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SINTERING TECHNIQUES AS APPLIED TO THE
IMPERIAL SMELTING PROCESS [1]

by

C. J. G. Evans
Imperial Smelting Processes Limited
Avonmouth
England

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1. INTRODUCTION

The word "sintering" has a number of meanings in the metallurgical industry all of which are variations of the general theme of agglomeration. In the metal forming industry powder metallurgical techniques are finding an increasing application. Essentially this comprises the forming of definite shapes in a mould using metallic powders which are subjected to heat and pressure. This process is frequently referred to as sintering.

In the extractive metallurgical industry it is usually necessary to subject the ores to one or more preliminary treatment stages before the metal producing stage can be operated successfully. One of the most important metal producing processes is the blast furnace and the nature of this unit is such that a lump charge is highly desirable. The process of agglomerating ores or concentrates into a form suitable for a blast furnace is generally termed sintering and it is this process which is the subject of this paper, with special reference to the production of sinter for the Imperial Smelting Furnace.

2. THE SINTERING PROCESS

2.1 General

In the non-ferrous extractive metallurgical industry the
sintering process is well known and widely used but it is only in
the last twenty-five years that it has gained recognition as an
important process in the preparation of iron ores and concentrates
as feed for the iron blast furnace. (It should be noted that there
is a current trend towards the use of pellets in the iron blast
furnace but these are produced from the very fine portion of the ore
and it is probable that the optimum furnace operation of the future
will result from a mixed burden of raw lump ore, sinter and pellets
and that pellet production will never completely replace sintering).
The broad objectives of sintering are:-

(i)   the drying, calcining and/or roasting of fine ores or
      concentrates

(ii) the agglomeration of fine ores or concentrates which
      could not be smelted economically otherwise, and

(iii) increased blast furnace productivity

The raw materials for non-ferrous sintering are usually fine
sulphide concentrates and the sintering process involves de-
sulphurisation as well as agglomeration. The roasting reactions
involved are exothermic and the heat generated is used for
agglomeration. Because the sinter machine capacity is dictated by
sulphur elimination rather than lump recovery or output tonnage
there is a high incentive to use the maximum fuel i.e. to burn
the maximum sulphur. In the ferrous industry there is no inherent
fuel in the raw materials and coke has to be added as a source of

heat. The machine capacity is dictated by lump recovery and in order to keep costs to a minimum considerably less selectivity is exercised on the output sinter and the returns to raw materials ratio is kept much lower.

Since there are often many other components in the sinter machine feed besides the copper, lead or zinc sulphides e.g. fluxes and secondary materials, the chemistry of the operation and the constitution of the sinter may be quite complex. Ferrous sintering tends to be more straightforward.

There is also the question of the composition of the sinter gases. The off-gas from a ferrous sinter plant usually contains little or no chemical values or obnoxious compounds and can be released to atmosphere after cleaning to remove any entrained dusts. On the other hand, the exit gas from a plant sintering non-ferrous concentrates contains considerable quantities of Pb and Cd bearing fume which is removed and retreated and also up to 8% sulphur dioxide which is obnoxious and in many cases quite valuable. Current practice is to use this gas for the production of sulphuric acid. For reasons of acid plant operation the sulphur dioxide content of this gas should be as high as possible and the attainment of this level has a considerable bearing on the sinter plant operation.

The scale of operation is another difference between the two sides of the industry. Sinter strands of over 300 m^2 effective area producing upwards of 6,000 tons per day are in service in the ferrous industry whereas the largest non-ferrous sinter machine to date is 132 m^2 effective area producing about 850 tons per day. This is a further reflection of the difference in returns ratio

already mentioned.

One final but vitally important difference is that in the sintering of lead concentrates, and to a lesser extent of copper and zinc, the hygiene aspect is of great importance and the precautions taken can involve a capital cost of up to one third the total plant cost.

Two basis methods of draughting a sinter machine are available namely downdraught and updraught. Without exception, ferrous sintering employs the downdraught technique while non-ferrous is showing an increasing trend towards updraughting, particularly in operations involving lead. All sinter plants associated with Imperial Smelting Furnaces use updraught sintering practices based on principles developed at tne Avonmouth Smelter of Imperial Smelting Corporation Limited, although the original idea of updraught sintering goes back to 1898 when it was used in the Huntington & Heberlein sinter pots. When the continuous sintering process was developed it was found difficult to work with updraught methods and the downdraught process became common practice for many years. The credit for the original development of updraught sintering as it is now must be shared between B.H.A.S., Port Pirie (1.2) and Lurgi Gesellschaft (3).

2.2 Sulphide Sintering

As previously stated, non-ferrous sintering usually involves the use of sulphide concentrates and it seems appropriate at this stage to consider sulphide sintering in more detail.

The sintering process may be divided into four major stages, viz:-

(1) conditioning of the raw materials

(ii) mixing of the sinter machine feed

(iii) sintering

(iv) handling the sintered material

The raw metal bearing materials are generally flotation
concentrates. These are finely divided and due to their nature
a certain amount of agglomeration can take place during storage
which must be broken down or else poor sulphur elimination will
be achieved during sintering. The high sulphur content of the
concentrates (15-33 per cent depending on concentrate type)
precludes its direct use on a sinter machine since the high fuel
content would result in excessive bed temperatures. This would
cause slagging of the material to take place and imperfect sulphur
elimination would ensue. Therefore the sulphur in the concentrates
is diluted by the addition of sintered product (returns) in order
to obtain a mixture which will combine high sulphur elimination
with the requisite degree of fusion to give a good quality,
cellular structured product. The preferred machine feed sulphur
content varies slightly with the type of sinter being produced but
is usually within the range 5-7 per cent.

Depending on the draughting method employed, either the whole feed
(in downdraught sintering) or a thin "ignition" layer (in updraught
sintering) is placed uniformly across the sinter machine which is
essentially an endless moving grate. The bed passes under an oil,
gas or coal fired ignition stove and the surface is ignited. In
the case of updraught sintering the "main" layer of feed is added
on top of the ignition layer after the ignition stage. The bed
then passes over a series of windboxes and air is either drawn

down or blown up through the bed thus propagating the ignition layer. As the hot reaction zone moves up or down through the bed the material is progressively reduced in sulphur while the gas becomes increasingly richer in sulphur dioxide. Sinter is discharged from the end of the sinter machine containing 0.4-0.8 per cent sulphur.

The gases from the discharge end of the sinter machine tend to be relatively lower in SO_2 and can be recycled. The gas from the feed end of the machine contains 5-7 per cent SO_2 and is passed to a sulphuric acid plant or, if economics and government regulations permit, can be blown to atmosphere after scrubbing.

During sintering the feed becomes fused together and is discharged from the sinter machine largely in lump form.

Subsequent handling depends on the requirements of the following reduction process but invariably the sinter is screened with the undersize providing the "returns" and the oversize product for future treatment.

3. **DEVELOPMENT OF UPDRAUGHT ZINC/LEAD SINTERING**

3.1 The Wind of Change

At the Avonmouth and Swansea Vale Smelters of Imperial Smelting Corporation zinc was produced originally by the Horizontal Distillation Process. In 1933, as the result of expansion, a New Jersey Vertical Retort Plant was commissioned at Avonmouth. Neither of these processes are blast furnace type and hence a relatively fine feed of zinc oxide was required. This was produced on straight line downdraught sinter machines each 2 m wide by 20 m effective length. The SO_2 bearing gas was passed to a contact sulphuric acid plant.

Although the Horizontal Distillation plants have since been shut-down, sinter is still produced for the Vertical Retorts on the Avonmouth machines.

However, I.S.C. were not satisfied with either zinc process. The Horizontal Distillation Process was intermittent in operation and a heavy consumer of fuel. Additionally the vast number of retorts required a high labour force working in hot and arduous conditions. The Vertical Retort Process was a considerable improvement because it was a continuous process. However it was small unit operation requiring a special quality coal and involving high capital and maintenance costs.

It was decided to investigate the possibilities of zinc production by other methods, preferably one based on the blast furnace since this would have the benefit of large unit continuous operation. Some small scale work was carried out at Avonmouth before the war but work did not commence in earnest until 1946. This development

of the Imperial Smelting Process created a demand for a sinter
suitable as a direct feed to a blast furnace.

3.2   "Hard" Sulphide Sintering

A primary requirement for such a sinter was that it should be
free from "fines" (i.e. $-\frac{1}{2}$" material), preferably in the size range
1 in. to 4 in. and should be resistant to breakdown during handling
and smelting.   Initially it was tried to agglomerate ("harden")
conventional sinter for the Vertical Retort and Horizontal
Distillation Plants ("soft" sinter) by increases in the sulphur
content of the feed mix and by additions of silica (in the form
of sand) and the sinter machine output was passed over a $\frac{1}{2}$ in.
screen.   The $-\frac{1}{2}$ in. fraction was crushed to returns sizing and
recycled and returns stock maintained by additions of soft
sinter and/or undersize sinter returned from the I.S.F.
Apart from this supplementation of the recirculating returns load,
general operation remained basically similar to that of the
normal soft sinter process.   Silica content of output was normally
about 6 per cent.

Continuing I.S.F. development resulted in an increase in the
complexity of the demands made on the Sinter Plant.   It was being
realised on the furnace that slag composition was of great
importance to continuity of operation and also that the furnace
could produce lead as well as zinc.   Therefore it became
necessary to incorporate limestone as well as lead and zinc
bearing secondaries from the I.S.F. and ultimately, lead in excess
of the recirculating residual load (the latter being equivalent to
about 5 per cent lead in output sinter) into the hard sinter mix.

Whilst the addition of lime and lead to the mix tended to assist
slagging and hence the production of lump, their presence rendered
the task of sulphur elimination much more difficult. The sulphur
content of such sinters was often in the range 1-2 per cent, well
in excess of the I.S.F. requirements at that time. A further
disturbing feature in the production of this type of sinter was
the marked tendency to form a persistent scale on the machine grate,
accompanied by an increase in the burning rate of grate bars.
Pallet bar life decreased from approximately 9 months (standard
soft sinter) to 5 weeks despite modifications to pallet bar design.
Burning of pallet webs also became apparent and continual loss of
sound bars from the grate took place.

The increased hardness of sinter necessitated the installation of
a prong breaker at the tip end of the sinter machine at about this
time. At this stage sinter had been made containing up to 17 per
cent lead, 7 per cent silica and 9 per cent lime with zinc content
about 35 per cent. Output per day was about 250 (long) tons + $\frac{1}{2}$ in.
Acid make as 100% H_2SO_4 was 100-105 tons/day.

3.3 Coke Sintering

In 1955, in order to produce sinter of good hardness combined with
low sulphur content containing appreciable quantities of lead,
lime and silica in addition to zinc, "coke" sintering was developed.
This process involved a primary desulphurising pass over a sinter
machine of a mixture of zinc concentrates and crushed zinc/lead ore
with appropriate quantities of returns. No attempt was made to
harden this sinter and all output was crushed to returns sizing.
The product, called "primary" sinter, contained up to 13 per cent

lead, 50-55 per cent zinc and approximately 1 per cent sulphur.
Primary sintering was normally carried out at the Swansea Vale
Works where there was available sinter machine capacity.
Primary sinter was then resintered at Avonmouth with additions
of limestone, silica, leady residuals and Waelz calcines (a material
containing 45 per cent zinc and 10-12 per cent lead made by treating
vertical retort and horizontal retort plant residues in a Waelz
Kiln), using dried anthracite slurry as a fuel. Carbon content of
the sinter mix was approximately 4 per cent. A standard sinter
machine was used, but machine gas was exhausted to atmosphere after
passage through a Beth bag filter plant and neutralising tower.
Output sinter was screened and $-\frac{1}{2}$ in. material crushed and
recirculated as in "hard" sulphide sintering. By this method it
was found possible to produce very hard sinters of similar
composition to the "hard" sulphide sinters previously made, but
with output sulphur analyses of 0.1 per cent or less.

The problem of grate scaling remained, however, and the
difficulties arising from excessive burning of pallet bars became
acute.

To avoid these difficulties, the No. 1 sinter machine was modified
in 1956 to enable sinter to be made by the updraught method.
The modifications were made in such a way as to permit the machine
to be operated, by re-arrangement of gas main blanks and igniter
stoves, on either coke or sulphide sintering by either the
updraught or downdraught method, as desired, a period of 12-18
hours being required to effect the conversion from one method to
the other.

After an initial development period, satisfactory coke sinter was made by the updraught method.

3.4 Updraught Sintering

Whilst good quality hard sinter could be produced by the updraught coke sinter process without the operating difficulties experienced on downdraughting, the process was not economically attractive due to the necessity for two sintering operations, first a desulphurising sintering, followed by the coke sintering operation.

Attempts were therefore made to produce a satisfactory sulphide sinter by the updraught method, thus combining effective desulphurisation, incorporation of all additives, and lump sinter production into one operation. Successful results were obtained in 1957, and production of sinter by the updraught sulphide method ensued. This method is now being practised at eleven plants associated with Imperial Smelting Furnaces.

4. DESCRIPTION OF UPDRAUGHT ZINC/LEAD SINTERING PROCESS

The Imperial Smelting Process requires a charge of lump material with low total sulphur content. To achieve this the sinter plant must simultaneously desulphurise and agglomerate the machine feed comprising the zinc, lead and/or mixed materials together with any secondary materials arising from the sintering and other process plants, such as the fume removed from the SO_2 rich gas from the sinter machine, ventilation dusts, "blue powder," dross and also such fluxes as are required to produce an essentially self-fluxing sinter.

4.1 Intake Handling and Proportioning Plant

New materials needed for the sintering process should be free from lumps and sized as follows:-

Sulphide Concentrates	100% - 1 mm
Fluxes	100% - 2 mm
Oxides	100% - 5 mm

It is desirable that the moisture content of these materials should not exceed 8% in order to facilitate accurate weighing in the proportioning section located before the sinter machine. These conditions are achieved by suitable bulk storage facilities and the provision of equipment for breaking up agglomerates in the circuit servicing the proportioning section.

Since a sinter of constant chemical composition is required for the blast furnace, the storage bunkers must be designed to minimise held-up of materials in the bunkers and also to ensure free flowing discharge. To maintain the correct proportions of materials, bunkers are fitted with independently controlled constant weigh feeding devices, all of which are ganged together so that the

required proportions can be maintained at different production rates. Additionally the extractor mechanism for each bunker is fitted with a low flow warning alarm device.

Special care is taken to smooth out the flow of feed from each weigh belt on to the common collector belt in order to maintain a chemically homogeneous mix.

Machine returns arising during the sinter process are also added to the feed to the sinter machine from a storage bunker fitted with a constant weigh feeder device ganged to the other feeders. Normally the combined raw materials contain more sulphur than can be eliminated in one pass over the sinter machine and these "natural" fines, after crushing to a suitable size, are ideal for diluting the sulphur to an acceptable level, viz. 5.5 - 6.5%. Since the sulphur is normally the fuel for the agglomerating process, this value must be carefully controlled and it is usually necessary to crush some output lump sinter in order to obtain sufficient fines.

Occasionally the combined raw materials coupled with the naturally occurring fines do not contain enough sulphur for the agglomerating process to work satisfactorily. In this case a controlled addition of coke breeze must be made to the machine feed to raise the fuel content to a satisfactory level.

4.2 Feed Mixing and Conditioning

Before being fed to the sinter machine the machine feed normally passes through a two-stage mixing and conditioning circuit to prepare it for sintering. It is important that the material is completely mixed and that the feed acquires a certain moisture content. If a mixing drum is used for the first stage, mixing is

enhanced by the installation of a paddle shaft. A second unit is
installed to enable a final water addition to be made and also to
promote nodulising to product a feed with a size ranging from 1 mm
to 6 mm. The water content of machine feed is vital for good
operation and therefore is automatically controlled.

4.3 Sintering

Since updraught sintering techniques are used the conditioned feed
must be divided into two fractions. A representative sample of
approximately 10% of the feed must be diverted into a small
ignition layer feed hopper, the backplate of which can be adjusted
to give a layer of material 25-35 mm thick on the sinter strand.
Provisions are made to prevent any +25 mm material from falling into
the hopper. This +25 mm material can jam against the levelling
plate thereby disrupting the ignition layer and possibly causing
serious damage by dragging the feed hopper from its supports.
As the machine moves this layer passes under an ignition stove and
the hot products of combustion are drawn down through the bed which
is thereby ignited. To ensure good ignition the machine speed
should be such that at least one minute is available for ignition.
Because of the relatively thin ignition layer, there is considerable
spillage into the downdraught ignition windbox. To reduce the
quantity it is desirable that the coarser fraction of the feed
material should rill to the bottom of the layer. Spillage must be
continuously extracted from the windbox to prevent blockage. To
prevent condensation in the windbox and associated gas mains, the
gas temperature is kept as high as possible by minimising the
ingress of cold air and by insulating the windbox and associated

gas mains.

The bulk of the feed is now laid on top of the hot ignition layer as it passes under the main layer feed hopper. This hopper is designed to hold about one-and-a-half minutes supply of feed at design rate and therefore must be kept free from build-up at all times. To facilitate the transfer of ignition on reversal of the draught, it is necessary that the main layer material in the interface be fine, hence the direction of rilling in the hopper is important.

The sinter strand now passes over a series of windboxes into which fresh air is blown. This air passes up through the sinter bed and the sulphides present are converted to oxides and sulphur dioxide is released. Other reactions result in the formation of complex silicates, ferrites and fusible oxides, and the heat from the oxidation reactions causes local melting to take place and this is the basis for the agglomeration process.

The sinter strand is covered with a hood and gases rich in sulphur dioxide are drawn from this hood, cleaned and converted into sulphuric acid.

Towards the discharge end of the strand the desulphurisation process is virtually complete and the gases in the hood are low in sulphur dioxide. These gases are withdrawn from the hood and recirculated up through the sinter bed above the discharge end windboxes. The recirculation of these gas results in an increase in the sulphur dioxide content of the gas to the Acid Plant. The hood gases above the first updraught windbox are also low in sulphur dioxide and can be recirculated to the discharge end windboxes. These gases are at low temperature and are high in

moisture and therefore the offtake is kept as short as possible
by bringing the recirculation gas offtake from the discharge end
to the feed end of the sinter machine hood.

4.4 Sinter Crushing and Screening

Sinter cake tips from the end of the sinter machine in massive
lumps, and at an average temperature of up to 700-800°C. To reduce
the lumps to the size required by the I.S.F., the sinter cake first
passes through a prong breaker located at the end of the sinter
machine. This reduces the sinter cake to less than 250 mm. The
sinter then falls on to a vibrating screen feeder. The undersize,
say -60 mm, falls directly on to a pan conveyor while the oversize
is fed into a crusher which is designed to produce the minimum
quantity of fine (- 25 mm) material. The purpose of this crusher
is to control the top size of the product sinter, this being of
the order of 80 mm. The crusher product rejoins the undersize
material on a pan conveyor and the sinter is now conveyed to a
screening unit where it is divided into two fractions:-

    (a) -25 mm

    (b) +25 mm

The oversize fraction is transported to the blast furnace stock
bin(s) or diverted to the Sinter Plant crushing circuit through
the corrugated rolls crusher.

The undersize material (-25 mm) from the screening unit, the
corrugated rolls crusher product and the undersize from the furnace
hot sinter screens (-25 mm) are conveyed to a cooling drum and
thence to a smooth rolls crusher. Alternatively the smooth rolls
crusher can precede the cooling drum.

The cooling of the hot materials in the cooling drum is achieved

by sludges such as those from the gas cleaning plant, the hygiene ventilation equipment and "blue powder" from the blast furnace augmented by water if necessary. Since an even moisture content in returns is an important operating parameter, the flow of returns into the cooling drum must be kept constant and an automatic moisture control provided.

The purpose of the smooth rolls crusher is to reduce the returns to a minimum amount of +5 mm material.

Returns sizing is another important operating parameter and therefore must be checked frequently and corrective action taken as required. To minimize wear on the roll tyres due to uneven feeding, the roll is fed by a feeding device which gives a ribbon width equal to the roll width and located at a height above the roll such that the speed of the feed falling into the rolls matches the roll peripheral speed. The crushed and cooled returns are conveyed by belt conveyor(s) to the machine returns stock bunker in the sinter proportioning section, thus completing the circuit.

Additionally, provision is made to enable lump sinter and/or machine returns to be removed to dump from the circuit and to be returned to the circuit from dump.

4.5 General

The process lends itself to a high degree of automation and is operated from a central control room which can also be the Acid Plant control room if so desired.

Fumes and dusts arising in the operation are high in lead and therefore safe working conditions must be maintained throughout

the plant. In particular, equipment handling or conveying hot
sinter must be adequately hooded and ventilated.

To facilitate maintenance, good access is provided to all major
items of equipment.

5. ZINC/LEAD SINTERING TECHNOLOGY

Over the years much investigational work into sintering has taken
place both on a laboratory pallet scale and on a full plant trial basis.
Much of this work has been done at Avonmouth and at the Cockle Creek
Works of Sulphide Corporation Pty. Limited (7) N.S.W., Australia, but
nearly every sinter plant has contributed something to the "art".
The requirements of the Imperial Smelting Furnace for sinter quality
are:-

(a) Small variation in chemical composition

(b) Hardness - to minimise the quantity of $-\frac{1}{2}$ in.
     material entering the furnace shaft

(c) Low total and sulphate sulphur

(d) High porosity

(e) Minimum size range

The factors exerting greatest influence on the sintering conditions are:-

(1) Sulphur content of the sinter machine feed

(2) Intensity of draughting

(3) "Returns" sizing

(4) Efficiency of mixing

(5) Moisture in sinter mix

(6) Chemical composition of sinter (8,9)

It is proposed to outline how the above factors exert an influence on the
requirement for sinter.

5.1 Sulphur Content of the Sinter Machine Feed

The sintering process is governed by the desulphurisation of zinc
and lead concentrates. The main reaction occurring are exothermic
and proceed autogenously once initiated. The heat generated by
these reactions causes partial fusion of the gangue material

resulting in the agglomeration of the mix.

As sulphur level in the machine feed is the fuel level it is important and fairly critical. It has been found in practice that there is a maximum quantity of sulphur which can be eliminated per pass over the sinter machine which is 4.25 - 5.25% depending on the degree of conditioning achieved. Since a low sulphur in sinter is required, the sulphur elimination achieved dictates the sulphur content in the machine feed. This is normally about 5-6.5%.

The sulphur level in new mix, i.e. zinc, lead and/or bulk concentrates, fluxes and secondaries generally is in the range of 17-23% sulphur. This is considerably in excess of the level which can be tolerated on the sinter machine and therefore it is the practice to dilute the new mix with machine returns, (2-3% S) until the desired level in machine feed is attained. This results in a returns: new mix ratio in the region of 4:1.

The optimum sulphur in machine feed depends on operational requirements. A higher fuel level tends to give a higher SO_2 content in the gas to the acid plant but higher fume production. Sinter hardness will increase but the sulphur elimination will drop and residual sulphur in sinter will rise with detrimental results on I.S.F. operation.

5.2 Intensity of Draughting

The capacity of the sinter machine itself is dictated by the sulphur elimination rate achieved. To improve sulphur elimination rates it is essential to keep the draught intensity as high as possible, particularly at the feed end of the sinter machine. This is achieved by good mixing and conditioning of the

sinter machine feed and even spreading of the feed across the machine. Also compaction of the feed on the machine is minimised. The result is a mix of uniform porosity allowing the maximum overall draught intensity without fluidisation.

If a high lead sinter is being produced, say +20% Pb, a high draught intensity at the tip end of the sinter machine is also desirable. During the sintering process, some metallic lead is produced and some of the sinter bed is either in a liquid or in a plastic state. Unless the draught intensity is kept high the weight of the sinter bed causing it to sink and a very dense sinter results. In addition to the increased sulphur elimination and therefore higher production rate, a high draught intensity is beneficial in producing a high porosity sinter.

5.3 Returns Sizing

High draught intensity and high sulphur elimination are the result of good sinter machine feed mixing and conditioning.

Returns are virtually inert in respect of sulphur content and therefore the object of the feed mixing and conditioning stages is to coat the new, high sulphur material on the outside of a returns "nucleus" where desulphurisation can take place most easily. If the returns sizing is too coarse there are insufficient "nucleii" for good mixing and a patchy feed is obtained. Also segregation of sizes takes place in the feed hoppers and uneven sintering results. On the other hand very fine returns give an excessively dense bed and slow sintering rates. Current aims are to have returns 100% − 5 mm with a minimum of −1 mm but this is rarely achieved in practice.

Laboratory tests show that a change in return sizing has no effect

on lump production and that the only effect on hardness was in
interactions with other variables.

5.4 Efficiency of Mixing

This is closely connected with the particle size of the individual
components in the feed. The object of mixing is to produce
chemically homogeneous mix with a particle size ranging from about
1 to 6 mm. The latter is preferable to a uniform pelletisation
since it promotes increased strength resulting from a greater
number of points of contact. Concentrates are inherently moist
and have a tendency to ball up so it is considered unwise to perform
any pre-mixing of raw materials only. Two stage mixing is usually
adopted, the first stage being the mixing stage and the second stage
the conditioning or nodulising stage. An overall mixing plus
conditioning time of five minutes is considered necessary.
Moisture additions are made during the mixing stages and it is
important that any added moisture is thoroughly digested into the
mix.

5.5 Moisture in Sinter Mix

Moisture in sinter mix, which is dependent on the nature of the new
feed, returns: new feed ratio, and the returns sizing, has a
considerable influence on the permeability of the sinter bed and
is normally in the 4-7 per cent region. This level is associated
with good bed permeability which is readily indicated by the back
pressure across the first updraught windbox. A drier mix will give
a higher back pressure resulting in blow holes in the sinter bed
and uneven sintering while a wetter mix tends to promote build-up
in feed chutes and hoppers and makes ignition difficult.

5.6 Chemical Composition of Sinter

Chemical composition of sinter plays a very important part in
producing hard sinter by the updraught method combining effective
desulphurisation and lump production into one operation. It has
already been mentioned that this type of sinter is essentially self-
fluxing and the flux additions are made to the sinter mix.
Sinter is composed mainly of compounds containing Zn, Pb, CaO, SiO_2,
FeO with MgO and Al_2O_3 in minor quantities. The sintering parameters
which determine the sintering performance and the quality of sinter
are sinter hardness, lump production, bed temperatures, total
sulphur and sulphate sulphur. It is proposed to outline the effect
of the different chemical constituents on these parameters.

5.6.1 Zinc

Sinter for the I.S. Furnace contains up to 45 per cent zinc
(in both zinc oxide and zinc ferrite forms). It has been
found that the quality of sinter does not depend on the amount
of zinc present in sinter. For reasons of furnace control
however the zinc in sinter should be maintained at a steady
level.

5.6.2 Lead

Lead is an important constituent in hard sintering and it
influences directly all the sintering parameters.

Sinter Hardness

This means simply the ability to withstand plant handling.
Both plant experience and laboratory tests support the view
that the effective hardening agents in this type of sinter
are lead and silica, sinter hardness increasing with an

increase in lead tenor. Unfortunately, due to the volatility of lead sulphide and oxide at temperatures below the peak temperatures normally encountered there is a substantial vapour transfer of lead in the gas stream, and this constitutes a considerable recirculating load.

Lump Recovery

Lump production increases very slightly with increasing lead tenor but this parameter is far more susceptible to other factors such as fuel level, ignition and bed permeability.

Bed Temperatures

Bed temperatures decrease with the increase in lead. As the rate of lead volatilisation is dependent on peak bed temperatures, these variations of peak temperature with composition have a bearing on the volatilisation of lead from sinter.

Total and Sulphate Sulphur

Sulphate sulphur content of sinter cake increases with the increase of lead level due to increased lead sulphate formation at higher lead levels and lower sulphate decomposition at the lower peak temperatures. Desulphurisation is independent of lead levels.

5.6.3 Limestone

Although hard sinters are essentially self-fluxing some additional hard burnt lime is added to the charge at the blast furnace in order to control slag composition. The lime level in hard sinter depends on the lime: silica ratio required but is generally in the 4-8 per cent region.

Sinter Hardness

Increase in lime increases sinter hardness although the
effect diminishes above 7.5 per cent lime to become
insignificant.

Lump Recovery

This is independent of lime level.

Bed Temperature

Lime addition reduces peak bed temperature.

Sulphur in Sinter

A higher sulphate sulphur in sinter is usually obtained at
higher lime levels. This is due to enhanced calcium
sulphate formation when the maximum peak temperature is
depressed.

5-6.4 Silica

Silica is an important constituent in producing quality hard
sinters. For economic considerations a low slag fall in the
blast furnace is required and so the silica is usually kept
to a minimum, this varying from 2.0 - 6.0 per cent depending
on the raw materials used and the lead content of sinter.
It is sometimes necessary to add silica sand to the feed in
order to obtain the required silica content in sinter.

Sinter Hardness

Silica, like lead, is a hardening agent for this type of
sintering. The relationship between sinter hardness and
silica is linear, the hardness increasing with increasing
silica content in sinter. Since increasing lead has a
similar affect it is usual practice to operate at low silica
and high lead areas, e.g. 5.0 and 50 per cent respectively

minimise the gangue content in the sinter.

Lump Recovery

A slightly higher lump output results from the increase in sinter hardness obtained at higher silica levels.

Bed Temperature

Peak bed temperature is reduced by increased silica.

Sulphur in Sinter

Both sulphide sulphur and sulphate sulphur increase with increasing silica. The effect on sulphate sulphur is due to decreased peak bed temperature with increased silica. More slag volume at higher silica can result in incomplete desulphurisation of the sulphide bearing concentrates which become embedded in the slag before the exothermic reaction ceases.

5.6.3 Iron

The iron content in sinter varies from 6 to 18 per cent depending on the concentrates used. If very low iron concentrates are available it may be necessary to add iron in the form of burnt pyrites to the feed in order to bring the iron in furnace slag within the required range. This is not common practice however.

It is found in laboratory tests that there is no significant difference between sintering parameters and iron level when the iron level is below 10 per cent level.

The hardness of high iron sinter (7.5 - 15% Fe) is profoundly influenced by the chemical combination in which iron is added to the mix; when iron is added as sulphide there is a

moderate decline in hardness with increasing iron content, but when iron is added as burnt pyrites the decline is more marked and extremely low hardness values are obtained at higher iron levels.

No definite change in sulphur content in output sinter is found with changing iron level.

It is quite evident that the magnitude of the effect of iron on sinter is dependent on the form in which iron is present in the raw materials. This suggests the desirability of knowing the mineralogical form of iron present in an ore or concentrate.

5.6.6 Alumina

Alumina is normally a minor constituent of sinter the typical level being 0.5 per cent. Some experimental work on a laboratory scale has been performed but results were generally inconclusive although satisfactory sinters were produced.

5.6.7 Magnesia

Magnesia is also a minor constituent around the 0.5% level. The level of magnesia in sinter is more important from its effect on the furnace slag than on sinter but it would appear that increasing magnesia content results in decreasing hardness but has no effect on the sulphur in sinter or the peak bed temperature.

6. CURRENT PRACTICE

6.1 Equipment

The basic requirements for I.S.P. sinter remain the same although in some cases the tolerances have been tightened i.e. the desirable size range is $\frac{1}{2}$ in. – 2 in.

The flowsheet of every plant is similar to that described in Section 4, but there are, of course, individual variations between the eleven plants.

Every proportioning system has constant weight feeders installed and it is generally agreed that these are essential if any degree of metallurgical control is to be achieved.

The old plants have only one mixing unit but the most recent plants have two. The equipment usually employed is a drum but at Noyelles-Godault, France a disc is used for the second stage mixer and this is found to be very successful. The Cockle Creek, Australia, plant is the exception because on this plant the feed is split into the ignition and main layer fractions before mixing and hence two mixing systems are installed.

Feed splitting is one of the regions of greatest variation between plants although there is universal agreement on the objective. Screw splitters, bucket splitters, reversing conveyors, table splitters, a trolley chute and a simple pivoted chute are all employed with varying degrees of success. No one system can be considered ideal however.

Distribution of feed across the sinter machine is done everywhere except at Kabwe, Zambia and Swansea Vale by reciprocating feeders. The sinter machines employed are essentially the same although different manufacturers have slightly differing designs. The

effective areas vary enormously however depending on age of machine
and amount of sulphur to be eliminated. The sealing arrangement
is a sliding grease seal in all plants with the exception of
Sumiko, Japan and Belledune, Canada where the spring-loaded grease
seal principle is employed. This system is not so satisfactory when
high gas strength is required but is frequently used in the ferrous
industry.

The auxiliary fuel used for ignition purposes is generally a heavy
or medium oil but natural gas is used at Copsa Mica, Rumania and
Town's Gas at Miasteczko, Poland with equal success.

To enable the optimum size of sinter to be delivered to the I.S.F.
sinter screening is carried out on double deck screens at
Hachinohe, Japan and Avonmouth. All other smelters employ single
deck screening.

Sinter cooling is performed just before or just after the final
crusher (smooth rolls) at all plants except Swansea Vale where the
original design incorporated a cooling table at the tip end of
the machine. This has the disadvantage of cooling all the sinter
cake and not just the returns fraction. Cockle Creek also have a
cooling table but located just before the smooth rolls. Otherwise
drums find universal application for cooling returns. Hot crushing
i.e. smooth rolls crusher before the cooling drum, is practised
at Berselius, W. Germany and Belledune.

6.2 Process

There are very few differences in the process methods of the various
plants and these are mainly due to limitations imposed by the
available equipment. Gas recirculation is practised at all plants

with the exception of Noyelles-Godault and Kabwe. This latter method
of operation results in a greater sulphur elimination per unit of
grate area but a slightly lower gas strength.
Due to the varying nature of the raw materials available at the
different smelters the typical analyses of the sinter produced are
widely difference i.e.

	Zn	Pb	FeO	CaO	SiO_2	S
Avonmouth	42.5	20.5	9.0	4.5	3.5	1.5
Belledune	31.0	20.0	21.0	7.5	5.5	1.2
Berzelius	46.0	18.5	10.0	4.0	3.0	0.7
Cockle Creek	46.0	20.0	10.0	4.0	2.5	0.6
Copsa Mica	38.0	18.0	12.0	8.0	5.5	1.2
Hachinohe	44.5	20.0	10.5	4.0	3.0	0.7
Miasteczko	42.5	20.5	9.0	6.5	6.0	1.0
Noyelles-Godault	46.0	17.5	11.0	4.5	3.5	0.9
Sumiko	47.5	16.0	9.5	5.0	3.0	0.7
Swansea Vale	45.0	19.0	9.5	5.0	3.5	1.1
Kabwe	27.0	22.0	15.5	12.0	7.5	0.9

It is to the credit of the I.S. Furnace that it (usually) manages to
digest so varied a diet.

7. FUTURE DEVELOPMENTS

7.1 New Processes

The sintering process as applied to the Imperial Smelting Furnace embraces both desulphurising and agglomerating and it is difficult to envisage an alternative process which achieves both these functions at one time. However, there is the possibility that two stage processes could be employed.

Roasting of zinc concentrates in fluid bed roasters is already a well established process and it is quite probable that the resulting calcines could be pelletised to form a feed suitable for the furnace c.f. the ferrous industry. One of the prime advantages of the Imperial Smelting Process is its ability to handle charges with up to 25% Pb and to date it is extremely difficult to roast materials containing more than 10-12% Pb except on a sinter machine, hence roasting and pelletising as an alternative to sintering would certainly be less flexible and probably require more capital expenditure.

As an alternative to pelletising, the oxide materials could be briquetted. Again, the limitations with lead will apply to the roasting stage but incorporation of secondary materials should be more easily accomplished with briquetting. It is doubtful, however, if there is any overall capital advantage.

It seems therefore that the I.S. Furnace will always have to be associated with a sinter plant if the flexibility of the furnace process is to be fully exploited.

7.2 Improvements in Sintering

Essentially these must be aimed at producing a better quality sinter

for the furnace to enable higher draughting rates to be achieved with
more efficient utilisation of coke. Coupled with this the sinter
plant must achieve higher production rates to match the increasing
demand of the furnace.

For reasons of sinter plant control and to achieve optimum sulphur
elimination a constant sulphur in the feed to the sinter machine is
highly desirable and continuous monitoring of this parameter with
automatic correction of the raw feed: returns ratio to maintain a
constant sulphur would constitute a major step forward.

Zinc, lime and silica analyses should also be constant for good
furnace control. Due to fluctuations in the sintering process
itself this is virtually impossible but on-stream analysis of
machine feed for these components would minimise any variations.

Sinter machine feed permeability is another important factor in
sintering since it allows higher sintering rates. There is scope
for considerable investigation into the mechanisms of feed
preparation in order to obtain the optimum mix.

Sinter machine operation is quite well established and highly
automated. However, one advance would be to blow the whole of the
updraught area with fresh air and have no gas recirculation. This
is being performed already at Noyelles-Godault and has resulted in
a 40% increase in sulphur elimination per unit area of grate.

A growing awareness of the importance of sinter size on furnace
operation means that increasingly more attention will be paid to
the handling of the sinter cake between the tip end of the sinter
machine and the furnace. A small size range is considered highly
beneficial and therefore the equipment in the sinter crushing

section must be capable of producing the maximum quantity of sinter within the optimum range from the sinter cake tipping from the machine.

Sinter returns are cooled normally by the return of process slurries. These are of variable solids content and the solids have a varying analysis. While the added solids constitute a small proportion of the recirculating load, on stream analysis and density control will help in the production of a sinter of uniform chemical composition.

8. **CONCLUSIONS**

The updraught zinc/lead sintering process used to produce sinter for the Imperial Smelting Furnace is well established, being operated currently at eleven smelters with three more either under design or construction. By 1972 it is estimated the Imperial Smelting Furnaces will be producing 800,000 tons of zinc and 500,000 tons of lead[10] annually. This will require the production of some 2,500,000 tons of sinter of a continuously improving quality. Clearly, although a well established process, there remains room for much improvement in this field.

9. ACKNOWLEDGEMENTS

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