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Description

This invention relates to a method of and an apparatus for reclaiming used foundry sand according to the preambles of the independent claims 1 and 8.

Conventionally, organically bonded foundry sand has been reclaimed by burning off the organic binder components using a fuel fired (gas or oi1) heated system operating in the temperature range 80O°C to 1000°C and in which the used sand is agitated during burning off of the organic binder components, for example in a rotary kiln.

In our prior specification GB 2,091,148A there is described a method of reclaiming used organically bound foundry sand in which the used sand is separated from castings and placed in a stationary container wherein the sand is maintained without agitation whilst combustion supporting gas is provided to the container and allowed to percolate through the sand by natural convection. The sand is held in a temperature range of 250°C to below 40O°C for a time sufficient to reclaim the sand. Whilst this method avoids the need for plant capable of operating at high temperature and of agitating the sand, such as a rotary kiln, it suffers from the shortcoming that for certain applications the time taken for reclamatian is inconveniently long and involves the storage of large quantities of sand in large containers as well as problems of conveying the sand and of control. The capital cost of the plant is, therefore, high and its efficiency relatively low.

In US-A-3685165, upon which the preambles of the independent claims 1 and 8 are based, there is proposed a method of reclaiming used organically bonded foundry sand comprising the steps of supplying the sand to a fluid bed at a feed region thereof, fluidising the sand with combustion supporting gas, maintaining the sand in the fluid bed in an elevated treatment temperature range to reclaim the sand, allowing the sand to pass from the feed region to a discharge spaced from the feed region and removing reclaimed sand from the fluid bed through the discharge. This proposal relies on the sand to be reclaimed being preheated, to a temperature below an elevated temperature range in which the sand is reclaimed in a fluidised bed in the presence of combustion supporting gas, by heat transfer from sand which has been previously reclaimed. This proposal is impracticable because the preheating would cause evolution of obnoxious fumes and cause "gumming up" and consequence solidification in the preheating section. Moreover, the fluidising gas is introduced through a single opening which would lead to unsatisfactory fluidisation.

The above mentioned disadvantages of the prior art are overcome in accordance with one aspect of the present invention by virtue of the sand, after separation from a casting, being supplied to a first fluid bed section, without heating the sand in a fluid bed in the presence of combustion supporting gas prior to supplying the sand to the first fluid bed section, combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain said sand in said treatment temperature range, is introduced into the sand in the first fluid bed section at a plurality of locations to fluidise the sand, the sand is maintained in said treatment temperature range to partially reclaim the sand; partially reclaimed hot sand from the first fluid bed section passes to a further fluid bed section; combustion supporting gas, which is also devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature ranges is introduced into the sand in the further fluid bed section at a plurality of locations to fluidise the sand; the sand in the further fluid bed section is maintained in said treatment temperature range whereby reclamation of the sand is continued; the sand then passes to a third, cooling, fluid bed section; combustion supporting gas, which is also devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, is introduced into the sand in the third fluid bed section at a plurality of locations to fluidise the sand therein; and the sand is then cooled in the third fluid bed section and reclaimed sand is then removed from the third fluid bed section.

As a result we have found that satisfactory reclamation is achieved in a time measured in minutes as opposed to the time measured in hours as disclosed in GB 2,091,148A, the need for storage of large quantities of sand in large containers is avoided and conveying and control problems are also avoided

Moreover, the evalution of obnoxious fumes and solidification of the pre-heating section and problems of fluidisation which occur in US-A-36851 65 are avoided.

This is achieved since the sand is brought to the treatment temperature range relatively quickly, e.g. in the order of ten secs. If the used sand is brought relatively slowly to the treatment temperature range, or is not brought into the treatment temperature range, in the presence of fluidising gas, then excessive fumes will be evolved.

Preferably, said sand is supplied to the first fluid bed section without fluidising the sand prior to entry into the first fluid bed section.

Preferably, after separating the sand from the casting, the sand is not heated in the presence of combustion supporting gas prior to supplying the sand to the first fluid bed section.

The sand nay be supplied into the fluid bed section in said treatnnent temperature range by virtue of being heated in a metal casting process in which the sand has been previously used, the metal casting temperature and the metal-to-sand ratio being such that the sand is heated so as to be in the treatment temperature range.

Alternatively the sand may be initially at or substantially at ambient temperature and the sand may be supplied into the first fluid bed section at or substantially at ambient temperature and heat is applied to the sand in the first fluid

bed section to bring the sand to said treatment temperature range.

Further alternatively, the sand may be supplied into the first fluid bed section at a temperature between ambient temperature or substantially ambient temperature and said treatment temperature range by virtue of being heated in a metal casting process in which the sand has been previously used and further heat is applied to the sand in the first fluid bed section to bring the sand to said treatment temperature range.

The sand may remain in the further fluid bed section without the application of heat or with the application of heat but a lesser amount of heat than is applied in the first fluid bed section.

The sand may be heated by a plurality of heating elements immersed in the sand, the heating elements may be electrical heating elements immersed in the sand, or a combustion chamber and/or smoke tubes of a furnace in which fuel is burned.

After separating the sand from a casting, the sand may be reduced to grain size or substantially to grain size.

Said sand may be selected from the group consisting of silica, zircon, olivine or chromite sand.

The binder may be selected from the group consisting of a chemically hardened resin binder or a thermo-setting resin or a "hot box" resign and may be selected from the group consisting of phenolic, furane, isocyanate or acrylic resign binder.

The treatment temperature may lie in the range 250°C to 60O°C, and preferably lies in the range 300°C to below 400°C and more preferably lies in the range 400°C to 500°C, and still more preferably lies in the range 450°C to 500°C.

According to another aspect of the invention, we provide a method of making a metal casting comprising the steps of making a mould using reclaimed used foundry sand and an organic binder, hardening the mould, casting molten metal into the mould to make a casting, separating said sand from the casting, reclaiming said sand by a method according to the first aspect of the invention and then using the thus reclaimed sand in a repetition of the method.

The metal may be a non-ferrous metal selected from the group consisting of aluminium, magnesium, copper and alloys based on said metals and said reclaimed sand of which the mould is made may be predominently reclaimed used zircon sand.

The mould may comprise in addition to a catalyst or hardening agent for the resin binder;

50% to 100% zircon sand, by total weight of sand;

0.4% to 1% resin binder, by total weight of sand;

0% to 50% sand or sands other than zircon sand, by total weight of sand.

Said sand of which the mould is made may comprise wholly or substantially wholly zircon sand.

The metal may be melted in a melting vessel, transferred from the melting vessel to a casting vessel and transferred upwardly from the casting vessel into the mould.

The metal may be transferred from the melting vessel into the casting vessel by flow of metal under gravity and the level of the top surface of the metal as the metal leaves the melting vessel may be above the top surface of the metal in the casting vessel by not more than a maximum distance above which excessive turbulence occurs; this maximum distance may lie within the range 50mm to 200mm.

The use of zircon sand as a foundry moulding material is well known in the production of iron and steel castings. Zircon sand is used mainly because of its high refractoriness, i.e. it does not fracture nor melt under conditions of thermal shock when casting ferrous materials. Usually such moulds are produced by the Croning (Shell) process, which uses phenolic based thermosetting resins. Although the process has a reasonable reputation for the accuracy of the resulting castings, the accuracy is necessarily limited by the use of hot metal patterns, which are subject to thermal distortion and the distortion of the thin shell moulds.

In ferrous foundries using the Shell Process, the expensive zircon sand is re-claimed by a number of existing thermal reclamation systems, most of which heat the sand to a temperature in the range 800°C to 1,000°C to burn off the remaining resin prior to re-coating with fresh resin. The high cost of such reclamation is usually recoverable in the relatively high price of such ferrous shell-moulded castings.

Because aluminium, magnesium, copper and other metals having a melting point below that of ferrous metals and alloys based thereon do not require the refractoriness of zircon sand, moulds for these metals have traditionally been made only in silica or other cheaper sands. Only occasionally have cores been made in zircon sand.

The use of zircon sand and its reclamation in accordance with the present invention provides a metal casting process having a number of extremely important and unexpected benefits as follows. The accuracy of cored holes and wall thicknesses defined by cores, are improved by a factor of up to twenty times. External features of castings are typically five times more accurate than their silica sand cast counterparts. This improvement in accuracy follows from the low expansion combined with the high thermal capacity of zircon sand compared to silica. It enables the accuracy to exceed the accuracy of all other casting methods known to date including investment and pressure die casting. The high thermal capacity increases freezing rate and also improves mechanical properties.

Sand expansion defects, such as scabs, rat-tails, finning, flash and the like are eliminated.

The levels of addition of the resin binder are significantly lower than those used for the Croning Shell Process. Because the patterns are used

at or near to room temperature, they retain their accuracy and so produce accurate moulds and cores. Also, the moulds can be made of any convenient thickness as a thick shell, or in the form of block moulds, or can be made in steel boxes or frames. In this way, also, accuracy can be conserved (compared and contrasted with a thin Croning Shell mould which is easily distorted).

According to a third aspect of the invention we provide a casting made using the method according to the second aspect of the invention.

According to a further aspect of the invention, we provide an apparatus for reclaiming used foundry sand containing an organic binder comprising sand supply means to supply the sand to a fluid bed at a feed region thereof, fluidising means to introduce combustion supporting gas into the sand to fluidise the sand, means to maintain the sand in the fluid bed in an elevated treatment temperature range to reclaim the sand and means for removing the reclaimed sand from the fluid bed at a discharge spaced from the feed region, characterised in that the apparatus includes means for separating a mass of the sand from a casting; the fluid bed comprises a first fluid bed section into which the sand supply means supplies the separated sand, in use; and having fluidising means to introduce combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, into said sand at a plurality of locations to fluidise the sand therein; means to maintain the sand in said treatment temperature range to partially reclaim the sand; sand passage means to pass partially reclaimed hot sand from the first fluid bed section to a further fluid bed section having fluidising means to introduce combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, into the sand, in the further fluid bed section at a plurality of locations to fluidise the sand therein; means to maintain the sand in the further fluid bed section in said treatment temperature range whereby reclamation of the sand is continued; sand passage means to pass sand from the further fluid bed section to a third, cooling, fluid bed section having fluidising means to introduce combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, into the sand in the third fluid bed section at a plurality of locations to fluidise the sand therein; means to then cool the sand in the third fluid bed section and means to remove reclaimed sand from the third fluid bed section.

Preferably the sand supply means supplies the sand to the first fluid bed section without fluidising the sand in the presence of combustion supporting gas prior to entry of the sand into the first fluid bed section. The sand supply means may supply the sand to the first fluid bed section without heating the sand prior to entry of the sand into the first fluid bed section.

The sand supply means may supply the sand to the first fluid bed section without fluidising the sand prior to entry into the first fluid bed section.

More generally, the sand supply means may restrict contact between the sand and combustion supporting gas prior to introduction of the sand into the first fluid bed section.

The first fluid bed section may have heating means to heat said sand to said treatment temperature range.

Means may be provided whereby the sand remains in the further fluid bed section in said treatment temperature range without application of heat so as to continue reclamation utilising heat in said sand from the first fluid bed section.

Alternatively, the further fluid bed section may be provided with heating means whereby the sand is maintained in the further fluid bed section in said treatment temperature range so as to continue reclamation partly by utilising heat in the sand from the first fluid bed section and with application of a lesser amount of heat than is applied in the first fluid bed section.

Where a fluid bed section has heating means, the heating means may comprise a plurality of heating elements immersible in the sand.

The heating elements may comprise electrical heating elements which may be electrical conductors in direct contact with the sand and through which electrical heating current at low voltage is passed, in use.

Alternatively, the heating elements may comprise a combustion chamber and/or smoke tubes of a furnace in which fuel is burned, in use.

The fluid bed sections may be disposed in a horizontal sequence.

The fluidising means may comprise a plurality of discrete openings through which said combustion supporting gas is directed to the sand, said openings being provided with shield means to shield the openings from ingress of sand.

Means may be provided to reduce the sand to grain size or substantially to grain size after separating the sand from a casting.

The invention will be described in more detail by way of example with reference to the accompanying drawings wherein:-

FIGURE 1 is a schematic illustration of a light alloy foundry casting plant for carrying out a method embodying the invention;

FIGURE 2 is a diagrammatic cross-sectional view of the melting and casting apparatus of the plant of Figure 1;

FIGURE 3 is a diagrammatic plan view of a sand reclamation apparatus of the plant of Figure 1;

FIGURE 4 is a section on the line 4-4 of Figure 3;

FIGURE 5 is a graph showing rise in temperature of sand during reclamation as a function of the sand's original temperature and air flow rate;

FIGURE 6 is a set of Time Temperature Transformation (TTT) curves for different extents of reclamation expressed as residual binder content as measured by loss on ignition (LoI) at an air flow rate of 400 l/min/m^2;

FIGURE 7 is a similar set of TTT curves but for

an air flow rate of 2000 l/min/m^2; and

FIGURE 8 is a similar set of TTT curves but for an air flow rate of 4000 l/min/m^2.

Referring now to Figure 1, a foundry plant suitable for casting aluminium, magnesium, copper and alloys based on said metals or the like comprises a moulding station 10 where moulds are made of organically, bonded foundry sand, in the present example zircon sand, but which may be made of other sands such as silica sand, olivine sand, chromate sand or a mixture of such sands. The sand is bonded with an organic binder such as a chemically hardened resin, such as a gas hardened resin, for example furane resin with methyl ethyl ketone peroxide (MEKP) hardened with $S0_2$ or isocyanate resin, hardened with amine gas or acrylic resin with MEKP hardened with $S0_2$, or a liquid catalyst hardened resin, for example furane resin hardened with sulphonic acid, or a thermosetting resin for example a thermosetting phenolic resin or "hot box" resin, or with any binder which can be reclaimed by heating in the presence of a combustion supporting gas to produce gaseous products of combustion/oxidation.

The mould may be made by ramming but, in the present example, are blown using an automatic mauld blowing machine. The mould may be used in conventional mould boxes or a boxless process, as in the present example may be used. In the present example, the mould comprises 98% zirconium silicate sand; 0.55% furane resin, by weight of sand; 0.20% methyl ethyl ketone peroxide, by weight of sand; 2% usual impurities such as oxides of transition elements and bound with furane resin. The resin was hardened using S02 gas amounting to about 0.25% S02 equivalent by weight of sand. The sand has an average grain size of 14μm.

If desired, the mould may comprise 50% to 100% zircon sand, by total weight of sand; 0.4% to 1% resin binder, by total weight of sand; 0% to 50% sand or sands other than zircon sand, by total weight of sand. Preferably however, the sand comprises wholly or substantially wholly zircon sand.

The zircon sand may have an average particle grain size lying in the range 50 to 500μm.

A core or cores similarly made of organic resin bonded sand either the same sand and binder system as the remainder of the mould or otherwise, is positioned, as necessary, within the mould cavity at a mould assembly station 11 where the cope and drag halves of the mould are closed.

These moulds are transferred by a conveyor 12 to a casting station 13 where molten metal, in the present example magnesium alloy, is cast through ingates into the mould cavity and around the core or cores when present. Details of the melting of the metal and casting are described below with reference to Figure 2. After casting, the filled mould is transferred by a conveyor 12 to a shakeout station 14 where the sand of the mould and core or cores, when present, is shaken out of the casting and the used sand is fed by a conveyor 15 to a sand reclaiming plant 16 to be described hereinafter in more detail with reference to Figures 3 to 8 where the sand is reclaimed and the thus reclaimed sand is then supplied by a conveyor 17 to the moulding station 10 where binder is mixed with the reclaimed sand and new cope and drag parts of the mould made and transferred to the mould assembly station 11.

In the present example the metal, which is a magnesium alloy, is melted in a melting vessel 20 comprising a conventional lip action tilting type furnace mounted for tilting movement about a horizontal axis 21 coincident with a pouring lip 22. The furnace is electrically heated by means of an induction coil 23 and has a refractory lining 24 within an outer steel case 25 and an insulated lid 26. A ceramic launder 27, provided with an insulated lid 28 having electric radiant heating elements 29, extends from the lip 22 to a casting vessel 30. The casting vessel 30 comprises a holding furnace having a lid 31 with further electric radiant heating elements 32 therein and has a relatively large capacity, in the present example one ton (1016kg).

The casting vessel is of generally rectangular configuration in plan view but has a sloping half 33 (to maximise its area/volume) extending towards the launder 27.

Interposed between the launder 27 and the filling spout 33 is a filter box 34 provided with a lid 35 having electric radiant heat elements 36. A weir 37 extends between side walls of the filter box 34 and has a battom end 38 spaced above the bottom 39 of the filter box. A replaceable filter element 40 is positioned between the weir 37 and the downstream end wall 41 of the filter box and is made of a suitable porous refractory material.

A pump 42 is positioned in relation to the casting vessel 30 so that an inlet 43 of the pump will be immersed in molten metal within the casting vessel and has a riser tube 44 which extends to a casting station sa as to permit uphill filling of a mould 45 thereat. The pump 42 has a stopper rod 46 to close the inlet 43 and an inert gas supply conduit 47. When it is desired to pump metal from the casting vessel 30 into the mould 45, the stopper rod is moved downwardly to close the inlet 43 and inert gas under pressure is supplied through the conduit 47 to force metal within the pump body upwardly through the riser tube 44 into the mould 45. The gas pressure is maintained at an appropriate level to ensure satisfactory filling of the mould sufficiently long to ensure that the casting formed in the mould cavity is solidified but not so long as to cause solidification to extend down ingates. The gas pressure is then released by venting the gas to atmospheric pressure and lifting the stopper rod 46 to open the inlet 43 thereby allowing the metal within the pump 42 to attain the same level as the metal in the casting vessel 30.

The axis 21 about which the melting furnace is tilted is positioned so that, in the present example, the top surface of the metal as it leaves

the melting vessel is 100mm above the minimum height to which it is intended that the level of metal in the casting vessel 30 and hence in the launder 27 should fall, so that the distance through which the metal falls freely is limited to 100mm. Whilst a height of 100mm is the distance in the present example, if desired the distance may be such that during the pouring the level of the top surface of the metal leaving the furnace is at a maximum distance of 200mm above the above mentioned minimum level. The above described melting, transferring casting pracedure provides a method which is capable of high and continuous production capacity in which turbulence and its effects are substantially eliminated and from which high quality castings are consistently produced, this is because free fall of metal through the atmosphere is minimised and pumping is performed in a quiescent manner.

Referring now to Figures 3 and 4, there is illustrated the reclaiming apparatus 16 in which sand is reclaimed by being maintained in a treatment temperature range in the presence of a combustion supporting gas.

The apparatus 10 comprises a series of connected fluid bed sections 51, 52 and 53 and a hopper 54 to which sand to be reclaimed is fed.

The sand in the present example is fed from a shake or knock-out station 14 of the magnesium alloy foundry casting plant at such a rate that the sand is only slightly above ambient temperature. Alternatively the sand may be fed in such a way, or stored in the hopper 54 for such a period, that it is at ambient temperature on leaving the hopper 54.

However, the sand may be delivered, for example, from a ferrous casting plant knock-out at such a rate and temperature and the reclaiming apparatus 16 operated at such a rate that the sand leaving the hopper 54 is at a temperature in the treatment temperature range. Alternatively, operating conditions may be such that the sand is at a temperature lying between ambient or substantially ambient temperature and the treatment temperature range. The sand is reduced to grain size or substantially to grain size by the shake-out or if necessary by an attrition unit, crushing unit or other means.

Sand to be reclaimed is fed from the hopper 54 to the first fluid bed section 51 by means of a screw conveyor, air slide or other convenient cantrolling device. The sand advantageously may be fed into the fluid bed section 51 below the surface of the bed by for example a screw conveyor.

The fluid bed section 51 contains a high density of electrical heaters 55 which heat the sand to a temperature lying in the treatment temperature range. The heaters 55 are preferably low voltage heaters operating at about 40-50 volts and camprising stainless steel strips through which low voltage electric heating current is passed in direct contact with the sand. The heaters 55 heat the sand as rapidly as possible so as to reduce smoke or other fume emission and to gain as much energy from the burning resin as possible. Sand is raised from slightly above ambient temperature to the treatment temperature range very rapidly in a matter of a few seconds at most in the present example.

Application of heat to the sand in the presence of combustion supporting gas prior to heating in the fluid bed section 51 is avoided and especially avoided are any steps involving feeding fluidising gas into contact with the sand prior to the sand entering the fluid bed section 51. For example there is no fluidisation of the sand at elevated temperature prior to entry of the sand into the fluid bed section 51 thereby minimising evolution of smoke and other fumes from the sand.

Of course, when the sand is already at a temperature in the treatment temperature range, no such heaters 55 are required and when the sand is substantially above ambient temperature, but below the treatment temperature range, a lower density of heaters in the fluid bed 51 may be provided. In such cases, it is preferred to take steps to minimise the time the sand remains at said elevated temperature prior to entering the fluid bed section 51 and to minimise contact of the hot sand with any high velocity gas which will drive out smoke and other noxious pollutants from the hot sand.

The first fluid bed section 51 is separated from the further fluid bed section 52 by means of a weir 56 and sand passes from the first to the second section over the top of the weir. In the further fluid bed section 52 sand is allowed to dwell in the treatment temperature range without further input of heat, thus allowing combustion of the organic binder to proceed in the fluidising air by utilising the heat in the sand from the first fluid bed section. As to be discussed in more detail hereinafter, the cooling of the sand from the fluidising air is measurable but not important in this section of the apparatus. If in any particular application supplementary heating is required in this section, the requisite number of heating elements may be provided to make up losses as necessary. If desired, a further fluid bed section or sections may be provided at which the sand is maintained in said treatment temperature range. The first and the or each further fluid bed section are thermally insulated to prevent heat loss therefrom except that heat can transfer between the first and further fluid bed sections via the weir 56.

The third fluidised bed section 53 is thermally insulated from the previous sections by means of an insulating weir 50 and a baffle 58 and contains cooling tubes 59 which are conveniently cooled by water but may be coaled by other liquid or gas. The sand is cooled in this section to the desired temperature. For example, with an SO_2/furane resin binder system the sand is cooled to a temperature in the range 30-35°C which is an optimum temperature for reuse with this sort of binder system.

In the present example, reclamation of the sand by combustion of the binder is completed to the required standard in the further fluid bed section.

However, the method may be operated so that the reclamation is not so completed in the further fluid bed section and reclamation is completed to the required standard in the cooling fluid bed section before the temperature of the sand is reduced to below the treatment temperature range in which reclamation occurs. In all cases however, reclamatian is completed to the required standard whilst the sand is fluidised. In the present example, the sand is reclaimed to the extent that the residual binder content as measured by "Loss on Ignition" lies in the range 0.05 to 0.10% but the process may be operated with more or less reclamation so long as adequate reclamation for re-use of the sand is achieved and the term "reclaimed" is used herein to refer to such an extent of reclamation. Typically, the minimum extent of reclamation for re-use is a residual binder content of 0.2% but we do not want to be limited to this since, for example, some people using furane resin binder accept a higher residual binder content whilst other people using phenolic resin binder insist on a lower residual binder content than 0.05%.

Other binder systems require the sand to be cooled to other optimum temperatures. For example, for the recoating of phenolic resins on shell sands the temperatures may lie in the range 120-150°C at the discharge from the cooling or third section 53. In this latter case air cooling in at least some of the cooling tubes may be desirable or the water caoling section reduced in size for the number or water cooling tubes reduced.

The sand exits from the third fluidised bed section 53 via a discharge tube 60.

Although in the present example the three fluid bed sections are separated by weirs, if desired they may be separated by other means such as separating plates having one or more openings therein or may be completely independent bed sections connected by ducts. Alternatively, the sections may not be separated by any physical barrier; each section being functionally defined. For example the first section may comprise a part of a single fluid bed having a high density of heater elements, the second section by a part of the fluid bed having no or a lower density of heating elements than in the first section and a cooling section, when provided, by a part of the bed which may have cooling elements.

Hot dusty gas is exhausted via ducts 61, 62 and is passed through a dust extraction system, not shown, prior to exhausting to atmosphere.

Fluidising gas, in the present example air, is provided to all three sections through a plurality of discrete openings which are provided with shield means to shield the openings from ingress of sand. The openings may be provided for example in a plurality of tubes immersed in the sand and to which fluidising gas is fed. The fluidising gas may be provided by means of sparge tubes or by means of porous bottom to the sections for example a gas permeable material, a foraminous plate or mesh. It is preferred however to introduce the gas through discrete openings since this avoids problems which can arise using porous material, a foraminous plate or mesh since these can suffer from blockage of an area of the porous material, plate or mesh causing the bed to become non-fluidised above these regions leading to localised overheating.

The above described apparatus is used to carry out a method of reclaiming used foundry sand which comprises, in the present example, feeding sand to be reclaimed into the hopper 54 and then from the hopper 54 into the first fluidised bed section 51.

The sand to be reclaimed is heated in the first fluidised bed section 51 to a treatment temperature range in which reclamation occurs. This range may be 450°C to 600°C. However, if desired the temperature may be anywhere in the range 250°C to 500°C, preferably in the range 30O°C to below 400°C and more preferably in the range 400°C to 500°C. The sand in the second fluid bed section 52 may be at the same temperature as in the first fluid bed section or at a lower temperature but still within the above mentioned treatment temperature range.

Since, in the present example, the temperature of the sand does not exceed 600°C the apparatus described with reference to Figures 1 and 2 may be made, for example, of mild steel as it does not have to withstand high temperatures. Of course, the electrical heaters are required to be made of a suitable high temperature material since these run at temperatures of up to 800°C. The electrical heaters may comprise instead of the above described low voltage heaters, conventional electric heaters operating at high voltage alternating current, i.e. a heating element within a tube so as to be electrically insulated from the sand. Electrical heating of the bed is useful to achieve simple control and to ensure that all the available oxygen in the air is available for burning the organic binder (and not the added fuel as is the case for a fuel fired bed):

If desired other means of heating the bed may be used which avoid combustion of the fuel within the bed. For example gas or oil or other fuel may be combusted in a combustion chamber and the products of combustion passed through smoke tubes immersed in the fluidised bed. If desired the combustion chamber may be immersed in the fluidised bed and may be with or without smoke tubes.

Experiments have been carried out to determine the range of temperature and air flow rates over which the method embodying the invention may be performed.

It has been found that if air is used as the combustion supporting gas and is forced through the sand to be reclaimed at a rate of at least 400 litres/min/metres^2 (1/min/m^2) and preferably equal to, or in excess of, 2000 1/min/m^2, then an adequate level of reclamation is achieved in a time scale measured in minutes. For example, approximately 10 minutes at 400°C and three minutes at 500°C for furane polymer resin containing (Methyl Ethyl Ketone Peroxide (MEKP) and hardened with sulphur dioxide gas.

Additionally, at a flow rate in the range approximately 2000-2400 1/min/m² is found that most foundry sands start to fluidise and satisfactory fluidisation is generally achieved over the range 2500-8000 1/min/m². Fluidisation can occur at lower flow rates depending on the grain size of the sand. Thus the apparatus used is simple, efficient and compact being in the form of a series of fluid beds through which the sand flows automatically without requiring any conveyar means.

At a flow rate above about 3000 1/min/m² cooling by the excess air starts to be noticeable although does not become significantly deleterious until the flow rate exceeds about 8000 1/min/m².

Referring now to Figure 5, there are shown three curves for reclaiming used sand at an original temperature of 500°C, 400°C and 300°C respectively. The temperature rise in the sand to be reclaimed, as a result of the exothermic reclaiming reaction, is plotted against the air flow rate in litres per minute per square metre. The curves indicate that for all three original temperatures an optimum performance is achieved in the region of 2000-3000 1/min/m².

Referring now to Figures 6 to 8, there is shown the rates of reclamation from sand having an original organic binder content of 0.75% as measured by loss on ignition (hereafter referred to LoI) for air flow rates 400, 2000 and 4000 1/min/m² respectively.

Referring now to Figure 6, this shows the rates of reclamation at a below optimum flow rate of air of only 400 1/min/m². The time temperature transformation (TTT) curve for a residual organic binder content of 0.2% (measured by LoI) indicates a useful working level at which reclamation is adequate for many processes, i.e. the sand is satisfactory for reuse. At this flow rate a time of 60 minutes is necessary to adequately reclaim sand at 400°C. At the optimum rate of air flow (2000 1/min/m² shown in Figure 5 the time required is thirteen minutes. This time lengthens to eighteen minutes as cooling becomes noticeable at 4000 1/min/m² as shown in Figure 8.

At 300°C the times far the same residual binder content, i.e. 0.2% (LoI) are thirty-three, thirteen and thirty-three hours respectively as can be seen from Figures 6, 7 and 8.

In practice the temperature and flow rate for the practical application of our method are chosen on the basis of TTT curves to achieve optimum operating canditions for the application concerned.

If desired the sand may be reclaimed at a treatment station 16 comprising a single fluid bed at which the sand is fluidised at a temperature in the treatment temperature range and heating elements may be provided at only the entry end of the bed or throughout the length of the bed at a uniform distribution or a non-uniform distribution so as to cause the temperature in the bed to decrease towards the exit end thereof. If desired, in anv particular application the sand may be fed from the treatment station at an elevated temperature without passing through a cooling fluidised bed section.

Compositions herein are expressed in % by weight.

Claims

1. A method of reclaiming used foundry sand containing an organic binder comprising the steps of supplying the sand to a fluid bed at a feed region thereof, fluidising the sand with combustion supporting gas, maintaining the sand in the fluid bed in an elevated treatment temperature range to reclaim the sand, allowing the sand to pass from the feed region to a discharge spaced from the feed region and removing reclaimed sand from the fluid bed through the discharge, characterised in that the sand, after separation from a casting, is supplied to a first fluid bed section, without heating the sand in a fluid bed in the presence of combustion supporting gas prior to supplying the sand to the first fluid bed section; combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain said sand in said treatment temperature range, is introduced into the sand in the first fluid bed section at a plurality of locations to fluidise the sand; the sand is maintained in said treatment temperature range to partially reclaim the sand; partially reclaimed hot sand from the first fluid bed section passes to a further fluid bed section; combustion supporting gas, which is also devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, is introduced into the sand in the further fluid bed section at a plurality of locations to fluidise the sand; the sand in the further fluid bed section is maintained in said treatment temperature range whereby reclamation of the sand is continued; the sand then passes to a third, cooling, fluid bed section; combustion supporting gas, which is also devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, is introduced into the sand in the third fluid bed section at a plurality of locations to fluidise the sand therein; the sand is then cooled in the third fluid bed section and reclaimed sand is then removed from the third fluid bed section.

2. A method according to Claim 1 wherein, after separating the sand from a casting, the sand is not fluidised prior to supplying the sand to the first fluid bed section.

3. A method according to Claim 1 or Claim 2 wherein the sand is supplied into the first fluid bed section at a temperature below said elevated treatment temperature range and heat is applied to the sand in the first fluid bed section to bring the sand into said treatment temperature range.

4. A method according to any one of the preceding claims wherein the sand remains in the further fluid bed section so as to continue reclamation at least partly utilising heat in the sand from the first fluid bed section.

5. A method according to any one of the

preceding claims wherein said treatment temperature range is 250° to 600°C.

6. A method of making a metal casting comprising the steps of making a mould using reclaimed used foundry sand and an organic binder, hardening the mould, casting molten metal into the mould to make a casting, separating the sand from the casting, reclaiming the sand by a method as claimed in any one of the preceding claims and then using the thus treated sand in a repetition of the method.

7. A method according to Claim 6 wherein the metal is a non-ferrous metal selected from the group consisting of aluminium, magnesium, copper and alloys based an said metals and the reclaimed sand of which the mould is made is predominently reclaimed used zircon sand.

8. An apparatus for reclaiming used foundry sand containing an organic binder comprising sand supply means (15, 54) to supply the sand to a fluid bed (16) at a feed region thereof, fluidising means to introduce combustion supporting gas into the sand to fluidise the sand, means (55) to maintain the sand in the fluid bed (16) in an elevated treatment temperature range to reclaim the sand and means for removing the reclaimed sand from the fluid bed (16) at a discharge (60) spaced from the feed region, characterised in that the apparatus includes means (14) for separating a mass of the sand from a casting; the fluid bed (16) comprises a first fluid bed section (51) into which the sand supply means (15, 54) supplies the separated sand, in use; and having fluidising means to introduce combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, into said sand at a plurality of locations to fluidise the sand therein; means (55) to maintain the sand in said treatment temperature range to partially reclaim the sand; sand passage means (56) to pass partially reclaimed hot sand from the first fluid bed section (51) to a further fluid bed section (52) having fluidising means to introduce combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, into the sand, in the further fluid bed section (52) at a plurality of locations to fluidise the sand therein; means to maintain the sand in the further fluid bed section (52) in said treatment temperature range whereby reclamation of the sand is continued; sand passage means (57, 58) to pass sand from the further fluid bed section (52) to a third, cooling, fluid bed section (53) having fluidising means to introduce combustion supporting gas, which is devoid of hot products of combustion sufficient to maintain the sand in said treatment temperature range, into the sand in the third fluid bed section (53) at a plurality of locations to fluidise the sand therein; means (59) to then cool the sand in the third fluid bed section (53) and means (60) to remove reclaimed sand from the third fluid bed section (53).

9. An apparatus according to Claim 8 wherein the sand supply means (15, 54) supplies the sand to the first fluid bed section (51) without fluidising the sand in the presence of combustion supporting gas prior to entry of the sand into the first fluid bed section (51).

10. An apparatus according to Claim 9 wherein the sand supply means (15, 54) supplies the sand to the first fluid bed section (51) without fluidising the sand prior to entry of the sand into the first fluid bed section (51).

11. An apparatus according to any one of Claims 8 to 10 wherein means are provided whereby the sand remains in the futher fluid bed section (52) in said treatment temperature range so as to continue reclamation at least partially utilising heat in the sand from the first fluid bed section (51).

12. An apparatus according to Claim 11 wherein further heating means are provided to heat the sand in the further fluid bed section (52).

13. An apparatus according to any one of Claims 8 to 12 wherein the heating means (55) comprises a plurality of heating elements immersible in the sand.

14. An apparatus according to Claim 12 or Claim 13 where dependent on Claim 12 wherein the further heating means comprises a plurality of heating elements immersible in the sand.

Patentansprüche

1. Verfahren zum Aufbereiten von verwendetem, ein organisches Bindemittel beinhaltendem Gießsand, unter Zuführen des Sandes in ein Fließbett an einem Speiseabschnitt von diesem, Fließfähigmachen des Sandes mit einem verbrennungsunterstützendem Gas, Halten des Gases in einem erhöhten Behandlungstemperaturbereich zum Aufbereiten des Sandes, Passierenlassen des Sandes von dem Speiseabschnitt zu einem von dem Speiseabschnitt beabstandeten Auslaß und Entnehmen des aufbereiteten Sandes aus dem Fließbett des aufbereiteten Sandes aus dem Fließbett durch den Auslaß, dadurch gekennzeichnet, daß der Sand nach der Trennung aus einer Gußform einem ersten Fließbettabschnitt zugeführt wird, ohne Erwärmen des Sandes in einem Fließbett in der Anwesenheit von einem Verbrennungsgas vor dem Zuführen des Sandes zu dem ersten Abschnitt des Fließbetts; Einführen von einem verbrennungsunterstützenden Gas in den Sand, das von heißen Verbrennungsprodukten frei ist in einer Menge ausreichend, um den Sand in dem Behandlungstemperaturbereich zu halten, in den Fließbettabschnitt an einer Vielzahl von Stellen, um den Sand fließfähig zu machen; der Sand in dem Behandlungstemperaturbereich gehalten wird, um den Sand teilweise aufzubereiten, teilweise aufbereiteter heißer Sand von dem ersten Abschnitt des Fließbettes zu einem weiteren Abschnitt des Fließbettes passiert, verbrennungsunterstützendes Gas in den Sand eingeführt wird, das auch frei ist von heißen Verbrennungsprodukten in einer Menge, die ausreicht, um den Sand in dem Behandlungstemperaturbe-

reich zu halten, in dem weiteren Abschnitt des Fließbettes an einer Vielzahl von Stellen, um den Sand fließfähig zu machen; der Sand in dem weiteren Fließbettabschnitt in dem Behandlungstemperaturbereich gehalten wird, wodurch die Aufbereitung des Sandes fortgesetzt wird, der Sand sodann zu einem dritten, zur Kühlung dienenen Abschnitt des Fließbettes passiert, ein verbrennungsunterstützendes Gas in den Sand eingeführt wird, das auch frei ist von heißen Verbrennungsprodukten in einer Menge, die ausreichend ist, um den Sand in dem Behandlungstemperaturbereich zu halten, in den dritten Abschnitt des Fließbettes an einer Mehrzahl von Stellen, um den Sand in diesem fließfähig zu machen; der Sand sodann in dem dritten Abschnitt des Fließbettes gekühlt wird und der aufbereitete Sand aus dem dritten Fließbettabschnitt entfernt wird.

2. Verfahren nach Anspruch 1, wobei der Sand nach dem Entfernen aus einer Gußform nicht fließfähig gemacht wird, bevor der Sand in den ersten Abschnitt des Fließbettes eingebracht wird.

3. Verfahren nach Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß der Sand in einen ersten Abschnitt des Fließbettes gebracht wird mit einer Temperatur unterhalb des erhöhten Behandlungstemperaturbereiches und Hitze aufgebracht wird auf den Sand in dem ersten Abschnitt des Fließbettes, um den Sand auf den Behandlungstemperaturbereich zu bringen.

4. Verfahren nach einem der vorangehenden Ansprüche, wobei der Sand in dem weiteren Abschnitt des Fließbettes bleibt, um die Aufbereitung fortzusetzen unter wenigstens teilweiser Verwendung der Wärme in dem Sand von dem ersten Abschnitt des Fließbettes.

5. Verfahren nach einem der vorangehenden Ansprüche, wobei der Behandlungstemperaturbereich zwischen 250° und 600°C liegt.

6. Verfahren zum Gießen von Metall unter Herstellen einer Form unter Verwendung von aufbereitetem Gießsand und einem organischen Bindemittel, Härten der Gußform, Eingießen geschmolzenen Metalles in die Form zur Herstellung des Gusses, Trennen des Sandes von dem Guß, Aufbereiten des Sandes durch ein Verfahren nach einem der vorangehenden Ansprüche und Verwendung des so behandelten Sandes unter Wiederholung dieses Verfahrens.

7. Verfahren nach Anspruch 6, wobei das Metall ein Nicht-Eisenmetall ist gewählt aus der Gruppe bestehend aus Aluminium, Magnesium, Kupfer und Legierungen basierend auf diesen Metallen und der aufbereitete Sand, aus dem der Guß geformt wird, aus zuvor bereits verwendetem Zirkonsand besteht.

8. Vorrichtung zum Aufbereiten von verwendetem, ein organisches Bindemittel beinhaltenden Gießsand, mit Zuführmitteln (15, 54) zum Zuführen des Sandes in ein Fließbett (16) an einem Speiseabschnitt von diesem, Fließfähigmachungsmittel zum Einführen von verbrennungsunterstützendem Gas in den Sand, um diesen fließfähig zu machen, Mitteln (55) zum Halten des Gases in dem Fließbett (60) in einem erhöhten Behandlungstemperaturbereich zum Aufbereiten des Sandes, und Mitteln zum Entnehmen des aufbereiteten Sandes aus dem Fließbett (16) an einem von dem Speiseabschnitt beabstandeten Ablaß, dadurch gekennzeichnet, daß die Vorrichtung Mittel (14) aufweist zum Trennen einer Sandmenge aus der Gußform; das Fließbett (16) einen ersten Fließbettabschnitt (51) aufweist, in das die Zuführmittel (50, 54) den getrennten Sand bei Einsatz einführen; und Fließfahigmachungsmittel zum Einführen eines von heißen Verbrennungsprodukten freiem, verbrennungsunterstützenden Gases zum Halten des Sandes in dem Behandlungstemperaturbereich in den Sand an einer Vielzahl von Stellen zum Fließfähigmachen des Sandes, Mitteln (55) zum Halten des Sandes in dem Behandlungstemperaturbereich zum teilweisen Aufbereiten des Sandes; Mitteln (56) zum Führen des teilweise aufbereiteten Sandes von dem ersten Abschnitt (51) des Fließbettes zu einem weiteren Abschnitt (52) des Fließbettes, der versehen ist mit Fließfähigmachungsmitteln zum Einführen eines von heißen Verbrennungsprodukten freien verbrennungsunterstützenden Gases in den Sand, um den Sand in dem Behandlungstemperaturbereich zu behalten, wobei der weitere Fließbettabschnitt (52) eine Mehrzahl von Stellen aufweist, um den Sand in diesem fließfähig zu halten; Mittel zum Halten des Sandes in dem weiteren Fließbettabschnitt (52) in dem Behandlungstemperaturbereich, wodurch die Aufbereitung des Sandes fortgesetzt wird, und Mittel (57, 58) zum Führen des Sandes von dem weiteren Abschnitt (52) des Fluidbettes zu einem dritten, zur Kühlung dienenden Abschnitts (53) des Fließbettes mit Fließfahigmachungsmitteln zum Einführen eines von heißen Verbrennungsprodukten freien Verbrennungsgases in den Sand ausreichend zum Halten des Sandes in dem Behandlungstemperaturbereich in den Sand, in dem dritten Abschnitt (50) des Fließbettes an einer Vielzahl von Stellen zum Flüssigmachen des Sandes in diesem, Mitteln (59) zum anschließenden Abkühlen des Sandes in dem dritten Abschnitt (53) des Fließbettes und Mitteln (60) zum Entnehmen des aufbereiteten Sandes aus dem dritten Abschnitt (53) des Fließbettes.

9. Vorrichtung nach Anspruch 8, wobei die Sandzuführmittel (15, 54) den Sand zu dem ersten Fließbettabschnitt (51) des Fließbettes zuführen ohne Fließfähigmachen des Sandes in der Anwesenheit von verbrennungsunterstützendem Gas vor dem Einführen des Sandes in den ersten Fließbettabschnitt (51).

10. Vorrichtung nach Anspruch 9, wobei die Sandzuführmittel (15, 54) den Sand zu dem ersten Fließbettabschnitt (51), Zuführen ohne Fließfähigmachen des Sandes vor dem Einführen des Sandes in den ersten Fließbettabschnitt (51).

11. Vorrichtung nach einem der Ansprüche 8 bis 10, wobei Mittel vorgesehen sind, durch die der Sand in dem weiteren Fließbettabschnitt (52) in den Behandlungstemperaturbereich bleiben, so daß die Aufbereitung wenigstens teilweis auf-

rechterhalten bleibt unter Verwendung der Wärme des Sandes von dem ersten Fließbettabschnitt (51).

12. Vorrichtung nach Anspruch 11, wobei weitere Erwärmungsmittel vorgesehen sind, um den Sand in dem weiteren Abschnitt (52) des Fließbetts zu erwärmen.

13. Vorrichtung nach einem der Ansprüche 8 bis 12, wobei die Erwärmungsmittel (55) eine Mehrzahl von in den Sand eingetauchten Elementen aufweisen.

14. Vorrichtung nach Anspruch 12 oder Anspruch 13 in Abhängigkeit von Anspruch 12, wobei die weiteren Erwärmungsmittel eine Mehrzahl von in den Sand eingetauchten Erwärmungselementen aufweist.

Revendications

1. Un procédé de recyclage de sable de fonderie usagé contenant un liant organique, comprenant les étapes d'amenée du sable dans un lit fluide en une région d'alimentation, de fluidisation du sable avec un gaz alimentant une combustion, de maintien du sable dans le lit fluide dans une gamme de températures de traitement élevées pour recycler le sable, de passage du sable de la région d'alimentation vers une décharge espacée de la région d'alimentation et d'enlévement du sable recyclé du lit fluide par la décharge, caractérisé en ce que le sable, aprés séparation d'une piéce moulée, est amené à une premiére section de lit fluide, sans chauffage du sable en lit fluide en présence du gaz alimentant la combustion avant d'amener le sable à la première section du lit fluide; le gaz alimentant la combustion, qui est exempt de produits de combustion chauds suffisants pour maintenir le sable dans la gamme de température permettant le traitement, étant introduit dans le sable dans la première section du lit fluide en plusieurs endroits pour fluidiser le sable; le sable étant maintenu dans la gamme de températures de traitement pour le recycler partiellement; le sable chaud partiellement recyclé de la première section de lit fluide passe dans une autre section de lit fluide; le gaz alimentant la combustion, qui est également exempt de produits de combustion chauds suffisants pour maintenir le sable dans la gamme des températures de traitement, est introduit dans le sable dans cette autre section de lit fluide en plusieurs endroits pour fluidiser le sable; le sable est maintenu dans la gamme de températures de traitement dans cette autre section de lit fluide, continuant ainsi son recyclage; le sable passe alors dans une troisiéme section de lit fluide, réfrigérante; le gaz alimentant la combustion, qui est également exempt de produits de combustion chauds suffisants pour maintenir le sable dans la gamme des températures de traitement, est introduit dans le sable dans la troisième section de lit fluide en plusieurs endroits pour fluidiser le sable qui y est contenu; le sable est alors refroidi dans la troisiéme section de lit fluide, et le sable recyclé est alors enlevé de la troisiéme section de lit fluide.

2. Un procédé conforme à la revendication 1, dans lequel après séparation du sable d'une piéce moulée, le sable n'est pas fluidisé avant d'être amené à la première section du lit fluide.

3. Un procédé conforme à l'une des revendications 1 ou 2, dans lequel le sable est amené dans la premiére section du lit fluide à une température inférieure à la gamme des températures élevées de traitement et où on apporte de la chaleur au sable de la premiére section du lit fluide pour le porter dans la gamme des températures de traitement.

4. Un procédé conforme à l'une quelconque des revendications précédentes, dans lequel le sable reste dans la section suivante de lit fluide, de façon à continuer le recyclage, en utilisant au moins partiellement la chaleur du sable de la première section du lit fluide.

5. Un procédé conforme à l'une quelconque des revendications prècédentes, dans lequel la gamme des températures de traitement s'étend de 250° à 600°C.

6. Un procédé pour faire un moulage de métal comprenant les étapes de fabrication d'un moule utilisant du sable de fonderie usagé recyclé et un liant organique, de durcissage du moule, de coulage du métal fondu dans le moule pour faire une pièce moulée, de séparation du sable de la pièce moulée, de recyclage du sable par un procédé tel que revendiqué dans l'une quelconque des revendications précédentes, et d'utilisation ultérieure du sable ainsi recyclé en répétant le processus.

7. Un procédé conforme à la revendication 6, dans lequel le métal est non ferreux et choisi dans le groupe comprenant l'aluminium, le magnésium, le cuivre et les alliages de ces métaux, et le sable recyclé dont est fait le moule est en grande partie du sable de zircone usagé recyclé.

8. Un appareil pour recycler du sable de fonderie usagé contenant un liant organique, comprenant des moyens (15, 54) pour amener le sable dans un lit fluide (16) en une région d'alimentation, des moyens de fluidisation pour introduire le gaz alimentant la combustion dans le sable pour le fluidiser, des moyens (55) pour maintenir le sable dans le lit fluide (16) dans une gamme de températures de traitement élevées pour recycler le sable, et des moyens pour sortir le sable recyclé du lit fluide (16) par une décharge (60) espacée de la région d'alimentation, caractérisé en ce que l'appareil comprend des moyens (14) pour séparer une masse de sable d'une piéce moulée; le lit fluide (16) comprend une première section (51) dans laquelle les moyens d'amenée du sable (15, 54) amènent le sable séparè usagé; et ayant des moyens de fluidisation pour introduire le gaz alimentant la combustion, qui est exempt de produits de combustion chauds suffisants pour maintenir le sable dans la gamme de températures de traitement, en plusieurs endroits du sable, pour fluidiser le sable qui y est contenu; des moyens (55) pour maintenir le sable dans la gamme de températures de traitement pour le recycler partiellement; des moyens de passage

du sable (56) pour passer le sable chaud partiellement recyclé de la première section (51) du lit fluide vers une autre section (52) du lit fluide ayant des moyens de fluidisation pour introduire le gaz alimentant la combustion, qui est exempt de produits de combustion chauds suffisants pour maintenir le sable dans la gamme de températures de traitement, en plusieurs endroits du sable de cette autre section (52) du lit fluide, pour fluidiser le sable qui y est contenu; des moyens pour maintenir le sable dans cette autre section de lit fluide (52) dans la gamme de températures de traitement, de sorte que le recyclage du sable continue; des moyens de passage du sable (57, 58) pour le passer de cette autre section (52) du lit fluide vers une troisième section (53) du lit fluide, réfrigérante, ayant des moyens de fluidisation, pour introduire le gaz alimentant la combustion, qui est exempt de produits de combustion chauds suffisants pour maintenir le sable dans la gamme de températures de traitement, en plusieurs endroits du sable, pour fluidiser le sable contenu dans la troisième section (53) du lit fluide; des moyens (59) pour refroidir ensuite le sable contenu dans la troisième section (53) du lit fluide; et des moyens (60) pour enlever le sable recyclé de la troisième section (53) du lit fluide.

9. Un appareil conforme à la revendication 8, dans lequel les moyens d'amenèe du sable (15, 54) amènent le sable à la première section (51) du lit fluide sans fluidiser le sable en présence du gaz alimentant la combustion avant l'entrée du sable dans la première section (51) du lit fluide.

10. Un appareil conforme à la revendication 9, dans lequel les moyens d'amenée du sable (15, 54) amènent le sable à la première section (51) du lit fluide sans fluidiser le sable avant l'entrée du sable dans la première section (51) du lit fluide.

11. Un appareil conforme à l'une quelconque des revendications 8 à 10, dans lequel des moyens sont prévus pour que le sable reste dans la section suivante (52) du lit fluide dans la gamme des températures de traitement de façon à continuer au moins partiellement le recyclage en utilisant la chaleur contenue dans le sable de la première section (51) du lit fluide.

12. Un appareil conformè à la revendication 11, dans lequel d'autres moyens de chauffage sont prévus pour chauffer le sable de la section suivante (52) du lit fluide.

13. Un appareil conforme à l'une quelconque des revendications 8 à 12, dans lequel les moyens de chauffage (55) comprennent plusieurs éléments chauffants immergeables dans le sable.

14. Un appareil conforme à la revendication 12 ou à la revendication 13, dépendante de la revendication 12, dans lequel les autres moyens de chauffage comprennent plusieurs éléments chauffants immergeables dans le sable.

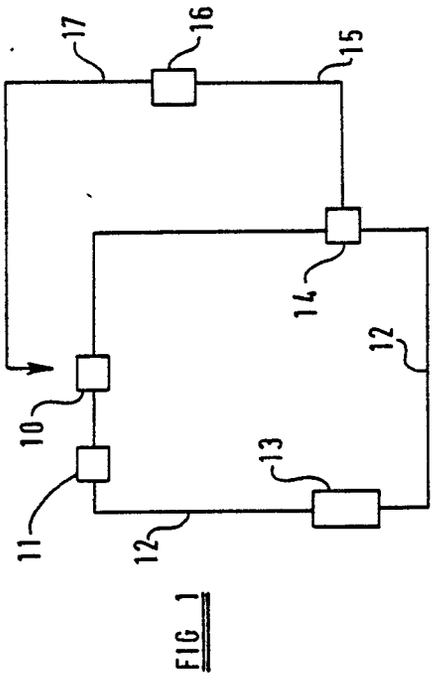
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FIG 1

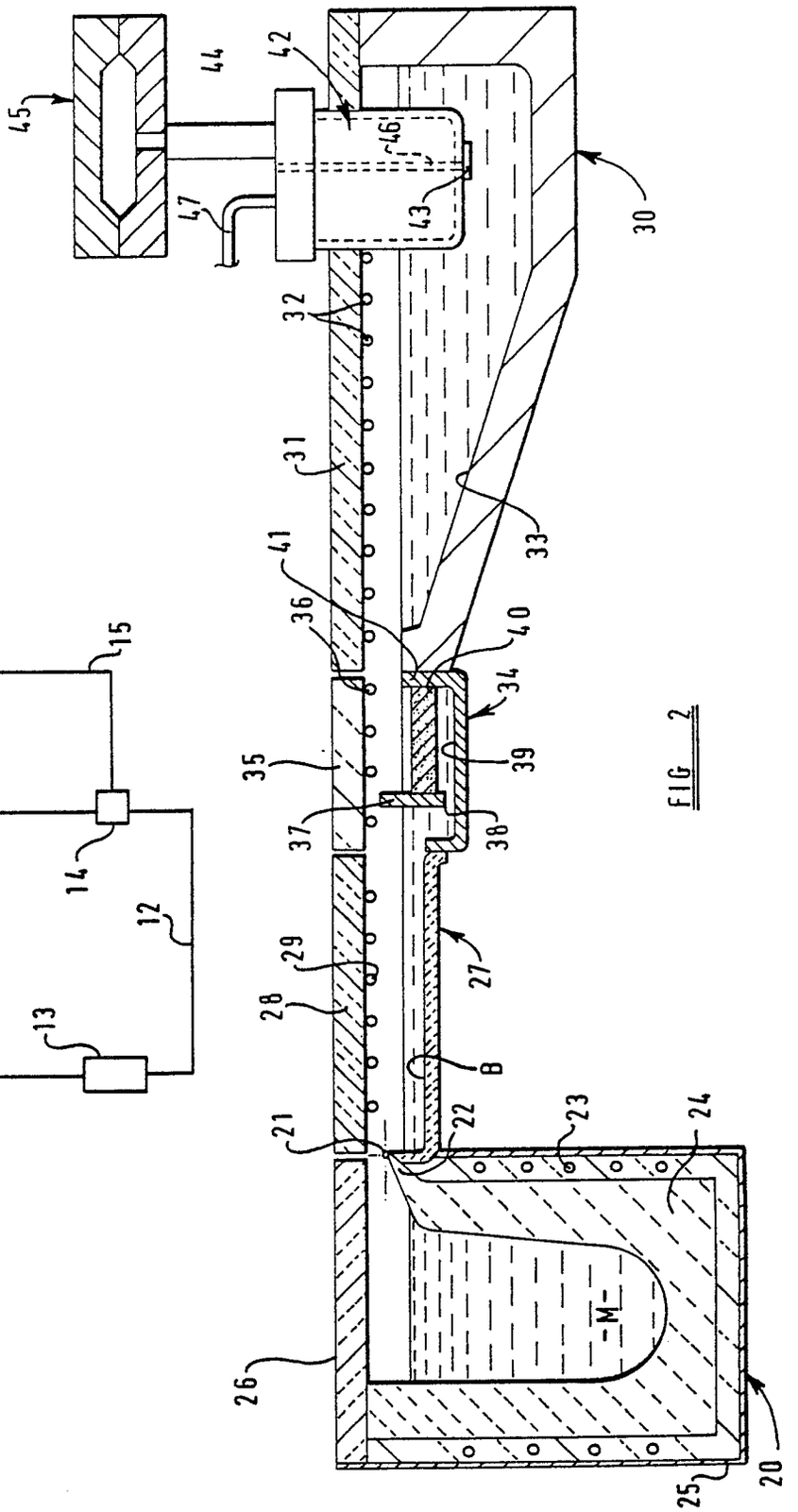
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FIG 2

FIG 3

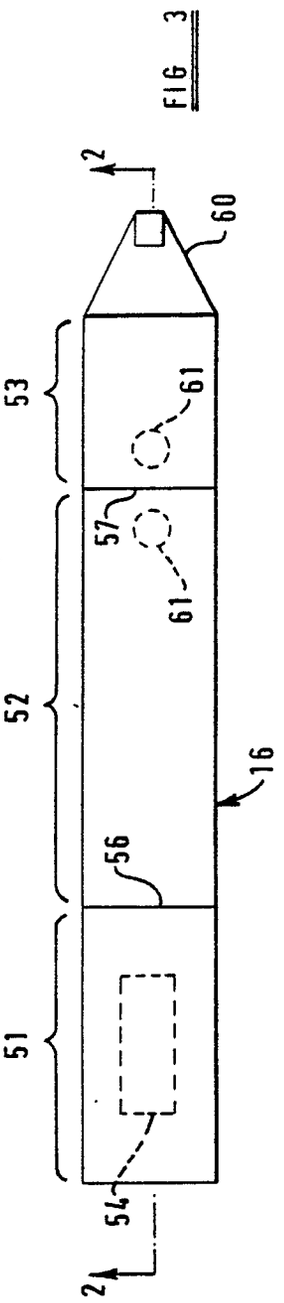
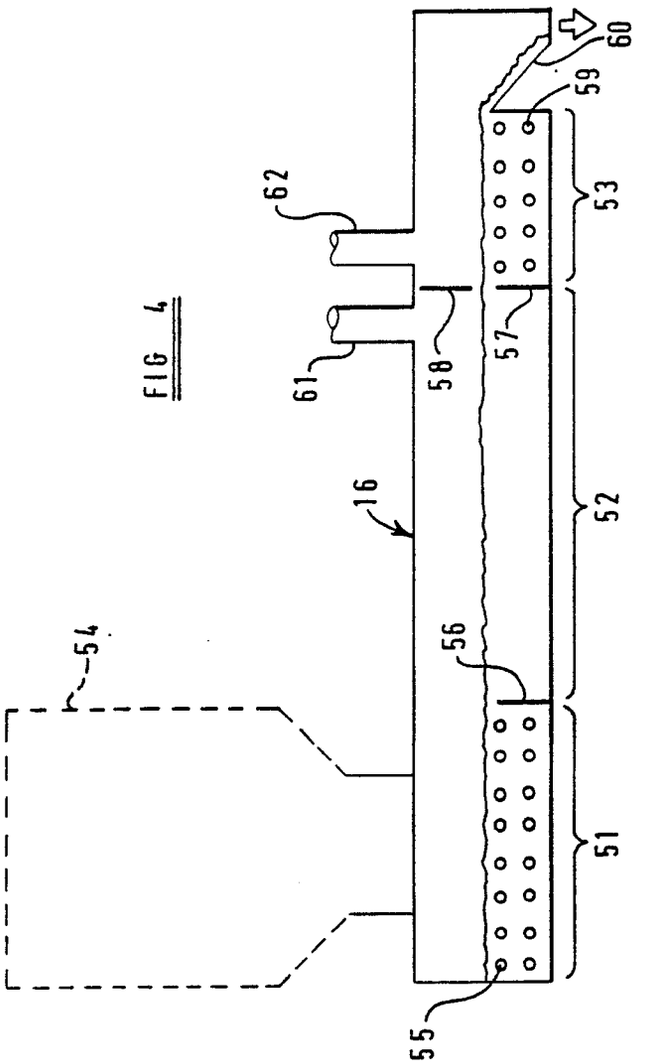
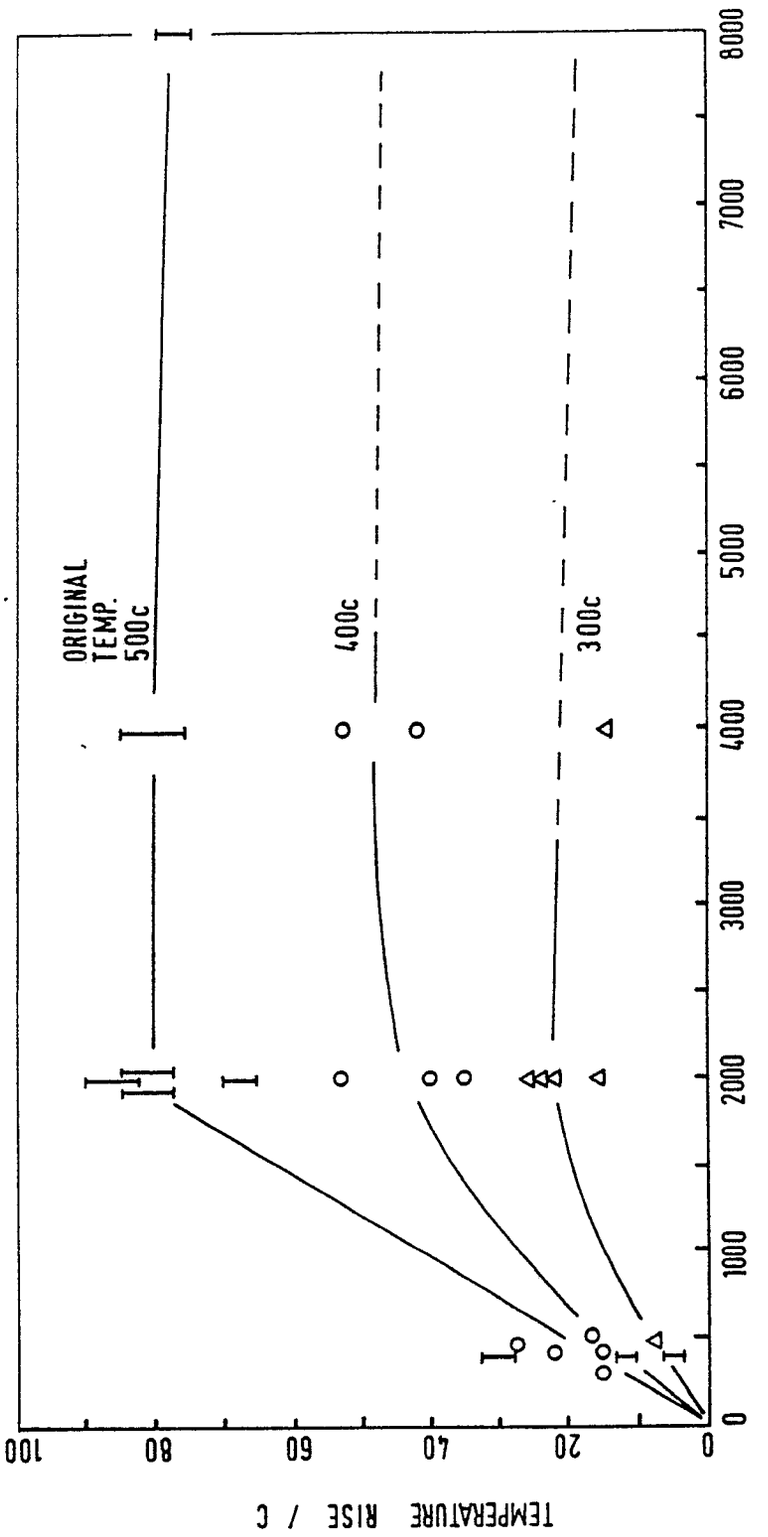


FIG 4




ORIGINAL
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300c
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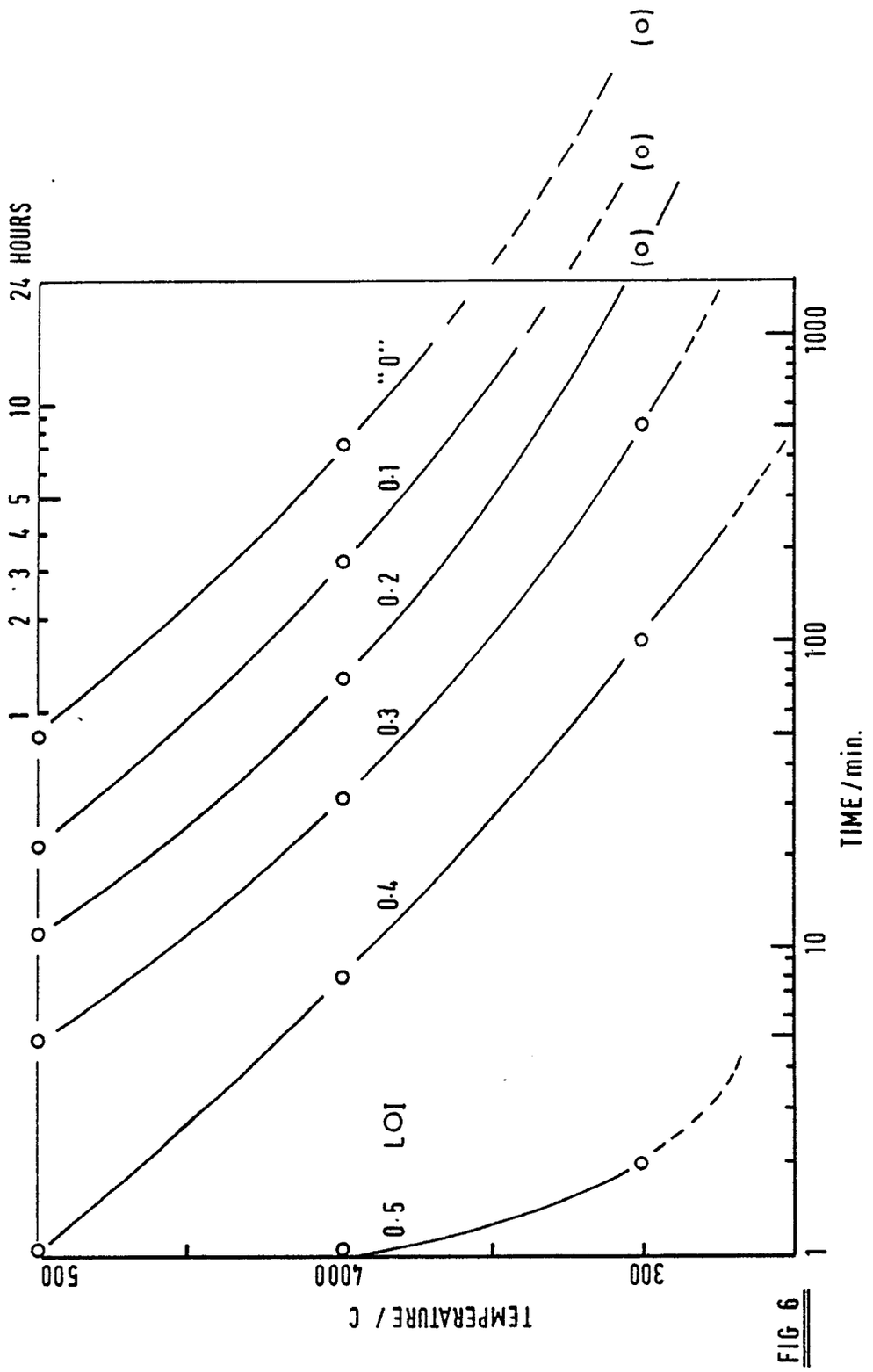
AIR FLOW RATE/litres per minute per square metre.

FIG 5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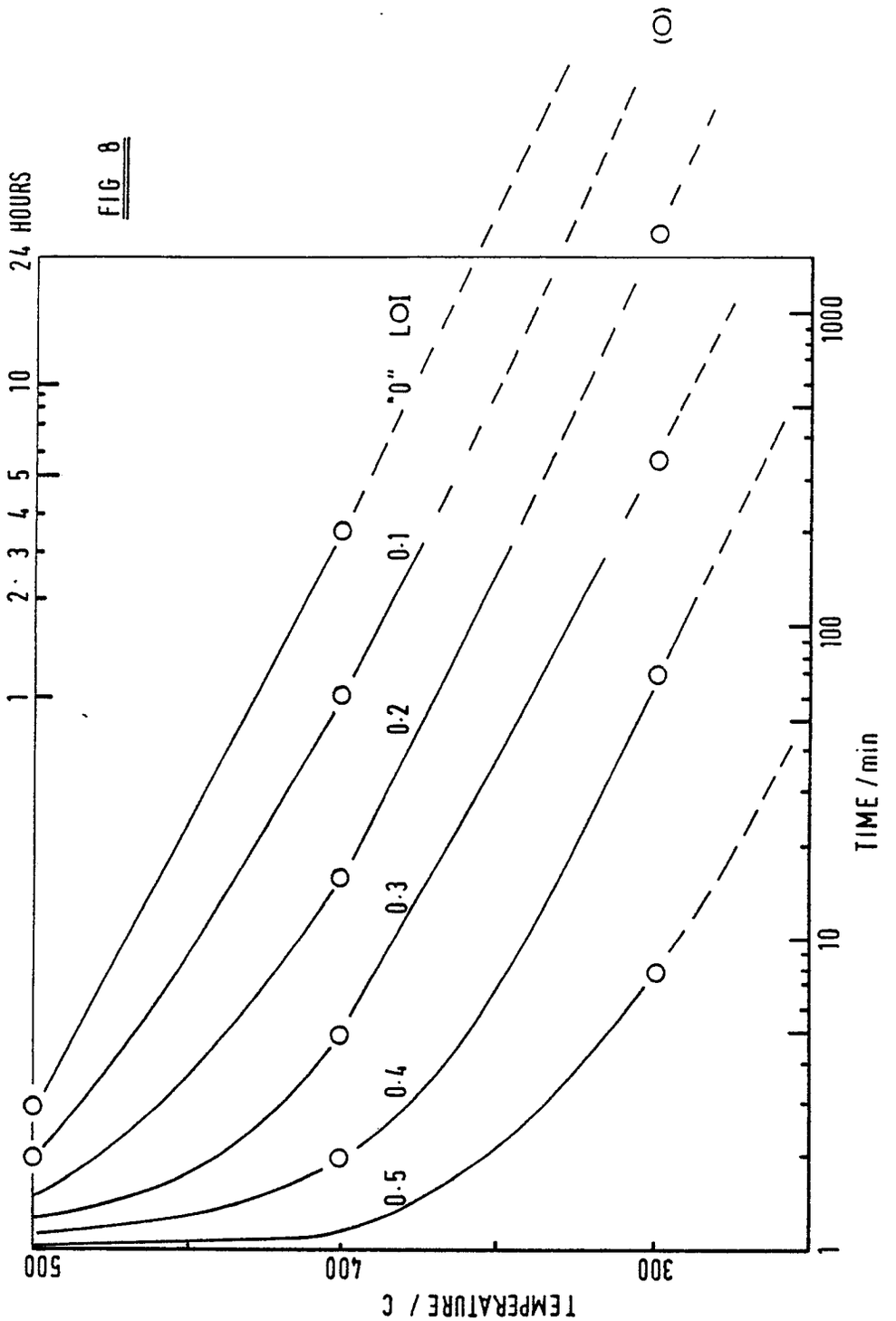
0·3
0·4
0·5
LOI
(o)
(o)
(o)
500
4000
300
TEMPERATURE / C
1
10
100
1000
TIME / min.

FIG 6

FIG 8


24 HOURS
10
5
4
3
2
1
"0" LOI
0·1
0·2
0·3
0·4
0·5
(O)
1000
100
10
1
TIME / min
500
400
300
TEMPERATURE / C

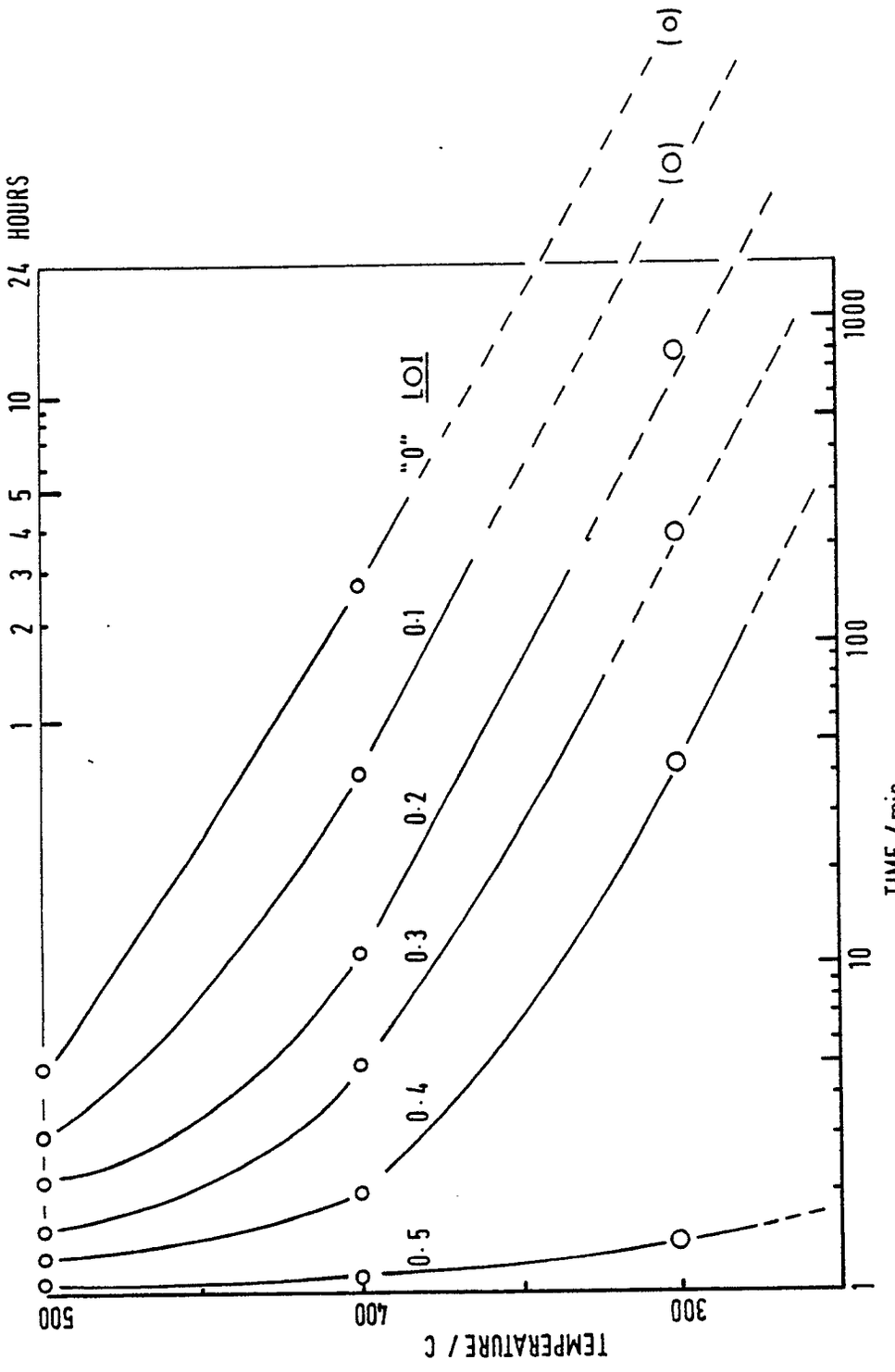

24 HOURS
10
5
4
3
2
1
LOI
"0"
0·1
0·2
0·3
0·4
0·5
(O)
(O)
1000
100
10
1
TIME / min.
500
400
300
TEMPERATURE / C

FIG 7