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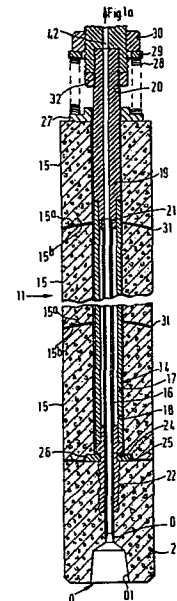
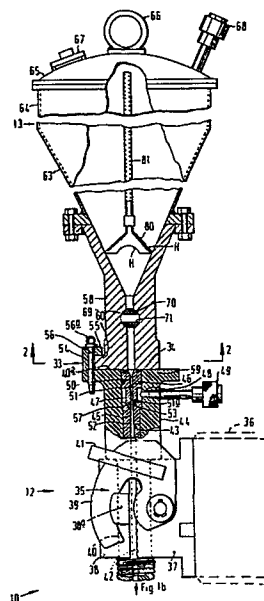
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54 **Method of and apparatus for making additions of particles to molten metal.**

57 A method of making additions of large dense particles such as lead to a bath of molten metal by accelerating the particles to a velocity of not less than 2200 cm per second. The particles can be introduced through a lance or through a port in a vessel containing the bath or by projection through the metal/slag/air interface. The particles are preferably introduced by means of a lance (11) having a reservoir (13) at one end containing the particles and to which gas under pressure is fed. The lance contains an accelerating means comprising a first passage part (51) and a second, diverging, passage part (52) and four inclined passages (53) extending to the throat between the parts (51) and (52) and through which is fed further gas under pressure which expands in the second passage part (52) and accelerates the particles.



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(Duport Steels Limited)

Title: Method of and apparatus for making additions of particles to molten metal.

Description of Invention

This invention relates to a method of, and apparatus for, making additions of particles to a bath of molten metal. The invention is particularly concerned with making additions of large dense particles as herein
5 defined. By large dense particles, we mean particles having a maximum dimension of not less than 0.25 mm and a density of not less than 4.5 gm/cc. Examples of such particles include lead shot, ferroboration, bismuth/lead alloy, calcium/barium alloy, ferroselenium, copper telluride,
10 ferrochrome, ferromanganese. These particles may be produced by grinding or gas atomisation, casting or other means.

Hitherto many proposals have been put forward for introducing, for example, lead into a bath of molten steel, see for example U.K. patent specifications Nos. 519 572;
15 520 024; 520 072; 520 227 which disclose the addition of lead shot to a stream of molten metal as it is being teemed from a ladle into ingot moulds. With such known techniques it has not been possible to achieve both good recovery of the added lead together with a substantially uniform distri-
20 bution of the lead in fine particles throughout the ingots.

It is accordingly an object of the invention to provide a method of, and apparatus for, making additions, particularly but not exclusively of particles such as lead shot, to a bath of molten metal in such a manner
25 as to achieve good retention of the addition in the metal whilst ensuring that so far as possible the addition is present in the metal in the form of uniformly distributed

fine particles.

This is achieved in accordance with one aspect of the invention by providing a method of making an addition to a bath of molten metal comprising the steps of accelerating large dense particles of addition material to a velocity of not less than 2200 cm/sec and directing the thus accelerated stream of particles into the bath.

Preferably the particles are accelerated to a velocity lying in the range 2750 cm/sec to 3650 cm/sec.

10 The particles may be accelerated by a fluid medium.

Additions may be introduced into the bath at a speed greater than that at which the accompanying fluid is introduced into the bath.

15 The addition and fluid may be introduced through a nozzle of a lance immersed in the bath or a nozzle of a port provided in a wall of a vessel in which the bath is contained.

20 Alternatively the particulate material may be accelerated in an accelerating means located above the molten bath, the particulate material being projected into the bath through the metal surface which may be slag covered.

25 When a lance or port is provided the particulate material may be accelerated within the lance or port by a gas to such a velocity that the particles pass through the bubbles of the gas formed in the bath.

If the particles did not pass through the bubbles the particulate material may be either ejected from the

surface of the bath as the bubbles burst on reaching the surface or the particles may melt and fuse together thus giving rise to an uneven distribution in the molten metal.

5 The gas may be ejected from the nozzle at such a pressure as to prevent the metal entering the nozzle as well as at such a rate as to eject the particulate material into the region of the bath agitated by the gas.

10 Preferably the gas is at the minimum pressure to prevent metal entering into the nozzle whilst achieving the desired amount of particulate material discharge.

It is desired to keep the amount of gas to the minimum to prevent excessive turbulence of the molten metal.

15 The lance may have a delivery nozzle at one end of the lance, a passage for additions extending longitudinally of the lance from the nozzle to the other end of the lance and said method may include the step of supplying addition to the passage at said other end of the lance and accelerating the additional particles by an accelerating means in the lance.

20

25 In all cases the particles may be accelerated by a gas in an accelerating means comprising a primary diverging passage for the particulate material downstream of a restricted throat and at least one secondary passage for admitting secondary fluid through the diverging passage at or downstream of the throat so that, in use, as fluid under pressure enters the diverging passage it expands and accelerates the particulate material.

30 The longitudinal axis of the or each secondarily passage preferably has a component extending in the direction of flow of the particulate material.

Four secondary passages may be provided at equi-
angularly spaced positions about the axis of the
primary passage.

5 The pressure of gas in the secondary passage or
passages may lie in the range 7.0 kg/sqm to 15.0
kg/sq. cm.

The flow rate of gas in the secondary passage or
passages may lie in the range 12.5 litres per
second to 25.0 litres per second.

10 The pressure of gas in the primary passage may lie
in the range 4.0 kg/sq cm to 10.0 kg/sq cm.

The flow rate of gas in the primary passage may
lie in the range 1.6 litres per second to 8.5
litres per second.

15 The invention has been developed to make additions,
to a molten steel bath, of lead which is dense and
normally in the form of lead shot having for example a
maximum dimension of about 0.5 to 1.0 mm and a particle
density of 11.3 gm/cc and a bulk density of 7.93 gm/cc.

20 However, the invention has wider application and
can be used to make any desired addition which is in the
form of large dense particles as herein defined to any
desired molten metal and may be used to make the addition
near the surface of the bath.

25 It has been proposed in, for example, U.K. Patent
Specification 748 474 and U.S. Specification 3 891 196
to introduce additions such as desulphurisation agents,
for example, calcium carbide which are relatively small

and light particles, into a bath of molten steel by first fluidising the relatively small and light particles and then passing them into the bath through a lance immersed in the steel. Such techniques however were of
5 no assistance to the applicants in achieving the object of their invention. Firstly, because such prior proposals were concerned only with adding desulphuration agents and the like and not with achieving good distribution of relatively large and dense particles such as
10 lead, a man of average skill in the art being well aware of the vast differences between the problems encountered in adding desulphuration agents such as calcium carbide and those encountered in adding materials such as lead.

Secondly, even if the use of such techniques had
15 been considered as a possible solution to the problem of achieving the desired metal recovery and distribution they would have been discarded since the teaching relates only to relatively light small particles which can be fluidised. Fluidisation of the addition particles
20 being an essential feature of the method disclosed in these two specifications. The applicants were the first to realise that the desired metal recovery and distribution could be achieved by accelerating the large dense particles preferably by means of a fluid under pressure.

25 In this specification the term "bath" is intended to refer to any mass of molten metal including, for example, the molten metal in a furnace crucible ladle or mould.

The fluid envelopes the addition particles during
30 its passage into the metal and thus prevents oxidation of the particles until they are introduced substantially in the metal.

According to another aspect of the invention we provide an apparatus for making additions of particulate material to a bath of molten metal comprising a passage for the addition material, a discharge nozzle at one
5 end of the passage, means to connect the other end of the passage to a supply of addition, means to connect a supply of fluid under pressure to the passage, the internal configuration of the passage being such that the addition material is accelerated, as a result of intro-
10 duction of the fluid into the passage, to a velocity of not less than 2200 cm/s

Preferably the material is accelerated to a velocity lying in the range 2750 cm/sec to 3650 cm/sec

Said discharge nozzle may be adapted, in use, to be
15 located above the surface of a bath of molten metal so as to project the particulate material into the bath through the metal surface which may be covered by a layer of slag.

Alternatively the nozzle may be adapted, in use
20 to be located at the end of a port in the wall of the vessel in which the bath is contained.

Further alternatively, the nozzle may be adapted in use, to be located at the end of a lance adapted, in use, to extend through the metal surface of a molten

bath so that the particulate material is discharged from the nozzle at a desired location within the bath.

The passage may be formed to provide an accelerating means comprising a primary diverging passage for the particulate material downstream of a restricted throat and at least one secondary passage for admitting secondary fluid to the diverging passage at or downstream of the throat so that, in use, as fluid under pressure enters the diverging passage it expands and accelerates the particulate material.

The longitudinal axis of the or each secondary passage preferably has a component extending in the direction of flow of the particulate material.

The or each secondary passage may be inclined to the axis of the primary passage at an angle lying in the range 25° to 35° .

The diameter of the throat may lie in the range 7.0 mm to 11.0mm.

The angle of divergence of the primary passage may lie in the range 4° to 10° .

The diameter of the or each secondary passage may lie in the range 1.00mm to 2.00 mm.

The lance may comprise a central tube on which a plurality of refractory sleeves are assembled with a biasing means providing an end load to the assembly of sleeves.

The central tube may be provided with a fixed abutment at its lower end and the biasing means being provided adjacent the upper end of the tube so as to

bias the refractory sleeves against the fixed abutment.

Preferably the refractory sleeves have annular or substantially annular abutting faces.

5 In order to avoid the nozzle outlet becoming blocked with solidified metal from the bath, as a result of the chilling effect of the gas and additions at the nozzle, the end of the nozzle is counterbored to provide a relatively large cross section recess concentric with
10 the passage of the nozzle. Due to the relatively large recess if there is any tendency for the metal of the bath to become solidified and to form a skin the solidifying metal is not permitted to build up on the nozzle tip but is caused to be redistributed and hence remelted
15 thereby avoiding any blockage of the nozzle.

A metering means may be provided to permit of adjustment of the flow rate of the addition.

20 The fluid under pressure to accelerate the particulate material may be introduced to the addition flow at or adjacent the metering means.

25 The metering means may comprise a replaceable metering spool comprising a passage, a first part of which provides a metering tube and other parts of which provides a metering tube and other parts of which providing said restricted throat and primary diverging passage as well as the or each secondary passage.

By selecting a spool having a metering tube of a desired X-section the flow rate of the addition can be adjusted. The addition may be supplied from a reservoir

fixed to the other end of the lance and the reservoir is preferably a sealable pressure vessel provided with means for connecting the interior of the vessel to a supply of inert gas, or other fluid under pressure.

- 5 The reservoir may be removably fixed to the other end of the lance preferably by means of a quick release coupling.

10 The reservoir may be provided with a shut-off valve operable to interrupt the flow of addition from the reservoir.

The metering means may be located between the reservoir and said other end of the lance.

15 The metering means may be provided in a holder body, the lance being connected to one end of the body and the reservoir being fixed to the other end of the body.

The holder body may be provided with a throughbore for the passage of addition and the metering spool being mounted within the throughbore.

20 The holder body may be adapted to be engaged by a clamp or the like provided on a device operable to introduce the lance into a bath of molten metal to a desired depth.

The central tube may comprise a pair of concentric tubes.

25 The invention will now be described in detail with reference to the accompanying drawings wherein:-

FIGURES 1a and 1b show a longitudinal cross sectional view through an apparatus embodying the invention,

FIGURE 2 is a transverse cross-sectional view through Figure 1,

30 FIGURE 3 is a cross-sectional view through a

refractory sleeve of the apparatus of Figure 1;

FIGURE 4 is a cross sectional view through an alternative embodiment of the refractory sleeve for the apparatus of Figure 1,

5 FIGURE 5 is a plan view of the sleeve shown in Figure 3,

FIGURE 6 is a sectional view through a fibre washer for use with the sleeve of Figures 3 and 5, and

10 FIGURE 7 is a cross sectional view showing the configuration of the washer of Figure 7, in use.

Referring to the drawings, the apparatus is indicated generally at 10 and comprises a lance 11, a holder body 12 and a reservoir 13.

15 Particles of addition, for example, lead are loaded into the reservoir 13 and are forced therefrom by inert gas, as hereinafter to be described, through the holder body 12 and lance 11 to be introduced into a bath of molten steel from the lower end of the lance.

20 The lance 11 comprises a central tube 14 surrounded by a plurality of annular in cross section refractory sleeves 15. The refractory sleeves 15 are preferably of the configuration shown in Figures 3 and 5 and it will be seen that, except for the top and bottom sleeves, 25 they have a part-spherical upper and lower surface and indicated at 15a and 15b respectively which are preferably formed with a pair of part circular in cross section grooves 15c. The central tube 14 comprises a thick wall hydraulic tube 16 located concentrically 30 within an outer larger tube 17 of the same type.

The outside diameter of the tube 17 is such that it is a clearance fit within the central bore 18 of the refractory sleeves 15.

At the top of the outer tube 17 a solid bar 19 is welded, the solid bar being machined to the outside diameter of the tube 17 and threaded at its upper end as indicated at 20 to provide a screw connection with the lower end of the holder body 12.

At its lower end the bar 19 is also internally threaded, as indicated at 21 to provide a threaded connection with the smaller diameter tube 16.

A lead-in is provided to this thread facilitating removal of the inner tube 16 should the lower end of the inner tube 16 be damaged whilst the outside tube 17 remains undamaged.

At its lower end the outer tube 17 has welded to it a fitting 22 to permit attachment of a refractory nozzle end 23. In the example the fitting 22 is provided with a coarse rounded thread which is engaged with a corresponding thread provided on the nozzle end 23. The fitting 22 and nozzle end 23 are bored to receive the central tube 16 with clearance.

A groove 24 is machined in the fitting 22 and receives a slotted washer 25 which is received in a rebate 26 formed in the lower end of the lower refractory sleeve 15.

At the upper end of the lance a shouldered washer 27 is urged against the upper end of the uppermost sleeve 15 by means of a coil compression spring 28 the other end of which is engaged by a washer 29 engaged with a spring tensioning nut 30 threadedly engaged with the lower end of the holder body 12. The above described arrangement of coil compression spring and tensioning nut 30 ensures that the refractory sleeves 15 are secured in position whilst at the same time allowing for

differential expansion between the refractory and the steel tubes 16 and 17.

The lance can be built up either with the tubes 16 and 17 in place in the holder 12 by assembling the refractory sleeves 15 with the central tube 14, introducing the washer 25 into the groove 24 and then tightening the tensioning nut 30 followed by screwing on and claying the refractory nozzle end 23. Alternatively, the lance can be built up by detaching the central tube 14 from the holder, in which case the nozzle end will be assembled first then the sleeves 15 and finally the washer 27 and spring 28.

In view of the fact that to force gas into molten steel at a pressure higher than that of the ferrostatic head at the depth of the lower end of the lance causes much turbulence in the ladle which results in great buffeting of the lance it is preferred not to use normal stopper rod sleeves for the sleeves 15 since they are recessed at one end and at the other end carry a spigot. The end which is recessed and has a spigot cemented into it is greatly weakened, and in the case of violent agitation, the end of the recess can break away and may take with it a major part of the sleeve. To avoid any such problems the sleeves 15 are provided with the above mentioned slightly convex concave surfaces 15a and 15b. If desired however, the sleeves may have annular end surfaces as indicated at 15d in Figure 4 and may again be provided with concentric grooves 15c.

As shown in the drawings the sleeves 15 are assembled with a compressible refractory fibre washer 31 therebetween, a fluid tight joint being made by the load of the spring 28 described above. With sleeves of

the configuration shown in Figures 3 and 5 the washers originally of the shape shown in Figure 6 will be compressed to adopt the shape shown in Figure 7. Violent agitation of the lance will not break the sleeves since
5 they are cushioned from each other by the refractory fibre washer 31.

The washers 31 of fibre refractory material should be of the same size internally as the outside diameter of the outer steel tube 17. Since refractory
10 products are generally variable in size, a close fit of the sleeve on the tube 17 cannot be expected so that by ensuring that the fibre washer has an internal aperture of the same size or slightly smaller than the external diameter of the tube 17 then as the sleeves
15 are tied together at each joint a fibre collar will exist in engagement with the outer tube 17 which will serve to insulate the sleeve from contact with or vibration of the tube.

The concavity desired above is not so great as
20 to weaken the end but is sufficient to render impossible any chance of error in assembly. The concave/convex end shape has the advantage that it takes care of any longitudinal flexing or bending of the lance.

In order to avoid the nozzle outlet 0 becoming
25 blocked with solidified metal from the bath, as a result of the chilling effect of the gas and additions at the nozzle, the end of the nozzle is counterbored to provide a relatively large cross section recess 01 concentric with the passage of the lance and in addition
30 the tube 16 is protected by cement O_2 and is recessed well back from contact with the molten metal.

With conventional nozzle tips the cooled metal is mostly swept away in the agitation caused by the injection process. The injection delivery pipe should never to exposed at its tip to the molten
5 metal, since adhesion of semi-frozen metal can take place, increase and bring the operation to a halt. However adhesion can on occasion take place between the molten metal and the refractory material of the lance tip with the same result.

10 This latter adhesion occurs particularly should there be a momentary irregularity in delivery through the lance, when molten or semi-frozen metal may enter the tip of the tube. Most lance tips are modified stopper rod ends or follow the same form.

15 Due to the relatively large recess of the present invention which is continuously filled with argon if there is any tendency for metal of the bath to become solidified and to form a skin the solidifying metal is not permitted to
20 build up on the lance tip but is caused to be redistributed and hence remelted thereby avoiding any blockage of the nozzle. Moreover, assimilation of the lead shot by the melt takes place away from the surface of refractories and from the tip of
25 the delivery tube.

5 The holder 12, as briefly mentioned above, has at its lower end an internal screw thread with which the thread 20 on the upper end of the bar 19 is engaged and a lock nut 32 is provided to lock the threaded connection between the bar 19 and the holder 12.

10 The holder 12 is machined from solid bar and has at its upper end a large diameter flange type quick release attachment 33 which mates with an interrupted flange 34 provided on the bottom of the reservoir 13 as hereinafter to be described. The central part of the holder is machined to fit inside a clamp 35 provided on an arm 36 connected to a raising and lowering mechanism whereby the lance can be introduced into and removed from a bath of molten steel.

15 The clamp comprises a fixed part 37 connected to the arm 36 and a movable part 38 which is pivotally mounted on the part 36 for pivotal movement about a vertical axis and is provided with an abutment 38a adapted to be engaged by a pivoted latch 39 so that when the latch 39 is in the position shown in the drawing the clamp parts 38 and 37 are urged towards each other and grip the central part 40 of the holder body 12. It will be appreciated that the parts of the clamp 37 and 38 which engage the holder body are formed with part cylindrical surfaces of a diameter to co-operate with the cylindrical surfaces of the part 40.

20

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The catch 39 is provided with the lever 41 to permit of its engagement with the abutment 38a.

A safety device, not shown, is provided to ensure that the catch 39 is locked in its lance holding position.

5 The holder body 12 is bored from end to end to provide a passage 42 for the addition material. The diameter of the majority of the passage 42 may be greater or smaller than shown in the drawing or could be considerably larger and be provided with interchangeable sleeves to permit of ready adjustment of the passage
10 diameter. In the case of the addition of abrasive materials, the sleeves may be hardened as, of course, may be the holder itself when no sleeves are provided.

At the upper end, the passage 42 is provided with a counterbore 43 in an enlarged diameter part 44 of the
15 holder body. The counterbore 43 is provided with a replaceable metering spool 45 provided with seals in the form of O-rings 46 and having a cylindrical stepped counterbored passage 43. An annular recess 47 is provided in the surface of the metering spool 45
20 and a radial passage 48 extends through the wall of the enlarged diameter part 44 of the holder body 12 and communicates with a quick release coupling 49 for connection to a supply of inert gas under pressure such as argon.

The metering spool 45 has an internal passage 50 having a first passage part 51 which provides a metering tube and a second, diverging passage part 52 which provides an accelerating tube. Between the parts 51 and 52 are provided a plurality, for example, four inclined passages 53 which extend from the annular recess 47 and provide a feed for argon to the interior of the passage 50. The passages in the present example have a diameter 0.061 inch if an argon pressure of 6 atmospheres is used and a diameter of 0.078 inch if an argon pressure of 3 atmospheres is used. The result is an argon velocity of 320 m/sec. The spool is made of hard steel finely finished and is easily exchangeable to provide different diameters of passage in accordance with the addition material to be added using the apparatus. The diameter, D , of the metering tube is related to the maximum particle dimension, d , by the expression $D > \sqrt{8d^2}$

By using different shapes and diameters for the passage parts, the flow rate of the addition material may be varied as may be the acceleration imparted to the addition particles by the argon introduced via the quick release coupling 49 thereby adjusting the time required for addition and the rate at which the addition material can be assimilated into the molten steel.

If desired, other means for introducing the argon flow into the stream of particles may be utilised. It is to be noted that the argon may be introduced at any location between the reservoir 13 and the upper end of the lance 11 and any device may be provided that operates on a venturi or similar action and which separates the addition particles and increases their energy by acceleration.

As mentioned briefly above, the reservoir 13 is connected to the upper end of the holder body 12 by means of the flange connection 33. This connection comprises a lower abutment surface 40a surrounded by an upstanding flange 54 at the upper end of which three inwardly extending lips 55 are provided each having an opening 56 and a locking pin 56a

At the lower end the reservoir 13 has an extension piece 58, a lower end surface 59 of which abuts the surface 40a of the holder body and has three outwardly projecting tongues 60 of such configuration that the reservoir and holder body can be assembled together by introducing the tongues 60 into the spaces 61 between the lips 55, as shown in full line in Figure 2, and then rotating the reservoir to the dotted line position shown in Figure 2 so that the tongues 60 lie beneath the lips 55 and the pin 56a is then introduced into any desired one of the apertures 56 to lock the reservoir and holder in the above described relative position the tongues 60 having semi-circular recesses 62 to receive the pin 56a.

Fixed to the upper end of the extension piece 58 is a conical part 63 of the reservoir, at the upper end of the part 63 is welded a cylindrical part 64 and the reservoir is closed by a cover 65.

The cover 65 is provided with a lifting eye 66, a filler plug 67 through which additional material may be introduced into the reservoir and a quick release coupling 68 for connection to a supply of inert gas such as argon under pressure.

Within the extension piece 58 a rotary shut-off valve 69 is provided comprising a rotatable cylindrical

plug 70 with a diametric passage 71. Remote control means are provided to permit rotation of the plug 70. By means of the rotary valve 69 flow of addition material into the melt can be interrupted if desired.

5 The vessel is of robust construction and is tested to pressures well above that for normal working. In the example described the reservoir is approximately of 3 cubic feet capacity and easily contains 900 lb of material weighing 498 lbs. per cubic ft.

10 Because the reservoir 13 is mounted direct upon the lance the particulate material passes through only a short distance before entering the metering spool and being accelerated. This avoids problems which would be encountered if the reservoir were at a location
15 remote from the lance and had to be fed through the lance through a relatively long path such as along a flexible conduit.

Because of the nature of lead particles, that is to say their density and relative softness, there is a
20 tendency for the particles to pack together in a substantially gas tight manner at the bottom of the reservoir which would prevent flow of particles from the reservoir. This effect is magnified because of the pressure applied to the reservoir which is
25 above the pressure in the exit from the reservoir.

To avoid this problem a perforated frusto conical member 80 is provided within a lower part of the reservoir. The member 80 may be pierced with holes or slots, or be so arranged as to be surrounded by an ann-
30 ular space between itself and the sides of the vessel. The drawing shows a series of semi-circular holes H about the outside edge. The holes are so arranged that the

cone can never be completely filled by lead shot. The sizes of holes or openings are decided so that the maximum flow through the holes by gravity alone must exceed the expected maximum delivery in the course of the injection process. This mixing space cannot become empty until all the charge has been passed through. A source of gas under pressure equal to that applied in the remainder of the reservoir is introduced into the reservoir beneath the plate 80 in this example by means of a tube 81 connecting the space above the charge with extreme lower end of the reservoir equalising the pressure below the mass of the charge with that which exist in the open space above. The tube is long enough for its upper end to stand well above the level which the maximum charge reaches in the vessel whilst at its lower end it finishes in the member 80 welded across the narrowing end of the reservoir so as to equalise the pressure on the particles at the bottom of the reservoir. This permits correct flow of particles from the reservoir.

In operation, as described below, when the rotary valve 69 is opened, the lead shot begins to flow and is followed up by shot flowing through the apertures in the cone, thus there exists in this area a continuous movement of the shot within the pressurised gas with which it becomes entrained ensuring an even and continuous delivery to the lance.

In use, addition material to be added to molten steel is introduced through the plug 67 into the interior of the reservoir 13. The quick release couplings 68 and 49 are connected to a supply of inert gas under pressure such as argon.

The argon supply is then turned on, the arm 36= is manipulated to lower the lance so that its nozzle end 23 is at the desired depth in a bath of molten steel, for example, in a furnace ladle. Then the valve 69 is opened to permit the addition particles to pass from the reservoir via the metering means and be accelerated therein by the argon introduced to the coupling 49 and then into the molten steel via the nozzle end 23. Typically 60 kg of lead per minute (equal to 0.0051 cubic metres/min) are added for 6 minutes.

The velocity applied to the lead particles is a product of three functions:-

- (a) the acceleration of a falling body due to gravity,
- (b) the translation of work produced by the expansion of argon through the jets of the accelerator into velocity of the lead particles;
- (c) the retardation of the particle by the surrounding gas through which it falls;
- (a.i) the acceleration of a falling body is 32 ft/second².
- (b.i) the work produced by the expansion of argon is

given by the formula

$$U_a = 144 P_a V_A \frac{\gamma}{\gamma-1} \left[1 - \left(\frac{P_1}{P_2} \right)^{\frac{\gamma-1}{\gamma}} \right]$$

Where U_a = work done in ft. lbs/lb argon

P_a = injector pressure p.s.i. abs.

P_1 = hopper pressure " "

P_2 = lance pressure " "

V_A = specific volume of argon at P_a pressure ft³/lb.

V_1 = specific volume of argon at P_1 pressure ft³/lb.

V_2 = specific volume of argon at P_2 pressure ft³/lb.

γ = ratio of specific heats i.e. 1.667 for monatomic gases.

Since $P_1 = P_2$ the expression $\left[1 - \left(\frac{P_1}{P_2} \right)^{\frac{\gamma-1}{\gamma}} \right]$ cancels out and the equation becomes $U_A = 144 P_A V_A \frac{\gamma}{\gamma-1}$

If the mass of argon injected per second is S_a , then the work per second is $U_a = 144 P_A V_A \frac{\gamma}{\gamma-1} S_a$

- 5 For example if $P_a = 7$ atmospheres; P_1 and $P_2 = 2.67$ atmospheres (equivalent to a ferrostatic head of 10 ft. (3.048M); the volume of argon at N.T.P. of 35.4 ft³ (1M³) per minute; and the lead injection rate of 60 kg. per minute, then the velocity imparted to the lead by the argon is about 95 ft/second (2895 cm/sec).

- 15 The lance is approximately 16 ft (49 m) long so that the dwell time of the lead after the accelerator would be approximately 0.168 seconds. Thus the velocity due to gravity acceleration will be about 5 ft/second (152 cm/sec). The velocity at the lance end will be, therefore, 100 ft/second (3048 cm/sec).

(c.i) The retardation of the particles can be calculated from, in this case, Newtons Law, since the Reynolds number applicable is higher than 500

$$R = \frac{f \pi D^2 \rho V^2}{8}$$

- 20 Where R = the retarding force.

f = the friction factor which is dimensionless.

D = the diameter of the particle.

ρ = the density of the gas af flowing.

- 25 V = the relative velocity of the particle and the gas.

- 30 In this case the as flowing velocity of the argon is about 60 ft/second (1830 cm/sec) so that V in the equation will be 40 ft/second (1220 cm/sec). This equates to 0.12 ft lbs/sec² an infinitesimal retarding force against the accelerating forces.

The parameters are chosen to ensure that the addition particles leave the nozzle at such a speed that they are projected through the bubbles of gas formed in the melt by the argon. If this were not the case
5 then the particles would be carried to the surface in the bubbles and be ejected from the surface when the bubbles burst at the surface and/or particles would conglomerate together and fume thus leading to uneven distribution of the addition in the melt.

10 The amount of argon leaving the lance is arranged so as to be the minimum necessary to prevent molten metal entering the nozzle whilst at the same time providing adequate acceleration to the addition particles.

The gas envelopes the addition particles during
15 its passage through the lance and into the metal and thus prevents oxidation of the lead particles until they are introduced substantially in the metal.

Although the particular case of argon and lead particles have been described hereinbefore if desired
20 the accelerating medium may be any suitable gas and whilst it will generally be an inert gas if for any particular metal or metal making operation a reactive gas is required then a reactive gas may be used. Also the process may be used to introduce any desired part-
25 iculate addition as hereindefined into any desired molten metal.

Although the invention has been described hereinbefore as applied in particular to a lance the nozzle of which is located adjacent the bottom of the bath, if
30 desired the lance may be utilised to introduce additives into the bath at any desired depth. Moreover,

the invention may be applied to an apparatus having an injection nozzle in the form of a port in the vessel in which the bath is maintained or an apparatus having an injection nozzle which is located, 5 in use, above the surface of the bath so that the particles are propelled through the surface of the metal at the top of the bath.

It will, of course, be appreciated that the argon pressure will in any case be above the ferrostatic 10 pressure obtaining at the nozzle location in any particular case.

If desired the metering means may be disposed at a location separate from the accelerating means.

As described previously the metering spool used 15 is chosen in accordance with the material to be added and the desired addition rate. Also as described previously the refractory material of the nozzle and the sleeves can be replaced conveniently as necessary as may be the inner tube 16 if its lower end becomes 20 damaged.

When the lance holder body and reservoir 13 have been assembled together as described hereinbefore they comprise a single unit which can be easily and conveniently attached to a manipulating device, such as the 25 arm 36 by the clamp 35.

By introducing the addition and inert gas into the bath simultaneously the bath is agitated and turbulence is set up in the bath and the addition is introduced into the turbulent region of the bath so that it 30 is distributed uniformly.

It is desirable to maintain the time for which addition is made as short as possible and hence it is desired to add the addition as rapidly as possible. It is considered that it might be possible to stop the inert gas addition as soon as the desired amount of addition has been made to the bath.

It should also be appreciated that the addition and fluid may be introduced through more than one nozzle at the same time and if desired additional or other fluid may be introduced through a separate nozzle at the same time as the addition is made.

The additions may be introduced into the bath by any desired means. The particles may be accelerated to the desired speed by any desired means including, for example, any mechanical projecting means or an explosive projecting means as well as that described hereinbefore using a venturi injector.

An apparatus according to the other aspect of the invention can be used to inject particles other than large dense particles. For example, particles of calcium carbide or calcium silicide.

Claims:

1. A method of making an addition of particulate material to a bath of molten metal comprising the step of directing large dense particles into the bath and character-
ised in the step of accelerating the particles of addition
5 material to a velocity of not less than 2200 cm/s prior to introduction into the bath.
2. A method according to Claim 1, wherein the addition and fluid are introduced through a nozzle (23) of a lance (11) immersed in the bath.
- 10 3. A method according to Claim 2, wherein the particulate material is accelerated by a gas to such a velocity that the particles pass through the bubbles of the gas formed in the bath.
- 15 4. A method according to anyone of the preceding claims wherein the particles are accelerated by a gas in an accelerating means (45) comprising a primary diverging passage (52) for the particulate material downstream of a restricted throat (51a) and at least one secondary
20 passage (57) for admitting secondary fluid to the diverging passage (52) so that, in use, as fluid under pressure enters the diverging passage (52) it expands and accelerates the particulate material.
- 25 5. A method according to Claim 4 wherein the longitudinal axis of the or each secondary passage (57) has a component extending in the direction of flow of the particulate material.
- 30 6. An apparatus for making an addition of particulate material to a bath of molten metal comprising a passage for the addition material, a discharge nozzle at one end of the passage, means to connect the other end

- of the passage ^{or} to a supply of addition, and means to connect a supply/fluid under pressure to the passage, characterised in that the internal configuration of the passage (50) is such that the addition material is accelerated, as a result of introduction of the fluid into the passage (50) to a velocity of not less than 2200 cm/s.
- 5
7. Apparatus according to Claim 6, wherein a nozzle (23) is located at the end of a lance (11) adapted, in use, to extend through the metal surface of a molten bath so that the particulate material is discharged from the nozzle (23) at a desired location within the bath.
- 10
8. Apparatus according to Claim 6 or 7, wherein the passage (50) is formed to provide accelerating means (45) comprising a primary diverging passage (52) for the particulate material downstream of a restricted throat (51a) and at least one secondary passage (57) for admitting secondary fluid to the diverging passage (52) at or downstream of the throat (51a) so that, in use, as fluid under pressure enters the diverging passage (52) it expands and accelerates the particulate material.
- 15
- 20
9. Apparatus according to Claim 8, wherein the longitudinal axis of the or each secondary passage (57) has a component extending in the direction of flow of the particulate material.
- 25
10. Apparatus according to Claim 7, or Claim 8 or Claim 9 when dependent upon Claim 7, wherein the addition material is supplied from a reservoir (13), fixed to the other end of the lance and the reservoir is a sealable pressure vessel provided with means (68) for connecting the interior of the vessel to a supply of inert gas, or other fluid under pressure.
- 30

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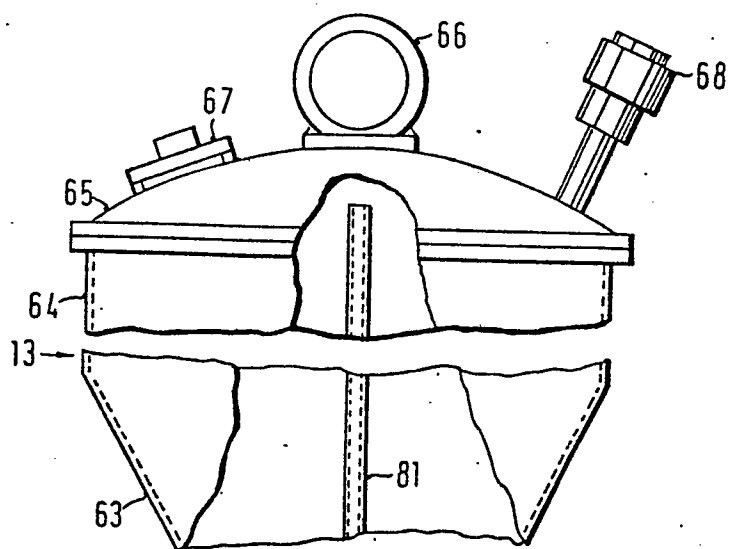


FIG. 1a

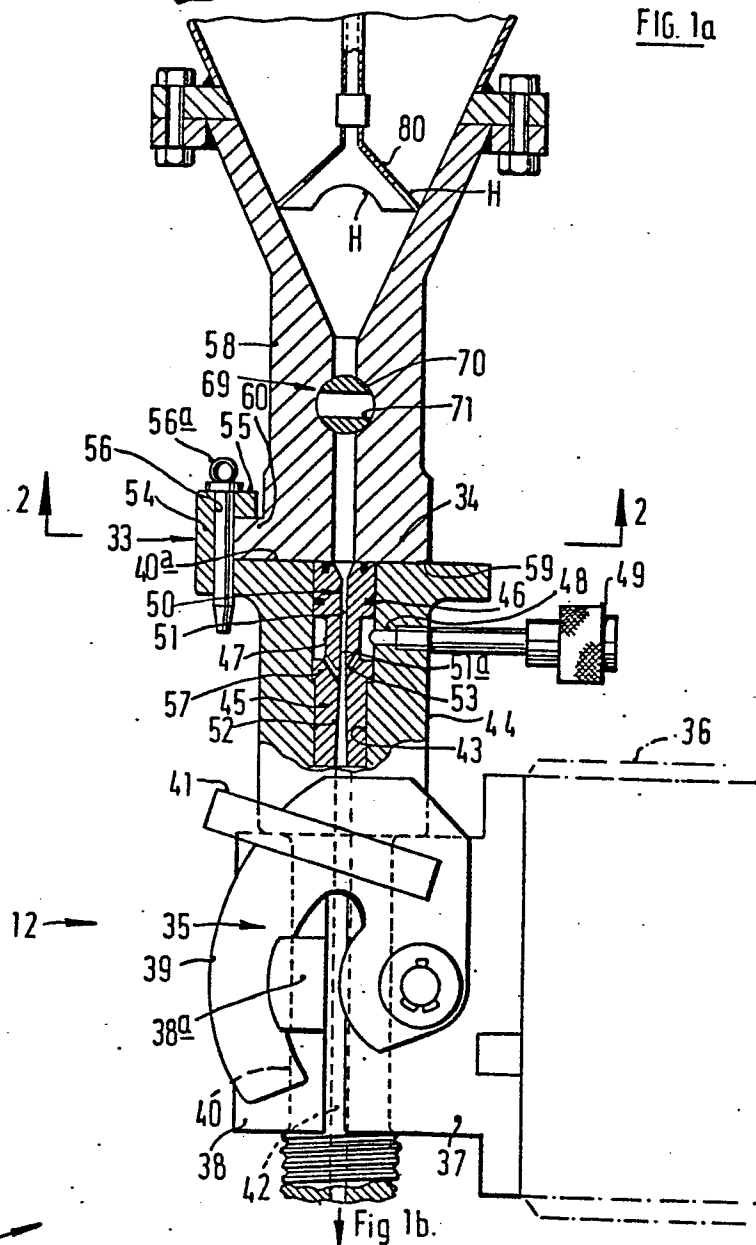
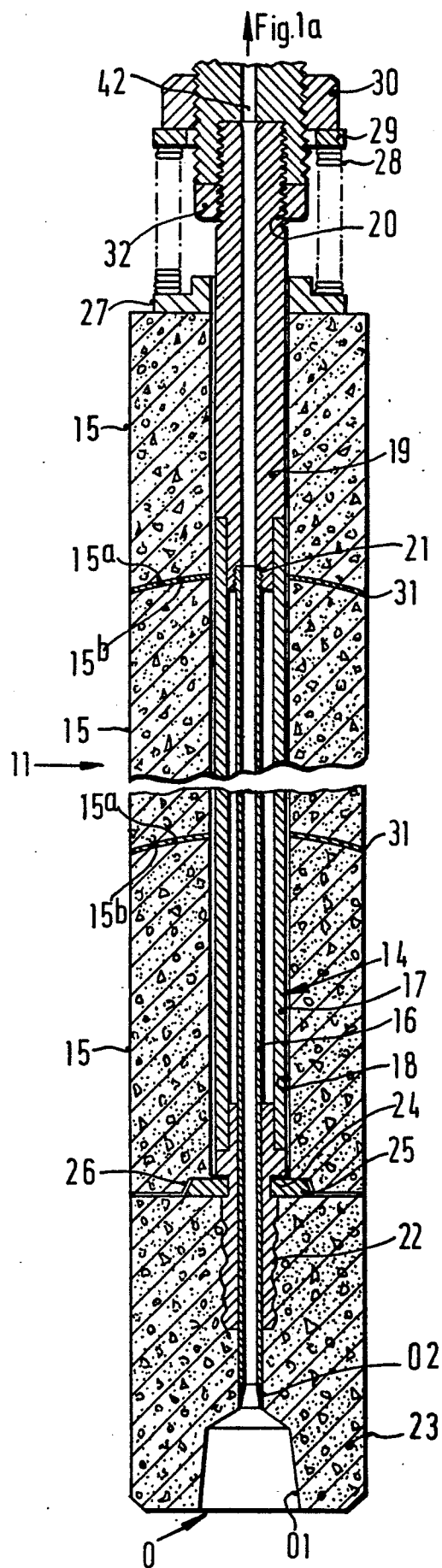


Fig 1b.



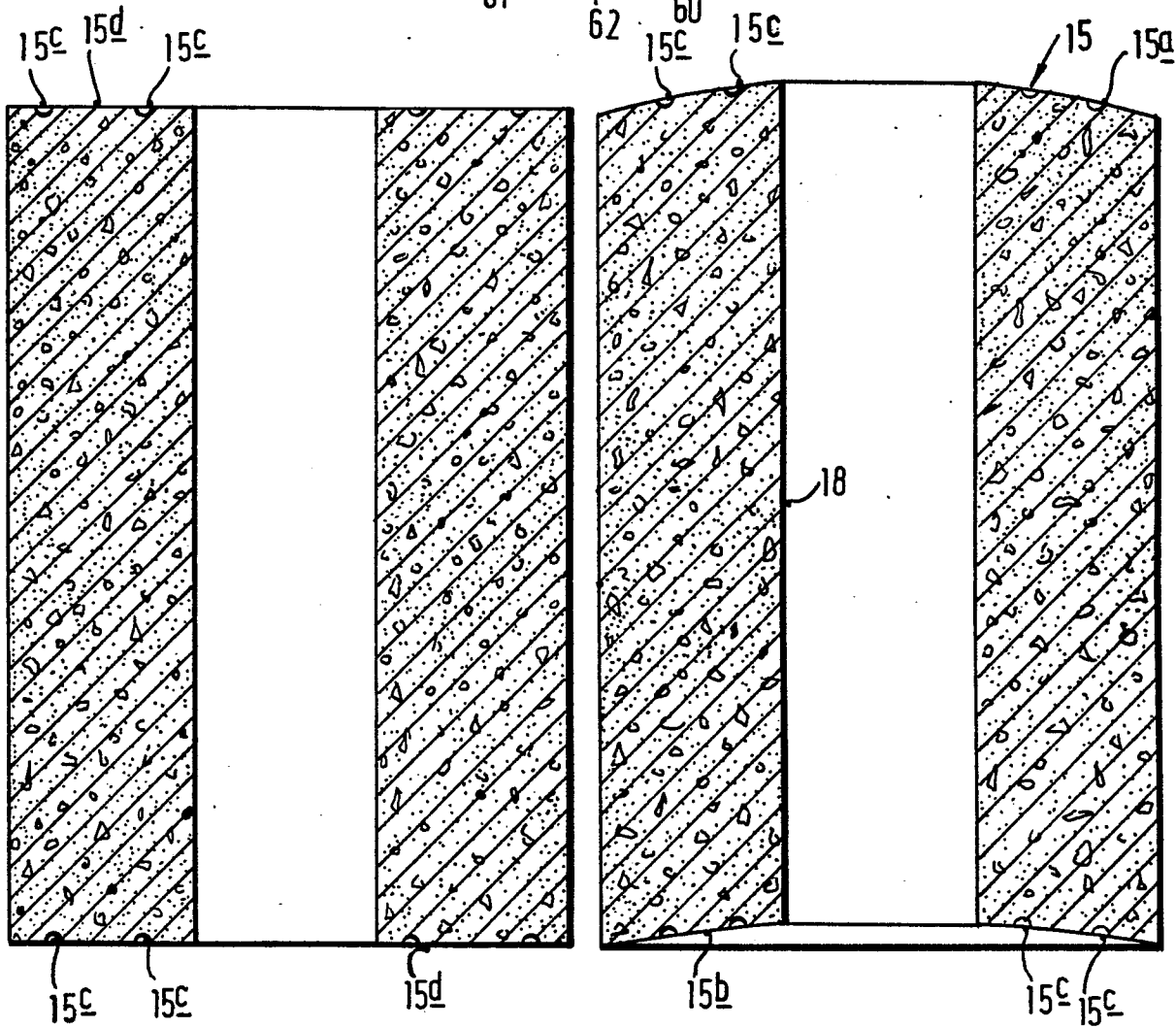
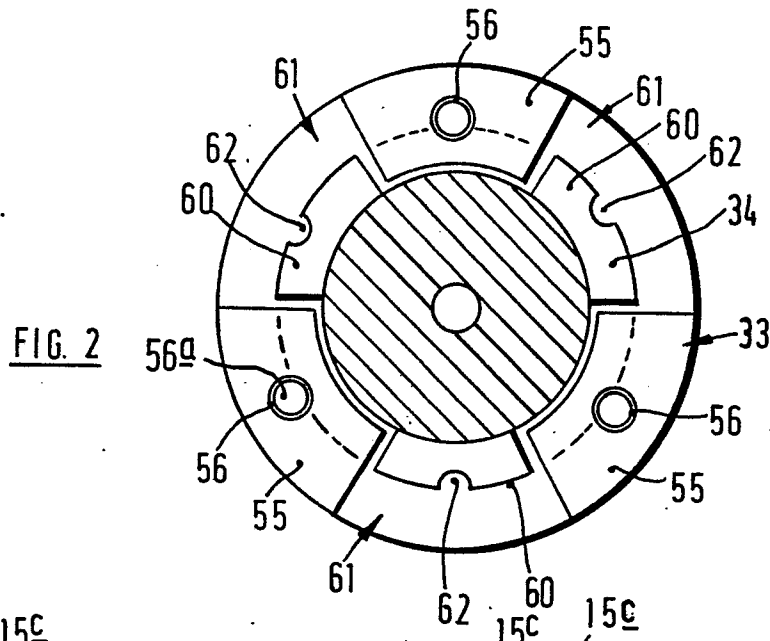
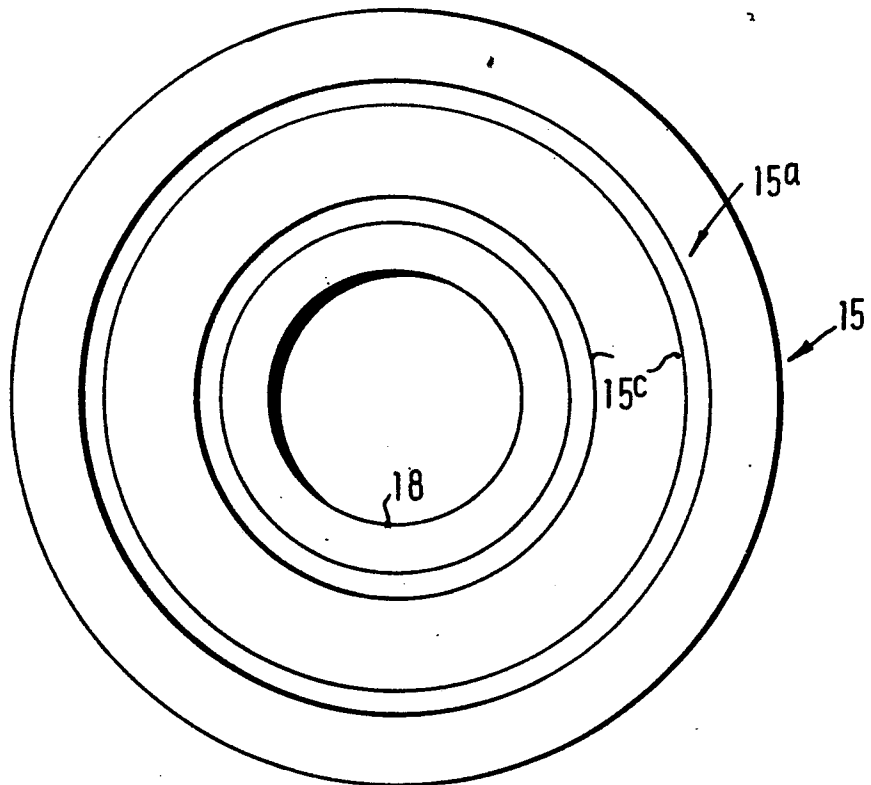
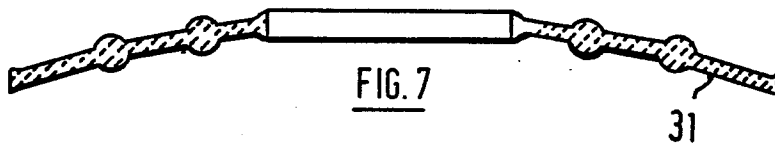


FIG. 4

FIG. 3

FIG. 5FIG. 6FIG. 7



European Patent
Office

EUROPEAN SEARCH REPORT

0015335
Application number

EP 79 300 372.4

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
D	<u>GB - A - 748 474</u> (AIR REDUCTION) * page 5 *	1	C 21 C 7/00 C 22 B 9/00

D	<u>US - A - 3 891 196</u> (THYSSEN) * fig. 1 and 3 *	6	

	<u>GB - A - 792 192</u> (LEDLOY) * page 4 *	1	

	<u>US - A - 3 141 767</u> (LUKENS STEEL) * column 3 *	1	C 21 C 7/00 C 22 B 9/00

	<u>DE - B - 1 583 967</u> (MAXHÜTTE) * column 4 *	1	

	<u>GB - A - 320 391</u> (PNEUMATIC CONVEYANCE & EXTRACTION) * fig. 1 *	6	

	<u>GB - A - 841 350</u> (PINTSCH BAMAG) * fig. 2 *	6	

	<u>GB - A - 1 031 578</u> (ALPINE MONTAN) * fig. 5 *	6	

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X	The present search report has been drawn up for all claims		TECHNICAL FIELDS SEARCHED (Int. Cl.)
			CATEGORY OF CITED DOCUMENTS
			X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
			&: member of the same patent family, corresponding document
Place of search Berlin		Date of completion of the search 15-11-1979	Examiner SUTOR