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(72) Inventors:
• **Torti, Alessandro**
27100 Pavia (IT)
• **Del Ponte, Roberto**
20123 Milano (IT)

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(74) Representative: **Modiano, Guido, Dr.-Ing. et al**
Modiano & Associati SpA
Via Meravigli, 16
20123 Milano (IT)

(71) Applicant: **Apt Engineering S.r.l.**
27100 Pavia (IT)

(54) **Method and apparatus for reducing the consequences of a fire in a tunnel**

(57) A method and an apparatus for reducing the consequences of a fire in a tunnel, the method consisting in generating, inside the tunnel (3), a wall (2) of non-flammable liquid upstream of a region affected by a fire and a wall (2) of non-flammable liquid downstream of the region. The walls of non-flammable liquid are ar-

ranged transversely to the longitudinal extension of the tunnel (3) and are adapted to prevent or substantially limit the spreading of the fumes, gases and heat produced by the fire to the regions that are contiguous to the region affected by the fire. The walls (2) of non-flammable liquid can be crossed by people fleeing the region affected by the fire.

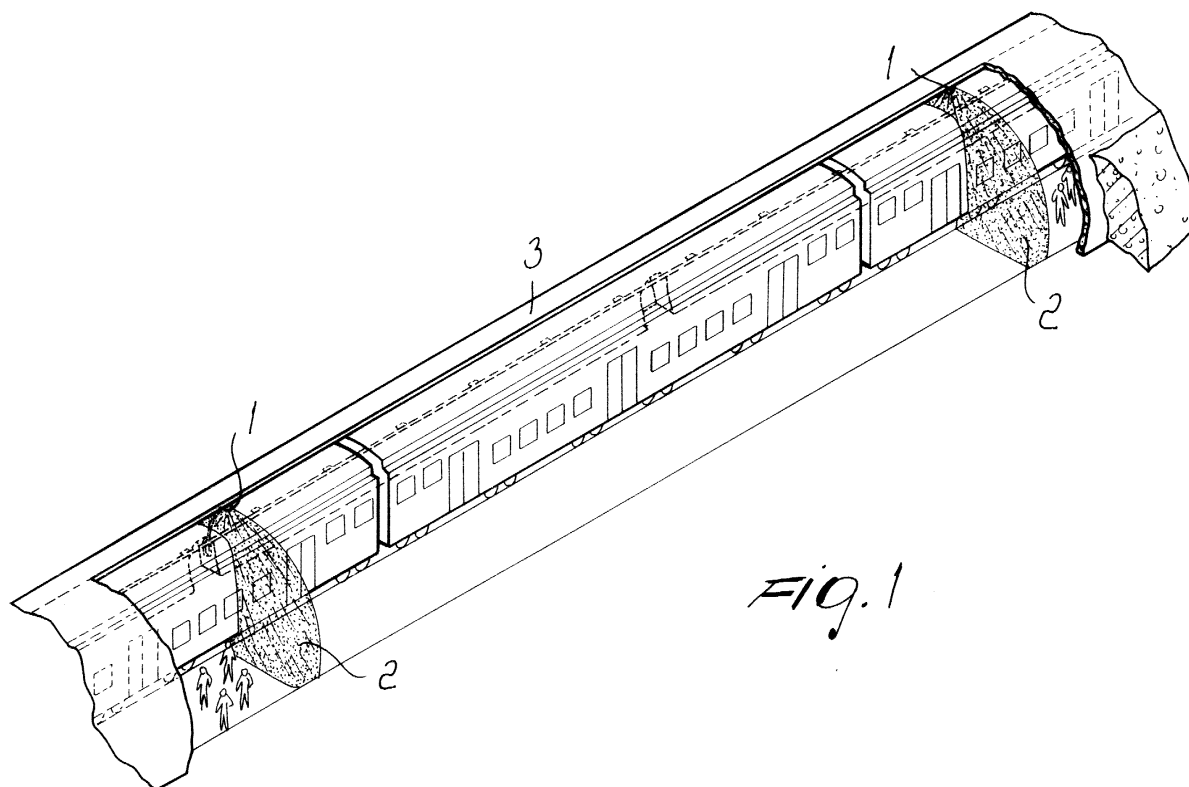


Fig. 1

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Description

[0001] The present invention relates to a method and an apparatus for reducing the consequences of a fire in a tunnel.

[0002] The problem of a fire in a road or railroad tunnel is not an extremely rare event and owing to the severity of its consequences it has always been an important factor in the design and operational definition of transportation systems.

[0003] The preventative measures and the emergency procedures that have long been used to limit the consequences of a fire in a tunnel have often proved to be insufficient due to various problems, the most important of which are summarized hereafter.

[0004] Generally, the amount of flammable material affected by the fire cannot be known in advance and limited.

[0005] The starting point of the fire is difficult to determine and even more difficult to predict.

[0006] The people involved usually have neither experience nor training regarding how to proceed in case of fire and can react inadequately and unpredictably due to the panic caused by the occurrence of a fire.

[0007] The temperature increases and the concentrations of toxic gases, even a short time after the beginning of the event and especially in the vicinity of the region affected by the fire, can be considerable and such as to make the environment inside the tunnel unlivable.

[0008] The parameters linked to visibility can reach in a few minutes, especially depending on the type and amount of fuel that is present, values which make any rescue action difficult or even impossible, even at a considerable distance from the point of origin of the fire.

[0009] The aim of the present invention is to solve the above problems by providing a method and an apparatus which allow to reduce the consequences of a fire in a tunnel.

[0010] Within this aim, an object of the present invention is to propose a method and an apparatus which allow to evacuate people from the region affected by the fire, limiting as much as possible the spreading of the fumes, gases and heat produced by the fire to the regions that are contiguous to the region affected by the fire.

[0011] Another object of the invention is to propose a method and an apparatus which, by limiting the diffusion of the fumes, gases and heat to the regions that are contiguous to the region affected by the fire, allow easier and more prompt fire-fighting operations.

[0012] Another object of the invention is to provide a method and an apparatus which can limit injury to people during evacuation.

[0013] Another object of the invention is to propose a method and an apparatus which can be adopted even in tunnels of considerable length and even in the absence of ventilation stacks or ducts.

[0014] This aim and these and other objects which will

become better apparent hereinafter are achieved by a method for reducing the consequences of a fire in a tunnel, characterized in that it consists in generating, inside the tunnel, a wall of non-flammable liquid upstream of a region affected by the fire and a wall of non-flammable liquid downstream of said region, said walls being arranged transversely to the longitudinal extension of the tunnel and being adapted to prevent or substantially limit the spreading of the fumes, gases and heat produced by the fire to the regions that are contiguous to the region affected by the fire, people fleeing the region affected by the fire being able to pass through said walls.

[0015] The method according to the invention is preferably performed by means of an apparatus comprising means for dispensing a non-flammable liquid which are suitable to generate walls of non-flammable liquid which lie on planes which are transverse with respect to the longitudinal extension of the tunnel, said dispensing means being mutually spaced along the longitudinal extension of the tunnel, means for feeding a non-flammable liquid to said dispensing means being provided which can be activated on command according to the location of a fire along the tunnel.

[0016] Further characteristics and advantages of the invention will become better apparent from the following detailed description of a preferred but not exclusive embodiment of the method according to the invention and of the apparatus for performing it, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

Figure 1 is a schematic perspective cutout view of a tunnel provided with the apparatus according to the invention;

Figure 2 is an enlarged-scale sectional view of the tunnel of Figure 1, taken along a vertical plane at one of the means for dispensing a non-flammable liquid;

Figure 3 is an enlarged-scale view of a detail of Figure 2;

Figure 4 is a side elevation view of the same detail of Figure 3;

Figure 5 is a schematic view of the means for feeding a non-flammable liquid for the dispensing means.

[0017] With reference to the figures, the apparatus for performing the method according to the invention comprises means 1 for dispensing a non-flammable liquid which are adapted to generate, with said non-flammable liquid, walls 2 which are arranged on planes which lie transversely to the longitudinal extension of the tunnel 3. The dispensing means 1 are mutually spaced along the longitudinal extension of the tunnel 3 and there are means, generally designated by the reference numeral 4, for feeding the non-flammable liquid to the dispensing means 1 which can be activated on command according to the location of a fire along the tunnel 3. More partic-

ularly, the feeder means 4 comprise at least one feed duct 5 for the non-flammable liquid, and said feed duct 5 runs longitudinally along the tunnel 3. Branches 6 are provided along the extension of the feed duct 5, at intervals of preset length, and connect the feed duct 5 to the dispensing means 1. Along each branch 6 there is a valve 7 which can be controlled remotely in order to provide or interrupt on command the connection of the feed duct 5 to the dispensing means 1 that is connected to the branch 6.

[0018] Each one of the dispensing means 1, as shown in particular in Figures 3 and 4, comprises a dispenser 8 which is connected to the corresponding branch 6 and is arranged proximate to the top of the tunnel 3. The dispenser 8 is provided with an outlet 8a whose dispensing direction is substantially parallel to the longitudinal extension of the tunnel 3; said outlet faces a substantially flat screen 9 which is arranged substantially at right angles to the longitudinal extension of the tunnel 3 so as to convert the jet of liquid that is dispensed by the outlet 8a into a liquid wall which is arranged on a plane which is substantially perpendicular to the longitudinal extension of the tunnel 3.

[0019] The feed duct 5 is connected to the delivery duct of at least one pump which propels the non-flammable liquid along the feed duct 5.

[0020] Preferably, for safety reasons, there is an electrically-powered pump 10 and an emergency pump 11 which is powered by an internal-combustion engine. Both of said pumps 10 and 11 are connected, by means of their delivery duct, to the feed duct 5 and can be actuated alternately with respect to each other.

[0021] In addition to these pumps there is also a compensation pump 12 which is operated electrically and is meant to keep under pressure the non-flammable liquid in the feed duct 5.

[0022] The pumps 10, 11 and 12 are connected in parallel, by means of their delivery duct, to the feed duct 5.

[0023] The non-flammable liquid can be simply constituted by water or by water mixed with flame-extinguishing substances, such as for example the product known commercially by the trademark "Bioversal".

[0024] In this case, the apparatus comprises a device 13 for mixing water and flame-extinguishing substances which is connected to the feed duct 5.

[0025] Depending on whether a water distribution system is available or not, the pumps 10, 11, 12 can be connected, by means of their intake duct, directly to the water distribution system, if it is available, or to one or more water storage reservoirs 14.

[0026] The apparatus further comprises detection means for monitoring the inside of the tunnel 3, which are meant to indicate the starting point of a fire along the tunnel 3.

[0027] The detection means can be simply constituted by conventional sensors which are arranged, so as to be appropriately spaced from each other, along the longitudinal extension of the tunnel 3 and are adapted

to promptly detect the start of a fire in the region that they cover.

[0028] The detection means can also comprise television cameras capable of constantly monitoring the entire longitudinal extension of the tunnel 3 in order to indicate the exact location of the region where a fire is developing to an operator or to an automatic control apparatus, such as for example a computer, which can drive the valves 7.

[0029] The apparatus for performing the method according to the invention can also comprise means for detecting wind direction and speed which are located proximate to the inlets of the tunnel 3.

[0030] The operation of the apparatus in performing the method according to the invention is as follows.

[0031] Preferably, in the inactive condition, the feed duct 5 is already full of non-flammable liquid, which is kept pressurized by the pump 12, and the valves 7, of the normally-open type, are closed.

[0032] The beginning of a fire along the longitudinal extension of the tunnel 3 is immediately detected by the above-cited detection means, which transmit the information to the operator or to the automatic control apparatus. In addition to providing the fire start information, the detection means also provide the indication of the exact location of the starting point of the fire or at least the location of the starting region of the fire located between two contiguous dispensing means 1.

[0033] The operator or the automatic apparatus opens the valves 7 located on the branches 6 of the two dispensing means 1 that are located respectively directly upstream and directly downstream of the region affected by the fire. The opening of the valves 7 causes a sudden drop in the pressure in the feed duct 5, and said pressure drop causes the activation of the pump 10 or 11. In this manner, the two activated dispensing means 1 generate, upstream and downstream of the region affected by the fire, respective walls 2 of non-flammable liquid. The liquid walls 2 constitute barriers which effectively contrast the propagation of fumes, gases and heat from the region affected by the fire to the contiguous regions.

[0034] The liquid walls 2, however, can be crossed by people fleeing from the region affected by the fire who can thus move away from the region affected by the fire without suffering, or suffering to a much lesser extent, the effects of the fumes, gas and heat produced by the fire.

[0035] The non-flammable liquid dispensed by the dispensers 8 also effectively has a cooling action and begins to extinguish the source of the fire.

[0036] Owing to the fact that the liquid walls 2 constitute a barrier to the diffusion of the fumes, gas and heat, the regions of the tunnel that are contiguous to the region at which the fire has occurred can be accessed by the rescue teams that have the task of putting out the fire.

[0037] The operator who monitors the inside of the

tunnel, during the fire, can also direct, by means of appropriate loudspeakers installed inside the tunnel, people toward the most appropriate direction of escape, also taking into account the direction and speed of the wind reported by the detectors located at the inlets of the tunnel.

[0038] In practice it has been observed that the method and the apparatus according to the invention fully achieve the intended aim and objects, since by limiting the diffusion of the fumes, gases and heat to the regions of the tunnel that are contiguous to the region where the fire has developed, they allow people to abandon the region affected by the fire, protecting them from the damaging effects of the fumes, gas and heat and maintaining for a sufficient time, inside the tunnel, conditions which are adapted to allow the intervention of rescue teams.

[0039] The method and the apparatus thus conceived are susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept; all the details may furthermore be replaced with other technically equivalent elements.

[0040] In practice, the materials employed, so long as they are compatible with the specific use, as well as the dimensions, may be any according to requirements and to the state of the art.

[0041] The disclosures in Italian Patent Application No. MI99A002466 from which this application claims priority are incorporated herein by reference.

[0042] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

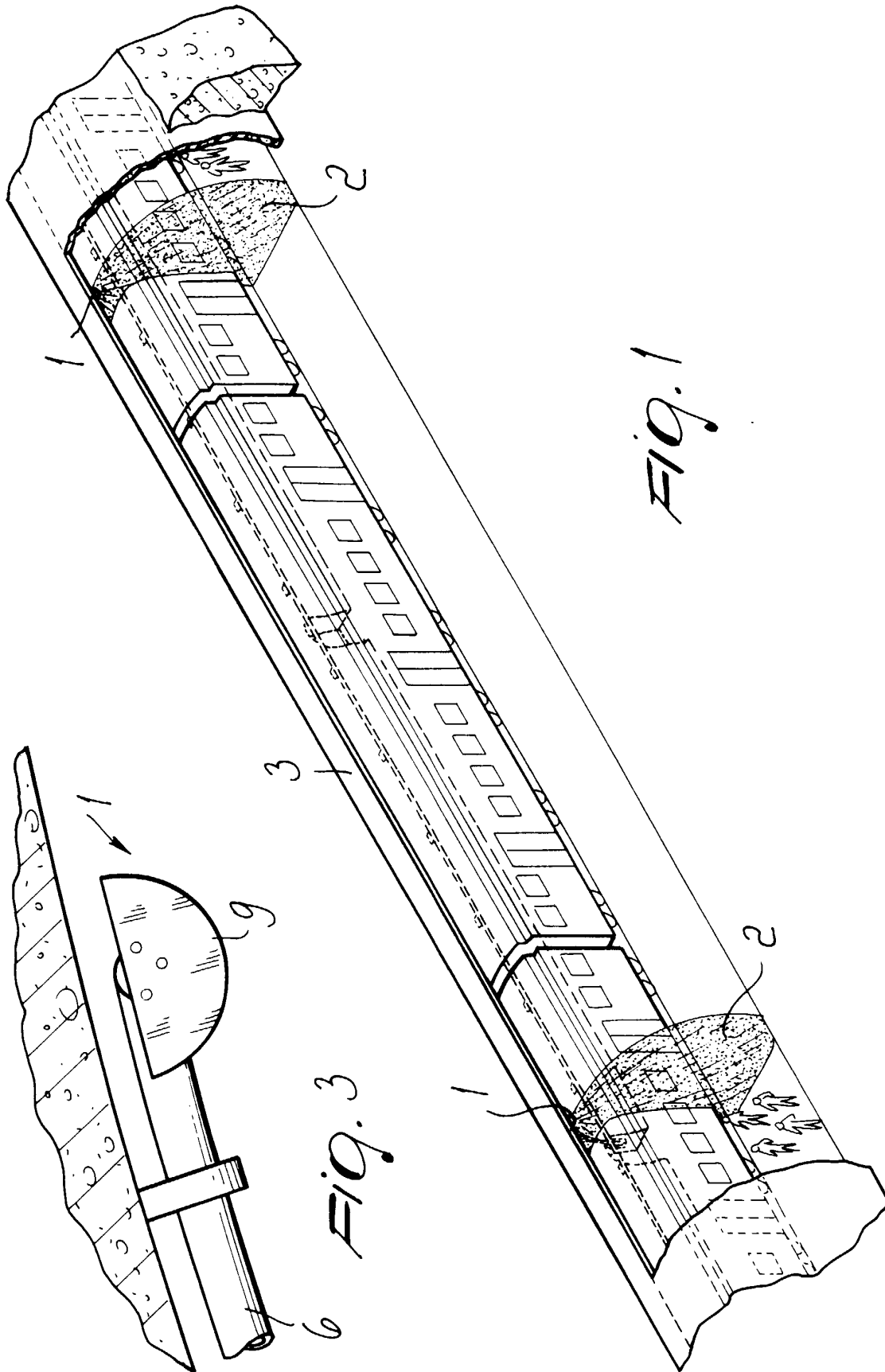
Claims

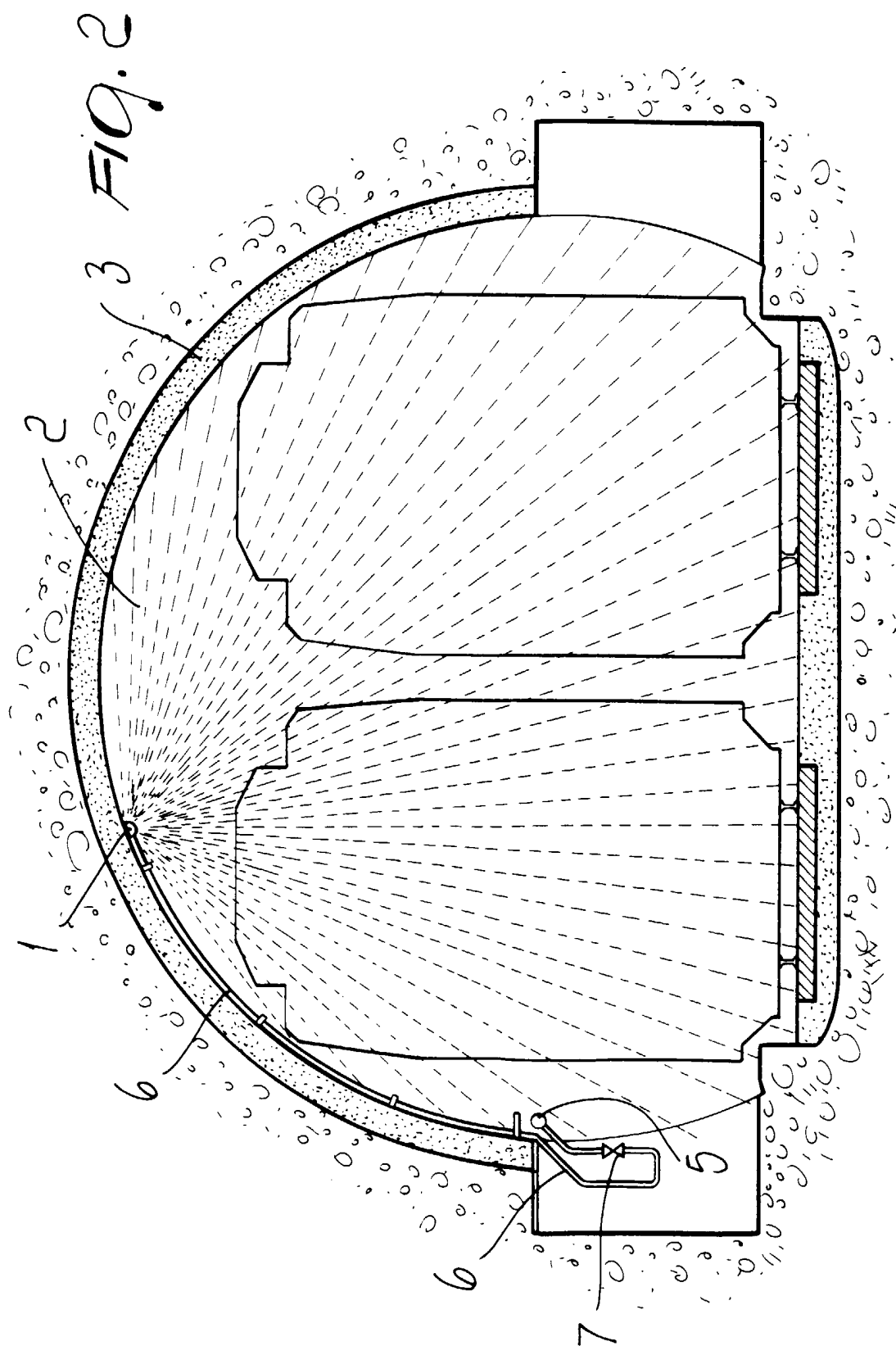
1. A method for reducing the consequences of a fire in a tunnel, characterized in that it consists in generating, inside the tunnel, a wall of non-flammable liquid upstream of a region affected by the fire and a wall of non-flammable liquid downstream of said region, said walls being arranged transversely to the longitudinal extension of the tunnel and being adapted to prevent or substantially limit the spreading of the fumes, gases and heat produced by the fire to the regions that are contiguous to the region affected by the fire, people fleeing the region affected by the fire being able to pass through said walls.
2. The method according to claim 1, characterized in that said non-flammable liquid is constituted by water.
3. The method according to claim 1, characterized in that said non-flammable liquid is constituted by water mixed with flame-extinguishing substances.
4. The method according to one or more of the preceding claims, characterized in that the tunnel is monitored in order to locate the start of the fire and generate said walls of non-flammable liquid upstream and downstream of the region affected by the fire.
5. An apparatus for reducing the consequences of a fire in a tunnel, characterized in that it comprises means for dispensing a non-flammable liquid which are adapted to generate walls of non-flammable liquid which lie on planes which are transverse with respect to the longitudinal extension of the tunnel, said dispensing means being mutually spaced along the longitudinal extension of the tunnel, means for feeding a non-flammable liquid to said wall generation means being provided which can be activated on command according to the location of a fire along the tunnel.
6. The apparatus according to claim 5, characterized in that said feeder means comprise a duct for feeding said non-flammable liquid, said feed duct running longitudinally along the tunnel; branches being provided along the extension of said feed duct, at intervals of preset length, in order to connect said feed duct to said means for dispensing a non-flammable liquid; a remotely controllable valve being provided along each one of said branches in order to connect, on command, said duct for feeding a non-flammable liquid to said dispensing means.
7. The apparatus according to claims 5 and 6, characterized in that said means for dispensing a non-flammable liquid comprise a dispenser which is connected to one of said branches and is arranged proximate to the top of the tunnel, said dispenser being provided with an outlet whose dispensing direction is substantially parallel to the longitudinal extension of the tunnel and faces a substantially flat screen which is arranged substantially at right angles to the longitudinal extension of the tunnel in order to convert the jet of liquid dispensed by said outlet into a liquid wall arranged on a plane which is substantially perpendicular to the longitudinal extension of the tunnel.
8. The apparatus according to one or more of the preceding claims, characterized in that it comprises at least one pump which is connected, by means of its delivery, to said feed duct.
9. The apparatus according to one or more of the preceding claims, characterized in that it comprises an electrically-powered pump which is connected, by

means of its delivery, to said feed duct, and an emergency pump which is driven by an internal-combustion engine and is connected, by means of its delivery, to said feed duct, said pumps being actuable alternately with respect to each other.

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10. The apparatus according to one or more of the preceding claims, characterized in that it comprises, in addition to said pumps, a compensation pump which is connected, by means of its delivery, to said feed duct in order to keep under pressure the non-flammable liquid in said feed duct when said at least one pump is not activated; said at least one pump being activated by a sudden pressure drop in said feed duct. 10
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11. The apparatus according to one or more of the preceding claims, characterized in that said at least one pump is connected, by means of its intake duct, to the water distribution system. 20
12. The apparatus according to one or more of the preceding claims, characterized in that said at least one pump is connected, by means of its intake duct, to a reservoir for storing non-flammable liquid. 25
13. The apparatus according to one or more of the preceding claims, characterized in that it comprises a device for mixing water and flame extinguishing substances which is connected to said feed duct. 30
14. The apparatus according to one or more of the preceding claims, characterized in that it comprises detection means for monitoring the inside of the tunnel which are adapted to report to an operator or to an automatic control apparatus the starting point of a fire along the tunnel. 35
15. The apparatus according to one or more of the preceding claims, characterized in that said detection means comprise television cameras which are arranged along the longitudinal extension of the tunnel in order to report to an operator or to an automatic control apparatus the starting point of a fire. 40
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16. The apparatus according to one or more of the preceding claims, characterized in that said automatic control apparatus is operatively connected to said controllable valves in order to open the controllable valves that are located on the branches of said feed duct that are located directly upstream and directly downstream of the starting point of the fire. 50
17. The apparatus according to one or more of the preceding claims, characterized in that it comprises wind speed and direction detection means which are located proximate to the inlets of the tunnel. 55





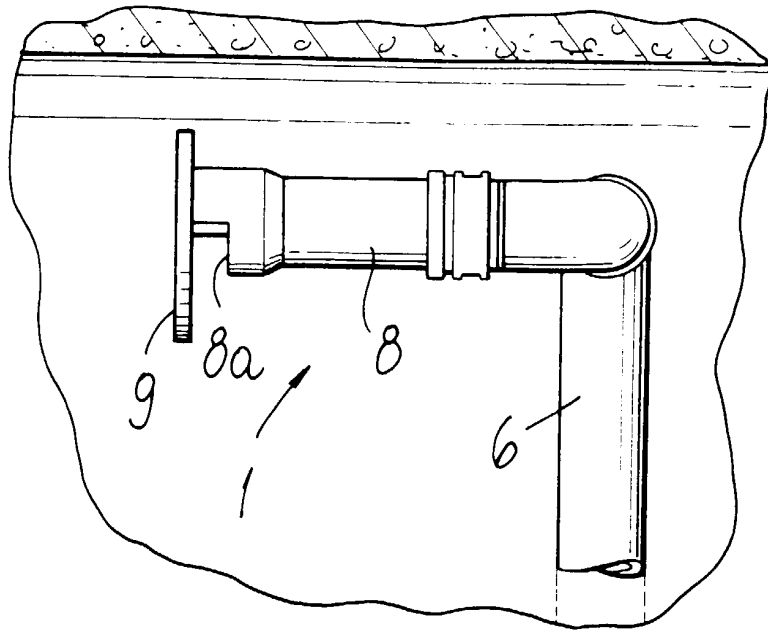


Fig. 4

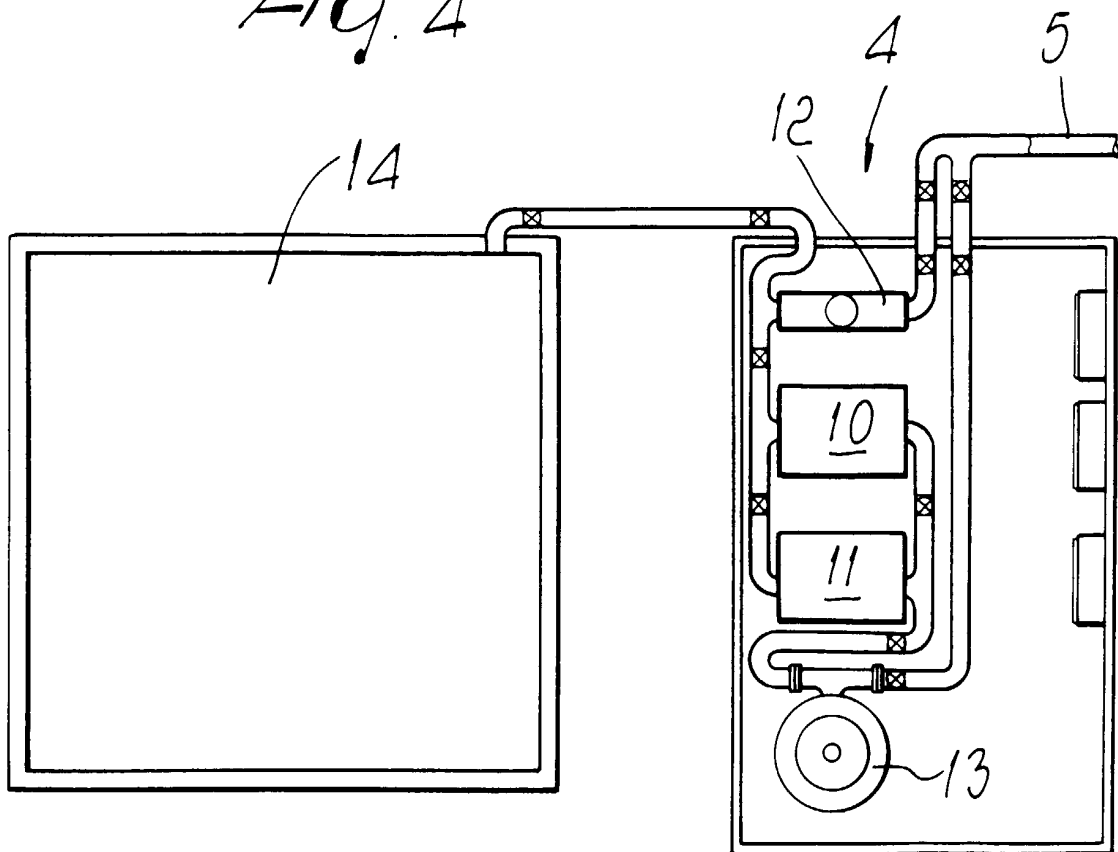


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 00 12 4392

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 28 March 2001	Examiner Fonseca Fernandez, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention 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			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 00 12 4392

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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