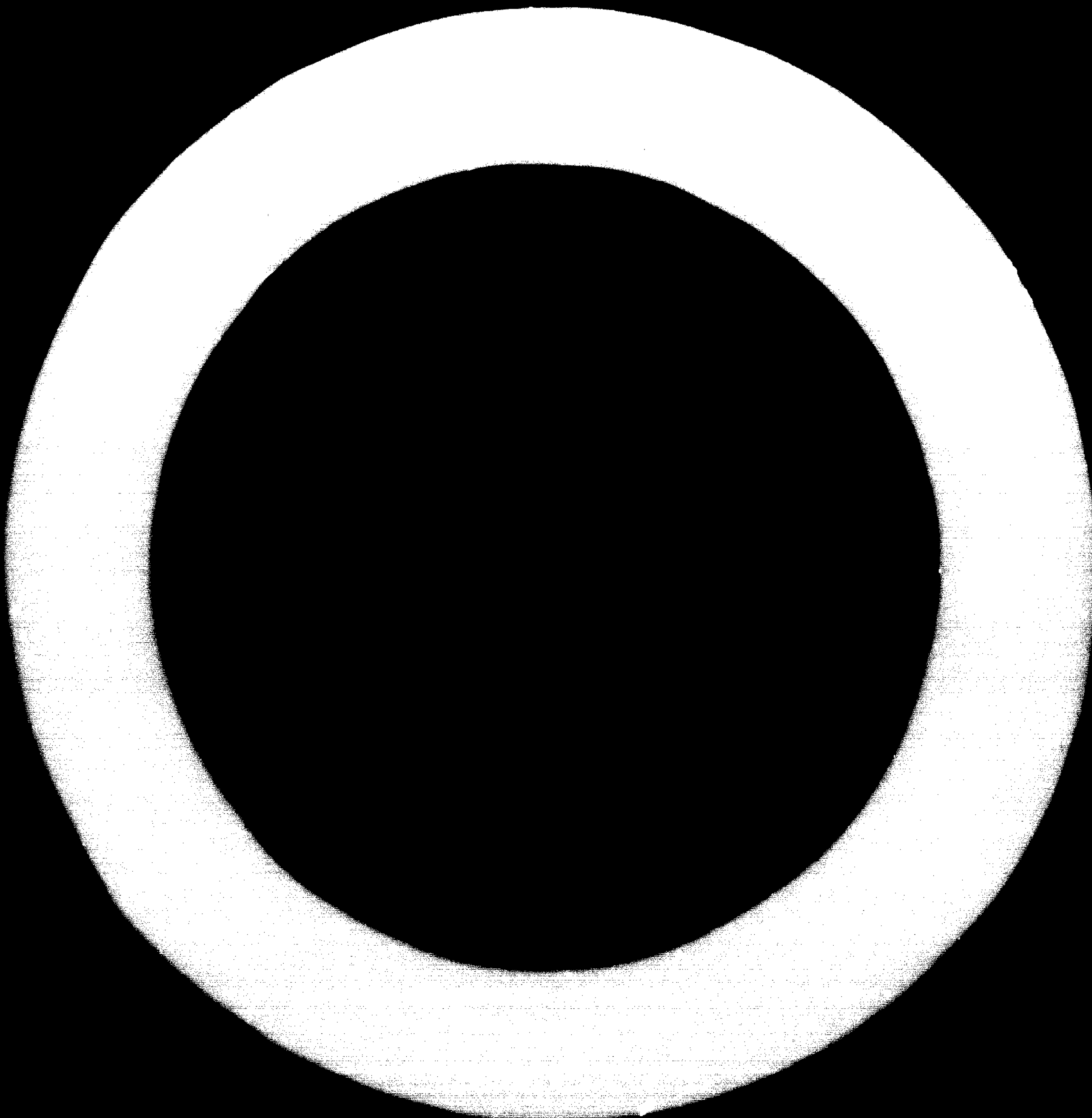


Figure 4a	Sintering Output and Sintering Time as Function of Moisture and Fuel Contents According to Killing	RUHR-CONSULTING



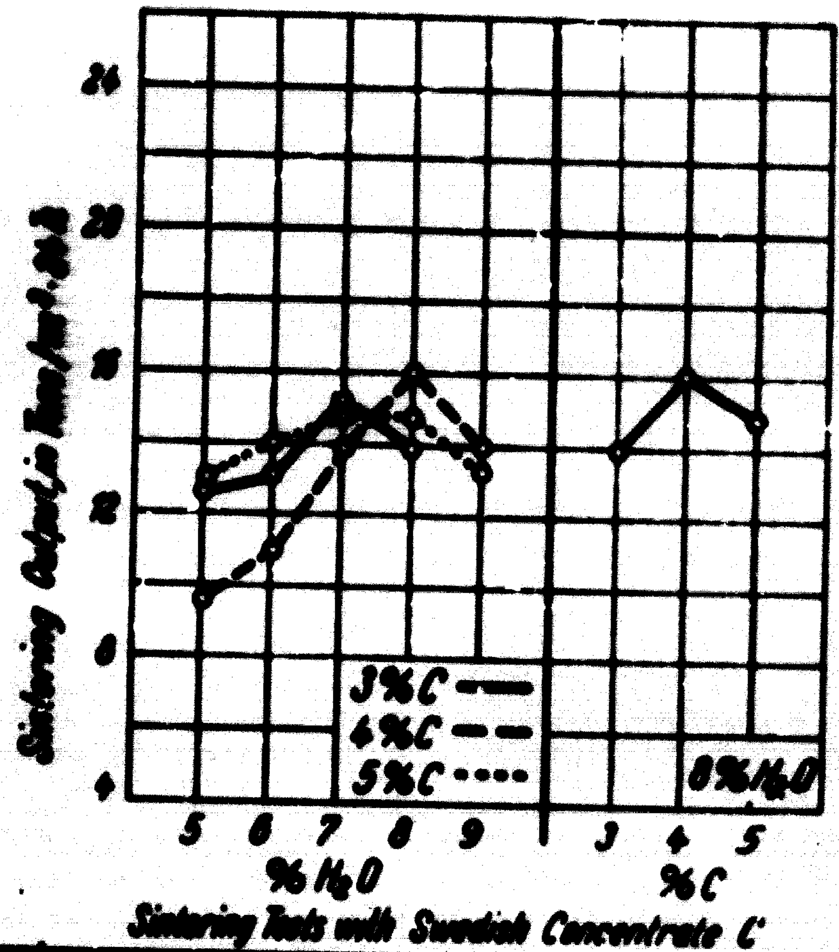
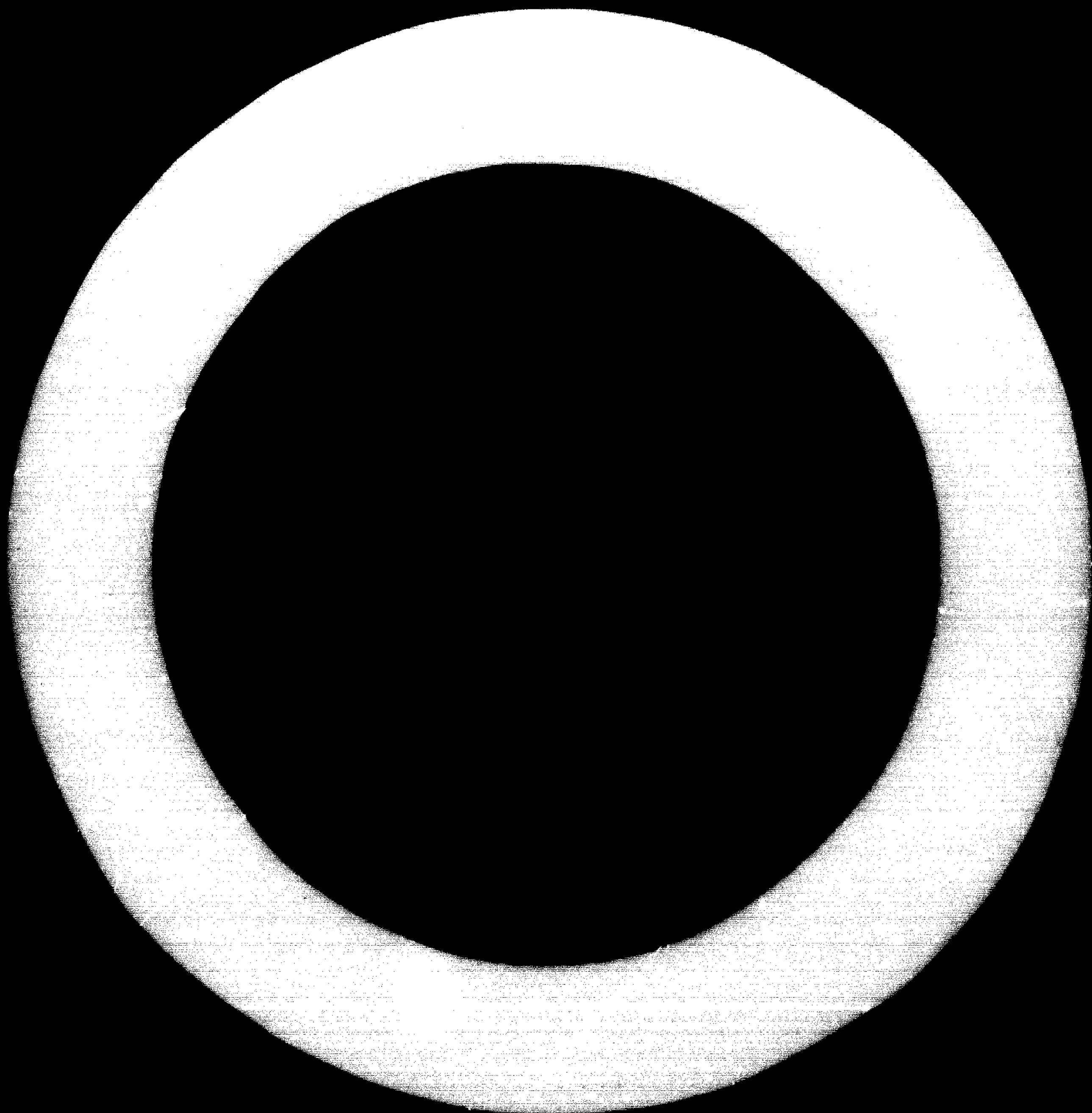


Figure 43 | Sintering Output and Sintering Time as Function of Moisture and Fuel Contents According to Killing | RUHR-CONSULTING



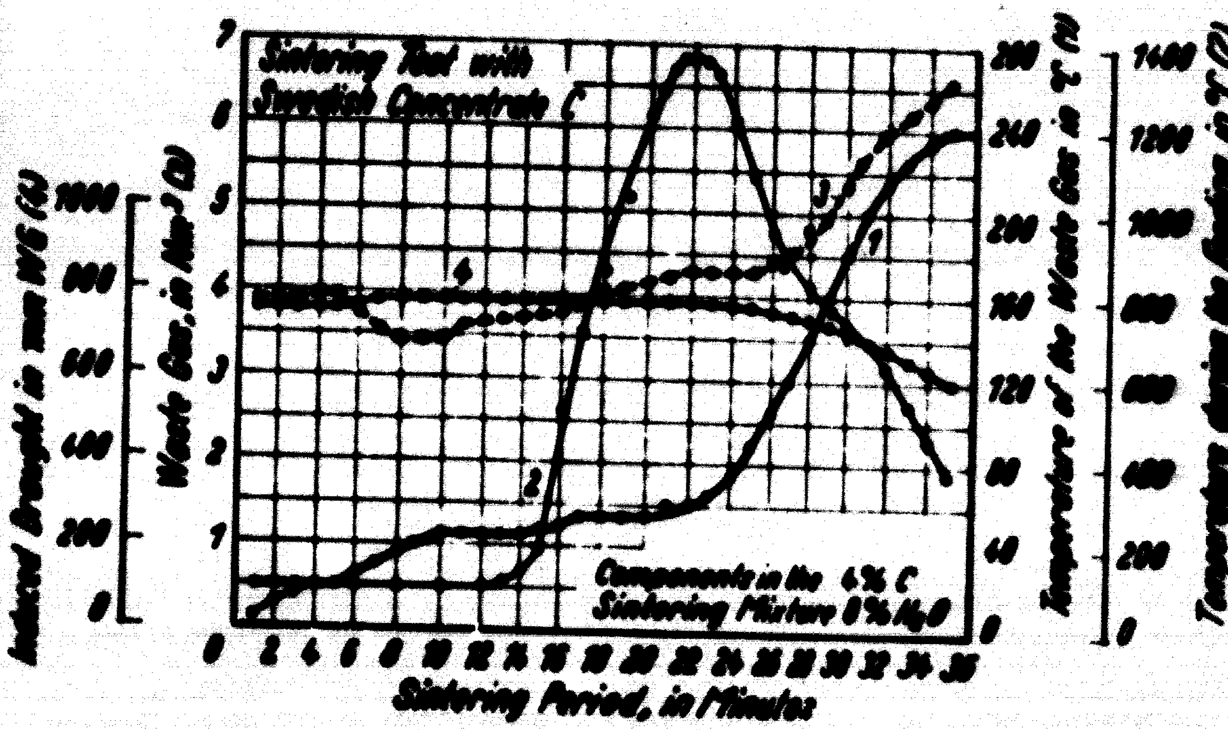


Figure 5	Temperature Gradients, Waste Gas Volume and Suction as Function of the Sintering Time. According to Killing	RUHR-CONSULTING

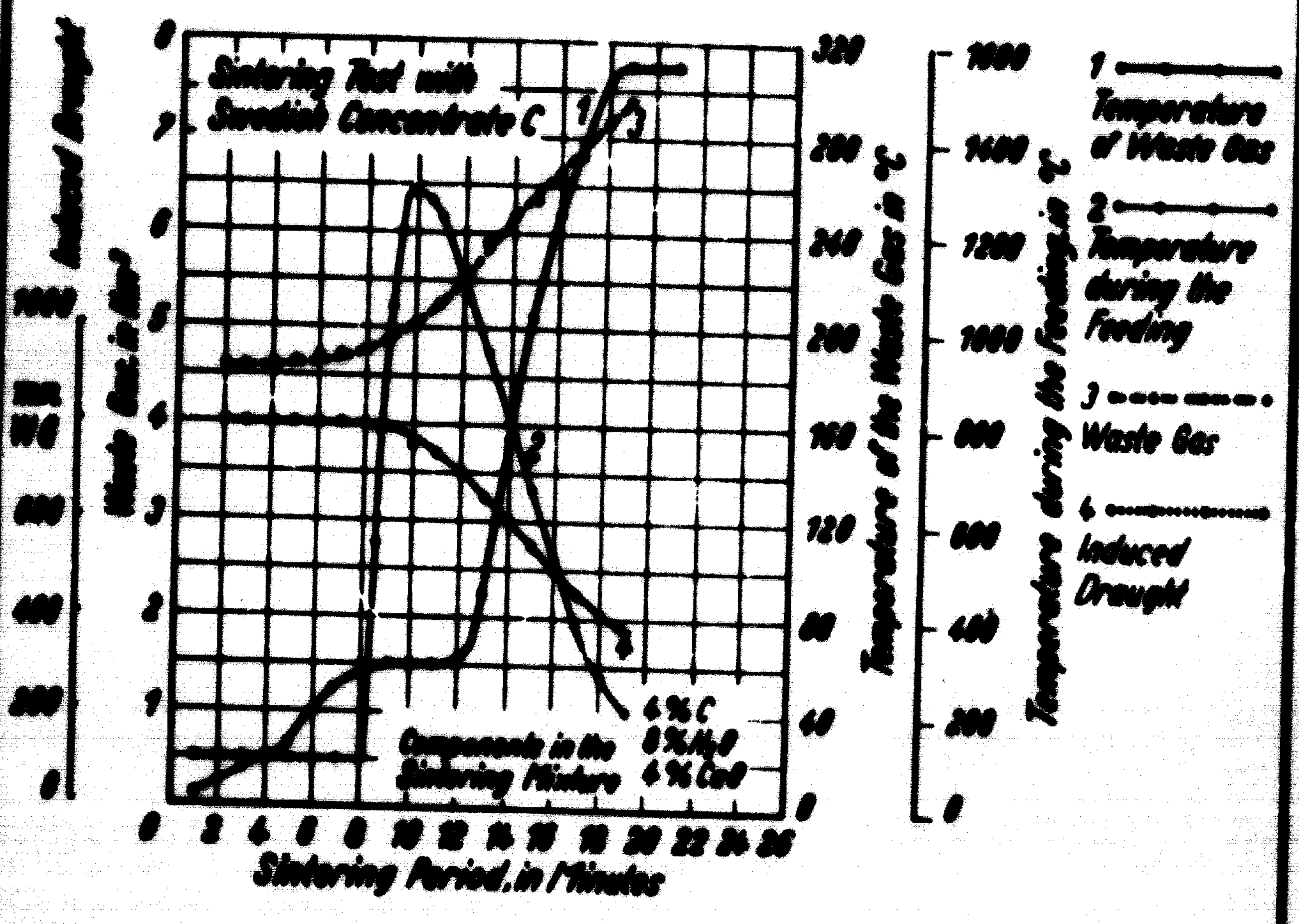
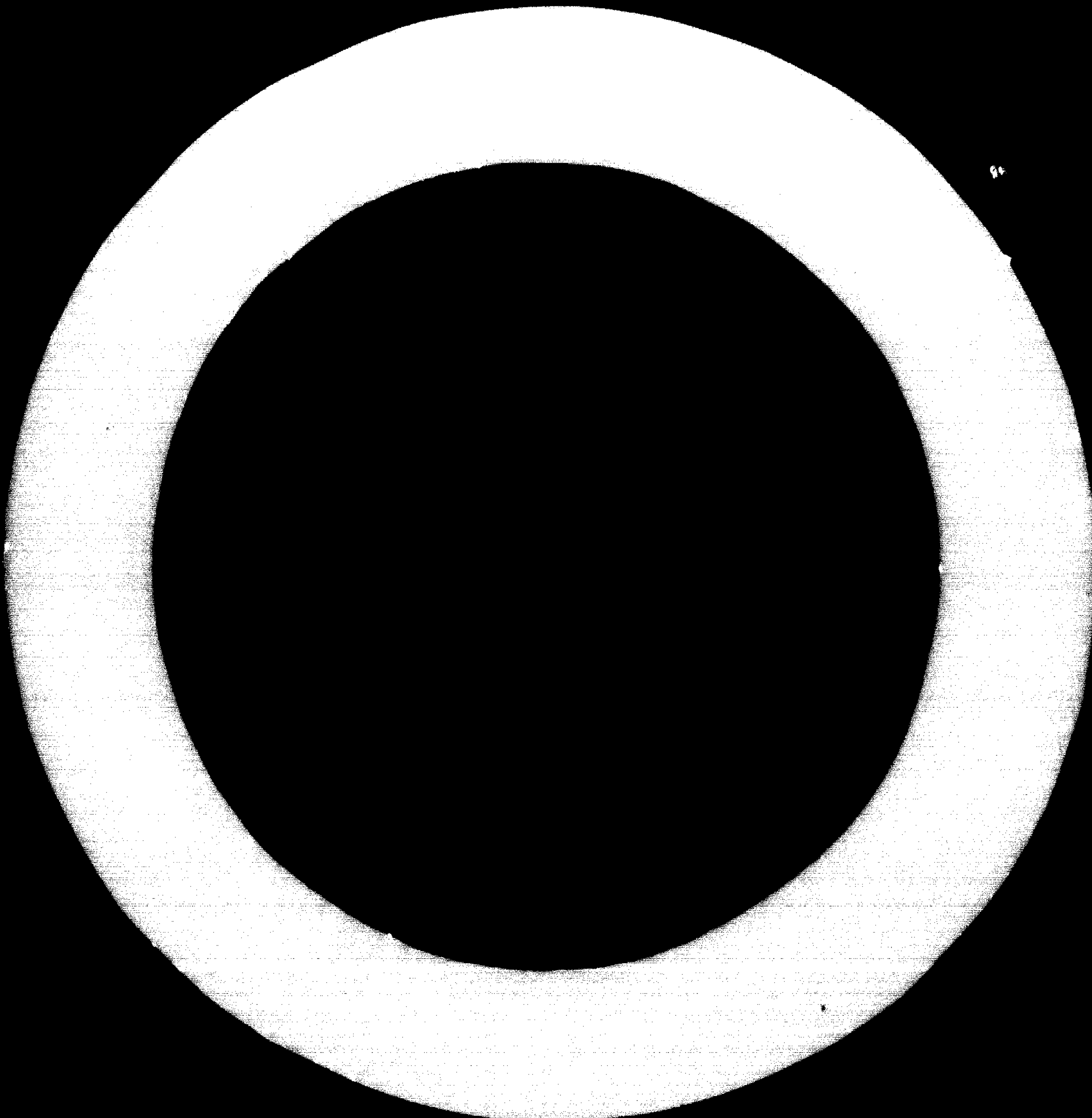


Figure 6 | Temperature Gradients; Waste Gas Volume and Suction as Function of the Sintering Time. According to Killing | RUHR-CONSULTING



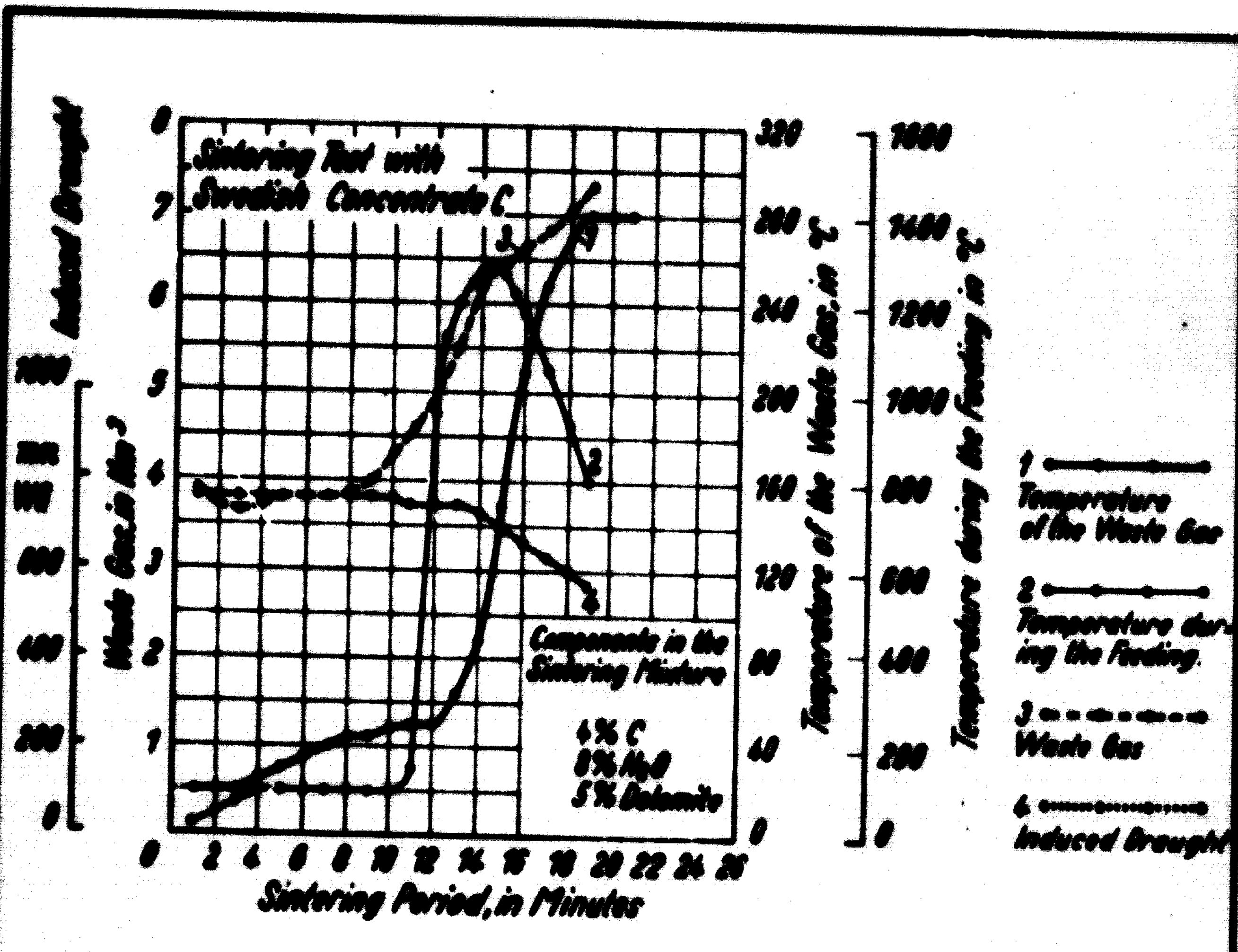
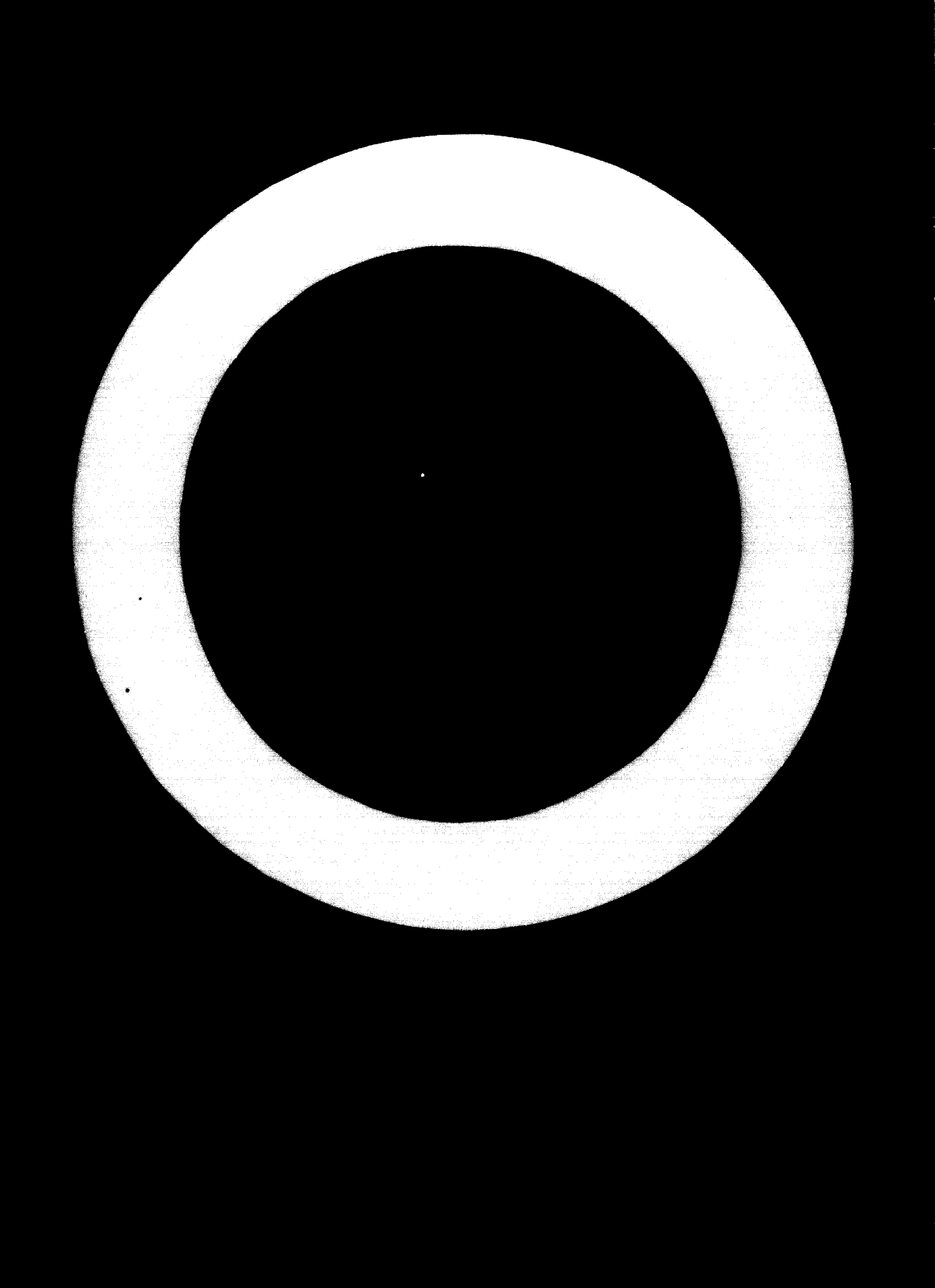


Figure 7	Temperature Gradients, Waste Gas Volume and Suction as Function of the Sintering Time. According to Killing	RUHR-CONSULTING



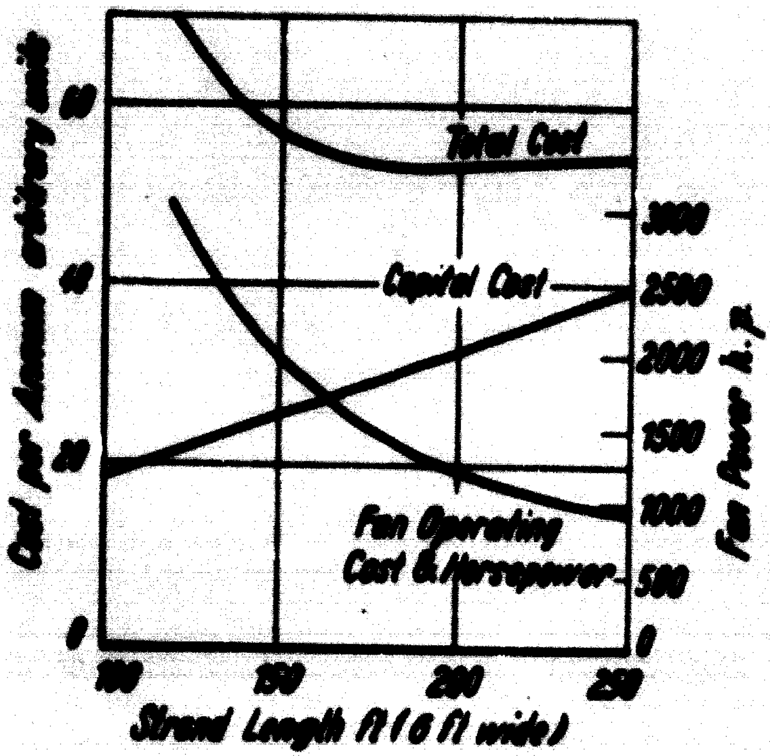


Figure 8

Optimum Length of Strand and Total Fan Horse-power to make 7000 tons of Sinter per Week with Certain Specified Conditions

According to W. Davies and D.W. Mitchell

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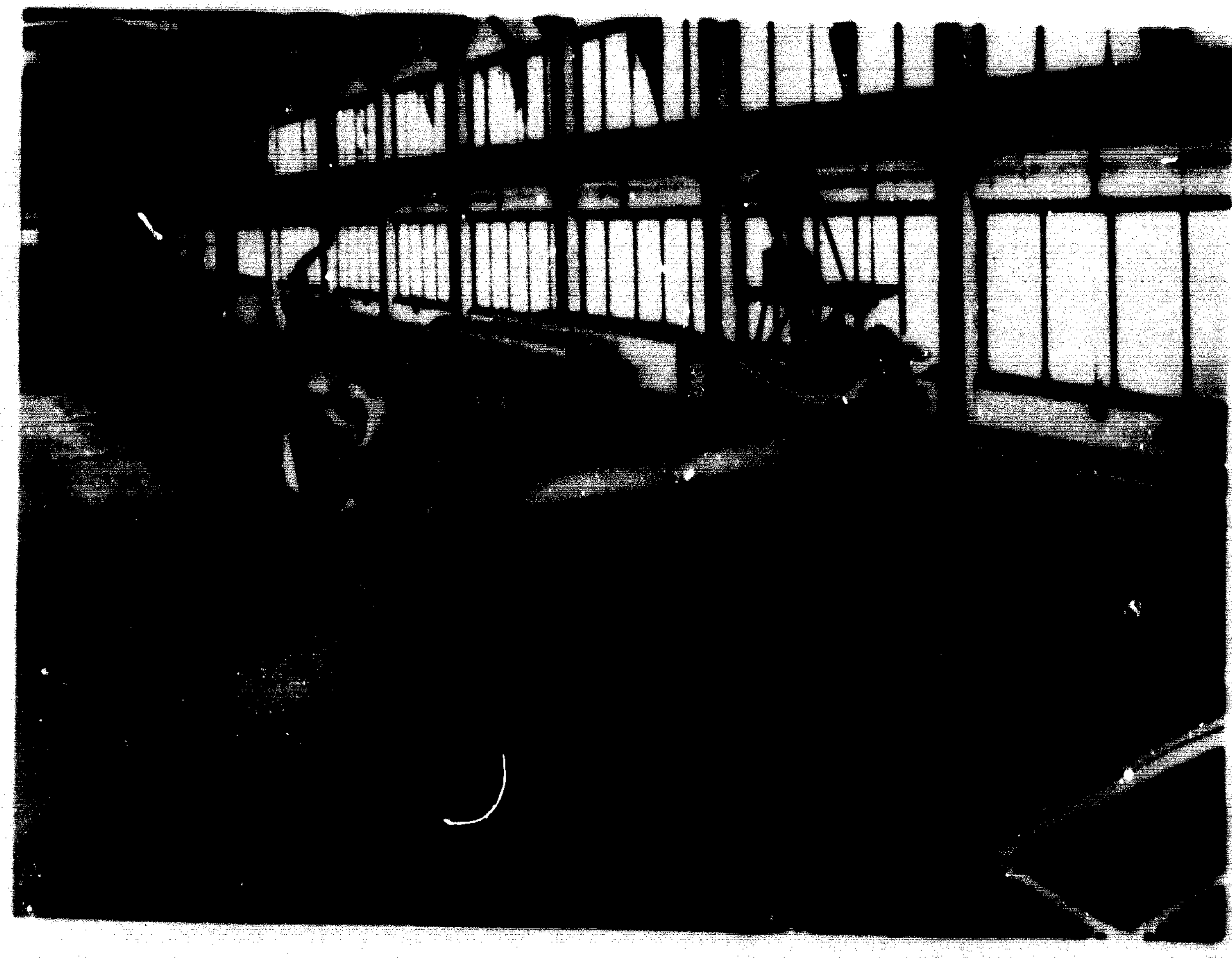


Fig. 9

Pan Plant according to the

Swedish System

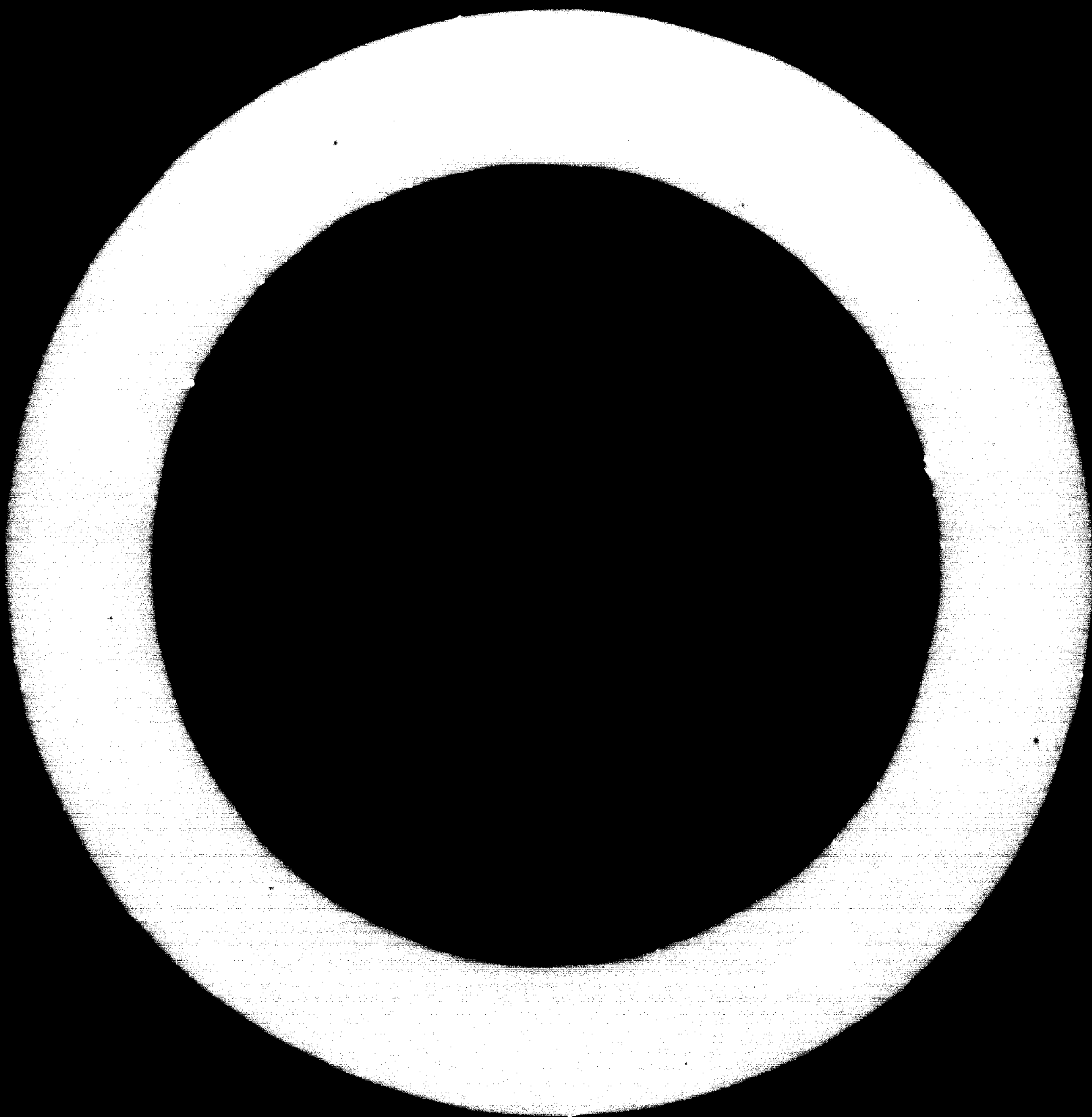


Fig. 10

Fan Plant according to the Swedish System

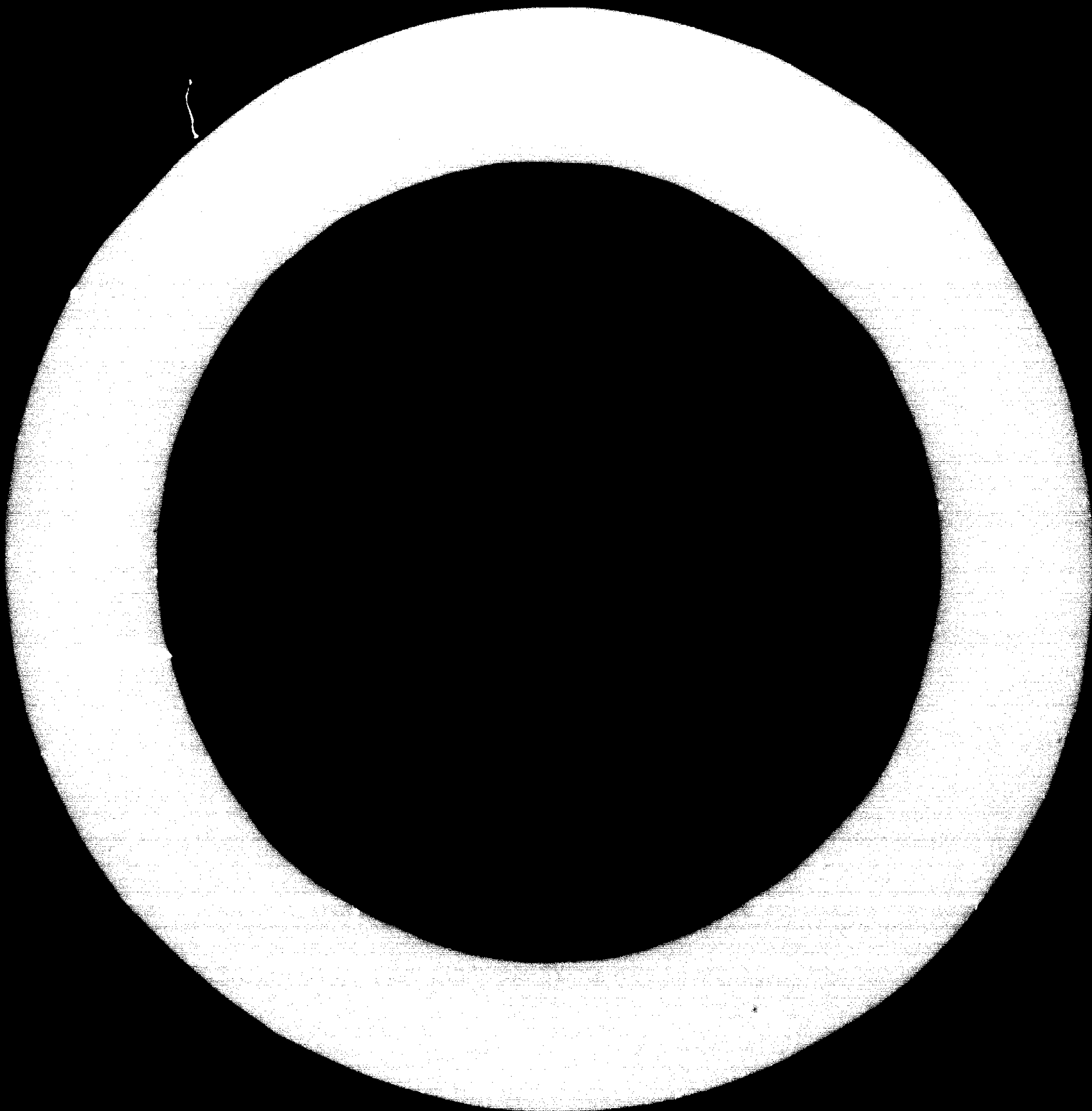
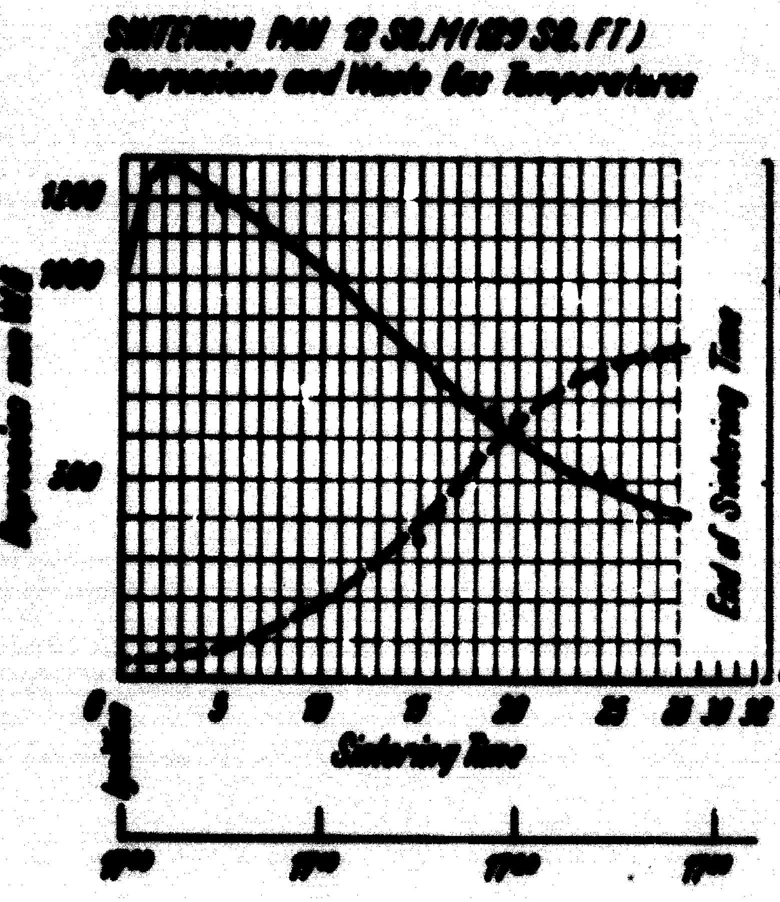


Figure 11



Waste Gas Temperature and Depression during Sintering in a Sintering Pan

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