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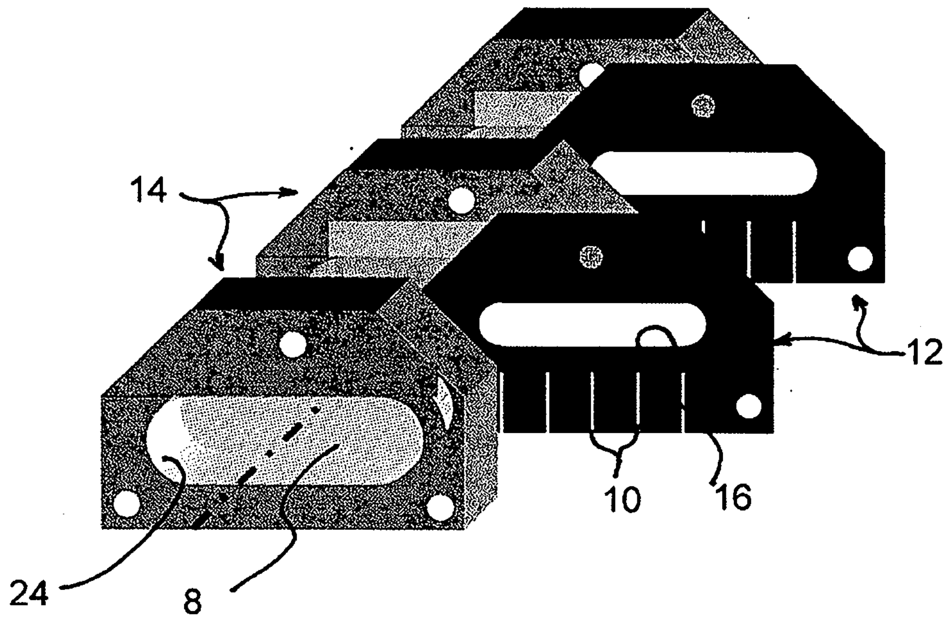
(54) **Fluid microjet system**

(57) A device for generating fluid micro streams comprises a body portion with a fluid supply cavity therein and a plurality of fluid micro channels interconnecting the fluid supply cavity with an external outlet face of the body portion, the body portion being formed from a plurality of stacked plates, said micro channels being formed at interfaces of at least certain of said stacked plates. The micro channels have an oblong cross-sectional profile over a certain section leading to the outlet face, with a major width that is greater than two times a minor width thereof, where the minor width is less than 200 μm.

Fig 1b



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Description

[0001] The present invention relates to a process and device for generating a plurality of fluid microjets.

[0002] A device with multiple fluid microjets is described in US 5,902,543 for cooling an article. The device comprises a plurality of micro channels with diameters from 30 to 100 μm formed as grooves in annular plates that are stacked one against the other so as to form a plurality of micro channels between adjacent plates, the cooling liquid being supplied through a central opening of the circular plates. This allows a dense arrangement of very fine jets of cooling liquid to be projected onto the surface of the article to be cooled, resulting in a wellcontrolled and efficient cooling.

[0003] Although the above-mentioned microjet cooling system has a high cooling efficiency compared to many other conventional systems, the pressure drop through the micro channels for creating the microjets is quite high and the desire to have essentially laminar flow limits the velocity of the microjet. Manufacturing of the stacked circular plates with grooves is also quite costly.

[0004] There is a continuous need for more efficient and effective cooling systems.

[0005] In certain cooling applications, such as metal quenching, a high degree of uniformity of cooling over or through the article is desired to minimize the generation of internal stresses.

[0006] The use of fluid microjets may also be envisaged for applications that are not limited to cooling alone, such as for heating, degassing various liquids such as molten metals, cooling of combustion gases, and chemical reactions between the microjets and a medium onto which they are sprayed.

[0007] An object of this invention is to provide a device for generating a plurality of fluid microjets that is compact, and that has a high uniformity of treatment and a high efficiency in terms of contact between the fluid and an article or medium to be treated.

[0008] It would be advantageous to provide a fluid microjet device that is compact and cost effective to manufacture.

[0009] It would be advantageous to provide a fluid microjet device that minimizes pressure loss for generating the microjets.

[0010] It would be advantageous to provide a fluid microjet device that is economical on fluid usage.

[0011] It would be advantageous to provide a fluid microjet device that is able to generate a high density of very fine microjets of essentially laminar flow, at high speed.

[0012] It is another more specific object of this invention to provide a device for cooling an article very rapidly and with a high efficiency and uniformity.

[0013] It would be advantageous to provide a microjet cooling device that enables rapid freezing of articles, for example for cryogenic freezing of processed food.

[0014] Objects of this invention have been achieved by providing a microjet cooling device according to claim 1.

[0015] Disclosed herein is a device for generating fluid microjets comprising a body portion with a fluid supply cavity therein and a plurality of fluid micro channels interconnecting the fluid supply cavity with an external outlet face or plurality of external outlet faces of the body portion, the body portion being formed from a plurality of stacked plates, said micro channels being formed at interfaces of at least certain of said stacked plates, wherein said micro channels have an oblong cross-sectional profile over a certain section leading to the outlet face that has an oblong shape with a major width that is greater than two times a minor width thereof, where the minor width is in the range of 1 to 200 μm.

[0016] Advantageously, the oblong cross-sectional profile of the microjet improves efficiency of treatment of an article or medium with respect to the conventional microjets that have a cross-section approximately square or circular, the oblong microjet having a greater surface area for a given laminar or turbulent flow rate.

[0017] The micro channels may advantageously be arranged such that their long axes are essentially parallel and essentially orthogonal to a direction of relative movement of an article or medium to be treated with respect to the device.

[0018] In a preferred embodiment, cross-section of micro channels at the outlet have a major width greater than three times the minor width, where the minor width is preferably less than 100 μm, more preferably less than 50 μm. In a preferred embodiment, the distance between adjacent micro channels in a direction of stacking of the plates is preferably less than 10mm. Preferably the distance between adjacent micro channels in the same plane is 0,5 to 10mm. Advantageously the density of micro channels in the device according to this invention may be greater than 4 micro channels per cm^2, preferably more than 10 micro channels per cm^2 up to as many as 1000 micro channels per cm^2.

[0019] The position of micro channels in adjacent plates may advantageously be offset in a direction orthogonal to the plate stacking direction thus giving a better surface coverage by the microjets of the article to be treated.

[0020] The micro channels may advantageously have a non-constant major width, the major width being larger towards the input side and narrower towards the outlet face. This advantageously allows the body portion to have the necessary mechanical integrity and good sealing between stacked plates, while reducing flow resistance and therefore the pressure drop across the micro channels. In an embodiment, the micro channels may advantageously be formed as slits in a first set of plates sandwiched between plates of a second set, central cavities of the second set of plates configured such that they overlap ends of the slits opposite the outlet end of the micro channel. The first set of plates also comprise a central cavity for passage of the supply fluid there-through, the cavity however being separated from ends of the slits by a certain width of material ensuring structural integrity of the first set of sheets. The minor width of the micro channels may thus be determined by the thickness of plates of the first set, the width of the slits that are cut through the plate determining the major width of the micro channels, at least over a longer section thereof.

[0021] The slits through the plates of the first set may be cut by various known cutting techniques, such as by laser cutting, by means of a die, high-pressure water jet cutting, electro-erosion and other known manufacturing techniques for cutting through thin plates as well as etching. The first set of plates may be made of the same material as the second set of plates, or of a different material whereby the combination of materials may be optimized for sealing effectiveness between the stacked faces, ease of cutting and forming the slits, and for cost reasons. The plates of the first set may for example be made of a ceramic, metal or plastics material, depending on the application and the environmental temperatures whereas the plates of the second set could be made of steel or plastic or ceramics depending on the application and operating temperature range. Plates of the second set may have smooth surfaces, for example polished surfaces with a low roughness thus reducing flow resistance in a fairly economical manner. The density of microjets can also be easily varied by varying the thickness of the plates of the second set, without affecting the micro channel geometry or the manufacturing process for the micro channels.

[0022] A fluid microjet device according to an embodiment of this invention may advantageously be used for rapid freezing of food stuffs and other perishable goods, the fluid microjet device being installed in an apparatus having a supply of cryogenic liquid, in particular liquid nitrogen, that is injected by the microjets onto the article to be frozen. The articles to be frozen may advantageously be transported on a mesh conveyor belt, fluid microjet devices being positioned either side of the conveyor belt such that jets of the cooling liquid are projected upon opposing sides of the article. The extremely rapid and efficient cooling resulting from the microjet geometry and arrangement according to this invention enables particularly rapid cooling with minimal use of the cryogenic liquid thus reducing freezing cycle time, and use of cooling liquid, thus reducing overall costs as well as improving product quality. Very rapid freezing of food stuffs reduces dehydration of the product during the freezing process, among other advantages.

[0023] Fluid microjet devices according to the invention may also be used in many other cooling applications, such as for cooling of metal articles in material treatment processes (high precision extrusion quenching, sheet and plate uniform quenching, roll cooling, cooling of polymer extrusions).

[0024] Further objects and advantageous features of the invention will be apparent from the claims and the following description and drawings in which:

Figure 1 a is a perspective view of a portion of a fluid microjet device formed of a stack of plates according to this invention;

Figure 1b is an exploded perspective view of a portion of a fluid microjet device formed of a stack of plates according to this invention;

Figure 2a is a view of a plate of a second set of plates of an embodiment of the invention;

Figure 2b is a view of a plate with micro channels of a first set of plates of the device according to this invention;

Figure 2c is a view of the stacked assembly of the plates of figures 2a and 2b;

Figure 3a is a perspective view of a section of an embodiment of the device according to this invention;

Figure 3b is a perspective representation of fluid microjets according to this invention;

Figure 3c is a partial view of a configuration of fluid microchannels according to an embodiment of this invention;

Figure 4a is partial detailed view of first and second plates of a device according to another embodiment of this invention, showing microchannels according to a second embodiment;

Figure 4b is a view similar to figure 2a, of a third embodiment;

Figure 5 is a perspective schematic view of part of an apparatus for cryogenic freezing of processed food products according to this invention.

[0025] Referring to the figures, a device for generating fluid microjets 7 comprises a body portion 4 comprising an outlet face 6 through which micro streams of fluid 7 are projected, a fluid supply cavity 8 within the body portion connected to fluid supply system (not shown), and a plurality of micro channels 10 in fluid communication between the fluid supply cavity 8 and the outlet face 6.

[0026] In a preferred embodiment, the body portion 4 comprises a stack of plates 12, 14 between which the micro channels 10 are formed.

[0027] In a preferred embodiment, the micro channels 10 are formed in plates 12 of a first set as slits that are cut through the entire thickness of said plates of the first set and plates 14 of a second set without slits are interposed therebetween. The micro channels 10 are thus formed by the slits in the first set of plates 12 sandwiched between the plates 14 of the second set in an alternating manner. The first plates 12 have openings 16 that form part of the boundary of the fluid supply cavity 8 in the body, the slits 10 extending from an outlet edge 18 that forms part of the body portion outlet face 6 to a closed end 20 that is separated at a certain distance R from an edge 22 of the opening 16, the distance between the end of the slit 20 and the edge 22 being sufficient to ensure mechanical integrity of the first plate 12 during handling and assembly between the second plates 14.

[0028] The second plates 14 also have openings 24 that form part of the fluid supply cavity 8, an edge 26 of the opening adjacent the outlet face 6 overlapping a portion 10a of the slits such that the closed ends 20 of the slits are in fluid communication with the cavity 8 as best seen in figure 2c, 4a and 4b . The second plates 14 may be of a simple planar construction with smooth surfaces thus lowering flow resistance in the micro channels 10.

[0029] The slits 10 may be produced by various conventional techniques, such as laser cutting, water jet cutting, electro-erosion, die stamping, etching, or by means of circular saws, depending on the material of the first plate 12 and the channel dimensions. The slit manufacturing method may also be chosen as a function of the surface smoothness of the micro channel and manufacturing costs. The alternate sandwich construction of first and second plates with the micro channels formed by slits in one of the two plates provides a large versatility in the choices of materials and manufacturing techniques for the plates to optimize the performance and cost for various applications. For high temperature applications, the plates 14 may for example be made of a high temperature stainless steel whereas the first plates 12 could also be made of steel, or a thin ceramic such as mica. For low temperature applications the first plates with slits 12 could be made out of a sheet of thin polymer or composite material. Depending on the desired density of micro streams, the second plates 14 may be from various thicknesses, without affecting the manufacturing of the micro channels.

[0030] The stack of plates forming the body portion 4 may be held together sealingly by means of compression bolts 11 extending through bolt holes 13 in the body portion, clamping the stack of plates together.

[0031] Referring to figure 4a, the micro channels 10 may advantageously have non-constant width, with a large width W_1 towards the closed end 20 in order to increase the channel cross-section at the fluid inlet, the channel width reducing to a narrow section W_2 corresponding essentially to the desired micro stream cross-sectional profile at the outlet face 6. The latter configuration reduces flow resistance and pressure drop through the micro channels without compromising on the structural integrity of the device and the sealing between adjacent plates. The enlargened closed ends of the slits may be easily manufactured, for example by a die stamping etching or electro-erosion process.

[0032] As shown in figure 4b, the micro channels may have non-constant profiles 27 also at the outlet end for example to create a laval shaped channel for the creation of supersonic fluid jets.

[0033] The micro channels could alternatively be formed as grooves on the surface of plates that are stacked one on the other where a side of the plate opposite the grooves is stacked against the side with grooves of the adjacent plate. Such plates could advantageously be made by injection moulding of a polymer or other injectable materials such as certain metal alloys, whereby the die imprinting the micro channels could be made by photo lithography and etching. For example the injection moulding die with the micro channel profiles could be made out of silicon in a standard etching process. This would allow micro channels of particularly small and well controlled dimensions to be produced. The injected micro channels could have non-constant profiles as discussed in relation to figures 4a and 4b above.

[0034] According to the invention, the micro channels advantageously have an oblong profile at or proximate the outlet face 6, defined by a minor width W_{min} and a major width W_{maj} where the major width is advantageously more than two times the value of the minor width. The micro channels are configured preferably such that the major width W_{maj} is defined by the narrow width W_2 of the slit 11 and the minor width is defined by the thickness of the first sheet 12. It is however possible to have a first plate thickness superior to the slit width W_2 such that the micro channel major width W_{maj} is defined by the plate thickness and the slit width W_2 defines the minor width W_{min}.

[0035] The micro channels in a first plane may be offset in a direction orthogonal to the stacking direction of the plates, which may advantageously correspond to a direction of relative movement between the fluid microjet device and an article to be treated such that the oblong micro streams have a better impact coverage across the surface to be treated.

[0036] The oblong shape of the micro streams, and in addition the offset arrangement of adjacent micro streams provides more uniform and more efficient cooling of the surface to be treated than the conventional microjets. As shown in Fig. 3c, a plurality of successive micro stream layers may be offset by a distance Os with respect to a first layer depending on the major width and spacing S (see figure 3) between micro streams and the cooling efficiency required.

[0037] Referring to figure 5, an apparatus for cryogenic freezing of articles, for example food stuffs, comprises a conveyor system 30 for conveying the articles through the apparatus, and one or more fluid micro stream devices 2 arranged along the conveyor system and configured to project micro streams on the articles as they are transported along the conveyor system. The conveyor system may comprise a conveyor belt that is preferably in the form of a mesh or grill in order to allow projection of micro streams from above and below the articles for more efficient and rapid all round cooling of the articles. Other conveyor systems may however be used, depending also on the articles to be cooled.

[0038] In the embodiment shown, fluid microjet devices are placed on opposite sides of the conveyor belt 32, across the width of the conveyor belt and project micro streams of fluid on top and bottom sides of the articles 34 to be cooled. Depending on the amount cooling required, a plurality of fluid micro stream devices can be arranged along the conveyor belt as shown in figure 3. For cryogenic freezing of articles, the cooling fluid supplied to the devices is advantageously liquid nitrogen although other very low temperature cooling liquids could be used, such as liquid helium. In view of the relatively high cost of liquid nitrogen and other cryogenic cooling liquids, the very rapid and efficient cooling provided by the micro streams enables minimum use of cooling fluid and moreover the velocity of micro streams may be easily varied with a direct effect on the rate of cooling. For example, the micro streams velocity may be reduced, by reducing pressure in the supply cavity towards the end of the cooling cycle. In the arrangement of figure 5, the most downstream fluid microjet device 2c may for instance have a lower supply pressure of cooling liquid than the most upstream device 2a.

[0039] The invention may advantageously be used in various applications not limited to cooling, such as for heating, degassing various liquids such as molten metals, cooling of combustion gases, and chemical reactions between the microjets and a medium onto which they are sprayed.

[0040] In applications for chemical reactions on liquid metals, the device for generating fluid microjets is supplied with liquid metal as the fluid for generating fluid microjets and the device is immersed in a reaction medium, in particular a reaction gas.

[0041] In applications for degassing liquid metals, the device for generating fluid microjets is immersed in the liquid metal and a degassing medium, such as an inert gas such as Argon, is supplied as the fluid for generating fluid microjets and injected into the liquid metal.

Examples

Example 1 : Quenching Aluminium Alloy

[0042] Cooling of Alluminium alloy strip, thickness of 0.5 to 5 mm, typical specific flow 20 liter/m^2/s. A typical set of values for microjets for this application are: W_{maj} = 120μm, W_{min} = 50μm, S = 3mm, H = 3mm.

[0043] Advantages compared to conventional cooling technology: More homogeneity in cooling, and consequently high mechanical properties homogeneously distributed, less residual stresses.

Example 2: Freezing Food

[0044] For cryo-freezing of foodstuffs such as meat, fish, fruits Typical specific flow 0.5 liter/m^2/s. A typical set of values for microjets for this application are: W_{maj} = 150μm, W_{min} = 20μm, S = 5mm, H = 5mm.

[0045] Advantages compared to conventional freezing technology: economy of cryogenic fluid (which is expensive). The quantity of cryo-coolant needed is minimal, since the freezing is optimally conducted and the heat-transfer is optimal. Rapidity of freezing and small jet impingement forces preserves also the integrity of the products as they are being frozen.

Example 3: Heating, degassing and chemical reactions on liquid metals.

[0046] In this example, liquid metal, for example aluminium, is sprayed as microjets. The ambient gas around the streams interacts with the liquid metal microjets. The gas may be used to heat the liquid metal, or to interact with it chemically, or for degassing. The liquid metal is thus supplied as the fluid for generating fluid microjets and the device immersed in a reaction medium, in particular a reaction gas. Typical specific flow 5 liter/m^2/s. A typical set of values for microjets for this application are: W_{maj} = 1000μm, W_{min} = 180μm, S = 6mm, H = 4mm.

[0047] Advantages compared to conventional technology: The surface of interaction and of contact between gas and liquid is maximal. Therefore the chemical reaction as well as the heat transfer is highly efficient.

Claims

1. A device for generating fluid micro streams comprising a body portion with a fluid supply cavity therein and a plurality of fluid micro channels interconnecting the fluid supply cavity with an external outlet face of the body portion, the body portion being formed from a plurality of stacked plates, said micro channels being formed at interfaces of at least certain of said stacked plates, **characterised in that** said micro channels have an oblong cross-sectional profile over a certain section leading to the outlet face, with a major width that is greater than two times a minor width thereof, where the minor width is less than 200 μm.

2. Device according to claim 1 wherein the minor width of the micro channels is less than 50 μm.

3. Device according to claim 1 or 2 wherein the major width is greater than three times the minor width.

4. Device according to any one of the preceding claims wherein the micro channels in adjacent plates are offset in a direction orthogonal to a plate stacking direction.

5. Device according to any one of the preceding claims wherein the density of micro channels is greater than 10 micro channels per cm^2.

6. Device according to any one of the preceding claims wherein the micro channels have a non-constant width, the width being larger towards the input side and narrower towards the outlet face.

6. Device according to any one of the preceding claims wherein the micro channels may advantageously be formed as slits in a first set of said plates, interposed between a second set of said plates.

7. Device according to the preceding claim wherein central cavities of the second set of plates are configured to overlap ends of the slits.

8. Device according to claim 6 or 7 wherein the first set of plates are made of a material that is different to a material from which the second set of plates are formed.

9. Apparatus for rapid freezing of food stuffs and other perishable goods, comprising a conveyor system, a cryogenic fluid supply system, and one or more devices for generating cryogenic fluid micro streams installed along the conveyor system, each fluid micro stream device comprising a body portion with a fluid supply cavity therein connected to the cryogenic fluid supply system and a plurality of fluid micro channels interconnecting the fluid supply cavity with an external outlet face of the body portion, the body portion being formed from a plurality of stacked plates, said micro channels having minor widths less than 200 μm and being formed at interfaces of at least certain of said stacked plates.

10. Apparatus according to claim 9 wherein the conveyor system comprises a mesh conveyor belt and wherein devices for generating cryogenic fluid micro streams are arranged on opposite sides of the conveyor belt.

11. Apparatus according to claim 9 or 10 wherein the cryogenic fluid is liquid nitrogen.

12. Apparatus according to claim 9, 10 or 11 wherein the micro channels have an oblong cross-sectional profile over a certain section leading to the outlet face, a major width of the channel being greater than two times a minor width thereof, where the minor width is less than 200 μm.

11. Apparatus according to any one of claims 9 to 12 wherein the devices for generating cryogenic fluid micro streams comprise the further features of the device according to any one of claims 2 to 8.

12. Apparatus for chemical reactions on liquid metals comprising a device for generating fluid microjets according to any one of claims 1 to 8, wherein the liquid metal is supplied as the fluid for generating fluid microjets and the device is immersed in a reaction medium, in particular a reaction gas.

13. Apparatus for degassing liquid metals, comprising a device for generating fluid microjets according to any one of claims 1 to 8, wherein the device is immersed in the liquid metal and a degassing medium, such as an inert gas, is supplied as the fluid for generating fluid microjets.

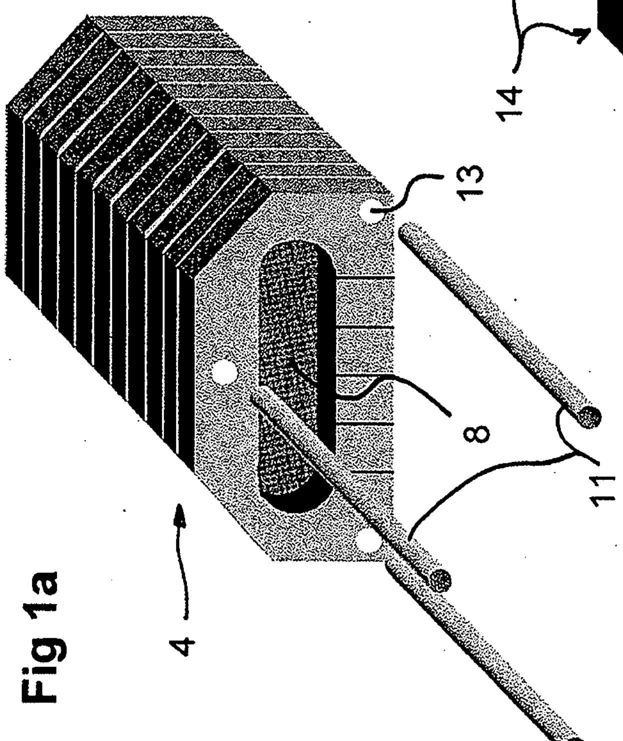

Fig 1a

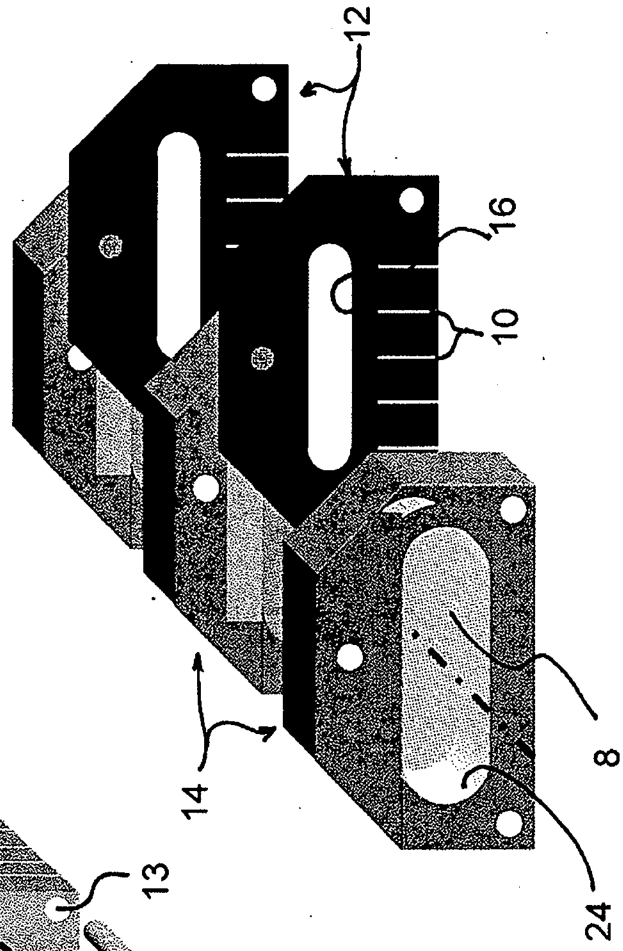

Fig 1b

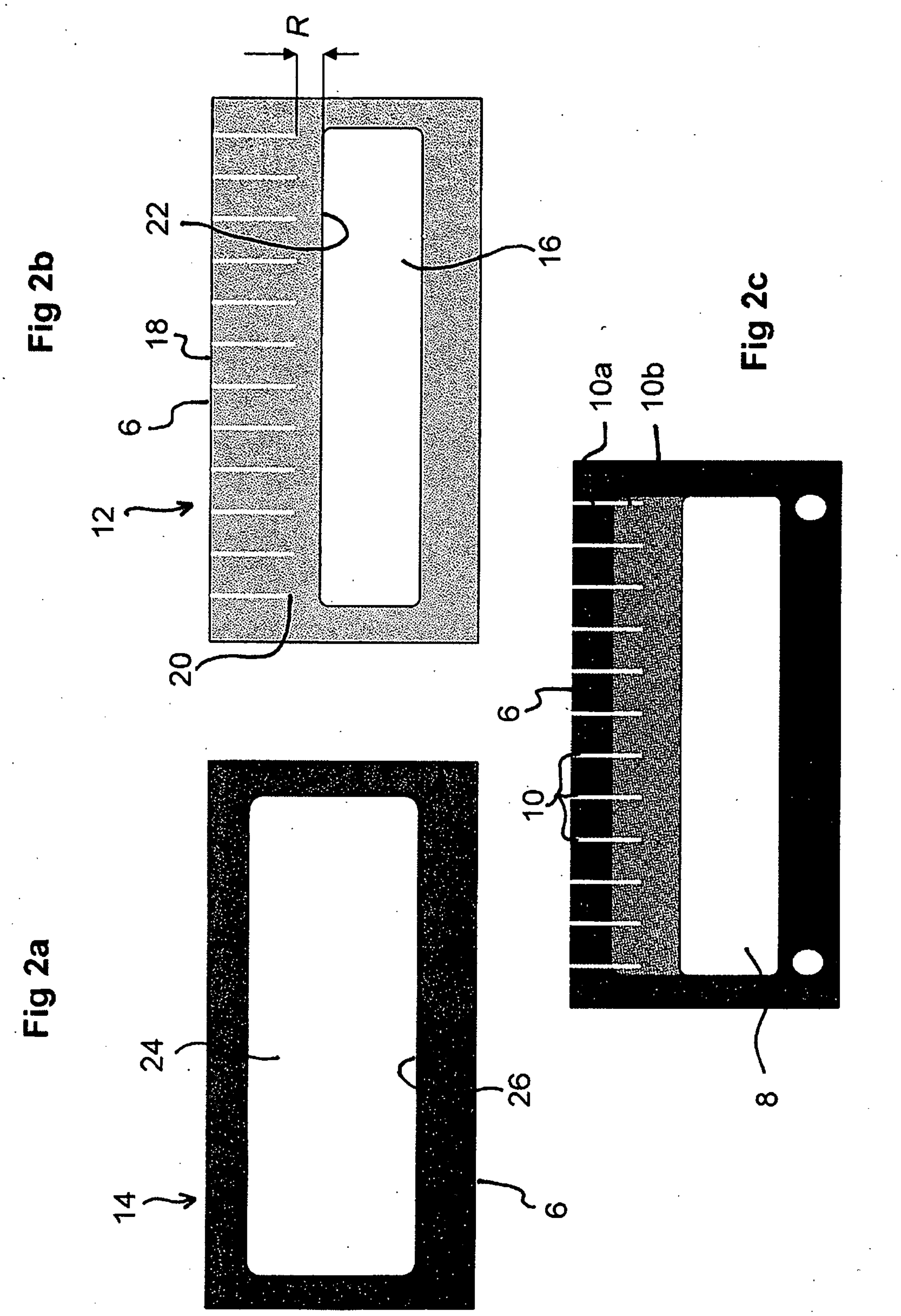
Fig 2a
Fig 2b
Fig 2c
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10a
10b
10
8

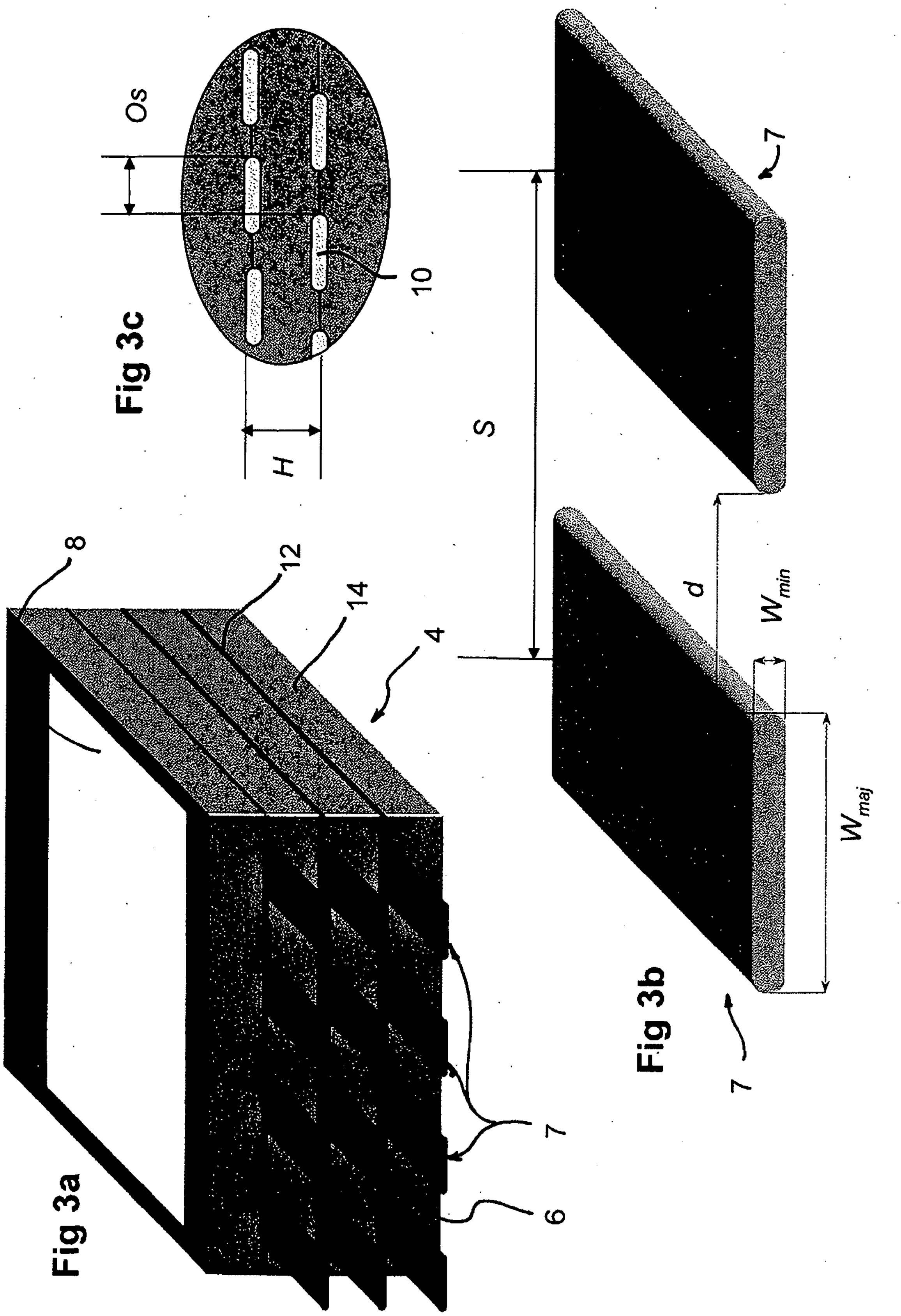
Fig 3a
8
12
14
4
7
6
Fig 3c
Os
10
H
S
d
7
W_min
W_maj
Fig 3b
7

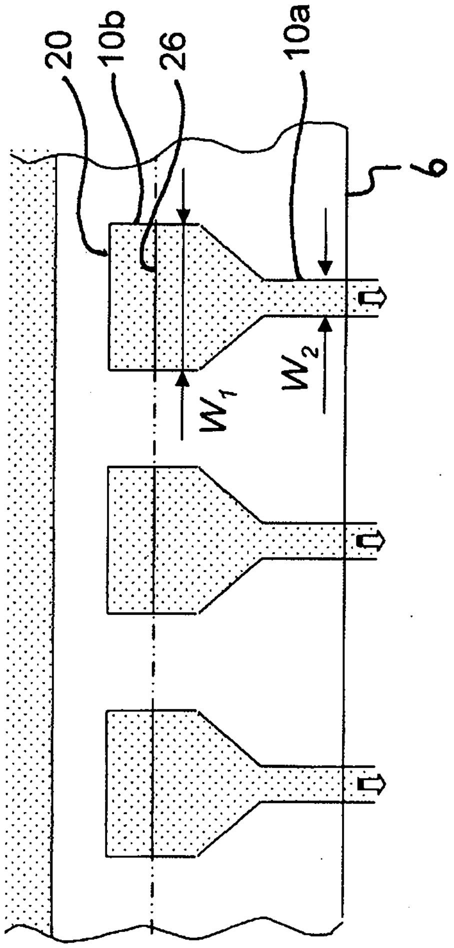

Fig 4a

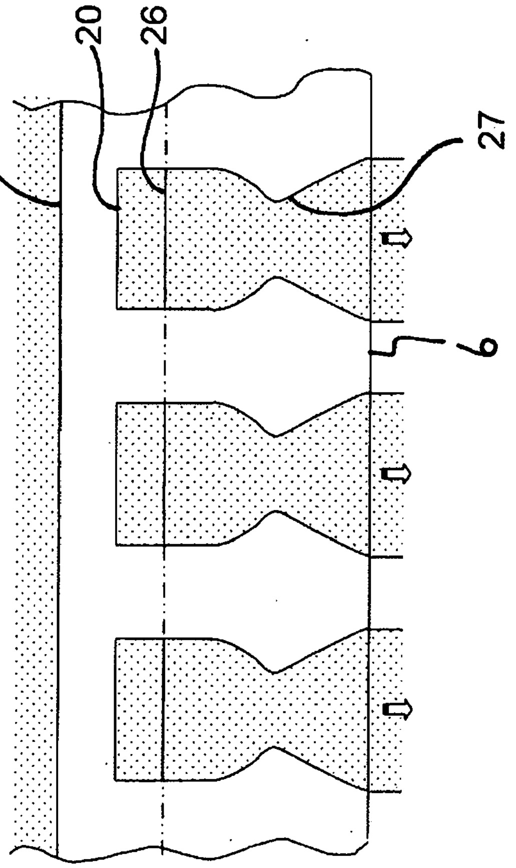

Fig 4b

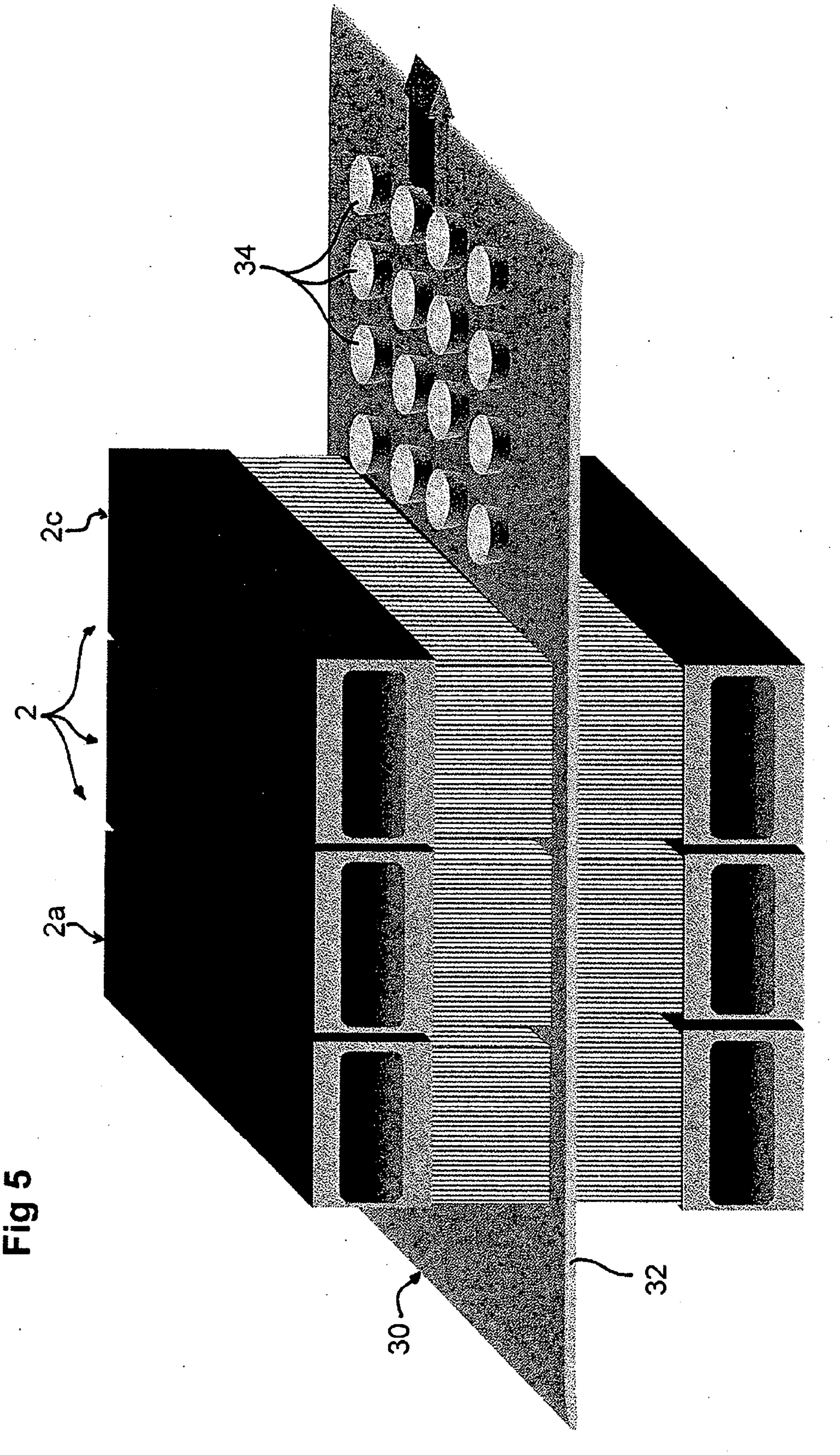

Fig 5

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EUROPEAN SEARCH REPORT

Application Number
EP 08 00 1981

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	US 4 565 325 A (LUDWIG BERNHARD [DE]) 21 January 1986 (1986-01-21) * column 1, lines 24-30 *	1-6	
X	US 2006/186229 A1 (COTLER ELLIOT M [US]) 24 August 2006 (2006-08-24) * paragraphs [0002], [0021], [0023]; claims 1-5; figures 2,5a,5b *	1-4,6,8	
A	US 2002/134866 A1 (SCHMIT LAURENT [FR] ET AL) 26 September 2002 (2002-09-26) * the whole document *	1-9,13, 15,16	
A	GB 1 279 366 A (KONINKLIJKE HOOGOVENS EN STAAL [NL]) 28 June 1972 (1972-06-28) * the whole document *	1-9,13, 15,16	TECHNICAL FIELDS SEARCHED (IPC)
A	US 4 750 331 A (BARTHELMES PATRICE [FR] ET AL) 14 June 1988 (1988-06-14) * the whole document *	10-14	C21D F28F B21B F25D H01L A23L B05B
A	US 4 210 288 A (DOBSON JOHN C [GB]) 1 July 1980 (1980-07-01) * the whole document *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	9 December 2008	Rischard, Marc

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

3

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 08 00 1981

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

- [ ] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- [X] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

- [ ] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

- [ ] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

- [ ] The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 08 00 1981

The Search Division considers that the present European patentapplication does not comply with the requirements of unity of invention and relates to severalinventions or groups of inventions, namely:

1. claims: 1-9, 13, 15-16

   Device for generatling fluid micros streams with high cooling uniformity and efficiency and use thereof

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2. claims: 10-12,14

   Apparatus for freezing perishable goods with reduced consumption of cryogenic liquid

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 00 1981

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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