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Le Diouron

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[54] **METHOD OF COOLING PRODUCTS**

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[52] **U.S. Cl.** **62/63**

[51] **Int. Cl.** **F25d 13/06**

[58] **Field of Search** 62/63, 374, 380

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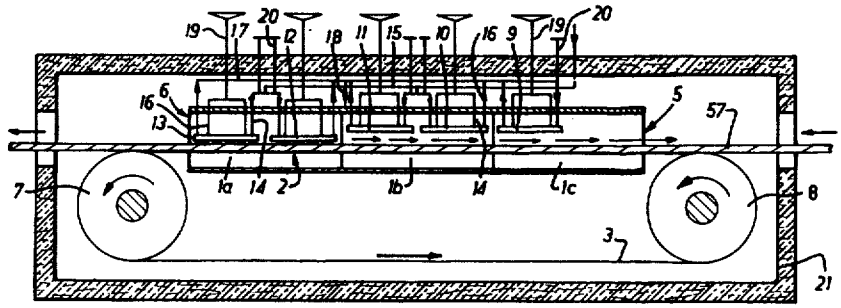
Assistant Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Young & Thompson

[57] **ABSTRACT**

A method of cooling a product of low heat conductivity, of the kind in which the product is displaced from the inlet to the outlet of an elongated cooling zone, into an intermediate point of which is introduced a gas which divides into two streams, one circulating in counter-flow towards the inlet and in contact with said product, and the other in concurrent flow towards the outlet of said zone, the latter comprising at least one heat exchanger traversed by a refrigerant fluid in course of vaporization, from which at least part of said gas is obtained, the flow of gas being turbulent in that part of its travel effected while in contact with said exchanger, and serving as a heat-transfer medium between the product and the exchanger; the refrigerant fluid is introduced at a pressure higher than that existing outside the cooling zone, and the said counter-flow stream closely envelops at least part of the product to be cooled. The method is suitable for handling products to be cooled such as rubber, plastic material, resins, glue, pasty chemical products, food products, etd.

7 Claims, 10 Drawing Figures



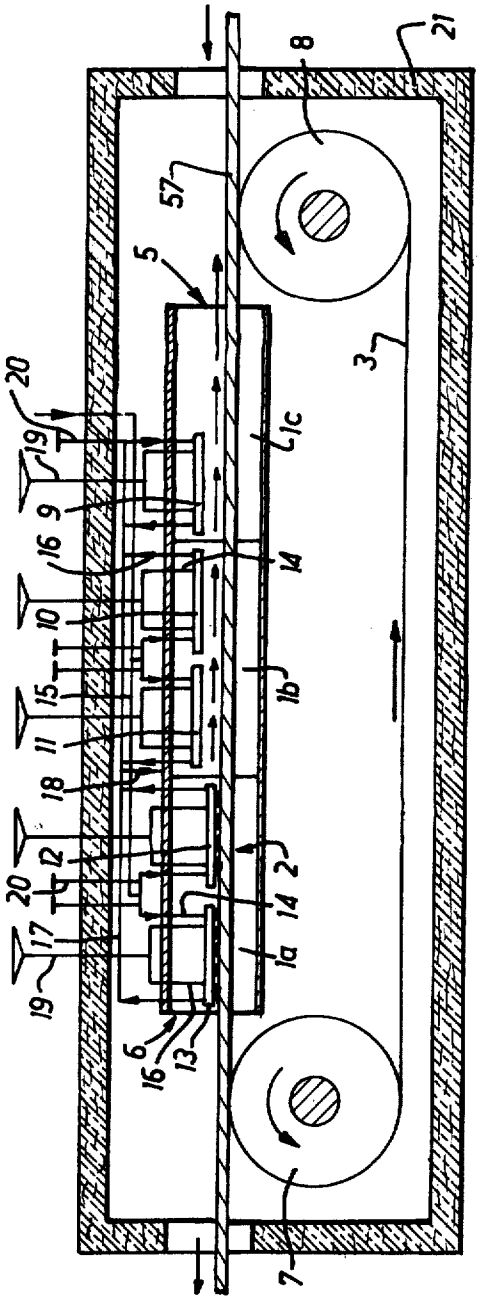

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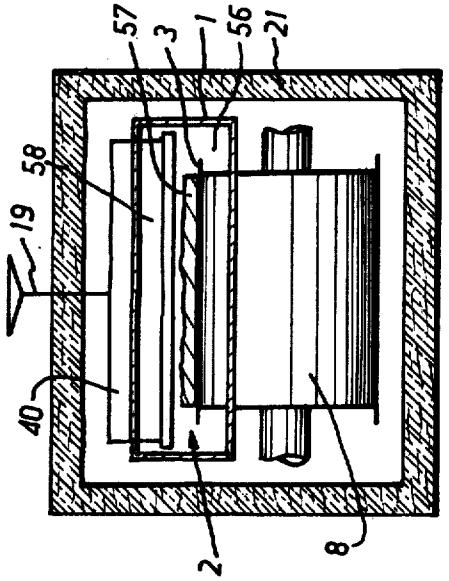
FIG. 1

FIG. 2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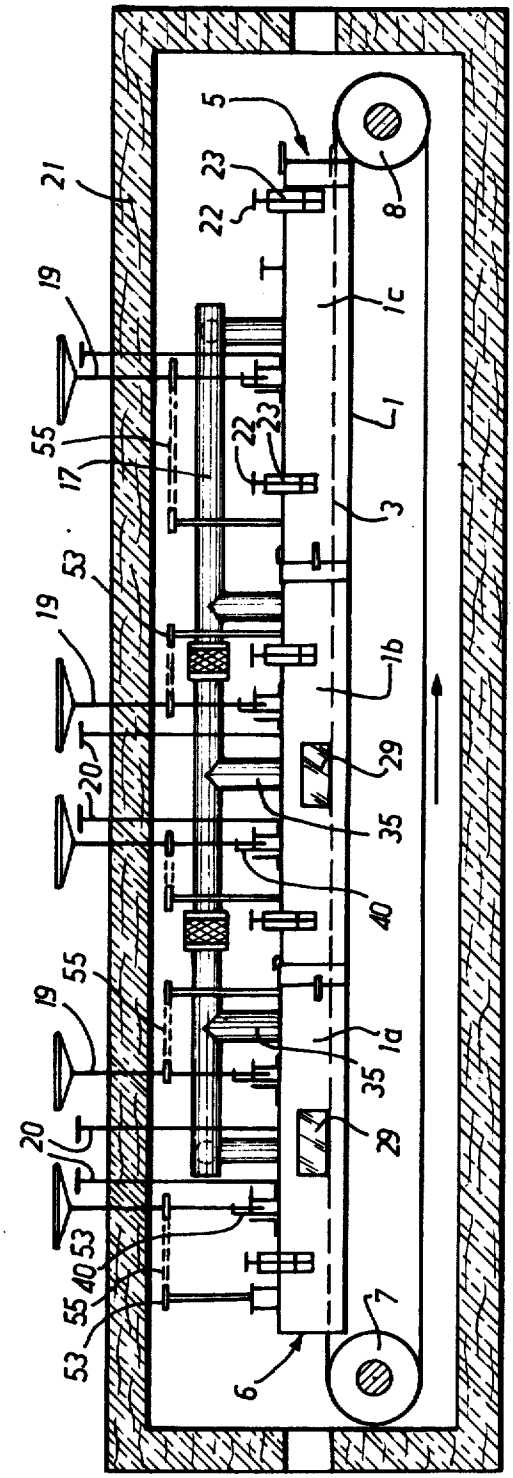
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FIG. 3

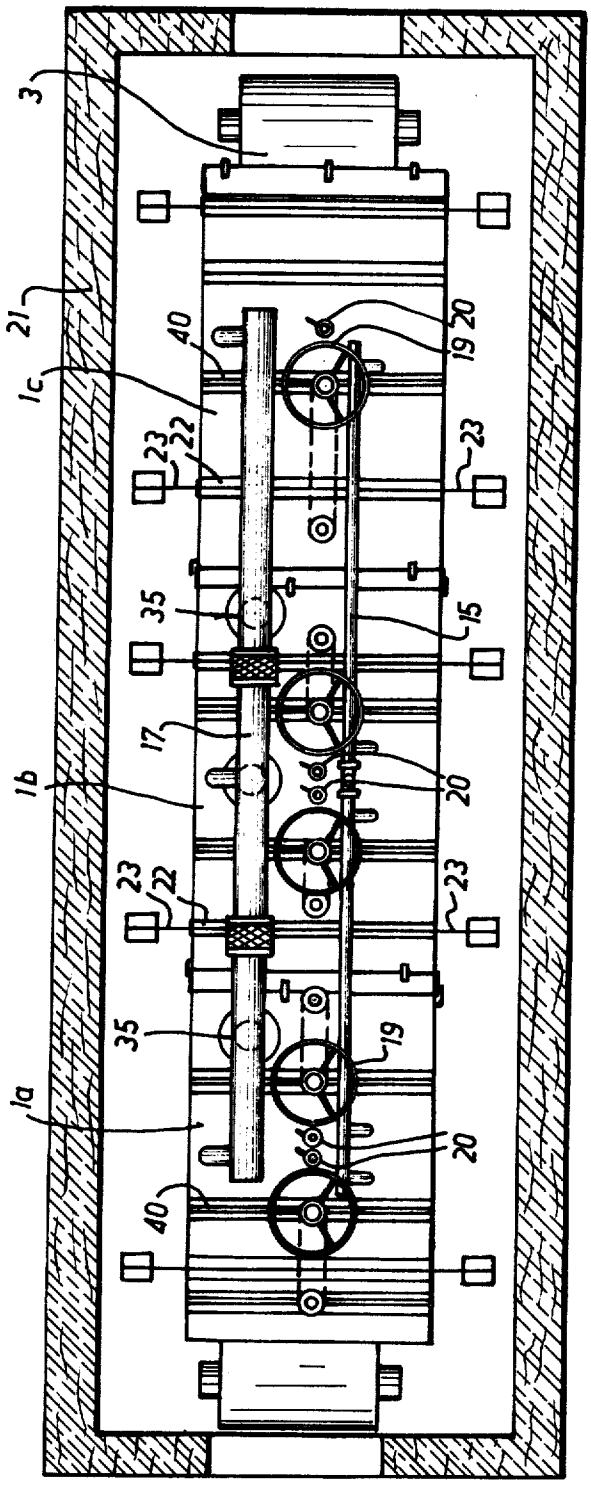

FIG.4

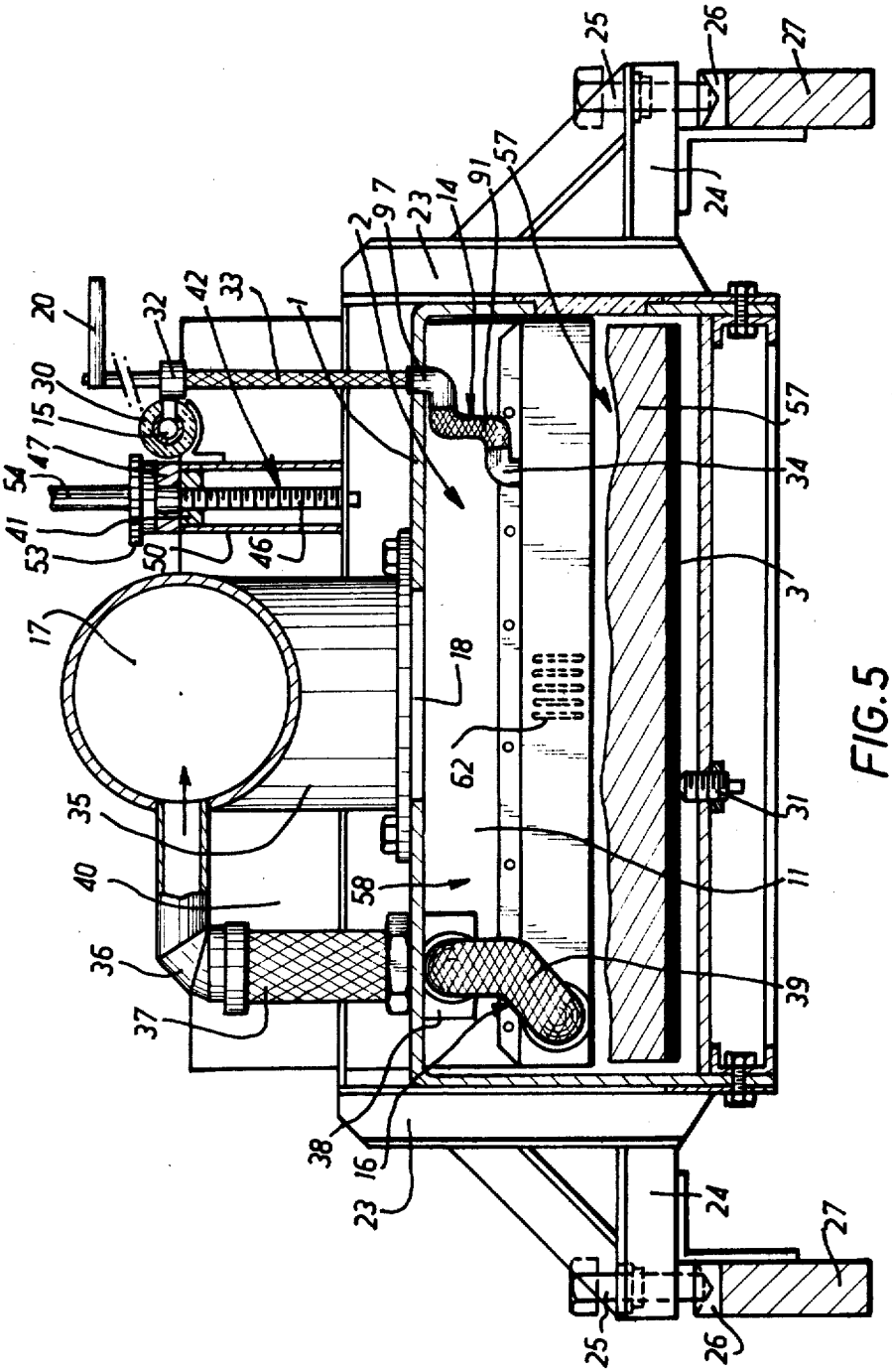
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FIG.5

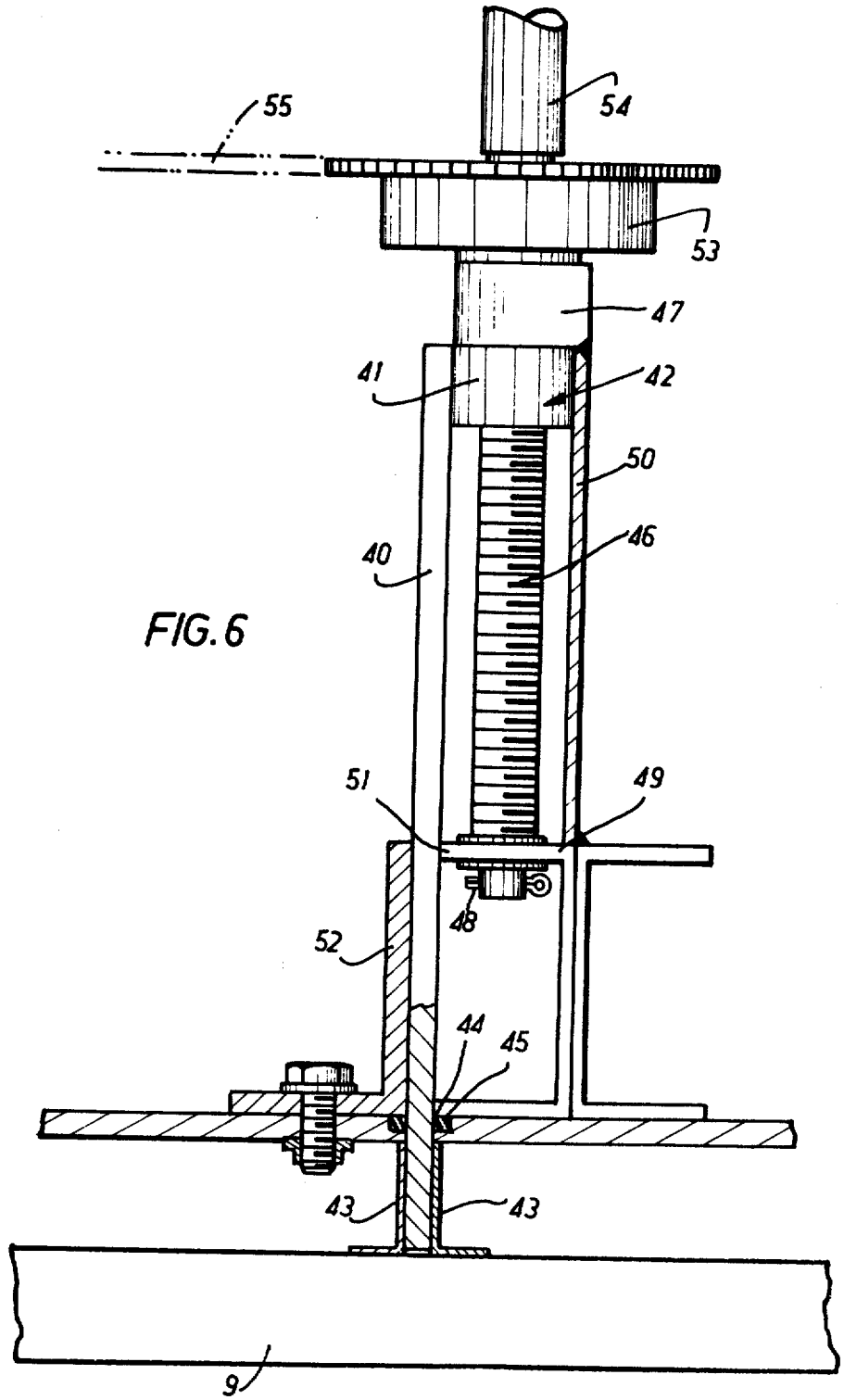

FIG. 6

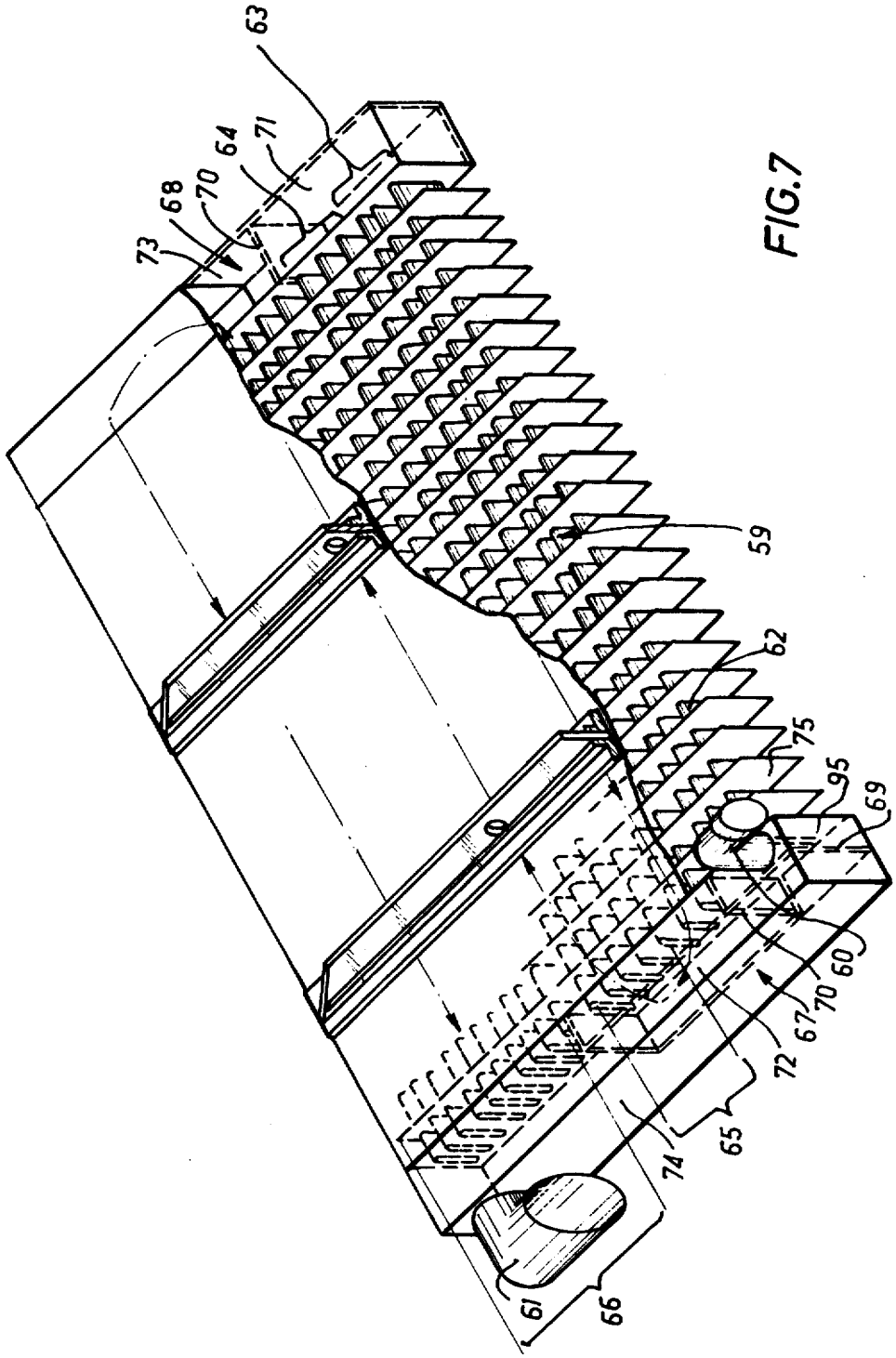

FIG.7

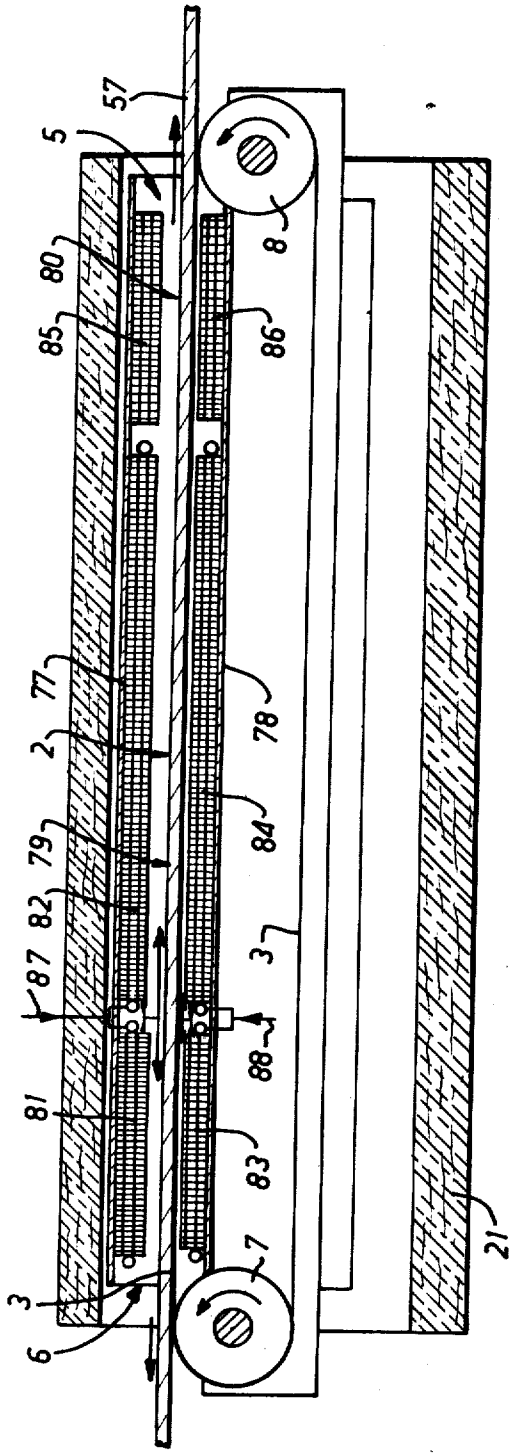

FIG.8

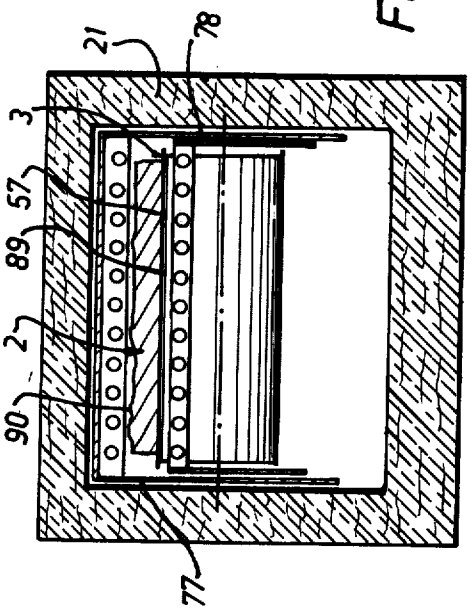

FIG.9

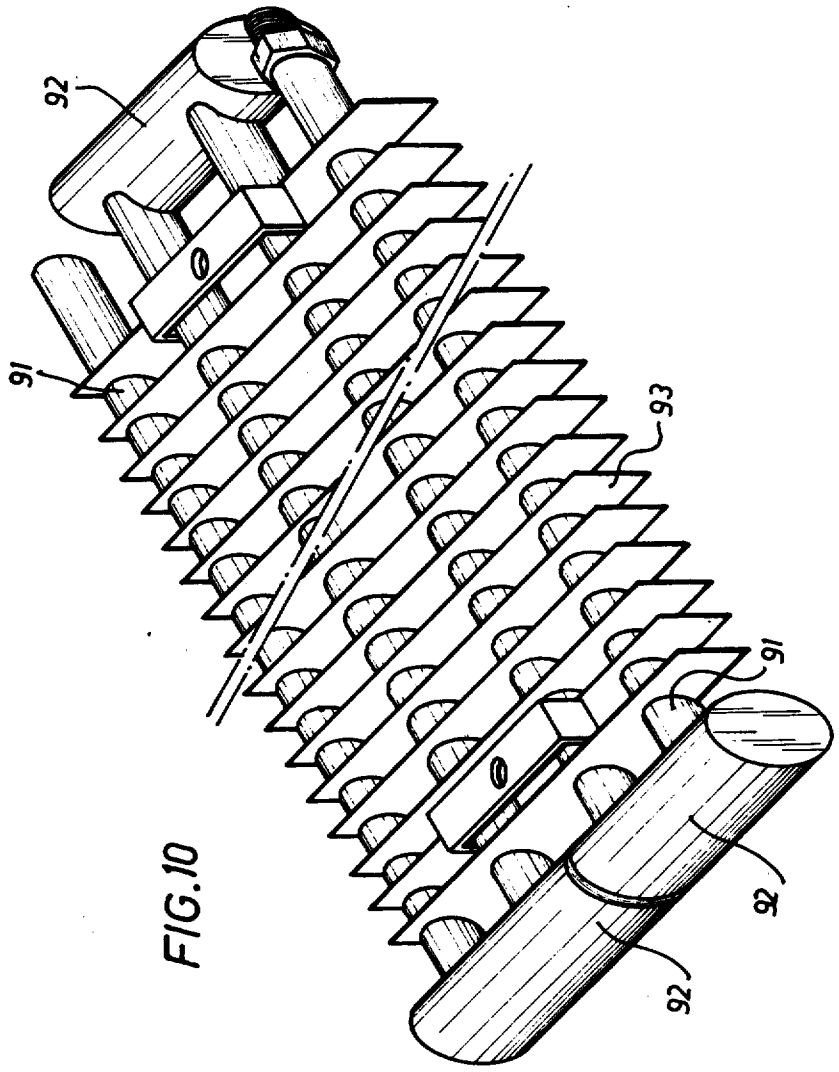

FIG.10

METHOD OF COOLING PRODUCTS

The present invention relates to a method of cooling of a body or substance which is in general a poor conductor of heat.

By a body which is a poor conductor of heat there ia meant any object or material or product having a low thermal conductivity and also a low thermal diffusion factor. There will comply with this definition for example, a nonmetallic material such as a rubber, a plastic material, a resin, a glue, but also food products, pasty chemical products, etc.

Very many continuous manufacturing processes encounter numerous difficulties in the cooling of the product treated, generally due to the low heat conductivity of this latter. In fact, as the material treated offers a substantial resistance to the flow of heat, the cooling of the product treated necessitates a considerable time of contact between this latter and the cooling medium. It follows that the cooling utilized is a very long operation which considerably reduces the productivity of a chain of manufacture.

In addition, it necessitates installations of considerable bulk, since the tunnels generally employed must have sufficient length to obtain a long time of contact between the cooling medium and the object to be cooled. These drawbacks become all the more important when it is attempted to increase the rate of manufacture and when the product to be cooled has a large section.

The cooling of a body by a gas circulating in contact with this latter is governed by the two following physical phenomena:

The exhanges of heat at the surface of the body between this latter and the cooling gas, characterized by a given coefficient of exchange. The higher the value of this coefficient, the more rapidly are extracted the calories available at the surface of the product to be cooled.

The exchanges of heat between the surface of the body to be cooled and the interior of this latter. These exchanges are a function of the geometry of the body to be cooled, but especially of the thermal conductivity of this latter. The heat is better diffused from the interior to the surface of the product when this conductivity is higher. Unfortunately, the thermal characteristics of the product treated are generally defective and cannot obviously be modified.

A desire to improve the speed of cooling of a product thus amounts to a simultaneous improvement in the kinetics of these two exchanges of heat. In fact, it is useless to wish to improve for example the coefficient of exchange between the surface of the body to be cooled and the cooling gas if the heat exchange between the heart of the said body and the said surface opposes a more rapid diffusion of heat to this latter. Conversely, it is useless to wish to improve the heat exchange in the interior of the body to be cooled if the heat exchange between the surface of the said body and the cooling gas does not permit a more rapid evacuation of the heat extracted from the body to be cooled.

Devices have already been proposed of the kind comprising: a heat-insulated wall forming a tunnel, at least one member for the introduction of a gas, means for displacing the body to be cooled from the entrance to the exit of the said tunnel, the said member permitting

the circulation of at least one counter-flow of the said gas towards the entrance of the tunnel, and further comprising at least one exchanger arranged in the interior of the said tunnel at a distance from the displacement means, in heat-exchange relation towards the interior of the said tunnel, intended for the circulation and the vaporization of a main refrigerant fluid, the portion of the tunnel associated with the said exchanger constituting a heat-transfer section of the said body to the said exchanger. The member introducing the said gas is arranged between the outlet and a central zone of the said tunnel and communicates with the evacuation orifice of the refrigerant fluid of the exchanger.

These devices necessitate the use of compartments which serve as heat-transfer sections.

The method employed in devices of this kind is such that the body to be cooled is displaced from the inlet to the outlet of an elongated cooling zone in a direction longitudinal to the movement of the said body, in which there is introduced into the said zone a gas of which at least one part circulates in counter-flow and in contact with the said body towards the inlet of the said zone, the cooling zone comprising at least one exchanger traversed by a refrigerant fluid in course of vaporization, such as liquid nitrogen, from which there is obtained at least part of the said gas, and of the kind in which the said gas, in the portion of its travel carried out in contact with the said exchanger, is substantially turbulent and serves as a heat-transfer medium between the said body and the said exchanger.

In the compartments in question, the gas serving as a heat-transfer medium between the body to be cooled and the exchanger is in a substantially turbulent state and is put into circulation by fans. This gas thus circulates circumferentially and normally to the general direction of displacement of the products to be cooled. There is in general one exhcanger per compartment serving as a heat-transfer section. It is clear that these devices have the disadvantage of being complicated and necessitating large capital investment, which makes them expensive.

The present invention proposes to utilize a method of this type, without necessitating the use of circulating means for the refrigerant fluid, such as fans.

The invention also concerns a method of cooling which is characterized in that the refrigerant fluid is introduced into the exchanger at a pressure higher than the pressure external to the said zone, and in that the said gas circulates in the longitudinal direction with respect to the exchanger, in the form of a counter-flow closely enveloping at least a part of the body to be cooled.

By refrigerant fluid at low temperature, there is meant any fluid having a boiling point lower than 0°C. at atmospheric pressure, such as liquid nitrogen.

Similarly, by a heat-transfer medium, there is thus meant a medium which restores to a cold source (exchanger) almost the whole of the heat acquired during contact with a hot source (body to be cooled). In consequence, when the exchanger is working at a substantially constant temperature, the heat transfer medium is characterized by the fact that its temperature remains substantially constant.

This results in a substantial economy in the space occupied by the equipment and a reduction of its produc-

tion cost, since it is no longer provided with fans which necessitate a considerable consumption of power.

The device for practicing the method according to the invention is of great simplicity by virtue of the longitudinal flow of the gas in counter-flow, which excludes the use of compartments. In addition, the compression of the refrigerant fluid in the liquid form is less expensive than inducing a gaseous flow by means of fans.

By the use of liquid nitrogen as the refrigerant fluid, the surface of the body to be cooled can be put into contact with a gaseous medium, the temperature of which may be substantially low. In this way it is possible to compensate for the considerable thermal resistance of the body to be cooled and its low conductivity, by a large temperature difference between the interior and the surface of the said body. This difference thus makes it possible to accelerate considerably the exchanges of heat between the heart of the body to be cooled and its surface. In this way, this contributes to a rapid cooling of the said body.

Since the counter-flow of gas circulating in contact with the body to be cooled is essentially turbulent, the coefficient of exchange between the surface of the body to be cooled and the said flow is thereby substantially increased. In consequence, this turbulence contributes to the acceleration of the exchanges of heat between the flow of gas and the surface of the body to be cooled.

The result of this is that the time of contact necessary for a given cooling can thus be considerably reduced, with a corresponding reduction in the size of the installations concerned.

In fact, if the flow of gas which takes place in the interior of the cooling zone in the substantially turbulent state considerably increases the heat exchange coefficient between the body to be cooled and the said gas, this is correlatively also true at the level of the exchanger, between this latter and the gas passing through the cooling zone. In consequence, the turbulent flow of the gas also increases the coefficient of exchange between the gas and the exchanger. The coefficients of exchange becoming appreciably large at the level of the exchanger and the body to be cooled, the thermal resistance of the gas between the body to be cooled and the exchanger than becomes very small.

Furthermore, or the same heat flux transmitted from the body to be cooled to the exchanger, the two coefficients of exchange previously examined being large, this implies that the differences of temperature between the exchanger and the gas and between the gas and the body to be cooled are not great. This amounts to saying that the largest heat gradient is located inside the exchanger in which the refrigerant fluid (liquid nitrogen for example) is vaporized. This fluid is therefore generally vaporized by the boiling of a film, and this means that it is always possible to inject into the cooling zone a gas having the lowest possible temperature which may be substantially close to that of the refrigerant fluid in course of vaporization.

In consequence, as the surface temperature of the product can be reduced to the vicinity of the boiling point of the refrigerant fluid employed, it follows that it is possible to accelerate considerably the heat exchange between the interior of the body to be cooled and its surface. The heat flux evacuated from the body to be cooled to the exchanger is thus substantially increased, since it is no longer limited by the speed of the heat exchange between the surface of the body to be cooled and the counter-flow of gas. The frigorific fluxes absorbed by the body to be cooled thus become very large, and a method of cooling according to the invention is characterized by a considerable frigorific power which can be transmitted to the body to be cooled.

It is of course not always possible to reduce the surface temperature of the body to be cooled to the low point desired. This temperature must remain compatible with the mechanical and thermal characteristics of this latter. Thus, for example, the coefficients of expansion of materials such as rubber or plastic material are relatively large. The result is that if these substances are put into contact with an ambient gas which is too cold, the surface of the substance becomes liable to split or the body to be cooled even runs the risk of bursting. This means that in each case the temperature of the flow of gas should be chosen in such manner as to have no adverse effect on the body to be cooled.

According to one form of embodiment of the present invention, the gas is introduced at a point in the cooling zone intermediate between the inlet and the outlet of the said zone, the said gas is divided into a counter-flow such as that previously described, and a concurrent flow, both circulating in contact with the said body, in a substantially turbulent state, the first flowing towards the inlet of the said zone and the second towards the outlet of the said zone.

At least part of the travel of the said concurrent flow is effected in contact with at least one other exchanger arranged in the cooling zone and traversed by the main refrigerant fluid in course of vaporization, and another part of the said gas is obtained by the vaporization of the main refrigerant fluid in the other exchanger, the said concurrent flow serving essentially, at least in that part of its travel which is effected in contact with the said other exchanger as a heat transfer medium from the body to be cooled to at least the said other exchanger.

According to another form of embodiment of the present invention, the cooling zone comprising at least one auxiliary exchanger provided inside the said zone, upstream of at least one said exchanger depending on the direction of displacement of the body to be cooled, there is sent into the auxiliary exchanger an auxiliary refrigerant fluid having a boiling point higher than that of the main refrigerant fluid, in particular water, and another portion of the path of the gaseous counter-flow circulating towards the inlet of the said zone is effected in contact with the auxiliary exchanger, the said counter-flow serving essentially, in the said other portion of its travel, as a heat transfer medium for the body to be cooled towards the auxiliary exchanger.

This enables the body treated to be pre-cooled by putting its surface into contact with a gaseous counter-flow having a temperature less low than which can be obtained with the main refrigerant fluid (such as liquid nitrogen). As the difference in temperature is still sufficient for the heat exchange to be still relatively rapid in the interior of the product to be cooled, this latter is thus pre-cooled by utilizing a frigorific power less costly than that which would be necessary with the main refrigerant fluid. The economy of the method of cooling is therefore improved.

According to a preferred from of embodiment of the invention, at least one of the said counter-flow and con-

current flow streams serves essentially as a cooling medium for the body to be cooled over at least one other portion of its travel, and becomes heated in contact with the said body.

In opposition to the "heat transfer medium" previously defined, there is meant by "cooling medium" a medium which utilizes practically the whole of the heat acquired in contact with a hot source (body to be cooled) in order to become heated, and is therefore a medium in which the temperature gradually rises.

The fact that a flow of gas which has served to transfer the heat extracted from the body to be cooled to the refrigerant fluid employed, in order to be used itself subsequently to cool the same body, essentially enables the said flow to be heated to a temperature as close as possible to the inlet temperature of the body to be cooled. This therefore permits the loss of the smallest possible amount of the cold available in this latter. The frigorific efficiency of the method utilized is therefore correspondingly increased.

Finally, according to this preferred form of embodiment of the invention, a cooling zone is composed of one or a number of heat transfer sections and of one or more cooling sections, in which the same flow of gas serves respectively to transfer calories extracted from the body to be cooled, to an appropriate cold source (exchanger) and to consume these calories in order to become heated.

According to another form of embodiment of the invention, the distance between an exchanger and the body to be cooled is varied in order to regulate the heat exchange coefficient obtained between the gas circulating in the cooling zone and the said body, over the portion of the travel of the said gas effected in contact with the said exchanger.

It is thus possible to vary simultaneously the coefficient of exchange between the said gas and the exchanger and in consequence the heat flux extracted from the object to be cooled. It is also possible in this way to regulate the surface temperature of the product to be cooled as a function in particular of its properties, as referred to above. The flexibility and adaptability of a method of cooling according to the invention are thereby improved.

The present invention will now be detailed and defined in the description which follows below, reference being made to the accompanying drawings, in which:

FIG. 1 shows a diagrammatic view in longitudinal cross-section of a first cooling device according to the invention;

FIG. 2 shows a diagrammatic view in transverse section of this first cooling device;

FIG. 3 shows a view in elevation of this first cooling device;

FIG. 4 represents a view looking on the top of this first cooling device;;

FIG. 5 shows a view in transverse section of this first cooling device;

FIG. 6 shows a view in longitudinal section of the means for regulating the height of a gaseous barrier in the first form of cooling device;

FIG. 7 shows a view in perspective and partly exploded, of an exchanger mounted in the interior of the first cooling device in accordance with the invention;

FIG. 8 shows a diagrammatic view in longitudinal section of a second cooling device according to the invention;

FIG. 9 represents a diagrammatic view in transverse section of this same second cooling device;

FIG. 10 represents a perspective view of an exchanger arranged inside this second cooling device.

In accordance with FIGS. 1 and 2, a cooling device according to the invention comprises diagrammatically three elements 1*a*, 1*b*, 1*c*, assembled together, of a metal wall 1 forming a tunnel 2 having a rectangular straight section and relatively flattened. Displacement means comprising a conveyor belt 3 enable a body 57 to be cooled, to be conveyed from the inlet 5 to the outlet 6 of the tunnel. The conveyor belt 3 is closed on itself around two pulleys 7 and 8, outside the tunnel, one or both the pulleys being driven by an appropriate mechanical or mechanical means. The carrier side of the conveyor belt 3 passes through the interior of the tunnel 2.

Five exchangers 9, 10, 11, 12 and 13, spaced apart from each other and substantially flat, in heat exchange relation to the interior of the tunnel 2, are arranged inside this latter at a distance from and above the carrier side of the conveyor belt 3. All these exchangers intended for the circulation and the vaporization of a main refrigerant fluid, comprise a supply 14 communciating with the same distributor conduit 15 of the refrigerant fluid, and an evacuation 16 communicating with a single collector conduit 17 for the refrigerant fluid which as circulated in each exchanger.

The collector 17 of the vaporized refrigerant fluid and therefore the evacuation 16 of each exchanger, communicate with at least one member or orifice 18 for the introduction of a gas, of which one opens into the tunnel 2 through the wall 1, between the outlet 6 and a central zone of the said tunnel, and more precisely between the exchangers 11 and 12. As will be seen later, the introduction orifice 18 makes it possible to circulate at least one counter-flow of the gas introduced, towards the inlet 5 of the tunnel 2.

Each exchanger is adjustable in the vertical position by means of the hand-wheel 19. The supply conduits 14 of each exchanger are variable in flow-rate by means of the keys 20. All these elements with the exception on the hand-wheels 19, the keys 20 and the driving device for the pulleys 7 and 8 are arranged inside a casing 21 of heat-insulating material, so that the wall 1 of the tunnel is thermally insulated from the exterior.

The above cooling device will now be described with more precision by reference to FIGS. 3 to 7. The wall 1 of the tunnel, of light alloy, is designed so as to be capable of withstanding an over-pressure with respect to the exterior of the tunnel, at least equal to 1 bar. The wall 1 of each element 1*a*, 1*b* and 1*c* is reinforced externally step-by-step by horizontal sections 22 which are rigidly fixed to the upper part of the wall 1, and by vertical sections 23 which are fixed on the two lateral portions of the wall 1.

A section 22 is welded or fixed to two lateral sections 23 and forms with these latter a transverse reinforcement of the wall 1 of the tunnel. These reinforcements have also the purpose of carrying the various parts of the cooling tunnel and the other means associated therewith.

For this purpose, each lateral section 23 of each armature is rigidly fixed to a bracket 24 resting by means of a screw 25 on an end-shoe 26 associated with a supporting foot 27. The position of the tunnel may thus be adjusted by means of the screws 25. An element of the

wall 1 may comprise a sight-hole 29 permitting the body to be cooled, to be examined in the interior of the tunnel 2.

The conveyor belt 3 is constituted by a thin sheet of stainless steel. It is supported step-by-step inside the tunnel by screws 31, adjustable in height and arranged in the lower portion of the wall 1. The distributor conduit 15 of the refrigerant fluid is arranged outside the tunnel 2 but inside the heat-insulated casing 21. It is further heat-insulated by a sheath 30 of heat-insulating material. On this conduit 15 are coupled the supply assemblies for the exchangers 9, 10, 11, 12 and 13. Each assembly for the supply of refrigerant fluid to an exchanger is composed of a cook 32 communicating with the conduit 15 and operated by a key 20, a first flexible metal conduit 33 connecting the cock 32 to an elbow 97 passing in a fluid-tight manner through the upper portion of the wall of the tunnel, and a second flexible metal conduit 91 connecting the elbow 97 to the supply orifice 34 of an exchanger.

The collector conduit 17 for the vaporized refrigerant fluid is also arranged outside the tunnel 2 but inside the insulating casing 21. It has a larger diameter than the conduit 15 and is supported in steps by cylindrical consuits 35 of the same diameter, each communicating with a gas introduction orifice 18 and the collector 17. On this conduit are connected the evacuation assemblies of the exchangers 9, 10, 11, 12 and 13. An assembly which enables two adjacent exchangers to be evacuated simultaneously is composed of a right-angle elbow 36 communicating with the conduit 17, of a flexible metal pipe 37 communicating with the elbow 36 and a coupling box 38 passing in a fluid-tight manner through the upper portion of the tunnel wall, and two flexible metal pipes 39 communicating with the box 38 and each of the two adjacent exchangers.

Each exchanger 9, 10, 11, 12 and 13 is suspended inside the tunnel from two rectangular transverse metal plates 40 which pass in a fluid-tight manner through the wall 1 of the tunnel. As will be seen below, these plates 40 also function as a gaseous barrier. They are rigidly fixed at their top edges to a nut 41 belonging to height-regulating means 42 for each plate 40, and therefore to regulating means in the vertical position of the corresponding exchanger. The lower edge of each plate 40 is arranged between two suspension angle-irons 43 belonging to the corresponding exchanger, and is rigidly fixed to these latter and therefore to the said exchanger, by any suitable means.

Each plate 40 has a transverse dimension or width which is substantially equal to that of the tunnel 2. It thus extends substantially to the lateral portions of the wall 1 of the tunnel 2. Each plate 40 is thus capable of sliding in a fluid-tight manner in a transverse slot 44 located at the upper portion of the wall 1 of the tunnel and ensuring the passage of the said plate.

Fluid-tightness is ensured by means of a suitable joint 45. The means for regulating each plate 40 in the vertical position, arranged outside the tunnel, essentially comprise a screw 46 associated with the nut 41 fixed on the upper edge of the said plate. Each screw 46 is held in the vertical position by passing in its upper position into a central hole of a boss 47, and being pivoted at its lower extremity by means of a key 48 on a transversal section 49 fixed on the upper portion of the wall 1.

The boss 47 is supported by a casing 50 partly surrounding the screw 46, welded at its upper edge on the boss 47 and at its lower edge on the section 49. The screw 46 is capable of rotating freely inside the boss 47. When each plate 40 slides in each corresponding slot 44, it is guided in its movement, on one side by the edge 51 of the section and on the other side by a guiding angle-iron 52 fixed on the wall 1 of the tunnel.

Each screw 46 is rigidly fixed, above the boss 47, to a toothed wheel 53 associated with a shaft 54 of the operating hand-wheel 19 of each screw 46. As a hand-wheel 19 is arranged outside the heat-insulating casing 21, it follows that the shaft 54 passes through this casing.

The height-regulating means for two plates 40 from which one single exchanger is suspended are mechanically coupled to each other in such manner that the said exchanger is vertically movable while remaining substantially horizontal. For that purpose, the two toothed-wheels 53, corresponding to two screws 46 associated with the same exchanger, are coupled to each other by means of a chain 55. It is then possible, by means of a single hand-wheel 19, to displace two consecutive plates 40 and the exchanger which is associated therewith.

As indicated in FIG. 5, the tunnel 2 is divided substantially into two parts by the exchanger or exchangers 9, 10, 11, 12 and 13. A first part comprised between the conveyor belt 3 and an exchanger forms a passage 56 for the travel of the body 57 to be cooled, the transverse section of which corresponds substantially to that of the said body. A second part comprised between the exchanger and the upper portion or roof of the tunnel 2 forms a leakage passage 58 for the gas introduced into the tunnel, towards at least one extremity of this latter. In this case, the plates 40 previously described play the part of a gas barrier and close the said leakage passage 58.

In accordance with FIG. 7, each exchanger 9, 10, 11, 12 and 13 is substantially flat. It comprises circulation means 59 for the refrigerant fluid, in heat exchange relation towards the interior of the tunnel 2, communicating with a supply orifice 60 and an evacuation orifice 61 for the refrigerant fluid. These circulation means comprise a plurality of substantially flat tubes 62, parallel to each other and elongated in the direction of the tunnel.

These tubes 62 may be re-grouped in four sections 63, 64, 65 and 66, elongated in the direction of the tunnel, in which the number of tubes increases from one section to another, and in which the refrigerant fluid is capable of circulating alternately and successively in the same and the opposite direction to that of the body to be cooled. For this purpose, two coupling boxes 67 and 68 are arranged transversely with respect to the direction of the tunnel, at the two extremities of each exchanger.

A first transverse partition 69 and a second partition 70 form inside the first coupling box 67 a compartment 95 for the introduction of the refrigerant fluid, communicating on the one hand with the introduction orifice 60 and and on the other hand with the first section 63 of the tubes 62 of the exchanger.

A partition 70 and the wall of the second coupling box 68 form in this latter a first compartment 71 causing the first section 63 to communicate with the second section 64 of the exchanger. The first partition 69 and the second partition 70 of the first coupling box 67 form a second compartment 72 located on the other

side of the first compartment **69**, causing the second section **64** to communicate with the third section **65** of the exchanger. The partition **70** and the wall of the second coupling box **68** also form in this latter a second compartment **73**, located on the other side of the first compartment **71** and causing the third section **65** to communicate with the fourth section **66** of the exchanger. The partition **69** and the wall of the first coupling box **67** form in this latter an evacuation compartment **74** for the refrigerant fluid, communicating on the one hand with the fluid evacuation orifice **61** and on the other hand with the fourth section **66** of the exchanger.

All the tubes **62** of an exchanger and in consequence the various sections defined above, are rigidly fixed to metal obstacles or fins **75**, transverse to the direction of the tunnel and intended to cause local turbulence in the circulation of the gas inside the tunnel. As these fins **75** are of metal, it follows that the various tubes **62** and in consequence the various sections of the exchanger, are in thermal contact with each other through the intermediary of these transverse obstacles **75**.

There will now be described in detail the operation of the tunnel which has just been specified. The body **57** to be cooled is set in movement by mans of the conveyor belt **3**. It passes at a hot temperature into the interior of the heat-insulation casing **21** and then moves from the inlet **5** to the outlet **6** of the elongated cooling zone or tunnel **2**; after cooling to a cold temperature, it is evacuated from the heat-insulating casing **21**.

Simultaneously, a main refrigerant fluid at low temperature such as liquid nitrogen is distributed under pressure into each exchanger **9, 10, 11, 12** and **13**, from the distributor conduit **15**. The flow-rates of fluid into each exchanger arè regulated by means of the regulating keys **20**.

By reason of the heat transferred from the body **57** to be cooled to the exchangers **9, 10, 11, 12** and **13**, as will be explained below, the refrigerant fluid distributed into each exchanger is vaporized during its travel into the interior of these latter. The vaporized main refrigerant fluid from each exchanger is collected by the collector conduit **17** and the gas collected in the collector **17** is introduced into the cooling tunnel **2** through the conduit **35** which opens directly into this latter between the exchangers **11** and **12** (the other conduits **35** have been closed).

The gas resulting from the vaporization of the main refrigerant fluid is thus introduced under pressure in the tunnel **2** into the various exchangers between the exchangers **11** and **12**, and therefore at a point in the tunnel comprised between the inlet **5** and the outlet **6** of the tunnel. From then on, the said gas is divided into a counter-flow circulating in the direction of the arrows in full lines, and therefore being directed towards the inlet **5** of the tunnel, and into a concurrent flow circulating in the direction of the arrows in chain-dotted lines, and therefore directed towards the outlet **6** of the tunnel.

In view of the conditions of flow, each of these two streams circulates inside the cooling zone in a substantially turbulent state. In fact, on the one hand each exchanger is regulated in height by means of the operating hand-wheels **19** in such manner that each of the gaseous streams circulating between the conveyor belt **3** and the corresponding exchangers closely envelops the body to be cooled, in the portion of their travel which is effected in contact with the said exchangers.

The distance between the exchanger and the body to be cooled is maintained below **3** cm. On the other hand, as previously mentioned, the gas is introduced into the tunnel **2** at a pressure higher than the pressure existing outside the tunnel. This excess pressure is preferably at most equal to two atmospheres. It also results from this over-pressure that the respective flow-rates of the counter-flow and the concurrent flow are adjusted so that the pressure losses, respectively between the point of introduction of the gas and the inlet **5** of the tunnel and between the said point and the outlet **6** of the tunnel, are equal.

From the considerations stated above, it results that each of the streams respectively directed towards the inlet and the outlet of the tunnel, under the conditions of flow which have just been defined, serves essentially as a heat-transfer medium for the body to be cooled to each of the exchangers. In consequence, in the whole part of their travel effected in contact with the various exchangers, the counter-flow and the concurrent flow of the gaseous medium utilized restore almost the whole of the heat acquired in contact of the body to be cooled to the various exchangers opposite which they circulate.

Thus, since each exchanger is at a substantially uniform temperature (the refrigerant fluid being vaporized therein by boiling in a film), each of these streams remains at a substantially constant temperature when it passes into contact with the said exchanger. These two streams are then respectively evacuated at the inlet **5** and the outlet **6** of the tunnel at a pressure substantially equal to atmospheric pressure. The flow-rate of liquid gas circulating between the exchangers and the roof of the tunnel **2** is limited to a minimum value by virtue of the gas barriers **40**.

According to an alternative form of this method, the body to be cooled **57** passing into the tunnel **2** can be pre-cooled, for example by injecting into the exchanger **9**, an auxiliary refrigerant fluid having a boiling point higher than that of the main refrigerant fluid, in particular such as water. In this case, the exchanger **9** plays the part of an auxiliary exchanger provided upstream of the main exchangers **10, 11, 12** and **13** along the direction of circulation of the body to be cooled, entirely separate and independent of this latter.

The auxiliary fluid is introduced in this case into the exchanger **9** quite independently of the distributor **15**, and is evacuated also independently of the collector **17**. In the same way, the counter-flow of gas directed towards the inlet **5** serves essentially as a heat-transfer medium of the body to be cooled to the auxiliary exchanger, in this portion of its travel. As the frigories are supplied in this case at a higher level of temperature than that of the main refrigerant fluid, the economy of the method of cooling is considerably increased.

According to another alternative form of the method, one of the gaseous streams previously specified, for example the counter-flow directed towards the inlet **5** of the tunnel, also serves, in another portion of its travel, as a cooling medium for the body to be cooled, and in consequence becomes heated by contact with the said body in this portion of its travel. For that purpose for example, the supply of the main refrigerant fluid to the exchanger **9** is interrupted. There cannot therefore be any further transfer of heat acquired by the flow of gas to the refrigerant fluid, and in this portion of its travel,

the flow of gas utilizes the heat acquired for heating this flow.

In consequence, the section of the tunnel corresponding to the exchanger **9** no longer play the part of a heat transfer section, but that of a cooling section. In this case, the exchanger **9** becomes merely a simple turbulence member for the flow of gas inside the tunnel, by virtue of the fins **75** or other obstacles, arranged transversely to the direction of the tunnel, at a distance from the conveyor belt **3**.

This alternative form of utilization enables the efficiency of the cooling method to be improved, by recovering the sensible frigories from the gaseous medium employed. It is clear that the supply may be cut-off from several of the exchangers **9** to **13**, in order that the tunnel may comprise several cooling sections in addition to the heat-transfer sections previously described.

By regulating the distance between an exchanger and the body to be cooled, it is possible to regulate the coefficient of heat exchange between the gas circulating in the tunnel and the said body, at the level of the various exchangers. It is therefore correspondingly possible to bring the surface of the body to be cooled to the temperature level desired, as a function of the characteristics of this body. The coefficient of exchange **4** is preferably maintained between 20 and 500 $W/m^2/°K$, and more precisely between **50** and 150 $W/m^2/°K$.

It is thus found that a tunnel according to the invention is perfectly autonomous in operation. A forced convection of the gaseous medium utilized is obtained without any compressed air barrier or any fan. Its method of operation can be varied at will, according to the product to be cooled or depending on the conditions of cooling desired.

By way of example, a tunnel having the structure described above makes it possible to reduce the average temperature of a strip of chemical product of 450 × 3 mm., travelling with a flow-rate per hour of 800 kg., and consuming about 800 litres per hour of liquid nitrogen for a product having a specific heat of about 0.45 calories/gram/°C.

In the description of the cooling device according to the invention and with reference to FIGS. **8** to **10**, the same numerical references are used for the elements of this tunnel which have already been referred to in the description of the tunnel in accordance with FIGS. **1** to **7**.

The second cooling device comprises two metal sheets **77** and **78**, bent to the shape of a U and fitting one into the other so as to form a tunnel, the height of which can be adjusted as a function of the respective positions of the sheets **77** and **78**. The sheets **77** and **78** are heat-insulated from the exterior by virtue of the insulating casing **21**. A metal conveyor belt **3** (metallic foil of beryllium bronze), enables the body to be cooled to be displaced from the entrance **5** to the exit **6** of the tunnel.

This latter comprises a heat-transfer section **79** including four exchangers **81**, **82**, **83** and **84**, and a cooling section comprising two members **85** and **86** for inducing turbulence for the flow of gas inside the tunnel. Each of the exchangers of the heat-transfer section **79** is arranged inside the tunnel **2** at a distance from the belt **3** which moves the object to be cooled, in heat-exchange relation with the interior of the said tunnel.

As previously, each exchanger is intended for the circulation and the vaporization of a main refrigerant fluid coming in through a conduit **87** common to the exchangers **81** and **82**, and through a conduit **88** common to the exchangers **83** and **84**. The heat-transfer section **79** comprises a main portion consisting of a first exchanger **82** arranged above the belt **3**, a second exchanger **84** arranged below this belt, opposite the first exchanger **77**, and a secondary portion comprising the two exchangers **81** and **83** arranged facing each other like the exchangers **82** and **84**.

The lower exchangers **83** and **84** form with the conveyor belt **3** a passage **89** for the circulation of gas. The upper exchangers **81** and **82** form with this same belt another passage **90** for the circulation of gas and also of the object to be cooled. These two passages communicate with each other through the sides of the belt **3**. The tunnel **2** also comprises two points of introduction **87** and **88** of the fluid vaporized in the exchangers, located on each side of the conveyor belt **3**, respectively between the exchangers **81** and **82** and between the exchangers **83** and **84**, and communicating respectively with the evacuation orifices of the refrigerant fluid of the exchangers **81** and **82** and those of the exchangers **83** and **84**.

These gas-introduction points, arranged between the outlet **6** and a central zone of the tunnel **2**, permit the circulation, in contact with the body **57** to be cooled, of a counter-flow towards the inlet **5**, above and below the belt **3**, and a concurrent flow towards the outlet **6**, under the same conditions.

As shown in FIG. **10**, one of the exchangers **81** to **84** comprises several tubular sections **91** elongated in the direction of the tunnel, communicating with each other through couplings **92** which extend conversely with respect to the direction of the tunnel, arranged at the two longitudinal extremities of the exchanger and ensuring a circulation of the main refrigerant fluid successively and alternately in identically the same and the opposite direction to that of the body to be cooled. These tubular sections **91** are rigidly fixed to fins **93** or other obstacles, arranged transversely and intended to cause local turbulence in the circulation of the gas inside the tunnel, putting these various sections into thermal contact.

The cooling devices **85** and **86** have a structure similar to that of the exchangers **81** to **84**, with the exception that no means of circulation of the refrigerant fluid is provided. The turbulence members **85** and **86** arranged inside the tunnel, on each side of and at a distance from the conveyor belt **3**, thus comprise a plurality of transverse obstacles similar to the fins **93**. The conveyor belt **3** and the upper turbulence member **85** form a circulation passage for the body to be cooled. An additional passage for the gaseous medium is formed between the belt **3** and the lower turbulence member **86**.

The operation of this tunnel is similar to that previously described. However, the gaseous counter-flow circulating towards the inlet **5** of the tunnel works in heat transfer in the transfer section **79** and in cooling in the cooling section **80**. In addition, each of the gaseous streams which circulate respectively towards the inlet and towards the outlet of the tunnel, circulates partly below the conveyor belt **3**.

The cooling method according to the present invention may be applied to a great variety of products: rubber, plastic material, food products, etc.

What I claim is:

1. A method of cooling a body, comprising;

a. displacing the body to be cooled inside an elongated cooling zone, from the inlet to the outlet thereof, in a longitudinal direction with respect to said cooling zone,

b. introducing into said cooling zone a pressurized gaseous medium, and causing at least part of said introduced gaseous medium to circulate in direct contact with said body, towards said inlet, in said longitudinal direction, as a countercurrent flow with respect to the displacement direction of said body,

c. pressurizing a refrigerant liquid to a pressure higher than the ambient pressure outside said cooling zone; vaporizing said pressurized refrigerant liquid in at least a longitudinal heat exchanger, said heat exchanger being in heat exchange relationship with said cooling zone, and in direct contact with said countercurrent flow; obtaining said pressurized gaseous medium from at least part of the vaporized refrigerant liquid issuing from said heat exchanger,

d. in at least a longitudinal flow path section of heat transfer, extending along said heat exchanger, constraining said countercurrent flow into a substantially turbulent and longitudinal gaseous stream, closely enveloping at least part of the body to be cooled, whereby said gaseous medium acts in at least said longitudinal flow path section as a heat transfer medium from said body to said heat exchanger and has a substantially constant low temperature along said longitudinal flow path section.

2. A method as claimed in claim 1, in which the distance between said heat exchanger and said body to be cooled is adjusted so as to regulate the heat exchange rate between said gaseous medium and said body, along said flow path section of heat transfer.

3. A method as claimed in claim 1, further comprising:

e. introducing said pressurized gaseous medium into said cooling zone, at a location intermediate the inlet and the outlet of said zone,

f. dividing said introduced gaseous medium into a countercurrent flow and a cocurrent flow, circulating in said longitudinal direction, in direct contact with said body, towards respectively the inlet and the outlet of said cooling zone,

g. vaporizing said pressurized refrigerant liquid in at least another longitudinal heat exchanger, said another heat exchanger being in heat exchange relationship with said cooling zone, and in direct contact with said cocurrent flow; obtaining said pressurized gaseous medium from at least part of the vaporized refrigerant liquid issuing from said another heat exchanger,

h. at least in another longitudinal flow path section of heat transfer, extending along said another heat exchanger, constraining said cocurrent flow into a substantially turbulent and lonitudinal gaseous stream, closely enveloping at least part of the body to be cooled, whereby said gaseous medium acts in at least said another longitudinal flow path section as a heat transfer medium from said body to said another heat exchanger and has a substantially constant low temperature along said another longitudinal flow path section.

4. A method as claimed in claim 3, in which the respective flow rates of said countercurrent flow and said cocurrent flow are such that the pressure losses between the intermediate introduction location of the gaseous medium and the inlet of said cooling zone, and between said intermediate location and the outlet of said zone, are substantially equal.

5. A method as claimed in claim 3, wherein the flow of said pressurized refrigerant liquid into at least one of said heat exchangers is interrupted, and consequently, the longitudinal flow path section extending along the interrupted heat exchanger comprises a cooling flow path section, wherein said gaseous medium acts as a cooling medium for said body to be cooled, and becomes heated along said flow path section.

6. A method as claimed in claim 1, further comprising:

i. providing with an auxiliary refrigerant liquid, having a boiling point above tat of said refrigerant liquid, at least an auxiliary longitudinal heat exchanger, located upstream of said heat exchanger with respect to the displacement direction of said body, said auxiliary heat exchanger being in heat exchange relationship with said cooling zone, and in direct contact with said countercurrent flow,

j. in at least an auxiliary longitudinal flow path section of heat transfer, extending along said auxiliary heat exchanger, constraining said countercurrent flow into a substantially turbulent and longitudinal gaseous stream, closely enveloping at least part of the body to be cooled, whereby said gaseous medium acts in said longitudinal auxiliary flow path section as a heat transfer medium from said body to said auxiliary heat exchanger.

7. A method as claimed in claim 6, in which said auxiliary refrigerant liquid is water.

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