(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 150 226**
A1

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 83113078.6

(22) Date of filing: 23.12.83

(51) Int. Cl.⁴: **B 22 D 27/00**, B 22 D 1/00, B 22 D 21/02, B 22 D 5/04

(43) Date of publication of application: 07.08.85 Bulletin 85/32

(84) Designated Contracting States: BE DE FR IT NL

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(54) **Process and apparatus for minimizing foam formation during free falling of molten metal into moulds, launders or other containers.**

(57) A process for minimizing foam formation on the surface of molten metal which forms a foam during free falling of molten metal, such as molten zinc, into moulds, launders or other containers is disclosed. The process comprises maintaining the molten metal during free falling thereof under an essentially non-oxidizing atmosphere so as to prevent entrainment of sufficient oxygen into the molten metal by the falling stream to form an excessive amount of bubbles having a tenacious oxidized film and which do not collapse when they float to the surface of the molten metal but rather produce undesirable foam on the surface. The process is preferably carried out on a continuous casting machine by providing a cover plate mounted at a predetermined distance above the cover plate and having an aperture therein for casting molten metal. The cover plate extends before and after such aperture and has a predetermined number of gas inlet ports from feeding a non-oxidizing gas through the cover plate to progressively develop a non-oxidizing atmosphere in the container as they approach the aperture in the cover and to maintain such atmosphere in the containers as they pass the aperture.

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PROCESS AND APPARATUS FOR MINIMIZING FOAM FORMATION DURING FREE FALLING OF MOLTEN METAL INTO MOULDS, LAUNDERS OR OTHER CONTAINERS

This invention relates to a process for minimizing foam formation on the top surface of molten metal during pouring of the metal into moulds or similar containers, or during free falling of molten metal from a furnace to a launder, or cascading of the metal from launder to launder.

During pouring or free falling of molten metal, such as zinc, a considerable amount of foamed metal is formed on the top surface of the molten metal. This foam is normally skimmed off the surface of the molten metal manually. The task is arduous, requires workers to be in close proximity to molten metal and produces significant amounts of foamed metal which must be reclaimed.

Experiments carried out by the applicant during pouring of molten zinc into moulds have revealed that the formation of foam was due to the entrainment of air by the falling stream of molten metal. Hence air is transported below the molten metal surface to form air bubbles within the molten metal. Due to oxidation, a thin but tenacious zinc oxide film is formed on the inside surface of the bubbles. These bubbles rise to the surface and, as they emerge at the surface, it is observed that the outer surface of the bubbles is also oxidized and, in the case of large bubbles (approximately ½inch diameter), that part of the upper skin of the bubble may freeze immediately although the metal pool beneath it remained liquid for several minutes longer.

Having realized that the foam formed on top of the molten metal is due to the formation of a zinc oxide film on the surface of the bubbles, applicant investigated several methods by which the bubbles could be either released or prevented from forming. As a result of such investigation, applicant has discovered, in accordance with the invention, that foam formation may be minimized by maintaining the molten metal, during filling of the mould, or free falling of the molten metal into launders or other containers, under an essentially non-oxidizing atmosphere so as to prevent entrainment of sufficient oxygen into the molten metal by the falling stream to form an excessive amount of bubbles having a tenacious oxidized film and which do not collapse when they float to the surface of the molten metal but rather produce undesirable foam on such surface.

The non-oxidizing atmosphere is preferably provided by an inert gas, such as nitrogen, and it can contain a small quantity of oxygen, e.g. up to 2% without producing excessive quantities of bubbles.

The above disclosed method may be carried out by placing a cover on the top of the molten metal container, and by providing an aperture therein for passage of the molten metal and means for introducing a non-oxidizing gas under the cover.

The invention could also be carried out on a continuous slab casting machine comprising a train of closely spaced open top ingot moulds mounted on an endless conveyor chain by providing a hood over the casting machine at the filling station and introducing a non-oxidizing gas under the hood. Seals would be required at the hood entrance and exit as well as on the sides to prevent excessive loss of non-oxidizing gas. The hood would of course require a sealed opening for introducing the molten metal through one of the walls thereof.

The process is preferably carried out on a continuous casting machine by an apparatus which does not require the use of any seals. Such apparatus comprises a cover plate located at a predetermined distance above a number of containers or ingot moulds and having an aperture therein for casting molten metal in each container as they pass under the aperture. The cover plate extends a predetermined distance before and after such aperture and has a predetermined number of ports therein for feeding a non-oxidizing gas through the cover plate to progressively develop a non-oxidizing atmosphere in the containers as they approach the aperture in the cover plate and to maintain such atmosphere in the containers as they pass such aperture.

The entrance length of the cover plate before the mould filling aperture is necessary to progressively develop the required non-oxidizing atmosphere while the exit length of the cover plate is needed to maintain the required non-oxidizing atmosphere. The entrance length is determined by the conveyor line speed, the container volume, the container to cover gap and the influence of these factors on the volume of purging gas required to obtain the desired atmosphere. The exit length is determined by the pneumatic resistance required to prevent back flow of air into the container being filled.

At a conveyor line speed of 2 in/sec. and with 56 pounds ingot moulds, it has been found that oxygen levels less than 0.5% can be achieved with gaps up to 0.3 in and gas flowrates lower than 2000 SCFH, using a plate having a length equal to the width of five moulds (three before and two after the mould filling aperture).

The invention will now be disclosed by way of example with reference to the accompanying drawings in which:

Figure 1 is an apparatus used to carry out laboratory experiments with a fixed slab mould;

Figure 2 is an example of an apparatus used in the casting of molten metal into discrete moulds on a continuous ingot moulding machine;

Figure 3 is a view taken along line 3-3 of Figure 2;

Figure 4 is a view taken along line 4-4 of Figure 2;

Figure 5 is a graph illustrating the effect of varying gap dimension on oxygen level in mould atmosphere for a fixed nitrogen consumption;

Figure 6 is a graph illustrating the effect of varying nitrogen consumption on oxygen level in mould atmosphere for two different gap dimensions;

Figures 7 and 8 show mould refinements to reduce the gas flow requirement; and

Figure 9 shows another possible refinement which reduces gas flow but involves a non rubbing seal.

Referring to Figure 1, the laboratory apparatus comprises a bottom-pouring tundish 10 which is used to feed molten zinc into a slab mould 12 through a cover 14 closing the top of the mould. The bottom of the tundish is provided with an opening registering with a corresponding opening in the cover 14 and is sealed to the cover by any suitable means such as by welding. The opening in the bottom of the tundish is closed by a plug valve 16 which may be opened when it is desired to pour molten metal into the mould. The cover is sealed to the mould by '0' ring 18. A metered nitrogen inlet 20 and exhaust vent 22 are provided through the cover to maintain a suitable non-oxidizing atmosphere on the top surface of the mould.

A preliminary experimental procedure was carried out involving filling the tundish with molten zinc and then opening the valve to fill the mould. A fair amount of foam was formed on the top of the molten metal. The same procedure was repeated except that the covered mould was purged with nitrogen before opening the valve to fill the mould. The mould was uncovered soon after filling, before solidification to allow freezing of metal in air. No foam appeared on top of the molten metal.

A series of casting trials were carried out while varying the metal casting temperature and the concentration of oxygen in nitrogen. The effects of varying metal

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casting temperature were observed in the normal zinc casting temperature range of 440-530°C. Purging was carried out at gas flow rates of 20 l/min. for one minute with nitrogen atmospheres ranging from commercial purity to concentrations of 2% oxygen. Foam-free surfaces on slab ingots were obtained with concentrations of oxygen in nitrogen varying from 0 to about 2%. It was also observed that the effects of temperature and oxygen are interactive as far as the production of acceptable slab surfaces is concerned. The conditions which produce acceptable surfaces on slab ingots are summarized below:

(a) Commercially-pure nitrogen atmosphere at temperatures less than 450°C. These conditions produce a brilliant, crystalline surface which is visible through a fully transparent oxide film. At temperatures higher than 450°C the phenomenon commonly referred to as "colouration" in which colours ranging from straw to dark purple was observed.

(b) Oxygen concentrations of approximately 2% at temperatures in the range of 450-475°C. These conditions result in a smooth silvery oxide film at the ingot surface.

The invention may also be carried out on a continuous slab casting machine, such as the Sheppard casting machine which has a number of moulds mounted on an endless conveyor chain. On such mahcines, the non-oxidizing atmosphere may be provided by means of a hood surrounding the casting machine at the filling station. Molten metal would be fed from a furnace to a pouring ladle located inside the hood and from the pouring ladle into the moulds as they move past the filling station. A metered nitrogen inlet and exhaust vent would be provided through the hood to provide a non-oxidizing atmosphere in the hood. The nitrogen atmosphere within the hood must be maintained at a slight positive pressure such that the ambient oxidizing atmosphere outside the hood cannot enter the hood through the mould entrance and exit ports. However, seals would be required at the hood entrance and exit to prevent excessive loss of nitrogen gas.

Referring to Figure 2, there is shown a train of closely spaced open top ingot moulds 30 mounted on an endless conveyor chain 32 moving at a line speed of about 2 in/sec. in the direction indicated by arrow A. The ingot moulds all have flat top surfaces. A stationary cover plate 34 is mounted adjacent to but spaced by a predetermined distance D from the top surface of the moulds and covers a predetermined number of moulds before and after a metal pouring station which is mounted on the top of the cover plate. The metal pouring station is a conventional design comprising a launder 36 which ends with a downspout 38 used to feed molten metal into a ladle 40. The ladle 40 is intermittently pivoted to successively pour metal into each mould through a pouring slot 42 in the cover plate. A trap 44 is positioned at the end of the launder to capture dross which may be floating on the surface of the molten metal.

As shown in Figure 3, the cover plate 34 is provided with a predetermined number of gas inlet ports 46 and an inert gas is fed into such ports through a front manifold 48 and a main manifold 50. Inert gas is fed to the front mould entering under the plate through three gas inlet ports to rapidly purge the moulds, and to the remaining moulds under the plate through a single row of ports to progressively lower and maintain the oxygen level at the pouring station below a predetermined value. An auxiliary manifold 52 is also provided for feeding inert gas to the ladle enclosure 54 and the downspout enclosure 56. Cover strips 58 are placed on the gaps between the moulds so as to prevent excessive leakage of gas through such gaps.

As shown in Figure 4, the width of the plate 34 is equal to that of moulds 30. Inert gas enters the moulds at gas ports 46 and flows out through the gaps at the sides and the ends of the cover plate. The width of the cover as well as the width of the container with respect to the container cavity are dependent on the pneumatic resistance required to prevent back flow of air into the moulds.

It has been found that by controlling the length of the cover plate 34, the number and location of gas emission ports, the gas flow rate and the gap between the moulds and the cover plate, a desired inert atmosphere can be maintained below the pouring slot 42 without having to use contacting seals. To facilitate investigation of the gas inlet port spacing, gap dimension and inert gas (nitrogen) flow rate, an apparatus was designed in the laboratory to simulate a conventional casting machine. The number of gas inlet ports in the cover plate was set so that, at any time there was a minimum of three and a maximum of four gas ports above a traversing mould. The length of the cover plate was such that at any time five moulds (three before and two after pouring slot 22) were located under the cover plate.

The tests were carried out by establishing a predetermined nitrogen flow rate through the cover plate and then traversing the moulds past the cover plate at the same speed as a conventional casting machine conveyor (2 in/sec.). Each mould was progressively purged as it entered under the cover plate. The mould atmosphere was sampled in the centre of the mould by pumping a sample to an oxygen analyser as the mould approached the pouring slot.

Experiments were carried out to determine the oxygen concentration in the mould atmosphere (a) at varying mould to cover gap dimensions and constant nitrogen flow rates and (b) at varying nitrogen flow rates and constant gap dimension. The results of these trials are presented in Figures 5 and 6. The front manifold flowrate in the test shown in Figure 5 was about 200 SCFH and the main manifold flowrate was about 1500 SCFH.

In the test shown in Figure 6, the front manifold flowrate was fixed at about 200 SCFH and the main manifold flowrate was varied from 500 to 3000 SCFH.

The results of the tests presented in Figure 5 revealed that the oxygen level increased very rapidly for gap dimensions greater than 0.25 in. More importantly, this curve illustrates that less than 0.5% oxygen can be achieved with gaps up to 0.3 in with economically feasible gas consumption ($\sim$2000 SCFH). The effect of varying nitrogen consumption on the oxygen level in the mould atmosphere is illustrated in Figure 6 for two different gap dimensions of 0.10 and 0.125 in. From these curves, it is evident that no gain is achieved by increasing atmosphere usage beyond 2000 SCFH and that acceptable oxygen levels are easily obtained with very low (1000 SCFH) gas consumption. The gap heights of 0.10 and 0.125 in. used in these tests are practical values which can be achieved and maintained on present casting machines. Closer tolerances, which should be aimed for in the design of future casting machines can result in less than 0.1% oxygen with economical usage.

Following completion of the above pilot plant tests, equipment such as shown in Figure 2 was installed on a slab ingot casting machine at Canadian Electrolytic Zinc Limited, Valleyfield, Quebec, Canada to demonstrate, under plant production conditions, that skimming-free slabs can be produced by pouring liquid zinc in a nitrogen atmosphere.

Atmosphere tests were initially carried out with the machine in operation but without pouring liquid metal. These tests indicated that oxygen levels could be maintained at the pouring station in the range of 0.3-0.5% and that no gain could be achieved by increasing the nitrogen flow rate above 2000 SCFH.

Liquid zinc was then started up with preheating flames on the launder and ladle. Nitrogen was first delivered at 250 SCFH to the front manifold and at 1500 SCFH to the main manifold of the cover plate and successively to the ladle and downspout enclosures at 250 SCFH. The oxygen level maintained at the pouring station was in the range of 0.35-0.45%.

Major reduction in the foam floating on cast slabs was observed even before start-up procedures were completed. Total absence of foam was achieved when the closure and purging of the ladle and launder enclosures were completed.

The slab ingot surfaces were seen to be bright and dross-free. Transparent oxide films identical to those obtained in the laboratory tests using oxygen levels in the range of 0.2-0.5% were observed on the slabs.

Figures 7, 8 and 9 show refinements to reduce loss of gas in between the moulds and so reduce the gas flow requirements. In Figure 7, the edges of the moulds are thicker than that shown in Figure 2 and this increases the resistance to gas flow in the gap 60 between the moulds. In Figure 8, the edges of the moulds are designed so that the gap 62 is horizontal in order to prevent direct flow of the gas from the cover ports. This design is in a way equivalent to the cover strips 58 of Figure 2 but is much more resistant to wear and tear. Figure 9 shows another method of reducing gas flow which involves the use of a seal 64 in between the moulds. This alternative is possible since this seal is non rubbing.

Although the method in accordance with the present invention has been disclosed in association with a specific apparatus, it is to be understood that it could be carried out by other apparatus including various types of continuous casting machines and that the process is not limited to carrying out the invention with the apparatus disclosed.

CLAIMS

1. A process for minimizing foam formation on the surface of molten metal which forms a foam during free falling of the molten metal into moulds, launders or other containers, so as to eliminate the need for skimming, which comprises maintaining said molten metal during free falling thereof under an essentially non-oxidizing atmosphere so as to prevent entrainment of sufficient oxygen into the molten metal by the falling stream to form an excessive amount of bubbles having a tenacious oxidized film and which do not collapse when they float to the surface of the molten metal but rather produce undesirable foam on said surface.

2. A process as defined in claim 1 wherein said non-oxidizing atmosphere is an inert gas atmosphere.

3. A process as defined in claim 2, wherein the inert gas is nitrogen.

4. A process as defined in claim 1, 2 or 3, wherein the non-oxidizing atmosphere contains a small quantity of oxygen.

5. A process as defined in claim 1, 2 or 3, wherein the molten metal is zinc.

6. An apparatus for minimizing foam formation on the surface of molten metal which form foam during free falling of molten metal into moulds, launders or other containers so as to eliminate the need for skimming, which comprises means for maintaining said molten metal during free falling thereof under an essentially non-oxidizing atmosphere so as to prevent entrainment

of sufficient oxygen into the molten metal by the falling stream to form an excessive amount of bubbles having a tenacious oxidized film and which do not collapse when they float to the surface of the molten metal but rather produce undesirable foam on said surface.

7. An apparatus as defined in claim 6, wherein said means for maintaining the molten metal under a non-oxidizing atmosphere is a cover closing the top of the molten metal container and having an opening for the passage of molten metal and means for introducing a non-oxidizing gas under the cover.

8. An apparatus as defined in claim 6, used on a continuous casting machine comprising a train of closely spaced open top containers mounted on an endless conveyor chain wherein said means for maintaining the molten metal under a non-oxidizing atmosphere is a hood enclosing a number of containers and having an opening for introducing the molten metal through one of the walls of the hood for filling the containers and means for introducing a non-oxidizing gas under the hood.

9. An apparatus as defined in claim 6, used on a continuous casting machine comprising a train of closely spaced open top containers mounted on an endless conveyor chain, wherein said means for maintaining the molten metal under a non-oxidizing atmosphere is a cover plate located at a predetermined distance above a number of said containers and having an aperture therein for casting molten metal in each container as they pass under the aperture, said cover plate extending a predetermined distance before and

after said aperture and having a predetermined number of ports therein for feeding a non-oxidizing gas through the cover plate to progressively develop a non-oxidizing atmosphere in the containers as they approach the aperture in the cover plate and to maintain said atmosphere in the containers as they pass through said aperture.

10. An apparatus as defined in claim 9, wherein said atmosphere is an inert atmosphere.

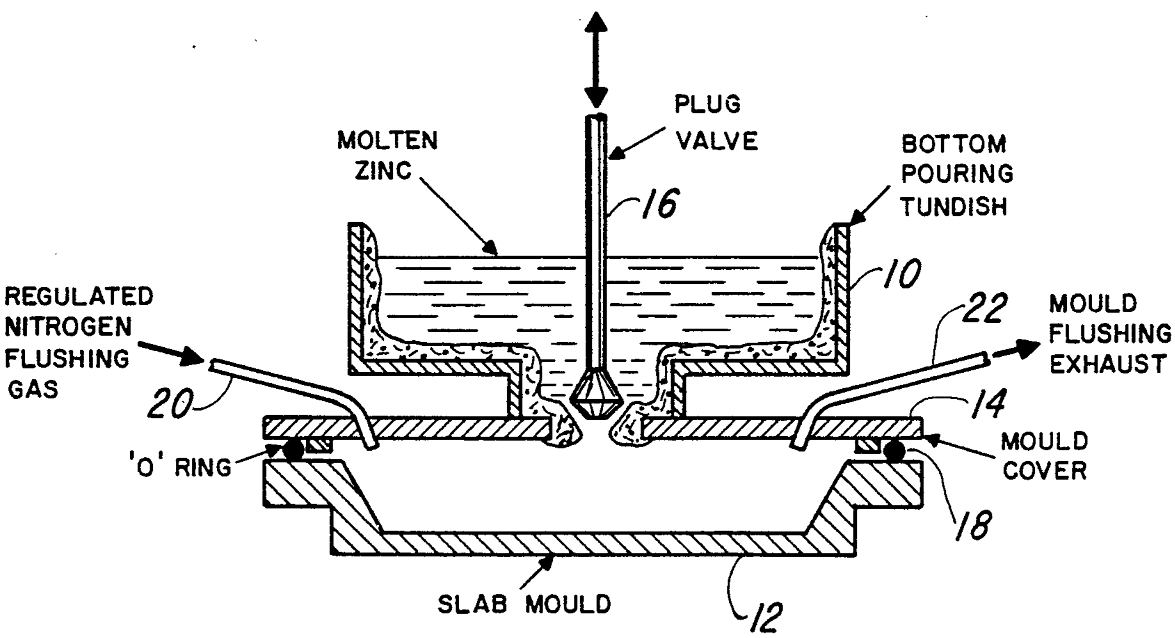
PLUG VALVE
MOLTEN ZINC
BOTTOM POURING TUNDISH
16
10
REGULATED NITROGEN FLUSHING GAS
22
MOULD FLUSHING EXHAUST
20
14
'O' RING
MOULD COVER
18
SLAB MOULD
12

Fig. 1

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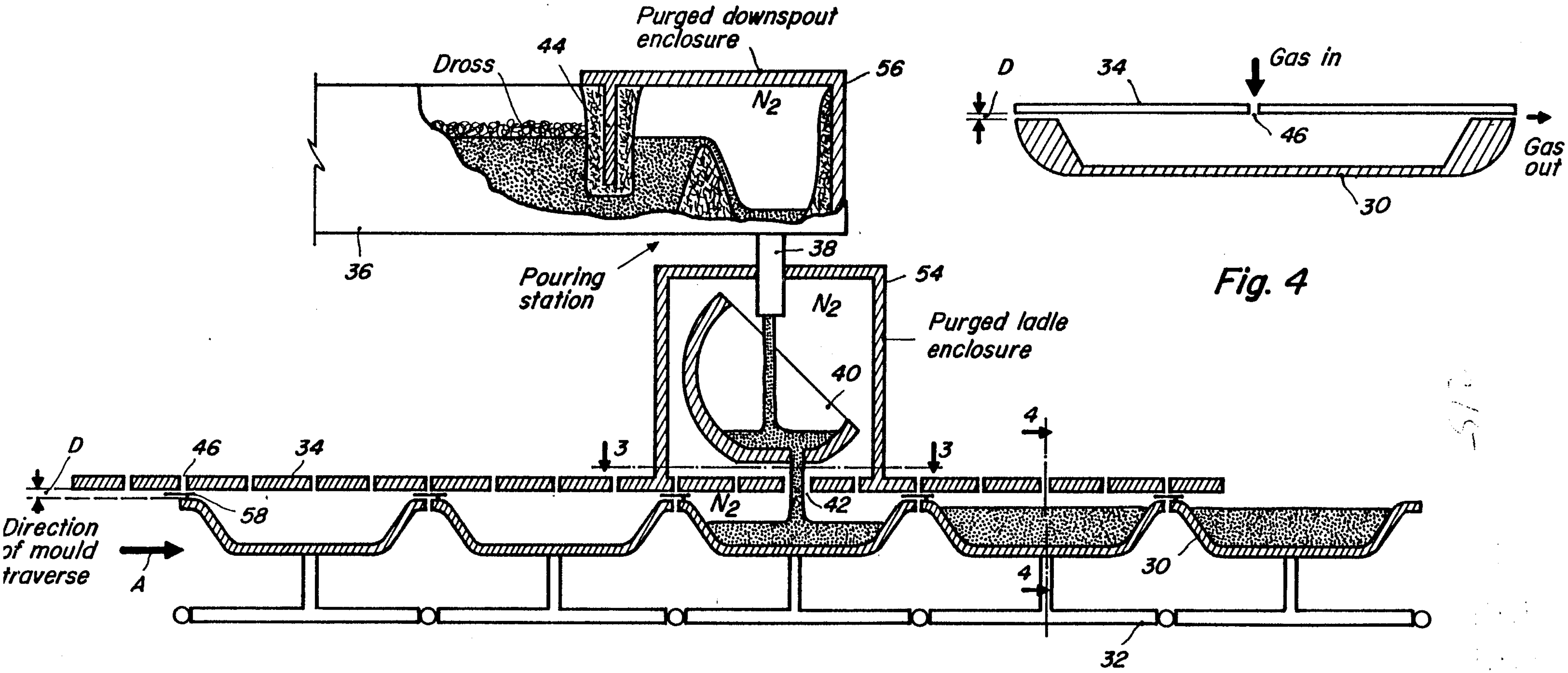
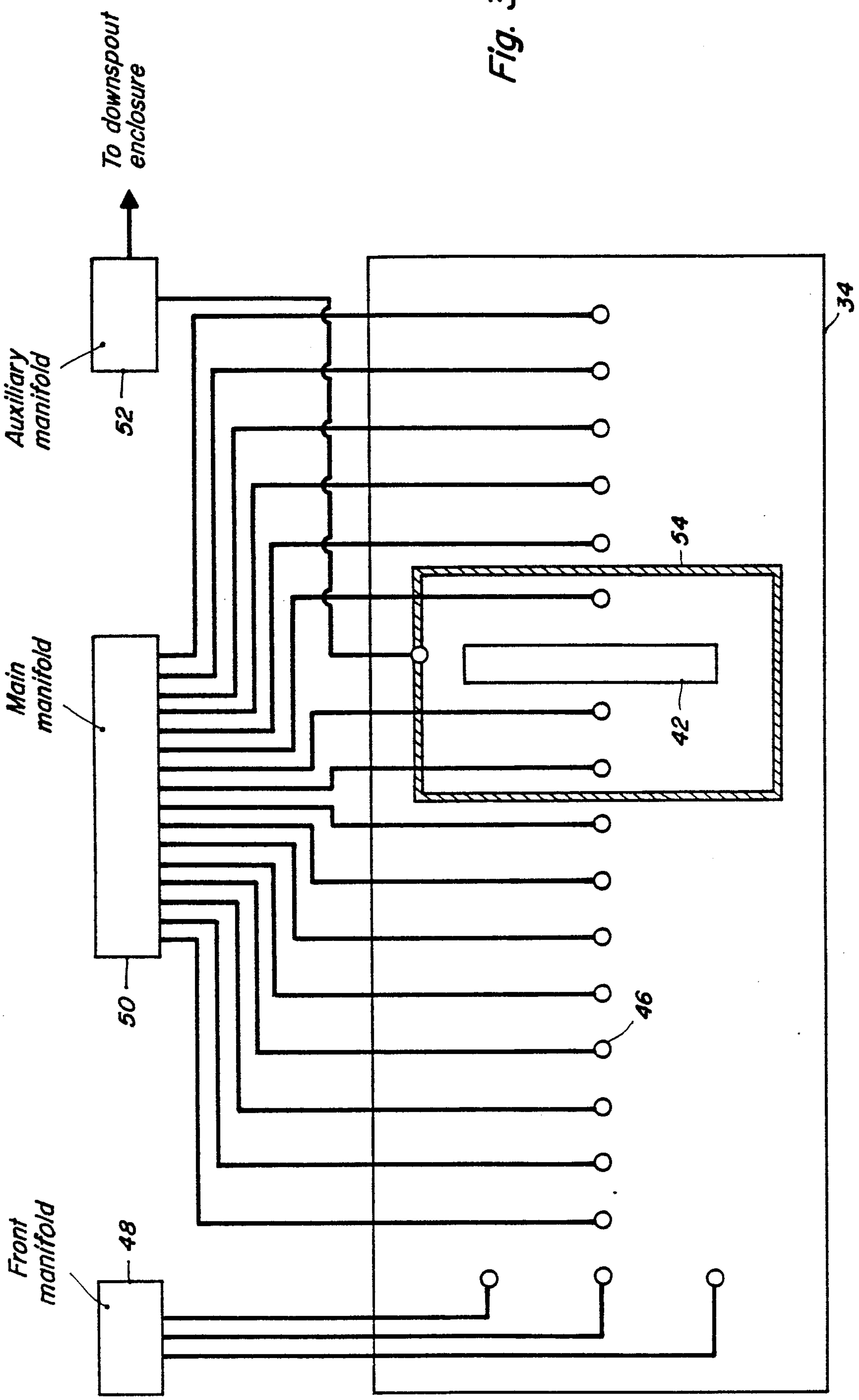


Fig. 2

Fig. 4



To downspout enclosure
Auxiliary manifold
52
Main manifold
50
Front manifold
48
34
54
42
46

Fig. 3

4/5

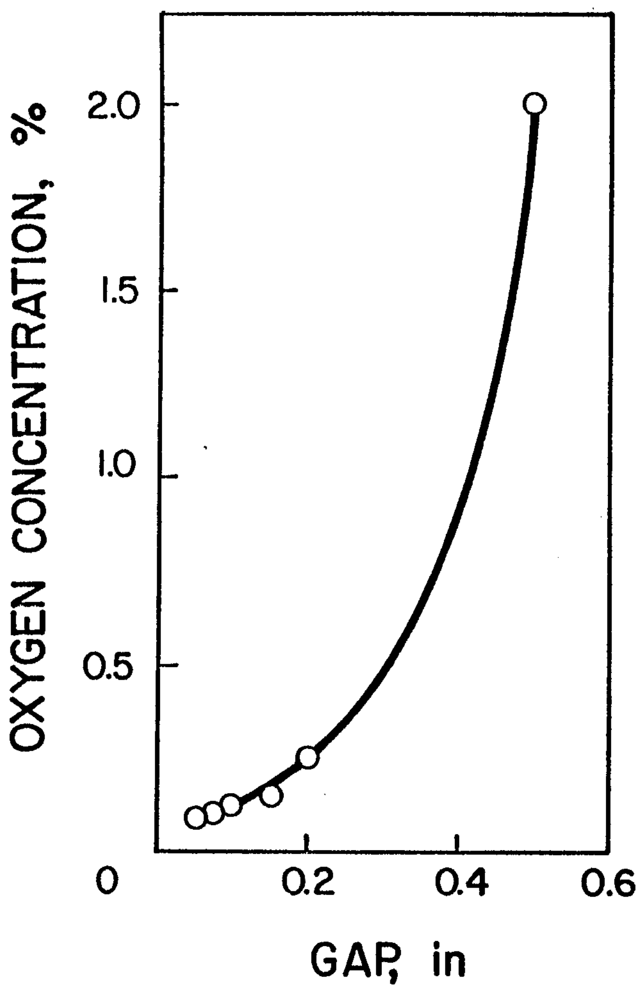

OXYGEN CONCENTRATION, %
2.0
1.5
1.0
0.5
0
0.2
0.4
0.6
GAP, in

Fig. 5

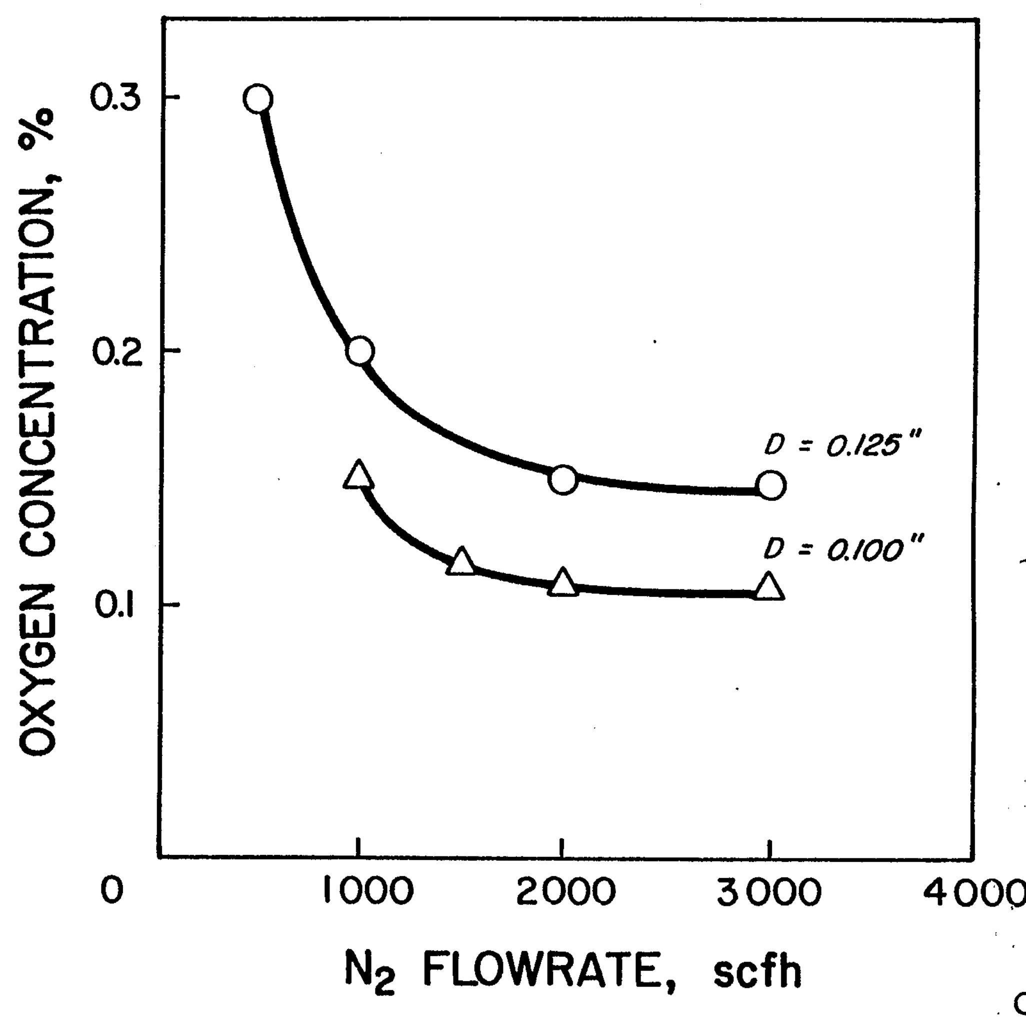

OXYGEN CONCENTRATION, %
0.3
0.2
0.1
0
1000
2000
3000
4000
D = 0.125"
D = 0.100"
N2 FLOWRATE, scfh

Fig. 6

515

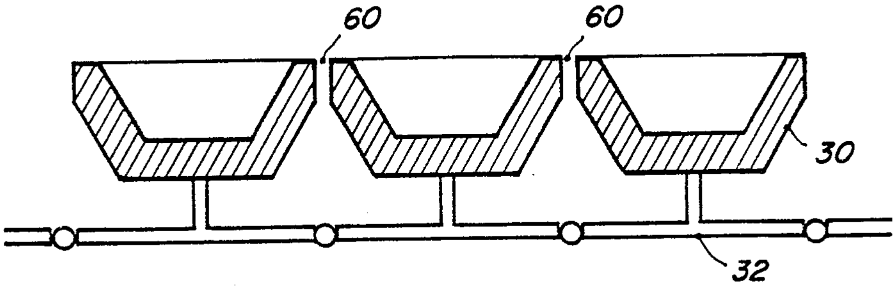


Fig. 7

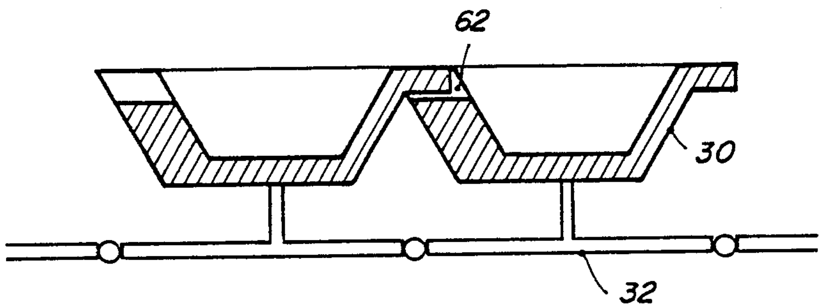


Fig. 8

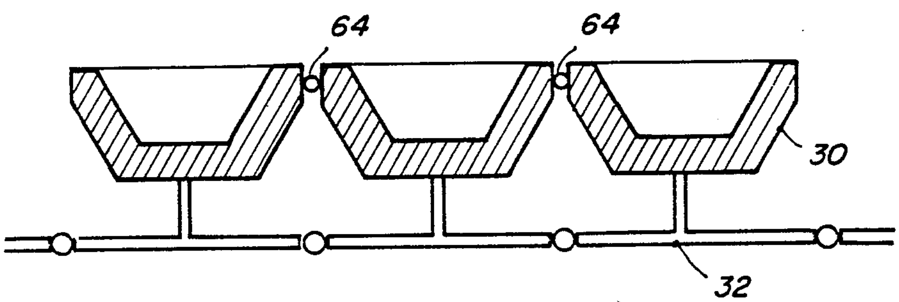


Fig. 9

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EUROPEAN SEARCH REPORT

0150226

Application number

EP 83 11 3078

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
			B 22 D 27/00 B 22 D 1/00 B 22 D 21/02 B 22 D 5/04
X	EP-A-0 088 701 (L'AIR LIQUIDE) * Abstract; page 3, lines 31-37; page 4, lines 1-37; page 5, lines 1-21; figures 1,2; page 6, lines 14-19 * ---	1-9	
X	US-A-2 099 208 (W.H.D. HORSFALL) * Page 1, right-hand column, lines 15-55; page 2, left-hand column, lines 1-40; figures 1-3,6 * -----	1,2,6, 7,8	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			B 22 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23-08-1984	MAILLIARD A.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document