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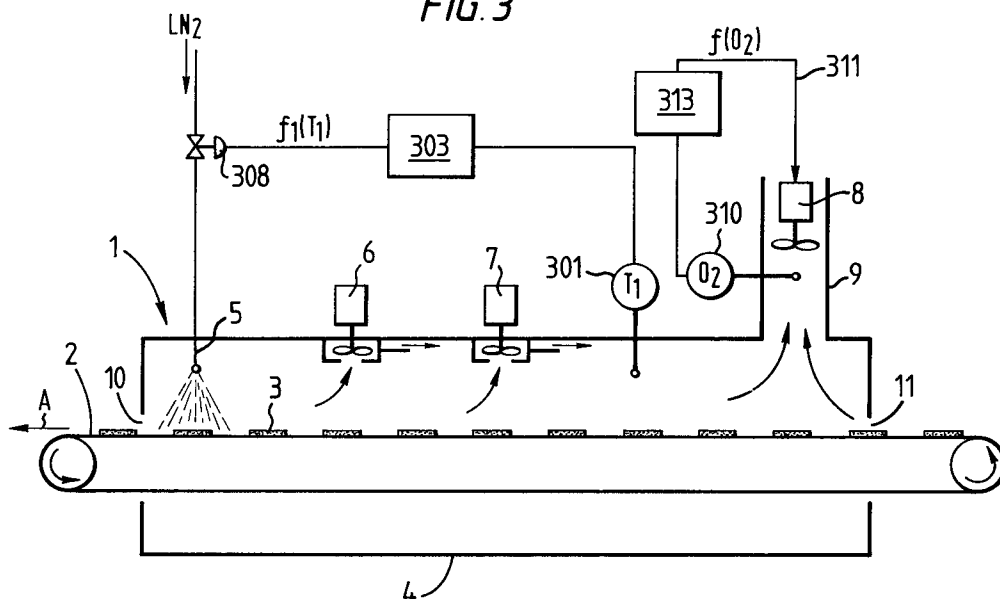
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(57) A control system for a tunnel freezer (1) comprises an oxygen sensor (310) mounted in an exhaust duct (9) and arranged to control the speed of a fan (8). The temperature in the tunnel (4) is deter-

mined by controlling the flow of liquid nitrogen through inlet pipe (5) via a control valve (308) which is controlled in response to the signal from a temperature sensor (301).

FIG. 3**EP 0 583 692 A1**

This invention relates to a freezer.

Many foodstuffs are commercially frozen by liquid nitrogen in tunnel freezers. The liquid nitrogen, which is at -196°C , rapidly cools the foodstuffs whilst substantially preserving their colour, flavour and appearance.

One of the problems associated with the use of liquid nitrogen is that its vapour is asphyxiating and consequently it is necessary to ensure that nitrogen vapour does not enter the workplace around the tunnel freezer. For this purpose tunnel freezers are provided with an exhaust duct and an exhaust fan for sucking nitrogen out of the tunnel freezer and venting it into the atmosphere remote from the workplace.

Ideally, the amount of gaseous nitrogen vented should exactly correspond to the amount of liquid nitrogen introduced into the tunnel freezer. However, in practice, in the interest of safety, the exhaust fan is operated so that all the nitrogen resulting from the vaporization of the liquid nitrogen is vented together with a small volume of air which is inevitably drawn into the freezer.

Control of the exhaust fan is important to both the safety and the economics of the process. Under-extraction could result in an asphyxiating atmosphere whilst over-extraction will result in excess air being drawn into the tunnel freezer via the product inlet and outlet thereby increasing thermal load from the cooling of the air and depositing frost from the water vapour in the air within the freezer. In extreme conditions this frost can build up to prevent efficient operation of the freezer, necessitating a lengthy defrost before freezing can be resumed.

At the present time there are two types of control system in use and these and their disadvantages are discussed hereinafter with reference to Figures 1 and 2 of the drawings.

The present invention, at least in its preferred embodiments, aims to overcome or at least reduce the problems associated with the prior art.

EP-A-0 159 858 is primarily concerned with determining the consumption of cryogenic fluid in a freezer. The specification contains a reference to controlling the speed of the exhaust fan as a function of the concentration of oxygen in the exhaust duct. However, there is no indication as to how such a modification would be implemented in an overall control system.

According to the present invention there is provided a freezer comprising a freezing section, an inlet for the admission of cryogenic fluid to said freezing section, an exhaust duct for conveying vapour from said freezing section, an exhaust fan for extracting vapour from said freezing section through said exhaust duct, and a control system for controlling the flow of cryogenic fluid through said

inlet and the flow of vapour through said exhaust duct, characterized in that said control system comprises

(a) a temperature sensor for producing a first signal indicative of the temperature in said freezing section,

(b) means responsive to said first signal to control the flow of cryogenic fluid through said inlet;

(c) a gas sensor for producing a second signal indicative of the concentration of a gas in said exhaust duct, and

(d) means responsive to said second signal to control the flow of vapour through said exhaust duct;

the arrangement being such that in use, the volume of cryogenic fluid admitted to said freezing section is determined by said temperature sensor and the volume of vapour extracted from said freezing section is controlled by said gas sensor.

Advantageously, said means responsive to said second signal to control the flow of vapour through said exhaust duct is arranged to vary at least one of:

(a) the speed of said exhaust fan;

(b) the pitch of the blades of said exhaust fan; and

(c) the closure of a member obstructing flow through said exhaust duct.

Preferably, said gas sensor is an oxygen sensor.

Whilst the present invention is applicable to all freezers which use a liquid cryogen for freezing it is particularly applicable to freezers in which the freezing section is a tunnel having a conveyor extending through openings at opposite ends thereof.

Preferably, said freezing section comprises at least one circulation fan for blowing cryogenic fluid towards said exhaust duct, a second gas sensor for sensing the concentration of gas adjacent the opening remote from said exhaust duct, and means responsive to said second gas sensor to vary the output of said circulation fan.

Advantageously, said second gas sensor is disposed outside said freezing section.

For a better understanding of the invention reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is a schematic diagram showing a freezer with one known control system;

Figure 2 is a schematic diagram showing a freezer with another known control system;

Figure 3 is a schematic diagram showing a freezer in accordance with the invention; and

Figure 4 is a schematic diagram showing a further refinement of the control system of the freezer shown in Figure 3.

In the accompanying drawings, the same reference numerals have been used to identify parts having similar functions in the various embodiments.

Referring to Figure 1, there is shown a conventional tunnel freezer which is generally identified by reference numeral 1.

The tunnel freezer 1 comprises a conveyor 2 which carries hamburgers 3 (or other items to be frozen) in the direction of arrow A.

Liquid nitrogen is introduced into the tunnel 4 through a spray bar via an inlet pipe 5 and heat transfer between the cold evaporating nitrogen and the hamburgers 3 is enhanced by scroll fans 6, 7 which suck the cold evaporating nitrogen (which tends to settle in the bottom of the tunnel 4) upwardly and blow it horizontally in counter-current flow to the hamburgers 3.

An exhaust fan 8 withdraws nitrogen vapour from the tunnel 4 and exhausts it through the roof of the factory via an exhaust duct 9.

The flow through the exhaust duct 9 is important. If it is too low then nitrogen will escape through the openings 10, 11 at either end of the tunnel 4. A build-up of nitrogen in this area could result in asphyxiation of staff and is thus unacceptable. On the other hand, if the flow through the exhaust duct 9 is too high nitrogen will be wasted and, more importantly, air will enter the tunnel 4 through the openings 10, 11. The moisture in this air will condense and freeze in the tunnel 4 and will continue to build up on the inside of the tunnel 4 and scroll fans 6 and 7 and exhaust fan 8 progressively impairing the efficiency of the tunnel 4.

At the present time there are two control systems in use.

Turning first to Figure 1, a first temperature sensor 101 is located in the tunnel 4 and a second temperature sensor 102 is located in the exhaust duct 9. In operation, the signals from the two temperature sensors 101, 102 are compared in a control unit 103 and a signal 104 is generated which is a function of the difference between the temperatures at the two temperature sensors 101, 102. This signal 104 is then used to control the speed of the exhaust fan 8 in the exhaust duct 9. The object of the control system is to ensure that the difference in temperature between the two temperature sensors 101, 102 is maintained at a constant, predetermined level.

The underlying principle behind this control system is that in order to ensure that nitrogen does not escape into the workplace the exhaust fan 8 is operated so that there is a small steady flow of air 105 into the tunnel 4 through the opening 11. The air 105 mixes with nitrogen vapour 106 and the mixture passes up the exhaust duct 9 where the temperature of the mixture is sensed by second

temperature sensor 102.

The temperature at the temperature sensor 101 is kept substantially constant by varying the supply of liquid nitrogen through inlet pipe 5 to the spray bar through control valve 108 in accordance with the temperature sensed at temperature sensor 101. Accordingly, the difference in temperature between the temperature sensors 102 and 101 is considered a measure of the proportion of air passing through the opening 11.

When the ambient air and the hamburgers entering the tunnel freezer 1 are at the same temperature, or at similar temperatures this control system works quite acceptably.

The disadvantages of this arrangement are that the two temperature sensors 101, 102 (and particularly the temperature sensor 102) are sensitive to ice build-up. In addition problems arise if the product entering the tunnel 1 is hot. In particular, the flow of product to a freezing tunnel is rarely uniform. As a hot product, for example a hot hamburger 104 enters the tunnel 4 through opening 11 it heats the local atmosphere which is sucked up through exhaust duct 9 raising the temperature at temperature sensor 102. The control system interprets this influx of heat as indicating a high proportion of air and reacts by reducing the speed of the exhaust fan 8 in an attempt to lower the temperature at temperature sensor 102 and thus restore the preset temperature differential. It can clearly be seen that this response may result in excess nitrogen passing through openings 10, 11 into the area surrounding the tunnel freezer 1. It should perhaps be emphasised that whilst the signal 104 could easily be compensated for a steady supply of hot items problems arise because the supply of product is rarely steady and, in practice, excess nitrogen is vented through exhaust duct 9.

Turning now to the control system shown in Figure 2, the temperature at a temperature sensor 201 is measured and a signal transmitter to a control unit 203. A signal 207 is then sent to the control valve 208 to open or close the control valve 208 with a view to maintaining the temperature at the temperature sensor 201 substantially constant. At the same time a signal 209 is sent to exhaust fan 8 to vary the speed of the exhaust fan 8 as a function of the liquid nitrogen entering the tunnel freezer 1.

This arrangement also has disadvantages. In particular, in most commercial installations there is an appreciable length of insulated pipe between the source of liquid nitrogen and the spray bar. According to the consumption of liquid nitrogen the quality of the liquid nitrogen immediately upstream of the spray bar may vary from all liquid to nearly all vapour. However, the setting of the control valve 208 does not take into account the quality of the

cryogen. Thus, the refrigeration for a given valve opening can differ substantially. However, the speed of the exhaust fan 8 is fixed for a given valve opening.

In a further refinement, shown in dotted lines, control unit 203 also regulates the speed of scroll fans 6 and 7 to blow the nitrogen from the spray bar towards the exhaust duct 9.

Turning now to Figure 3, an oxygen sensor is disposed in the exhaust duct 9 upstream of the exhaust fan 8. The signal from oxygen sensor 310 is transmitted to control unit 313 which generates a signal 311 which controls the exhaust fan 8 so that the concentration of oxygen at the oxygen sensor 310 is at a constant predetermined level.

The flow of liquid nitrogen to the tunnel freezer 1 is controlled in response to the temperature sensed by temperature sensor 301. In particular, the temperature sensor 301 generates a signal representative of the temperature at the temperature sensor 301. The signal is then sent to a control unit 303 which opens and closes control valve 308 with the aim of maintaining the temperature at temperature sensor 301 constant at a predetermined level.

In operation, it will be assumed that the tunnel freezer 1 is in equilibrium with a steady stream of liquid nitrogen being dispensed from the spray bar to maintain a steady temperature at temperature sensor 301. The exhaust fan 8 is operating at a steady speed and a small amount of air is being drawn in through opening 11 so that the concentration of oxygen at the oxygen sensor 310 is about 10.5% (by volume).

If extra hot hamburgers, or plates of pre-prepared meals are introduced into the tunnel 4 through opening 11 this has no effect on the exhaust fan 8 since the oxygen content at oxygen sensor 310 remains unaltered.

As the hot hamburgers pass temperature sensor 301 the temperature rises indicating an increased heat load. Control unit 303 opens valve 308 to admit more liquid nitrogen through the inlet pipe 5 to the spray bar. As the liquid nitrogen vaporizes it expands and has the effect of inhibiting the flow of air into the tunnel 4 through the opening 11. This causes the concentration of oxygen detected by oxygen sensor 310 to fall and control unit 313 to generate a signal 311 to increase the speed of exhaust fan 8 until sufficient air is sucked through opening 11 to return the concentration of oxygen at oxygen sensor 310 to its desired level.

If the heat load decreases the signal from temperature sensor 301 causes control unit 303 to close control valve 308. As the flow of liquid nitrogen through spray bar 5 decreases the volume of nitrogen travelling along the tunnel 4 decreases. As a consequence more air is sucked in through open-

ing 11 and the concentration of oxygen at oxygen sensor 310 rises. The signal from oxygen sensor 310 is processed by control unit 313 which lowers the speed of the exhaust fan 8 until the oxygen concentration at oxygen sensor 310 returns to its desired level.

It will be noted that the speed of the exhaust fan 8 is independent of the setting of control valve 308 which reduces the problems associated with the prior art.

Turning now to Figure 4 there is shown a refinement of the arrangement shown in Figure 3. In particular, in addition to the parts shown in Figure 3, a second oxygen sensor 410 is disposed between the opening 10 and the spray bar. The oxygen sensor 410 transmits a signal to a control unit 411 which controls the speed of scroll fans 6 and 7 to maintain the concentration of oxygen at the oxygen sensor 410 substantially constant.

Various modifications to the embodiments described with reference to Figures 3 and 4 are envisaged. For example, whilst an oxygen sensor is preferred, a nitrogen sensor could also be used. If desired, the oxygen sensor 410 in Figure 4 could be disposed in the vicinity of the opening 10 outside of the tunnel 4. In such an embodiment the speed of the scroll fans 6 and 7 would be increased if excess nitrogen was detected in the atmosphere.

Although the speed of the exhaust fan 8 is varied to control the flow through the exhaust duct 9 various alternatives are available, for example the pitch of the blades of the fan could be varied. Alternatively, the speed of the exhaust fan 8 could be kept constant and the effective diameter of the exhaust duct varied by, for example varying the setting of a butterfly valve or a variable shutter in the exhaust duct 9.

Claims

1. A freezer comprising a freezing section (4), an inlet (5) for the admission of cryogenic fluid to said freezing section (4), an exhaust duct (9) for conveying vapour from said freezing section (4), an exhaust fan (8) for extracting vapour from said freezing section (4) through said exhaust duct (9), and a control system for controlling the flow of cryogenic fluid through said inlet (5) and the flow of vapour through said exhaust duct (9), characterized in that said control system comprises:-

- (a) a temperature sensor (301) for producing a first signal indicative of the temperature in said freezing section (4),
- (b) means (308) responsive to said first signal to control the flow of cryogenic fluid through said inlet (5);

(c) a gas sensor (310) for producing a second signal indicative of the concentration of a gas in said exhaust duct (9), and

(d) means (8) responsive to said second signal to control the flow of vapour through said exhaust duct (9);

the arrangement being such that in use, the volume of cryogenic fluid admitted to said freezing section (4) is determined by said temperature sensor (301) and the volume of vapour extracted from said freezing section (4) is controlled by said gas sensor (310).

2. A freezer as claimed in Claim 1, characterized in that said means responsive to said second signal to control the flow of vapour through said exhaust duct (9) is arranged to vary at least one of:
 - (a) the speed of said exhaust fan (8);
 - (b) the pitch of the blades of said exhaust fan (9); and
 - (c) the closure of a member obstructing flow through said exhaust duct (9).
3. A freezer as claimed in Claim 1 or 2, characterized in that said gas sensor (310) is an oxygen sensor.
4. A freezer as claimed in Claim 1 or 2, characterized in that said freezing section is a tunnel (4) having a conveyor extending through openings (10, 11) at opposite ends thereof.
5. A freezer as claimed in Claim 4, characterized in that said freezing section (4) comprises at least one circulation fan (6,7) for blowing cryogenic fluid towards said exhaust duct (9), a second gas sensor (410) for sensing the concentration of gas adjacent the opening (10) remote from said exhaust duct (9), and means responsive to said second gas sensor (410) to vary the output of said circulation fan (6,7).
6. A freezer as claimed in Claim 5, characterized in that said second gas sensor (310) is disposed outside said freezing section (4).

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FIG. 1

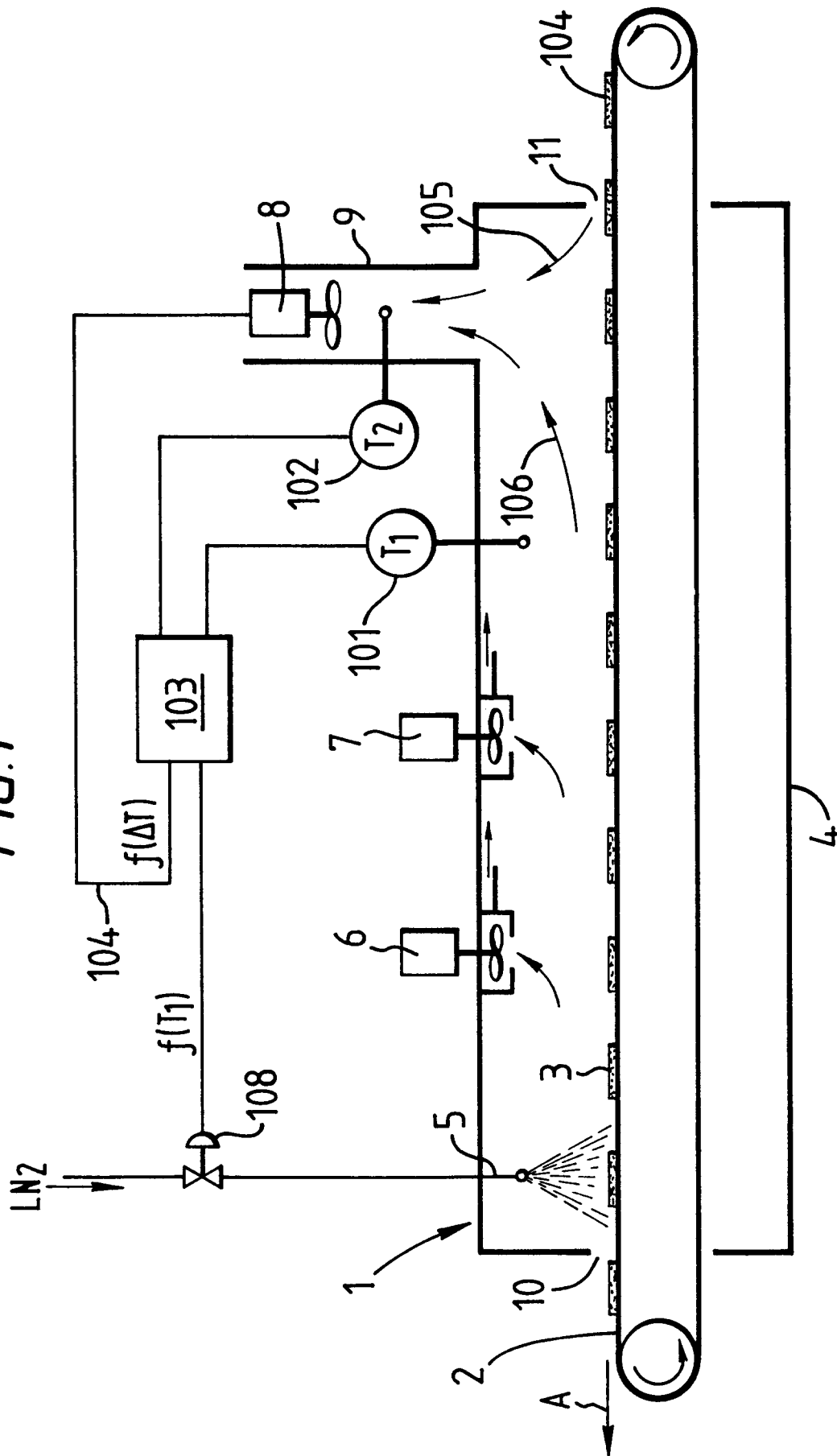


FIG. 2

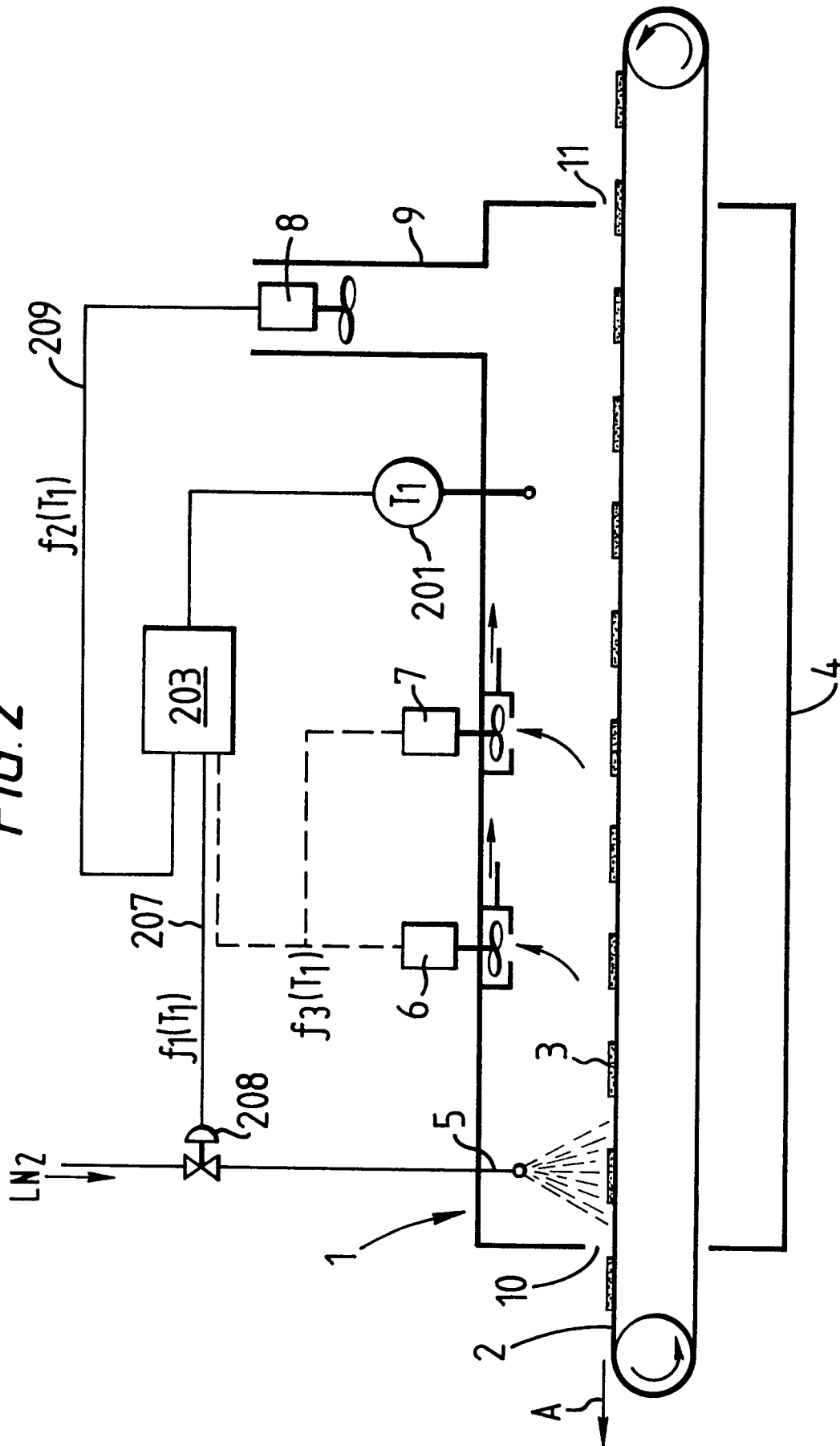
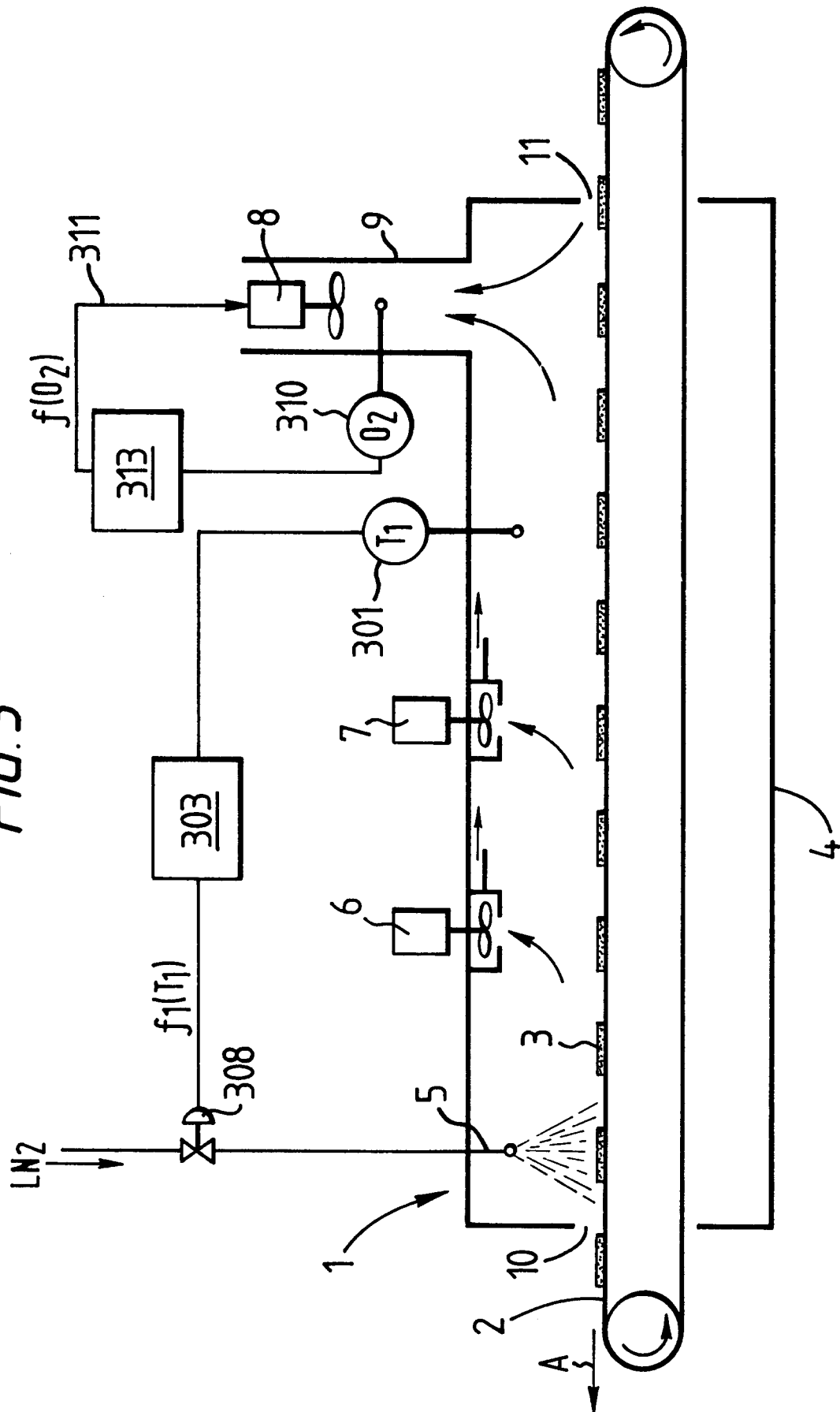


FIG. 3





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EUROPEAN SEARCH REPORT

Application Number
EP 93 11 2539

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.5)
Y	US-A-4 627 244 (WILLHOFT)	1	F25D29/00
A	* column 3, line 38 - line 68; figure *	2-4	F25D3/11
D	& EP-A-0 159 858 (WILLHOFT)		

Y	US-A-3 277 657 (HARPER)	1	
A	* column 3, line 55 - column 10, line 59; figures 1-9 *	2,4	

A	US-A-4 276 753 (SANDBERG)	1,4	
	* column 3, line 16 - column 7, line 62; figures 1-3 *		

A	US-A-4 142 376 (SANDBERG)	1,4	
	* column 3, line 29 - column 12, line 34; figures 1-3 *		

A	US-A-4 955 206 (LANG)	5	
	* column 5, line 14 - column 18, line 22; figures 1-15 *		

A	US-A-3 728 869 (SCHMIDT)		TECHNICAL FIELDS SEARCHED (Int.Cl.5)

A	US-A-3 892 104 (KLEE)		F25D

A	US-A-4 800 728 (KLEE)		

The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		10 December 1993	Boets, A
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone		T : theory or principle underlying the invention	
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