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

(11) EP 1 120 180 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.08.2001 Bulletin 2001/31

(51) Int Cl.[7]: **B22D 11/041**, B22D 11/07, B22D 11/115

(21) Application number: **01101347.1**

(22) Date of filing: **22.01.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **26.01.2000 IT MI200096**

(71) Applicant: **DANIELI & C. OFFICINE MECCANICHE S.p.A.**
33042 Buttrio (UD) (IT)

(72) Inventors:
- **Poloni, Alfredo**
  34070 Fogliano Redipuglia (Gorizia) (IT)
- **Pavlicevic, Milorad**
  33100 Udine (IT)
- **Kolesnichenko, Anatoly**
  252147 Kiev (UA)
- **Codutti, Andrea**
  33100 Udine (IT)

(74) Representative: **Gervasi, Gemma, Dr.**
Notarbartolo & Gervasi S.p.A.,
Corso di Porta Vittoria, 9
20122 Milano (IT)

(54) **Process and device for the continuous casting of metals**

(57) In a continuous-casting plant which uses a tank (1) made of refractory material set on top of the crystallizer (9) for removing the meniscus and the supernatant layer (7) of covering powders from the solidification area, around the said tank there are electromagnetic means (5, 6) designed to generate variable magnetic fields for slowing down and making uniform the disordered flow of liquid metal inside the said tank, whilst at the joint between the tank and the crystallizer, other electromagnetic means (11) are set which are designed to generate a direct magnetic field so as to remove locally the liquid metal from the walls of the tank (1) and of the crystallizer (9).

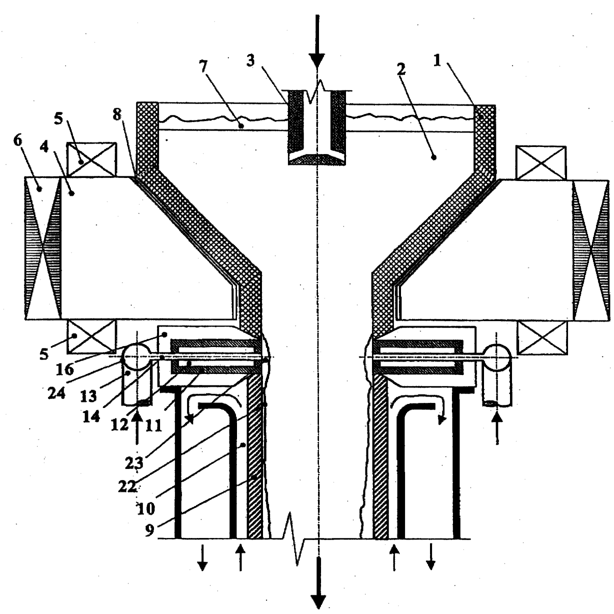

Fig. 1

EP 1 120 180 A1

Description

Field of invention

[0001] The present invention refers to a process for improving the quality of continuously cast metallic bodies and to the corresponding implementation device. More precisely, it refers to an essentially electromagnetic process and to the corresponding implementation device, which may be used in continuous-casting plants for casting billets, blooms and slabs, for improving the surface and internal quality of the cast product, when a tank made of refractory material is set upstream of the crystallizer.

State of the art

[0002] Continuous casting is a technique extensively used in the production of metallic bodies having various shapes and sizes (blooms, slabs, and billets), which has reached a high level of efficiency, both in terms of reliability of the plants and systems and in terms of quality of the products obtained, which is generally satisfactory.

[0003] However, in the casting process, certain events may occur which damage the surface and internal quality of the cast products and/or lead to disastrous leakage of liquid metal from the solidified shell. For example, (i) especially in the presence of marked fluctuations in the level of the meniscus, non-metallic particles coming from the tundish and from the covering powders may be drawn to the interface between the liquid metal and the crystallizer, and here be englobed in the solidifying metal, thus causing defects, such as internal inclusions; (ii) lack of uniformity in rate of flow of the liquid metal in the crystallizer may cause a nonuniform solidification accompanied by possible tearing of the shell that is forming, in particular on account of the high rates of casting, at which the said shell is thinner, and/or by cracks on the surface or within the slab; (iii) disturbance of the stability of the meniscus may cause poor lubrication, which leads to the solidifying metal to stick to certain points of the walls of the crystallizer, so increasing the likelihood of causing tearing of the shell and/or defects in its surface; (iv) the longitudinal oscillation of the crystallizer, which is necessary to prevent the solidifying metal from sticking to the walls of the crystallizer and to facilitate penetration of particular lubricants between the crystallizer and the solidifying shell, may, in the presence of a disturbed meniscus, bring about deep and irregular markings on the surface of the skin due to oscillation.

[0004] These are just a few of the problems that can crop up; they are of considerable importance both as regards the quality of the cast product obtained and as regards the maximum productivity achievable, as well as for the cost of the subsequent transformation of the cast product and for the quality of the finished products.

[0005] In fact, precisely in view of the possible defectiveness of the slabs, it is necessary to inspect them and possibly subject them to surface-conditioning treatments. Frequently such operations cannot be carried out with the slabs hot, and the cast product must be cooled down in specifically designed areas of the plant, undergo surface inspection, be conditioned, and finally be brought back up to a high temperature (1200 - 1400 °C) for it to be further processed, for example, hot rolled. Clearly, all this results in an increase in production costs and/or in a poorer quality of the end product.

[0006] Numerous solutions have been proposed to overcome such drawbacks. For example, it is known that the use of particular powders, referred to as "covering powders", for limiting oxidation of the molten bath and for lubricating the interface between the solidifying metal and the walls of the crystallizer in a more stable way, produces positive effects on the surface and internal quality of the cast product.

[0007] By using particular discharging devices between the tundish and the crystallizer it is possible to control the flow of the liquid metal entering the crystallizer, so as to reduce the non-metallic inclusions in the product and favour flotation of the surface gases, reduce disturbance of the meniscus, where the initial solidification occurs, and avoid direct "hot" flows of molten metal, which could lead to the partial remelting of some areas of the shell that is forming.

[0008] Optimization of the longitudinal oscillations (frequency and amplitude, nonsinusoidal waveforms of the oscillation) considerably reduces the presence of markings due to oscillation.

[0009] Attempts to improve the fluid-dynamic conditions in the crystallizer refer to the use of particular "tanks" made of refractory material and set immediately upstream of the crystallizer with the purpose of removing the meniscus of the liquid metal from the area of start of solidification, thus limiting the possibility of drawing particles of refractory material or scale into the solidifying metal, and favouring uniformity of the rates of processing, of lubrication and of heat exchange between the cast product and the crystallizer, especially in the area of initial solidification.

[0010] The above technique, albeit interesting, poses further problems. In fact, the area of joining between the refractory material of the walls of the "tank" and the contiguous edge of the cooled metal crystallizer, referred to as "triple point", proves very delicate both on account of the possible desegregation of the refractory material due to the sharp thermal jump between the latter and the cooled crystallizer, and because the molten metal tends to start solidifying precisely at the said joining point, with a high likelihood of adhesion to the refractory material and corresponding problems of formation of surface defects in the bodies produced, or, worse still, of catastrophic tearing of the skin and consequent leakage of the liquid metal, which may cause damage to the casting machine and the stoppage of operations.

[0011] The use of a gas, such as nitrogen or argon, or of solid lubricants (see, for instance, the US patents Nos. 5 027 887, 5 045 276, and 4 130 423), injected at the said joint to form a protective layer has not yielded particularly encouraging results, essentially because the liquid metal, which is considerably heavier than the lubricant and the gas, frequently manages to tear the protective layer and to come into contact even so with the walls of the "tank" that are made of refractory material. It is also difficult, in such conditions, to control the uniformity of distribution of the pressure of the gases, which gives rise to cavities on the surface due to instability, or else to the formation of pin holes on the surface caused by the gas being englobed in the solidifying metal. In addition, the use of gas in solution does not enable the introduction of lubricating material between the solidifying shell and the crystallizer.

[0012] The US patents Nos. 5 494 095 and 5 379 828 propose to set, between the "tank" made of refractory material and the crystallizer, an insert consisting of a material having a thermal and electrical conductivity lower than that of the material of which the crystallizer is built, so that the molten metal will start to solidify at the insert itself. The joint between this and the refractory material of the tank is heated by means of an alternating electromagnetic field.

[0013] A similar solution, but without heating of the joint between the refractory material and the intermediate insert is proposed by the US patent No. 4 773 469.

[0014] In continuous casting, in particular of thin slabs (i.e., just a few centimetres thick) or of strip (just a few millimetres thick), it has been proposed to use electromagnetic fields in order to obtain confinement of the molten metal (see, for example, the US patents Nos. 4 353 408 and 5 513 629).

[0015] Up to now, to the knowledge of the present inventors, in connection with machines for continuous casting which include a tank made of refractory material that is directly connected to the cooled metal crystallizer and is set immediately upstream of the latter, systems using electromagnetic fields for rendering the flow of the liquid metal uniform, prior to its entry into the cooled crystallizer, and for preventing solidification of the metal at the joint between the tank and the crystallizer have not been proposed.

Summary

[0016] The aim of the present invention is to overcome the drawbacks discussed above, improving the surface quality of the continuously cast product, making possible a quality cast at higher speeds and hence obtaining a bigger output, by rendering the flow and the temperature of the liquid metal in the said tank uniform, preventing adhesion of the solidifying metal at the joint between the tank and the cooled crystallizer, thus reducing the depth of the markings due to oscillation in the longitudinal direction of the crystallizer and possibly getting rid of them altogether.

[0017] The process according to the present invention uses a tank made of refractory material (set on top of a crystallizer), into which, by means of a special discharging device, liquid metal is poured continuously, the said liquid metal moving with disordered motion towards the crystallizer, and in the latter starting to solidify at a point corresponding to the joining area (i.e., the aforesaid "triple point") between the tank and the crystallizer, forming a so-called "skin" on the cast body, the skin being continuously extracted from the crystallizer, the said tank having the purpose of removing, from the area of start of solidification, the free surface of the metal, the supernatant scale and the area of molten metal having perturbed flow as a result of the continuous addition of metal. The aforesaid process is characterized by the combination, in a relationship of co-operation, of a first action of slowing down and rendering regular the disordered motion of the liquid metal, the said action being implemented in the tank, and of a second action of detachment of the liquid metal at the said triple point, the said detachment of the liquid metal being possibly accompanied also by the detachment of the said skin from the walls of the crystallizer. The said first action of slowing down and of rendering uniform the motion is achieved by electromagnetic fields which are periodically interrupted and modified in direction and intensity, the said electromagnetic fields being generated by an induction system made up of a first continuous core, set around the tank and equipped with at least four poles arranged at regular intervals all around the tank, and of windings arranged around each pole, the said poles being energised in a pre-defined order (for example, simultaneously but with different intensity and sign, as illustrated in Figure 3) for a given period of time Δt, and with a time interval between two consecutive energising corresponding to 0.1-0.2 Δt. The current value used will range, as shall be seen in what follows, from 1 kA to 200 kA. The currents are considered positive when the magnetic field generated is directed towards the liquid metal.

[0018] Such a scheme of energising of the poles of the induction system generates electromotive forces which induce, in the liquid metal, appropriate action of rendering the motion of the fluid threads of the metal itself uniform and of slowing them down, so limiting the hydrodynamic disturbance caused both by immission of the steel and by the action of the electromagnetic system at the triple point, which will be described hereinafter.

[0019] The second action of detachment of the liquid metal from the triple point is achieved by means a pulsating magnetic field, which is generated by a second induction coil consisting of a plurality of turns inserted into a second magnetic core which completely surrounds the crystallizer and is generally electrically insulated from the external environment. The second induction coil is activated by means of a pulse current, having an intensity of between 5 kA and 200 kA, preferably between 30 kA and 200 kA, with pulses having a duration of between 50 µs and 500 µs, preferably between 100 µs and 200 µs, and a frequency of between 2 Hz and 150 Hz. preferably between 10 Hz and 100 Hz The magpetic field thus produced generates electromagnetic forces directed towards the liquid metal, which in turn cause detachment of the latter from the walls of the tank-crystallizer ensemble, thus creating a stable cavity between the surface of the liquid metal and the said walls.

[0020] The second induction coil can be set between the tank and the crystallizer, and in this way it directly faces onto the area in which the liquid metal is contained. In this case, the second induction coil must be appropriately protected by means of cooling, or else it can be set outside the crystallizer.

[0021] The process according to the present invention also envisages the possibility of carrying out a distribution of lubricant at the aforesaid triple point, with the purpose of favouring sliding of the skin being formed against the walls of the crystallizer. This distribution of lubricant may be omitted if means for favouring detachment of the solidifying skin from the crystallizer walls are used. Preferred means for this purpose are exciters of an electrodynamic, pneumatic, magnetostrictive, or piezoelectric type, etc., applied outside the crystallizer, with at least one on each wall, to make the crystallizer vibrate both transversally and longitudinally, in order to reduce friction between the solidified skin and the walls of the crystallizer.

[0022] The process according to the present invention also envisages the possibility of using a lubricant with ferromagnetic properties, preferably consisting of a mixture of ferromagnetic particles, sized smaller than 100 µm, in quantities of between 5 wt% and 25 wt%, and the usual powdered oxides and/or oils of the type commonly used in continuous casting.

[0023] In use, at the triple point, the part of lubricant that is in contact with the internal walls of the tank and of the crystallizer, and possibly with the second induction coil, assumes a relatively low temperature, maintaining a permeability higher than unity. In this way, the magnetic field produced by the second induction coil keeps the lubricant in contact with the induction coil itself, if the latter is facing towards the inside of the tank-crystallizer ensemble, and in contact with the said internal walls. In addition, the presence of ferromagnetic particles in the lubricant ensures that on the surface of the liquid metal in contact with the lubricant itself there are electromagnetic forces which are considerably higher, for example 80 to 100 times higher, than those obtainable in the absence of the said ferromagnetic particles.

[0024] The above-mentioned forces are appropriately directed towards the liquid metal and prevent the liquid metal, which is much denser than the lubricant, from breaking the layer of lubricant, and hence from coming into contact with the walls of the tank and of the crystallizer.

Brief Description of the Drawings

[0025] For clarity of exposition, first of all the device according to the invention will be described with reference to an embodiment thereof which is presented merely to provide a non-limiting example and illustration of the purposes and of the scope of the present invention and which is represented in the attached plates of drawings, where:

Fig. 1 is a schematic cross sectional view of the device according to the invention;

Fig. 2 is a schematic representation of the arrangement of the turns in an electromagnetic system for rendering the flow of molten metal uniform;

Fig. 3 is a representation of one operating mode of the system shown schematically in Fig. 2;

Fig. 4 is a schematic representation of the effect that the use according to the present invention of the electromagnetic system of Fig. 2 according to the operating mode illustrated in Fig. 3 has on the circulation of the molten metal in the tank, and hence on the uniformity of the flow of the metal itself;

Fig. 5a is a partial schematic representation of the joining area between the tank made of refractory material and the cooled metal crystallizer, in the case where electromagnetic means are used for generating the forces necessary for detachment of the molten metal from the tank-crystallizer ensemble;

Fig. 5b is an enlargement of the joining area of Fig. 5a;

Fig. 6 is a partial schematic view of the joining area between the tank made of refractory material and the cooled metal crystallizer, in which the induction coil is set outside the crystallizer;

Fig. 7 represents a view of a cross section according to A-A of Fig. 6;

Fig. 8 represents a view of a cross section according to B-B of Fig. 7;

Fig. 9 represents a variant of the solution illustrated in Fig. 6, in which the use of lubricants is avoided by adopting mechanical means designed to reduce friction between the shell being formed and the walls of the crystallizer; and

Fig. 10 represents a further variant of the solution of Fig. 6.

Detailed Description of the Invention

[0026] The device according to the present invention comprises a container 1, referred to as "tank", made of refractory material, possibly tapered towards the bottom, for example as represented in Fig. 1, set on top of a metal crystallizer 9 which is cooled by means of a cooling system 10 of its own with forced water circulation. In a first embodiment of the invention, between the tank 1 and the crystallizer 9 is set an induction coil 11 (the outer surfaces of which are coated with a deposited oxide layer having an appropriate thickness, to guarantee electrical insulation) comprising a lubricant injection system 24. The tapered part of the container 1 is surrounded by a magnetic core 6 equipped with four poles 4, each of which is provided with a cooled gap 8 and with a winding 5.

[0027] The induction coil 11 is made up of a plurality of turns, which are made of a material having high electrical and thermal conductivity and are inserted in a magnetic core 16, the said induction coil 11 being equipped with water-cooling means 12 and having inside it a plurality of ducts 14, which are set on one and the same plane and are fed by means of manifolds 13 with a lubricating material which is injected by means of a positive-displacement pump system (not shown) at the joint between the container 1 and the crystallizer 9, the said crystallizer 9 carrying, at its initial part where it is in contact with the tank 1, high-permeability inserts 15 (Figs. 5a and 5b), which are designed to concentrate the magnetic flux and are provided, on their working surfaces that are in contact with the liquid metal 2, with a coating layer 21 (Figs. 5a and 5b) deposited, for example, by laser-welding surface-treatment techniques, with the purpose of electrically insulating the crystallizer from the liquid metal 2.

[0028] According to a variant embodiment of the invention, represented in Figures 6-8, the induction coil 11 is not set in contact with the liquid metal, but outside the crystallizer (electrically insulated in an appropriate way from the latter), which is in turn connected to the tank by means of a joint made, in this case, preferably, by providing the outer walls of the part of the tank in contact with the crystallizer with a generically ogival or parabolic profile, the said outer walls being set in a housing having a specular profile, which is made in the top part of the crystallizer, as represented, for instance, in Fig. 6. In this embodiment, the crystallizer presents, within its walls, a system of channels 10b, for circulation of the cooling water, which may be connected to channels 10c for enabling cooling also of the induction coil 11. A series of slots 28, as shown in Figure 8, is preferably made in the top part of the crystallizer in order to favour, together with the special shape of the said top part described previously, passage and concentration of the electromagnetic forces 19 at the triple point, thus enabling a cavity 23 to be obtained having satisfactory dimensions and high stability. Lubricant can be supplied, in this case, by way of the bottom part 14b of the said slots 28, which are filled, for the rest of their length, with refractory material, or in any case electrically insulating material.

[0029] A further embodiment of the present invention, which enables elimination of the use of lubricant, involves the use of a plurality of mechanical exciters 30, of a pneumatic, electromechanical, piezoelectric, or magnetostrictive type, etc., which are applied outside the crystallizer, as illustrated in Figure 9, at least one on each wall of the crystallizer, to induce, in the latter, vibrations in the transverse and longitudinal directions with the purpose of promoting and maintaining detachment of the solidified skin from the walls of the crystallizer, thus reducing friction between the skin and the walls. The frequencies of the exciters are preferably the resonance frequencies of the crystallizer-cast product system, in order to limit the power applied. The said frequencies generically depend upon the shape of the cast body, the geometry of the crystallizer, and the temperatures reached on the latter. To provide an indication, such frequencies may range between 100 Hz and 25000 Hz.

[0030] Finally, in the case where crystallizers are used that are made up of a plurality of plates or vertical segments mounted in such a way that they are electrically insulated from one another, coils 31 can be used, which are shown in Figure 10, each of which is equipped with a cooling system, for example an internal cooling system 32, and with an insulation system, with respect to the crystallizer 9, around which they are mounted. The said coils are supplied with a pulse current having an intensity of between 5 kA and 200 kA, preferably of between 30 kA and 100 kA, a pulse duration of between 50 μs and 500 μs, preferably of between 100 μs and 200 μs, and a frequency of between 2 Hz and 150 Hz, preferably of between 10 Hz and 100 Hz. In this way, electromagnetic forces 19b are induced on the solidified skin 20, which make it possible to detach the skin that has just formed from the walls of the crystallizer, thus reducing friction and facilitating passage of the lubricant.

[0031] In operation, the tank 1-crystallizer 9 system, which is initially closed at the bottom by a dummy bar, is filled with molten metal by means of a discharging device 3. The liquid metal is protected from oxidation by means of a floating layer 7 of powders and scale, or else by the creation of an inert atmosphere of argon. The poles 4 of the core 6 are energised in a particular order, for instance, as in Figure 3, by means of open-closed actuation of the corresponding power supplies, not shown in the Figures, in direct current for the windings 5. The working diagram is given in Fig. 3, in which I_A, I_B, I_C, I_D, indicate the currents in the four windings 5, which are considered positive when the magnetic field generated is directed towards the liquid metal, and Δt indicates the duration of the current pulse. Two consecutive pulses are separated by a time interval corresponding to 0.1-0.2 Δt.

[0032] The molten metal 2 fed into the tank 1 by the discharging device 3 does not have a regular motion, and this causes lack of uniformity of temperature and the possibility of formation of non-metallic inclusions, such as fragments of scale or of refractory material, being drawn inside the molten bath and as far as the start-of-solidification area. Activation of the windings 5 with DC pulses causes the formation of magnetic fields, the flux lines of which are indicated by continuous lines, for example in Fig. 4, in the case of casting of billets/

blooms. In this way, electromagnetic forces are generated according to well-known modalities, and a motion, represented by dotted lines, is thus induced in the liquid metal 2. By interrupting supply of the windings 5 and by changing the intensity and/or the direction of the DC supply current, according to the diagram of Figure 3, slowing down of the disordered motion of the liquid metal, i. e., the motion generated by the modalities of introduction of the liquid metal into the tank 1, is obtained, and the liquid metal 2 flows downwards being moved almost exclusively by the force of gravity, with a practically uniform distribution of speed.

[0033] The duration of each phase of activation of the windings is between 1 and 15 seconds, preferably between 4 and 10 seconds, with an interruption between two consecutive phases of a duration of between 10 and 20% of the activation time.

[0034] The molten metal, with a flow rendered uniform according to what has been illustrated previously, flows down in the tank, until it reaches the boundary area, or triple point. Here a further induction coil, which is set between the tank 1 and the crystallizer 9, or else is set outside the said crystallizer, and is supplied by a pulse current as specified previously, generates a field of electromagnetic forces that is able to create a cavity 23 which removes the liquid metal away from the triple point, thus preventing its solidification in contact with the tank refractory walls, or in contact with the induction coil. At the level of the triple point, a lubricant may be injected into the said cavity, which will advantageously contain ferromagnetic particles that favour concentration of the said electromagnetic forces, thus enabling the formation of a larger and more stable cavity 23.

Claims

1. Device for continuous casting of blooms, slabs, or billets, consisting of a cooled crystallizer (9) in the form of an open hollow body and of a tank (1) made of refractory material set on top of the crystallizer (9), into which liquid metal to be cast is poured, characterized in that the said tank (1) made of refractory material is equipped with means (4, 5, 6) designed to slow down and render uniform the disordered motion of the liquid metal, and in that means (11) are present, set at the height of the boundary between the crystallizer (9) and the tank (1), which are designed to cause and to maintain detachment of the molten metal (2) from the walls of the tank-crystallizer ensemble.

2. Device according to Claim 1, wherein the said means for slowing down and rendering uniform the disordered motion of the liquid metal consist of a continuous core (6) set around the tank (1) and equipped with at least four poles (4) and with windings (5) set around each pole (4), and of means, adapted to interrupt and modify periodically the electrical supply of the said windings, thus creating electromagnetic fields which are periodically interrupted and modified in direction and intensity.

3. Device according to Claim 1, wherein the said means adapted to cause and maintain detachment of the molten metal from the walls of the tank-crystallizer ensemble are made up of an induction coil (11), supplied by a pulse current, consisting of a plurality of turns inserted in a magnetic core (16).

4. Device according to Claim 3, wherein the said induction coil is set between the tank (1) and the crystallizer (9), and is provided with a wall facing towards the inside of the tank-crystallizer ensemble.

5. Device according to Claim 3, wherein the said induction coil is set outside the crystallizer (9), the contact surface between the tank (1) and the crystallizer (9) consisting of profiles of the end parts of the tank and of the crystallizer which are complementary and generically ogival or parabolic.

6. Device according to Claim 5, wherein the crystallizer (9) has, in its part close to the tank (1), through slots (28).

7. Device according to Claim 6, wherein the said slots (28) are at least partially closed by material transparent to electromagnetic fields, in which case one part (14b) of the said slots (28) that has remained free serves for passage of a lubricant.

8. Device according to Claim 5, wherein the said induction coil (11) is provided with a plurality of ducts (14) for introducing, into the said compartment, lubricating material, fed in by means of manifolds (13).

9. Device according to Claim 7, wherein the said crystallizer is provided with ducts (10b) for the coolant, which are connected to similar ducts (10c) made in the induction coil (11), for cooling the latter.

10. Device according to Claim 4, wherein the crystallizer (9), at its initial part set facing towards the tank (1), has inserts (15) which have high permeability and are provided with an electrically insulating coating on their surfaces that are in contact with the liquid metal.

11. Device according to Claim 1, wherein outside the crystallizer (9), mechanical exciters (30) are set of an electrodynamic, pneumatic, magnetostrictive, or piezoelectric type, and the like, the frequency of which corresponds to the resonance frequency of the crystallizer-cast body system and is between

100 Hz and 25 000 Hz.

12. Process for improving the quality of metallic bodies obtained from continuous casting, in which a tank made of refractory material is used, which is set on top of a crystallizer having the shape of an open hollow body, and into which, by means of a special discharging device, liquid metal is continuously poured which advances with a disordered motion towards the crystallizer and in the latter starts to solidify at a joining area (referred to as "triple point") between the tank and the crystallizer, thus forming a so-called "skin" of the cast body extracted continuously from the crystallizer, the said tank having the purpose of removing, from the region of start of solidification, the free surface of the metal, the supernatant scale, and the area of molten metal with a flow that is perturbed as a result of the continuous addition of metal, the said process being characterized in that, in the said tank, a first action is carried out of slowing down and rendering uniform the disordered motion of liquid metal in the tank, which is combined with a second action of detachment of the liquid metal from the walls of the tank and of the crystallizer at the said joining point.

13. Process according to Claim 12, wherein the said first action of slowing down and rendering uniform the motion of the liquid metal is obtained by means of electromagnetic fields that are periodically interrupted and modified in direction and intensity.

14. Process according to Claim 13, wherein the said electromagnetic fields are generated by means of an induction system consisting of a first continuous core, set around the tank, provided with at least four poles and with windings set around each pole, the said poles being energised in a pre-set order for a given period of time Δt, and with a time interval, between two successive energising, of 0.1-0.2 Δt.

15. Process according to Claim 14, wherein the said time period Δt is between 1 and 15 seconds.

16. Process according to Claim 15, wherein the said time period Δt is between 4 and 10 seconds.

17. Process according to Claim 14, wherein the current used for generating the said electromagnetic fields is between 1 kA and 200 kA.

18. Process according to Claim 12, wherein the second action of detachment of the liquid metal from the triple point is obtained by means of a pulsating magnetic field generated by a second induction coil consisting of a plurality of turns inserted into a second magnetic core which completely surrounds the crystallizer and is electrically insulated from the external environment.

19. Process according to Claim 18, wherein the said second induction coil is activated by means of a pulse current, having an intensity of between 5 kA and 200 kA, with a pulse duration of between 50 µs and 500 µs, and a frequency of between 2 Hz and 150 Hz.

20. Process according to Claim 19, wherein said current intensity is between 30 kA and 200 kA.

21. Process according to Claim 19, wherein the duration of said current pulses is between 100 µs and 200 µs.

22. Process according to Claim 19, wherein the frequency of the said pulse current is between 100 Hz and 200 Hz.

23. Process according to Claim 12, wherein, in an area corresponding to the said triple point, lubricant is injected in order to favour sliding of the forming skin against the walls of the crystallizer.

24. Process according to Claim 12, wherein, in addition to the detachment of the liquid metal, also detachment of the solidifying skin from the walls of the crystallizer is obtained, which is favoured by subjecting the crystallizer to vibrations both in the transverse and in the longitudinal directions with respect to the axis of the crystallizer, by means of mechanical exciters of an electrodynamic, pneumatic, magnetostrictive, or piezoelectric type, or the like, applied outside the crystallizer, with at least one per wall.

25. Process according to Claim 23, wherein the said lubricant has ferromagnetic properties.

26. Process according to Claim 25, wherein the said lubricant comprises a mixture of ferromagnetic particles having a size smaller than 100 µm, in a quantity of between 5 wt% and 25 wt% of the total lubricant.

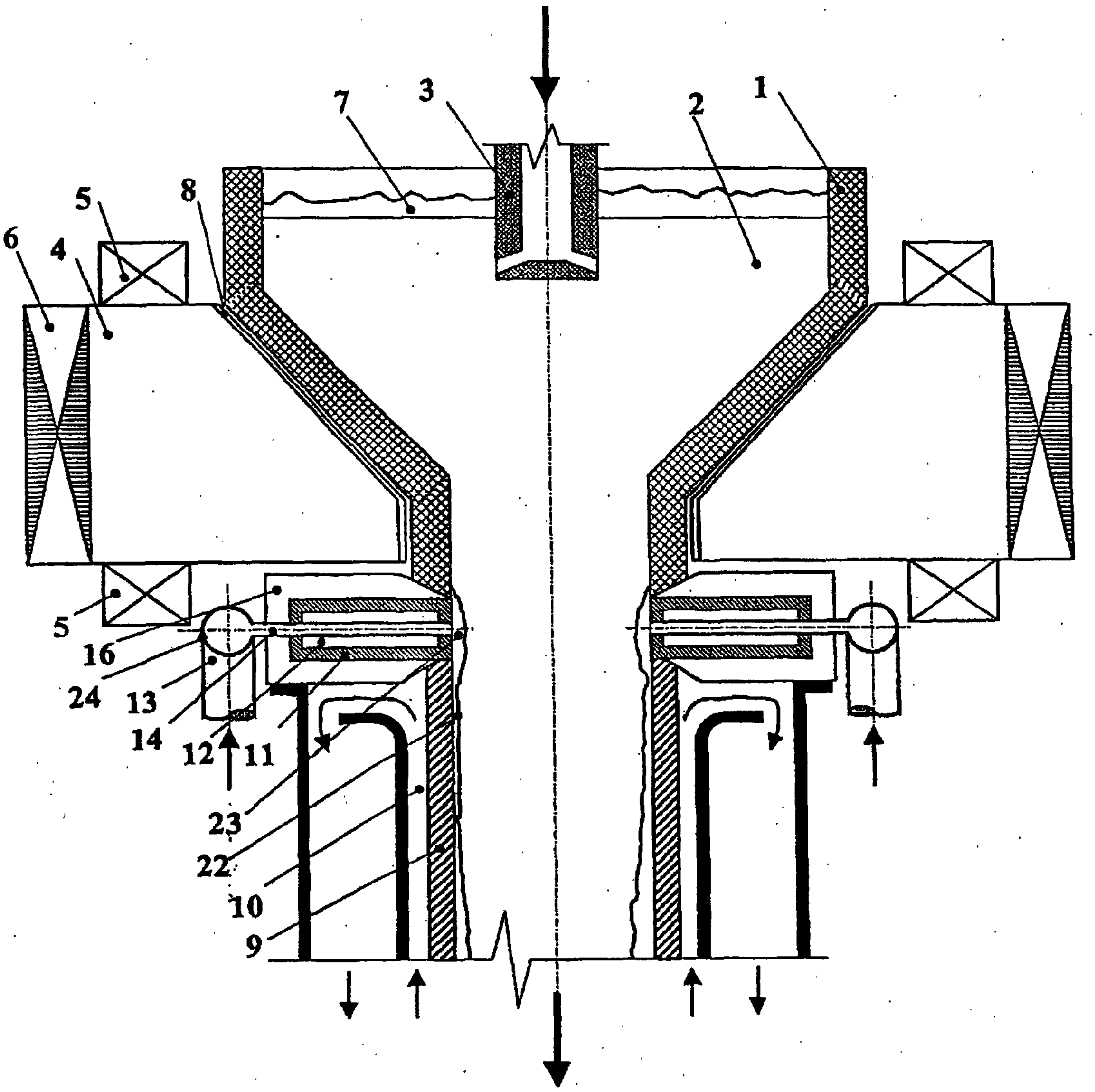

Fig. 1

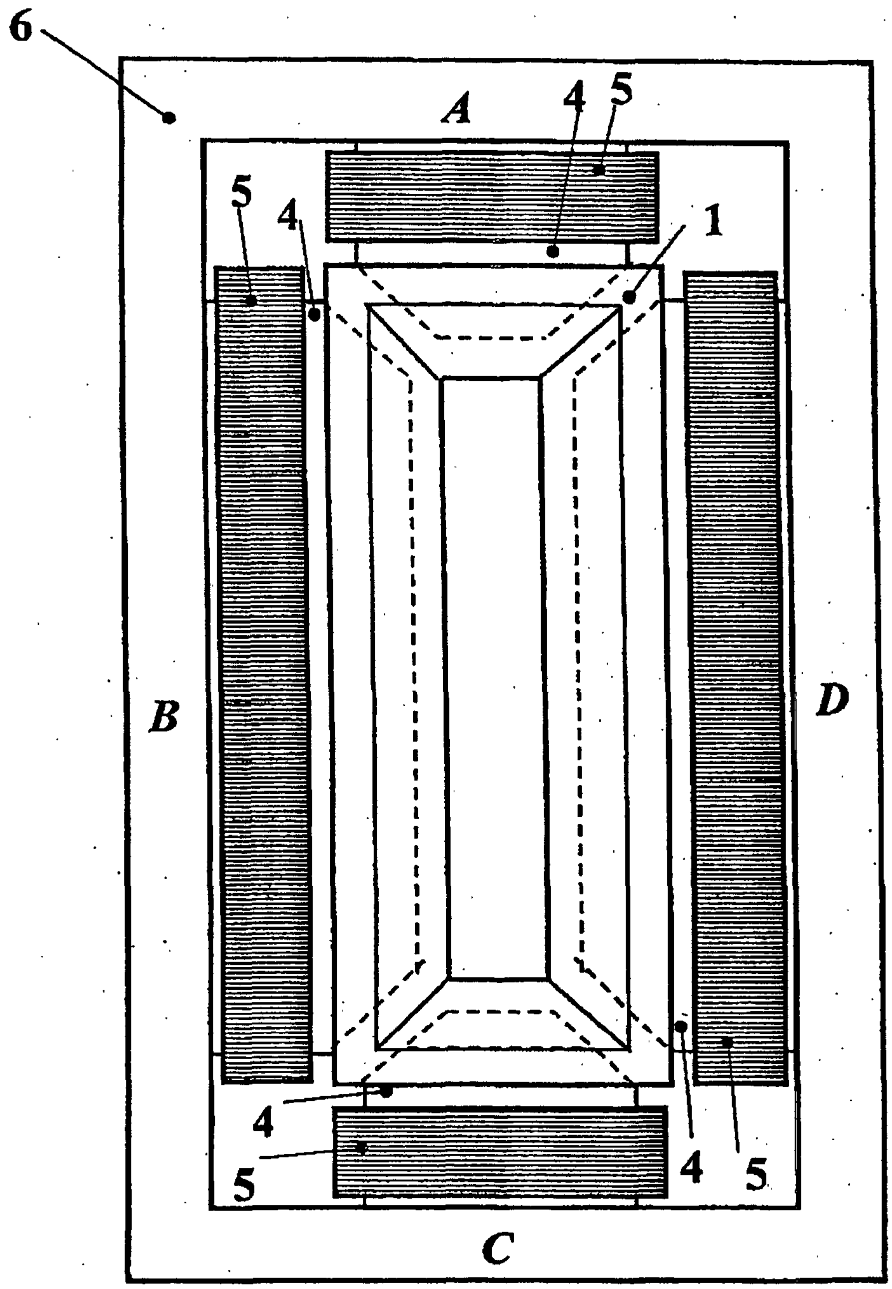

Fig. 2

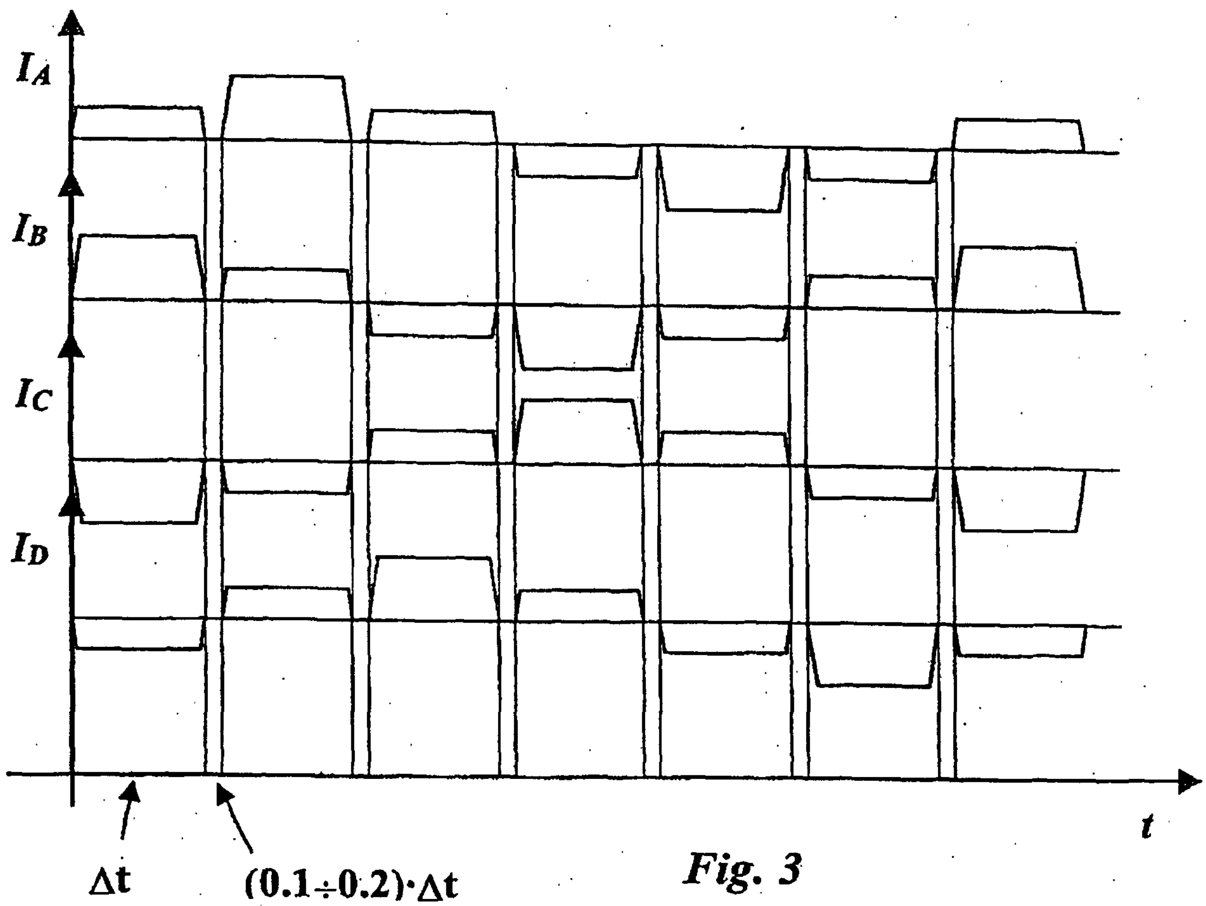

Fig. 3

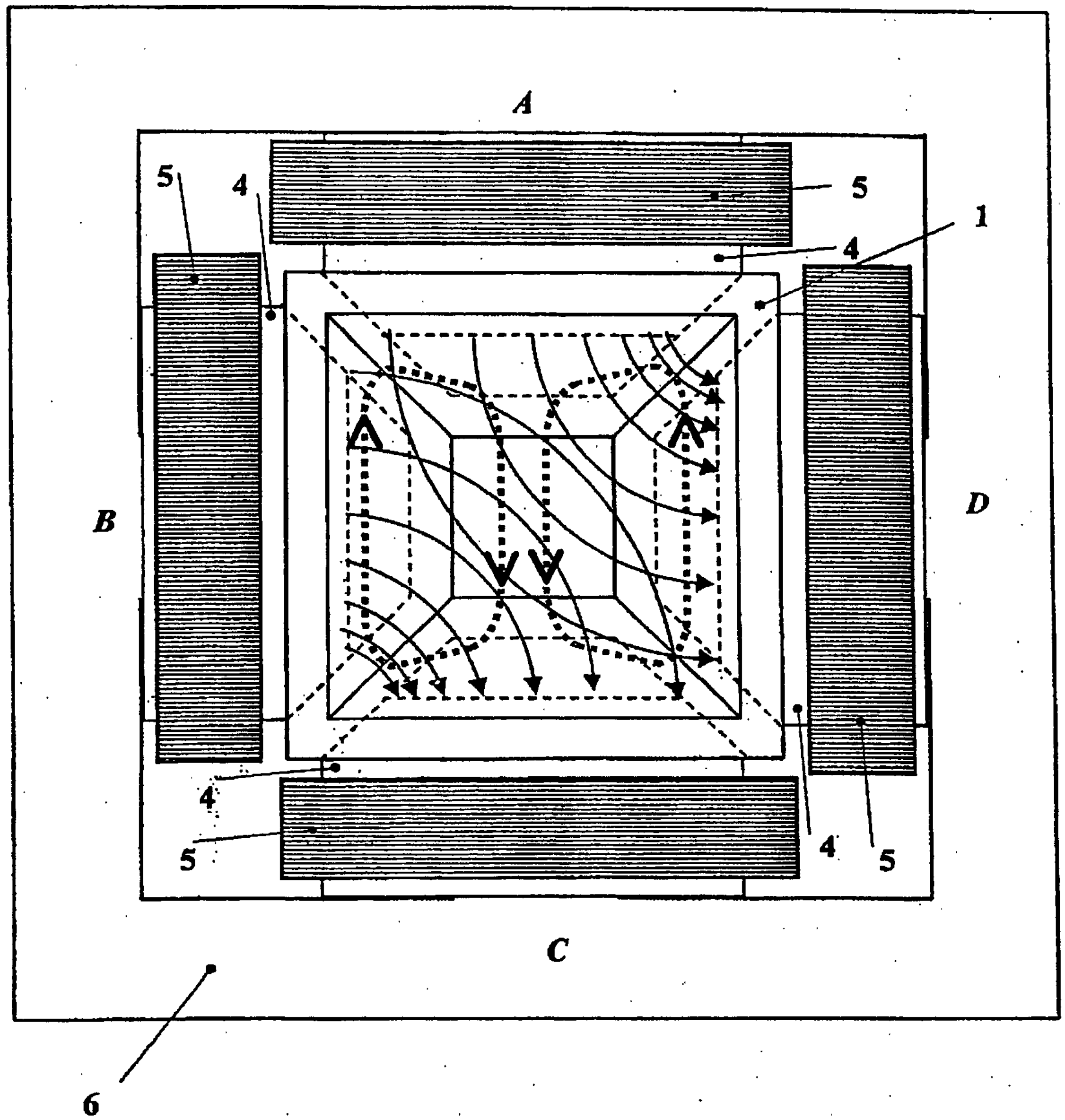

Fig. 4

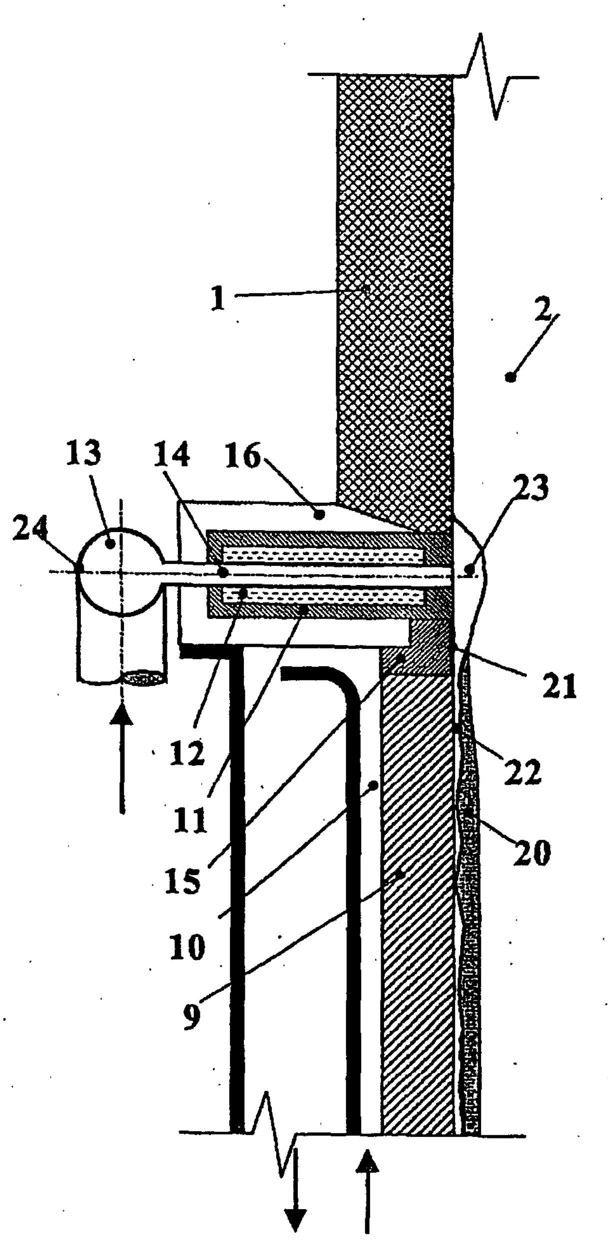

Fig. 5a

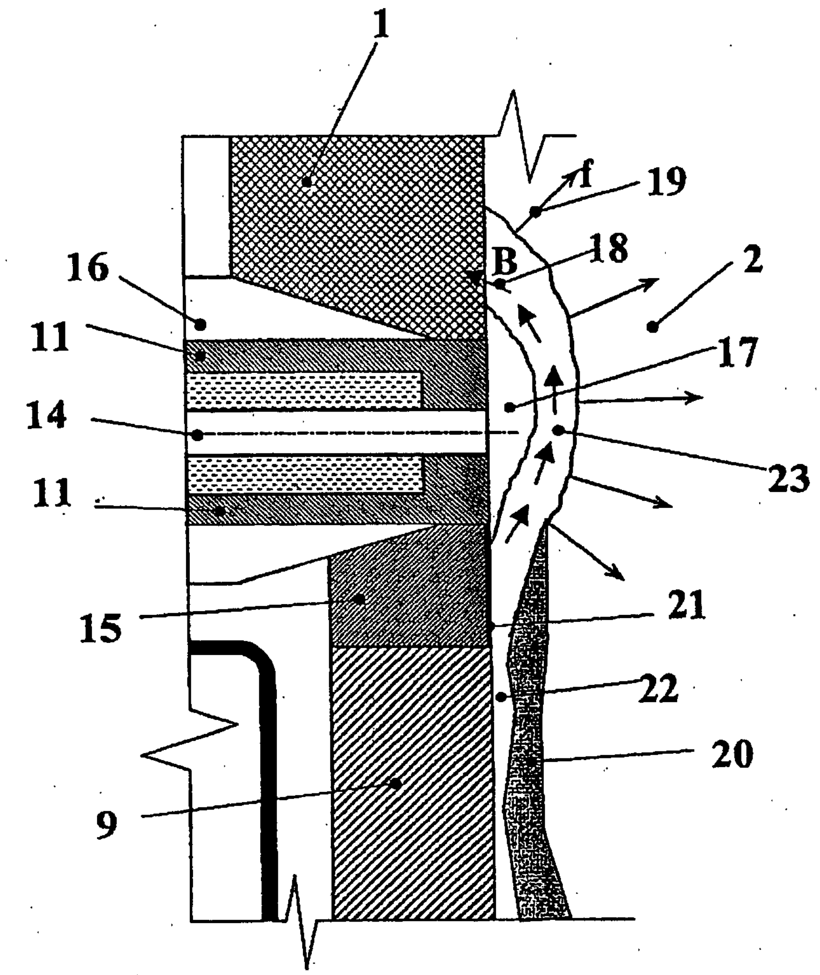

Fig. 5b

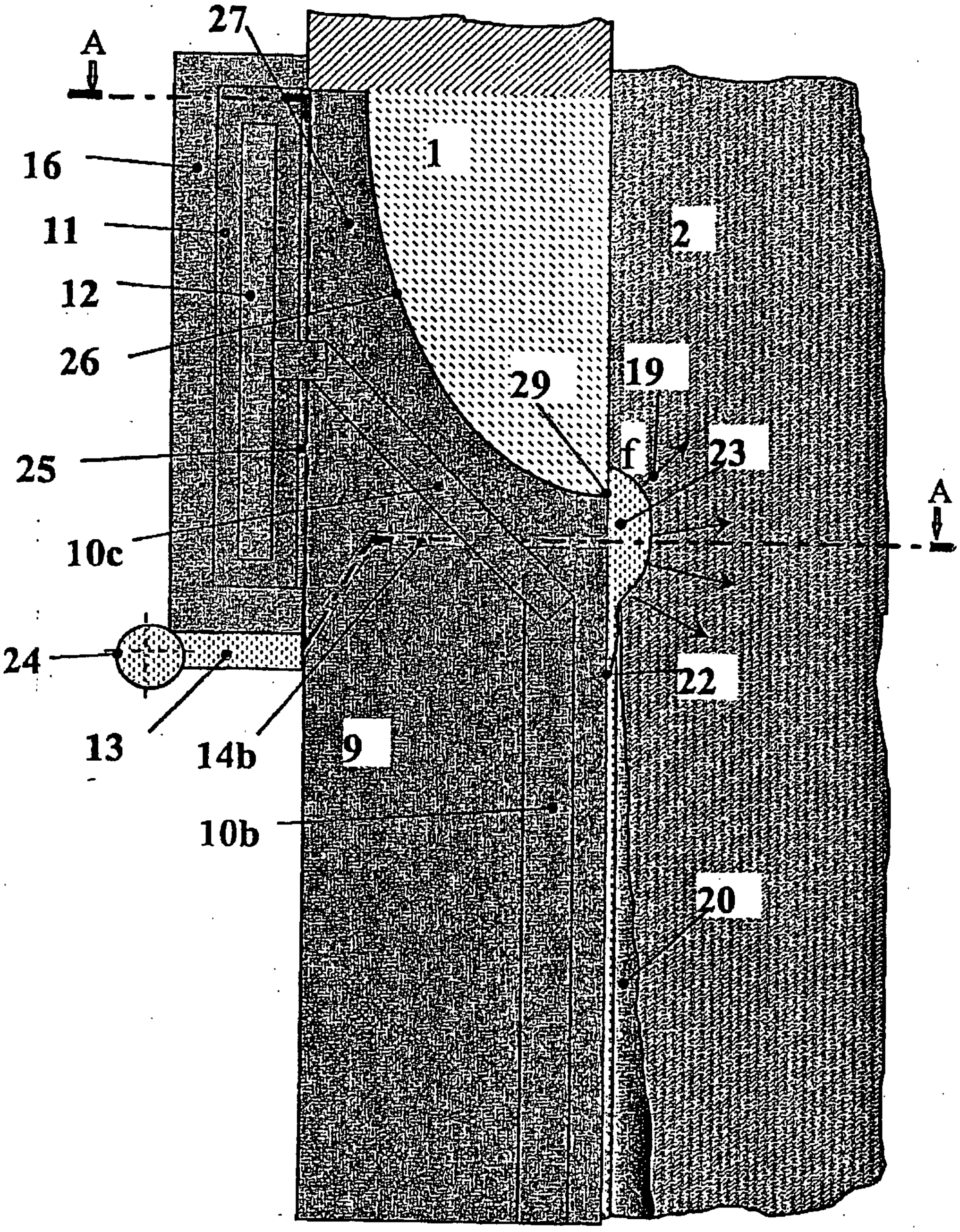

Fig.6

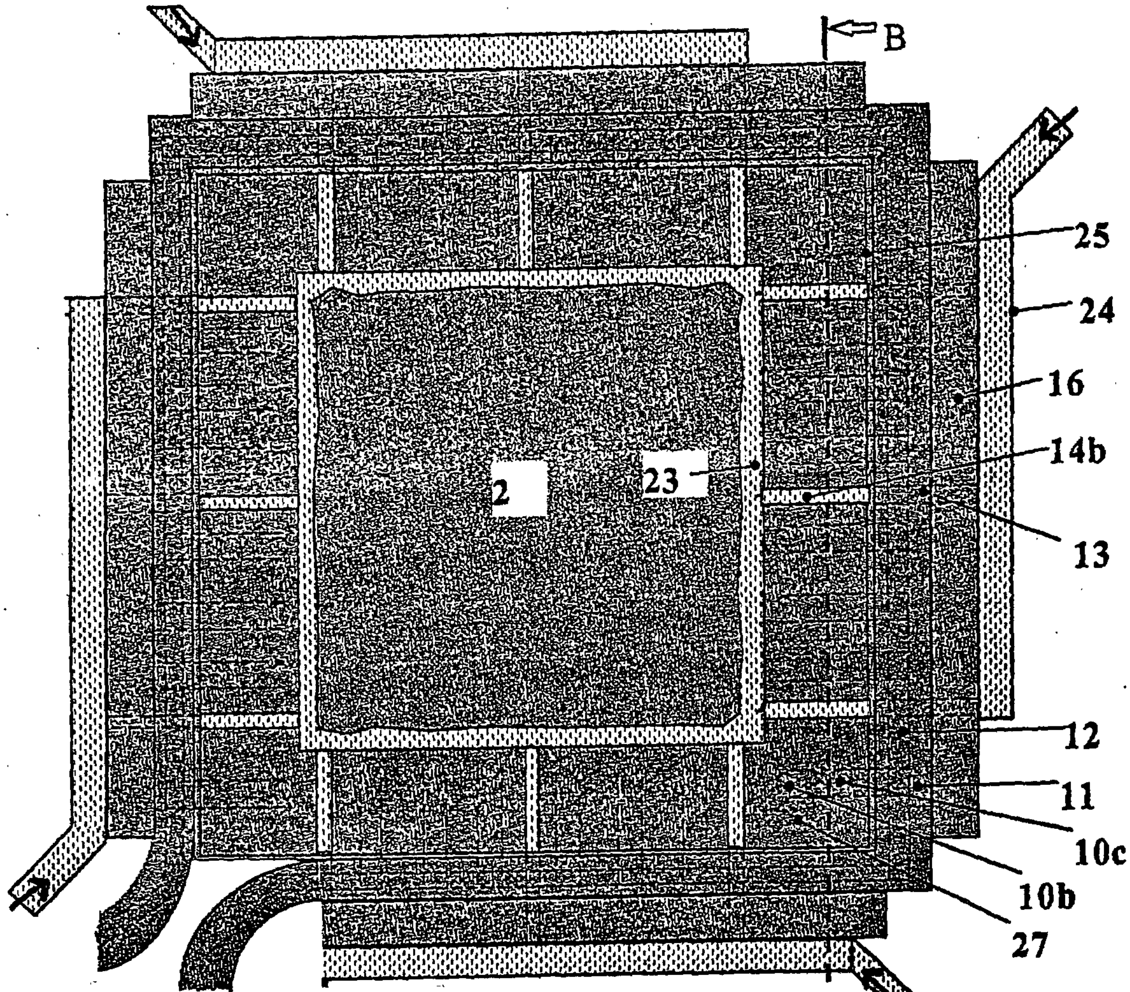

Fig. 7: sec. A-A of Fig. 6

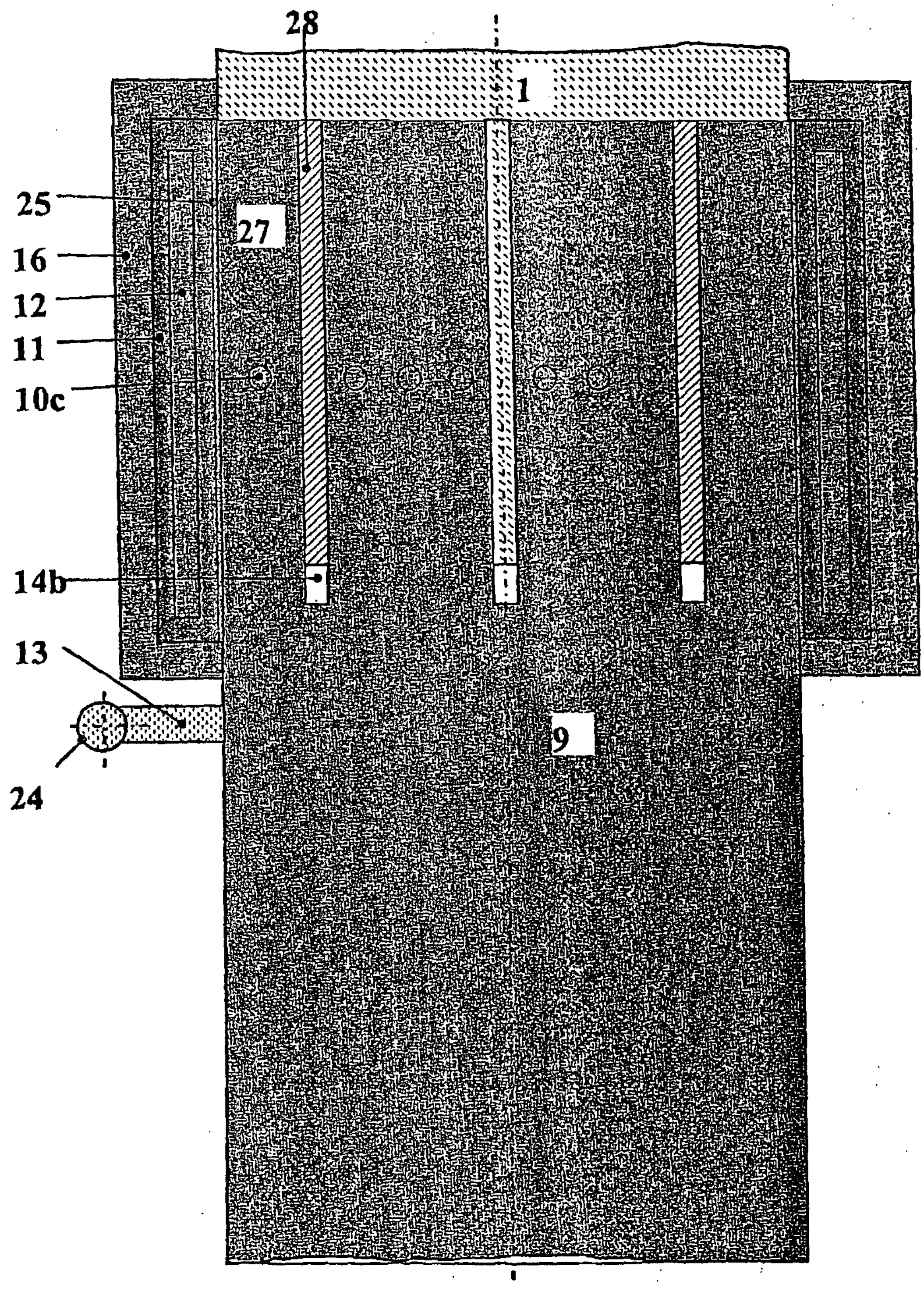

Fig. 8: sec. B-B of Fig. 7

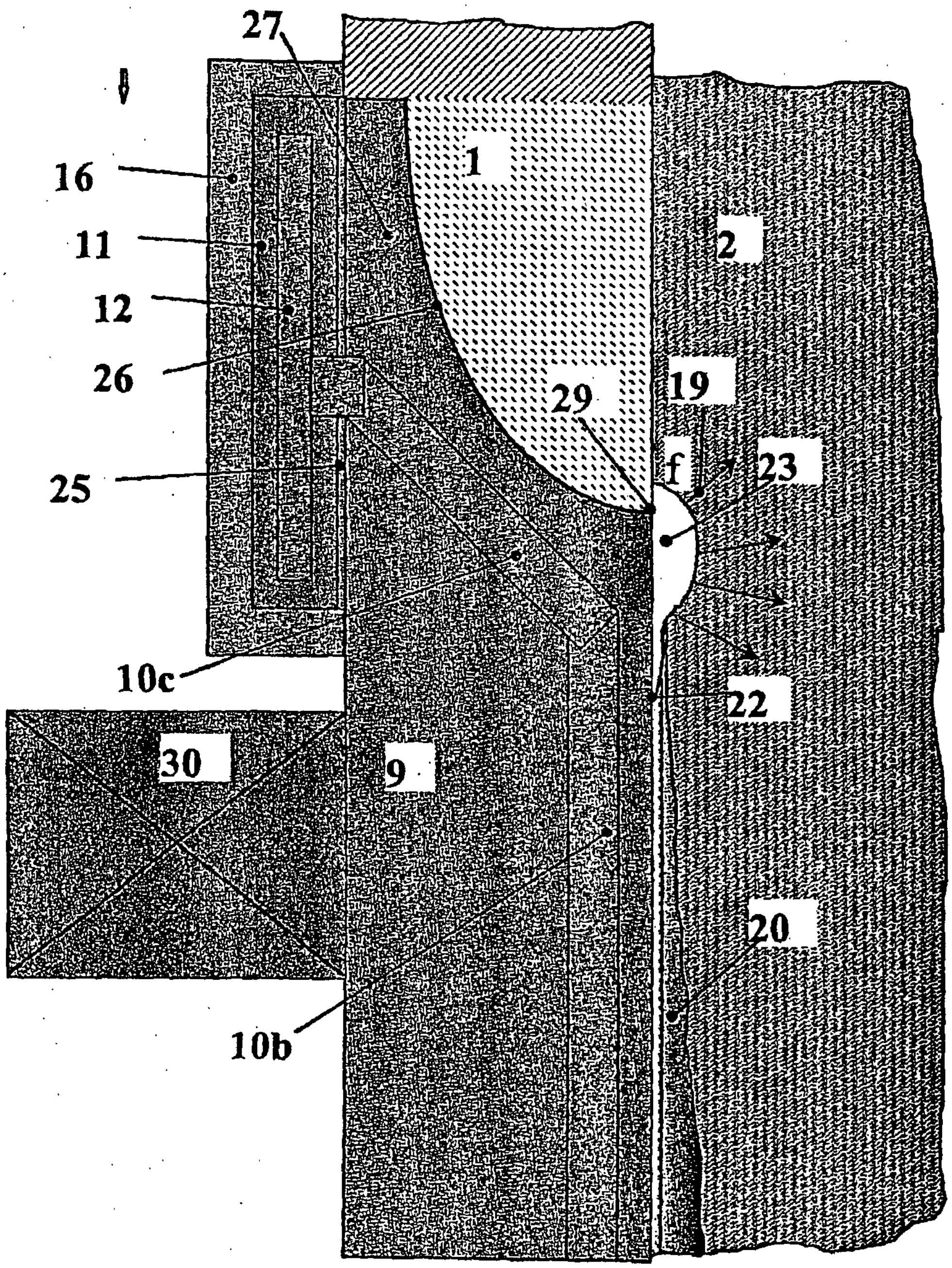

Fig.9

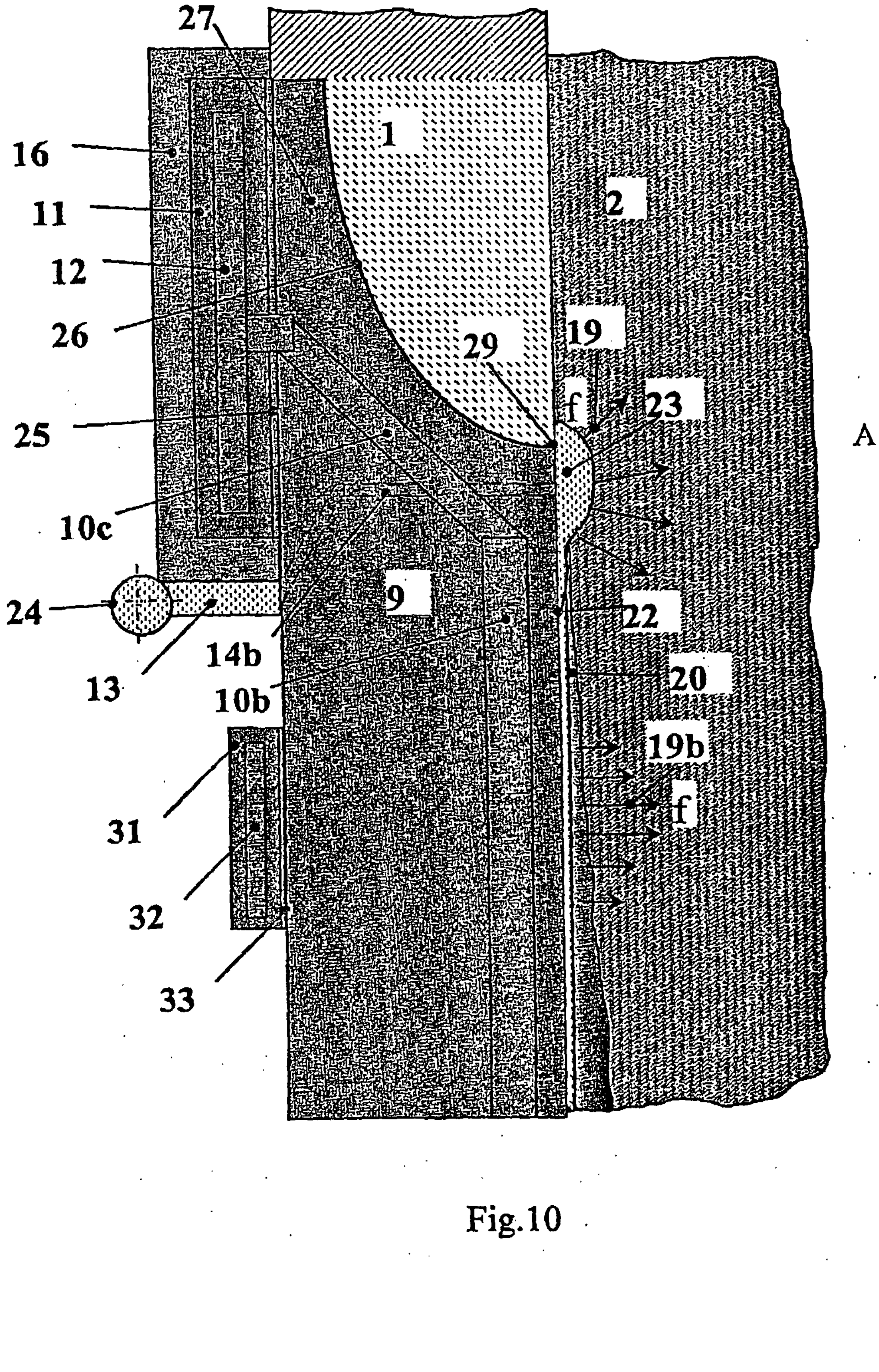
27
1
16
11
2
12
26
19
29
25
f
23
A
10c
9
24
22
14b
13
20
10b
19b
f
31
32
33

Fig.10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 10 1347

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 3 987 840 A (BIRAT JEAN-PIERRE) 26 October 1976 (1976-10-26) * column 4, line 25; figure *	1,12	B22D11/041 B22D11/07 B22D11/115
A	FR 2 501 550 A (FIVES CAIL BABCOCK) 17 September 1982 (1982-09-17) * claims 1-7; figure 3 *	1,12	
A	EP 0 620 062 A (LORRAINE LAMINAGE ;ASCOMETAL SA (FR); UNIMETALL SA (FR)) 19 October 1994 (1994-10-19) * claims 1-11; figure 1 *	1,12	
A	US 4 495 982 A (KANEKO HIDEO ET AL) 29 January 1985 (1985-01-29) * abstract; figures 2-33 *	1,3,4, 12,24	
A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 224 (M-170), 9 November 1982 (1982-11-09) & JP 57 127553 A (SUMITOMO KEIKINZOKU KOGYO KK), 7 August 1982 (1982-08-07) * abstract *	1,12	TECHNICAL FIELDS SEARCHED (Int.Cl.7) B22D
A	US 4 450 892 A (HEINEMANN WILFRIED ET AL) 29 May 1984 (1984-05-29) * abstract; claims 1-13; figures 1-5 *	1	
A	US 4 082 207 A (GARNIER MARCEL A ET AL) 4 April 1978 (1978-04-04) * abstract; figures 1-3 *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 May 2001	Mailliard, A

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 10 1347

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-05-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3987840 A	26-10-1976	FR 2252154 A	20-06-1975
		BE 822575 A	26-05-1975
		CA 1016722 A	06-09-1977
		DE 2455816 A	05-06-1975
		ES 432401 A	16-09-1976
		GB 1491724 A	16-11-1977
		IT 1030807 B	10-04-1979
		JP 50085524 A	10-07-1975
		LU 71367 A	20-08-1975
FR 2501550 A	17-09-1982	NONE	
EP 0620062 A	19-10-1994	FR 2703609 A	14-10-1994
		AT 166812 T	15-06-1998
		DE 69410688 D	09-07-1998
		DE 69410688 T	25-02-1999
		DK 620062 T	22-03-1999
		ES 2117238 T	01-08-1998
US 4495982 A	29-01-1985	JP 1005985 B	01-02-1989
		JP 1521633 C	12-10-1989
		JP 58086958 A	24-05-1983
		JP 1403843 C	09-10-1987
		JP 58086959 A	24-05-1983
		JP 62010743 B	07-03-1987
		JP 1403844 C	09-10-1987
		JP 58086960 A	24-05-1983
		JP 62010744 B	07-03-1987
		DE 3266426 D	24-10-1985
		EP 0079580 A	25-05-1983
		KR 8700714 B	09-04-1987
JP 57127553 A	07-08-1982	NONE	
US 4450892 A	29-05-1984	CH 648500 A	29-03-1985
		AT 6476 T	15-03-1984
		BR 8104428 A	30-03-1982
		CA 1176427 A	23-10-1984
		DE 3162508 D	12-04-1984
		EP 0043987 A	20-01-1982
		ES 504334 D	01-06-1982
		ES 8205141 A	16-09-1982
		JP 1446829 C	30-06-1988
		JP 57044454 A	12-03-1982
		JP 62057420 B	01-12-1987
		KR 8402039 B	06-11-1984

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 10 1347

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-05-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4082207 A	04-04-1978	FR 2316026 A	28-01-1977
		CA 1074854 A	01-04-1980
		DE 2629045 A	27-01-1977
		GB 1559099 A	16-01-1980
		JP 1433694 C	07-04-1988
		JP 52024128 A	23-02-1977
		JP 62042704 B	09-09-1987
		SE 417792 B	13-04-1981
		SE 7607561 A	05-01-1977

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82