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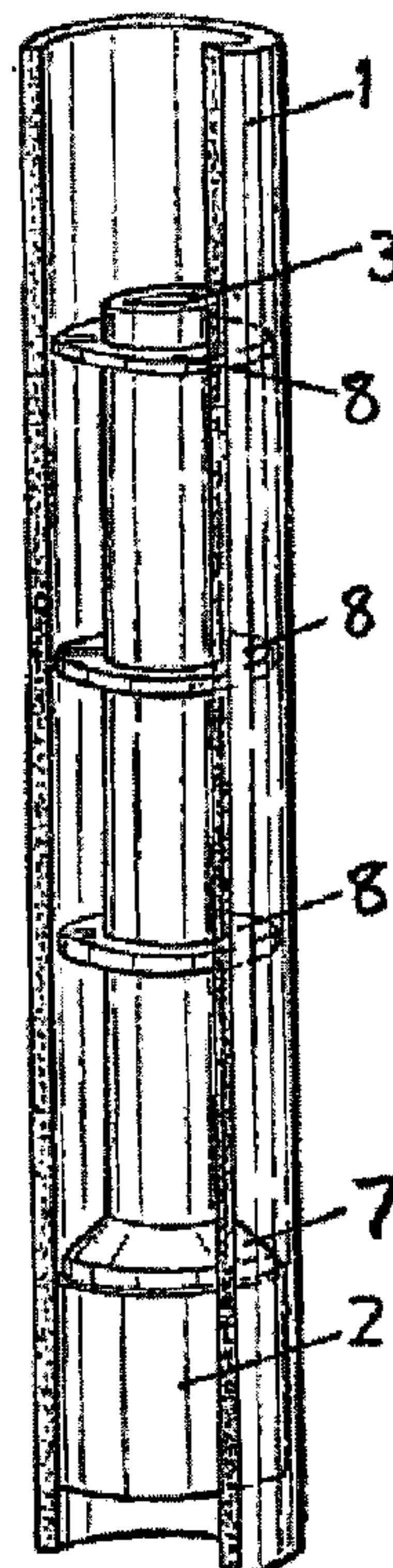
(72) Inventeur/Inventor:
EDEN, ROBERT D., GB

(73) Propriétaire/Owner:
RAWWATER ENGINEERING COMPANY LIMITED, GB

(74) Agent: MARKS & CLERK

(54) Titre : PROCEDE ET APPAREIL DE SCELLEMENT

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(57) Abrégé/Abstract:

According to the present invention there is provided an apparatus for forming a plug in a passageway, the apparatus comprising a carrier which in use is lowered into the passageway, the carrier comprising an elongate body of a material resistant to creep which supports first and second spaced apart portions and a skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway; a body of material supported on the carrier, said material having a melting point which is higher than the temperature within the passageway and which expands as it solidifies; and means for melting the body of material such that melted material fills a space defined between the first and second portions, and flows into the clearance defined between the skirt and the passageway.



ABSTRACT

According to the present invention there is provided an apparatus for forming a plug in a passageway, the apparatus comprising a carrier which in use is lowered into the passageway, the carrier comprising an elongate body of a material resistant to creep which supports first and second spaced apart portions and a skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway; a body of material supported on the carrier, said material having a melting point which is higher than the temperature within the passageway and which expands as it solidifies; and means for melting the body of material such that melted material fills a space defined between the first and second portions, and flows into the clearance defined between the skirt and the passageway.

SEALING METHOD AND APPARATUS

The present invention relates to a method and apparatus for plugging a passageway. Such passageways include underground components which may be plugged to prevent leakage of hydrocarbon fluids from those components.

In the oil and gas extraction industries, abandoned wells have to be plugged to keep the contents of deep high pressure environments which communicate with those wells from invading levels at or adjacent the surface. Plugs can be inserted at any point in a well, for example adjacent the surface or at a substantial depth. Typically, plugs are formed by injecting cement or resin into the well so as to fill for example a fifty metre length of the well. Experience has proved however that such plugs are not particularly reliable and often leak.

The known plugs tend to leak for a variety of reasons. Firstly, as the well wall is typically not particularly clean and is also covered with a hydrocarbon film, it is difficult to produce a reliable contiguous seal. Often a contiguous seal of only a metre or so in length is formed with a plug fifty times that length. Furthermore, as cement and resin based plugs solidify they contract which tends to open up a gap between the plug and the well wall. Although when a plug is initially inserted there may be little dynamic pressure in the well, after the plug is in situ substantial pressures can build up and as a result a plug which appears initially to be working satisfactory may subsequently be found to leak. If hydrocarbons leak past the plug contamination of the surface environment or for example a sub-surface aquifer can result. It is well known in the industry that a significant proportion of abandoned wells leak. As a result leaking abandoned wells often have to be re-plugged which is an expensive and time consuming operation.

It is an object of the present invention to provide an improvement to existing methods and apparatus for sealing such structures.

According to an aspect of the present invention there is provided an apparatus for forming a plug in a passageway, the apparatus comprising

- i. a carrier which in use is lowered into the passageway, the carrier comprising an elongate body of a material resistant to creep which supports first and second spaced apart portions and a skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway;
- ii. a body of material supported on the carrier, said material having a melting point which is higher than the temperature within the passageway and which expands as it solidifies; and
- iii. means for melting the body of material such that melted material fills a space defined between the first and second portions, and flows into the clearance defined between the skirt and the passageway.

According to another aspect of the present invention, there is provided a method for forming a plug in a passageway, wherein the method comprises

- i. placing a carrier in the passageway, the carrier defining an elongate body of material resistant to creep which supports at least two spaced apart portions and a skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway;
- ii. melting in the passageway a body of material the melting point of which is higher than the temperature within the passageway and which expands as it solidifies such that melted material fills a space defined between the spaced apart portions and flows into the clearance defined between the skirt and the passageway; and
- iii. causing and/or allowing the melted material in the clearance to rapidly cool and solidify.

According to another aspect of the present invention, there is provided an apparatus for forming a plug in a passageway, the apparatus comprising

- a. a carrier which in use is lowered into the passageway, the carrier comprising an elongate body of a material resistant to creep which supports first and second spaced apart portions and a hollow skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway;
- b. a second body of material supported on the carrier, said second body of material having a melting point which is higher than a temperature within the passageway and which expands as the second body of material solidifies; and

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- c. means for melting the second body of material such that melted material fills a space defined between the first and second portions, and flows into the clearance defined between the skirt and the passageway.

According to another aspect of the present invention, there is provided a method for forming a plug in a passageway, wherein the method comprises

- a. placing a carrier in the passageway, the carrier defining an elongate body of material resistant to creep which supports at least two spaced apart portions and a hollow skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway;
- b. melting in the passageway a second body of material the melting point of which is higher than a temperature within the passageway and which expands as the second body of material solidifies such that melted material fills a space defined between the spaced apart portions and flows into the clearance defined between the skirt and the passageway; and
- c. causing and/or allowing the melted material in the clearance to rapidly cool and solidify.

The present invention provides a means by which a spacer in the form of a skirt extending from the bottom of the carrier defines a clearance between the skirt and the wall of the well casing for receipt of molten material which can then rapidly cool, solidify and expand to block further flow through the clearance. In doing so, the solidified material around the skirt supports the body of molten material around the carrier above the skirt while it cools and solidifies to thereby enhance the overall integrity of the well plug. It was previously thought that to provide an effective seal the apparatus used to plug a well would need to incorporate a downwardly depending "packer" dimensioned

so as to be a tight fit within the well bore. Surprisingly, however, the deviser(s) of the present invention have determined that such an arrangement is not in fact always required. While not wishing to be bound by any particular theorem, it is currently thought that by replacing the tight-fitting packer with a skirt that is a loose fit within the passageway and an appropriate type of meltable material that, once melted, can flow into the gap between the skirt and the inner wall of the passageway, and then rapidly lose heat to its surroundings (e.g. water within the well and/or the material of the skirt) the material within the gap can cool and solidify sufficiently rapidly to occupy the gap and thereby form a tight seal around the skirt. As such, the apparatus of the present invention provides a "packerless" means of deploying a sealing plug within a passageway. This affords a number of advantages over prior art systems incorporating a packer, including easier deployment, wider manufacturing tolerances since a close conformity between the size of the skirt and the passageway is no longer required, and greater flexibility in the range of applications in which apparatus of a single size can be employed, all of which reduce the costs associated with plug deployment.

Once the apparatus has been deployed within the passageway it will typically be submerged in water already resident within passageway, often to a very significant depth of, for example, around 300 to 400 m. Such depths of water provide a hydrostatic pressure of 3 to 4 MPa which is sufficient to prevent the water adjacent the hot molten material from being able to boil. Again without wishing to be bound by any particular theorem it is currently believed that the water, by virtue of having such a high specific heat capacity (around $4.2 \text{ J/cm}^3 \text{ K}$ at 25°C), contributes significantly to the rapid cooling of the melted material within the gap around the skirt, and that the melted material within the gap contacting the cooling water exhibits flow behaviour akin to the pahoehoe flow behaviour exhibited by certain types of lava flows. As a result, the solidified material quickly forms a strong and reliable seal around the skirt of the apparatus which can support the body of molten material around the carrier which will in turn cool, solidify and expand to provide an effective seal.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figures 1 to 5 illustrate an assembly for forming a plug in a well in accordance with a first preferred embodiment of the present invention;

Figure 6 illustrates a cross-sectional view of part of the assembly of Figure 1 to 5; and

Figure 7 illustrates a cross-sectional view of a similar part of an assembly as shown in Figure 6 but in which the assembly is in accordance with an alternative preferred embodiment of the present invention.

Figures 1 to 6 show an assembly according to the invention which can be used to form a bismuth alloy plug within a well casing 1. A solid bismuth alloy plug is formed from an amount of bismuth alloy delivered in solid form on a carrier spool to the required depth within the casing 1.

The carrier spool may comprise 1% manganese steel and is therefore resistant to elongation as a result of creep. The carrier spool comprises a cylindrical skirt 2 connected to a tubular mandrel 3. In the embodiment shown in Figures 1 to 6, the skirt 2 is formed of concrete cast on to an inverted T-bar 4 (visible in Figure 6) secured to a lower end 5 of the mandrel 3. A single T-bar 4 is shown which is connected to the centre of the lower end 5 of the mandrel 3, but it will be appreciated that two or more such T-bars, or any other form of mounting point, could be used to support the cast concrete skirt 2. Moreover, the skirt 2 could be produced from any other suitable tough volume-filling material, such as cement (optionally with fibre reinforcement), or a plastic material which is then attached to the lower end 5 of the mandrel 3 using an adhesive 6 or some other form of fixing, such as a rivet, bolt, screw or the like, passing through a portion of the skirt 2 and the mandrel 3 as depicted in Figure 7. The skirt 2 can be formed of any appropriate material provided it can withstand the conditions to which it will be exposed during and after deployment. By way of further example, the skirt 2 could be made from steel or a suitable rubber-based material.

In the particular embodiment depicted in Figures 1 to 6, the lower end 5 of the mandrel 3 incorporates a frustoconical head 7, from which the cylindrical skirt 2 extends axially downwards so as to define a skirt region, the purpose of which will be described in more detail below. The head 7 does not have to be frustoconical, however, and may in

fact take any convenient form such as a flat radially extending flange, or be completely omitted such that the skirt 2 extends directly from the lower end 5 of the mandrel 3, with the upper end of the skirt 2 presenting a step extending radially outwards from the mandrel 3.

The mandrel 3 has a plurality of circular flanges defining fins 8 distributed at intervals along its length. The mandrel 3 also has an upper open end 9. In the embodiment depicted in Figures 1 to 6, the diameter of each fin 8 is approximately equal to the diameter of the base of the head 7 and the skirt 2. In alternative embodiments including a head 7 the diameter of the head 7 may be larger or smaller than that of the fins 8 provided the head 7 is still suitably dimensioned to enable it to be slid down the casing 1 and to provide the required spacing between mandrel 3 and any liquids (e.g. water) in the well, and between the edge of the skirt 2 and the well casing 1, for reasons discussed more fully below. In embodiments not including a head 7, the skirt 2 may again have a similar diameter to the fins 8, or a larger or smaller diameter. By way of example and with reference to Figure 7, the head 7 is omitted and the skirt 2 has a diameter which is approximately the same as the mandrel 3, such that the skirt 2 extends axially downwards from the lower end 5 of the mandrel 3 so as to define a substantially continuous curved peripheral surface made up of the lower portion of the mandrel 3 and the skirt 2.

In delivery form (shown in Figure 3), metal to be melted to form a plug locates along the length of the mandrel 3 between the head 7 and an upper fin 8, defining a cylinder extending as far as the peripheral edge of the upper fin 8. The metal may comprise, for example, pure bismuth, an admixture of 95% bismuth and 5% tin, or an admixture of 52% bismuth and 48% tin. In each case the metal may be doped with sodium. In this form the carrier spool is inserted into the casing 1 (skirt end first) and lowered to the required depth.

Thus positioned the bismuth alloy is melted in situ by a heater which normally locates within the mandrel 3 (but which is illustrated for clarity in Figure 4 outside the mandrel 3). The heater defines a cylinder, an upper portion of which comprises an ignition source 10 and a lower portion of which comprises a heater element 11. The heater element 11 may comprise an admixture of aluminium and iron oxide (a thermite

mixture). The ignition source 10 may comprise a barium peroxide fuse, an electrical heater or an electrical match. It will be appreciated that other forms of both ignition source 10 and heater element 11 could be used. For example, the ignition source 10 and heater element 11 may be completely replaced with a suitable electric heater (not shown) located within the mandrel 3, or an intermetallic gasless pyrotechnic heat source, such as a nickel-aluminium powder admixture.

Activation of the ignition source 10 triggers the heater element 11. Heat produced from the heater element 11 causes the bismuth alloy supported on the mandrel 3 to become molten.

The molten bismuth alloy slumps into a volume defined by the mandrel 3, the fins 8, the upper surface of the head 7, the peripheral surface of the skirt 2 and the casing wall 1 (as shown in Figure 1). It has been established that the strength and integrity of the seal can be enhanced by providing the skirt 2 with suitable dimensions that allow a small amount of the molten bismuth to slump down passed the head 7 so as to reside, and then rapidly cool, within the gap defined between the peripheral surface of the skirt 2 and the casing wall 1 by rapid heat transfer from the molten bismuth alloy to the surroundings (primarily any water resident within the well bore). For this to be achieved, the skirt 2 should have a diameter that is smaller than that of the well casing 1 so as to define a peripheral gap extending around the edge of the skirt 2, and the skirt 2 should also be of a sufficient axial length so that the molten bismuth alloy can slump sufficiently far from the heated mandrel 3 to rapidly cool and solidify within the gap rather than slumping passed the lower end of the skirt 2 and out of the volume resulting in an ineffective seal. That being said, a balance needs to be achieved between the cost of the bismuth alloy which is intended to slump into the gap between the skirt 2 and the well casing 1 and the integrity of the seal that is to be formed. It is clearly necessary to provide sufficient bismuth alloy so that the volume of material which slumps into the gap is sufficient to form a reliable seal around the lower end of the assembly, but given the cost of the alloy, it would be uneconomic to use too much of the material. As such, an optimum size of skirt 2 should be selected for a particular well which will define a gap for molten alloy of sufficient volume to enable a reliable seal to be formed at reasonable cost.

As compared to the diameter of the fins 8, the skirt 2 may have a diameter which is around 50 to 120 % of the diameter of the fins 8, provided, of course, that both the fins 8 and skirt 2 are small enough to allow the assembly to be passed down the well. The skirt 2 may have a diameter that is around approximately equal to that of the mandrel 3 (as shown in Figure 7), or may have a diameter which is larger, for example, around 50 to 100 % larger, than the diameter of the mandrel 3. The diameter of the skirt 2 may be at least around 50 % of the inner diameter of the well casing 1 at the level the well is to be sealed, but may be at least around 60 % or around 75 to 90 % of the inner diameter of the well casing 1 so as to ensure that the radial dimension of the volume defined between the skirt 2 and the well casing 1 is large enough to accommodate expansion of the molten alloy as it cools and a sufficient volume of molten material to provide a seal with the required strength, but not so large as to waste costly material or to cause unequal cooling to occur across the radial dimension of the volume of molten alloy resulting in the volume possessing a heterogenous structure and thereby providing an unreliable seal. By way of example, tests have determined that a strong and reliable seal can be formed in the manner described above using apparatus incorporating a tubular skirt having an outer diameter of around 7.5 cm (3 inches) in a cylindrical passageway similar to a conventional well bore having an inner diameter of around 11.5 cm (4.5 inches) and which therefore defines an annular clearance of around 2 cm (0.75 inches) between the skirt and the passageway for receipt of the molten bismuth alloy.

With regard to the axial length of the skirt 2, this also defines the volume and therefore the cost of the alloy that will reside within the gap between the skirt 2 and the well casing 1. A longer skirt 2 provides a greater volume to facilitate effective cooling of the alloy before it slumps passed the bottom of the assembly and thereby ensure an effective seal is formed around the skirt 2. A longer skirt 2, however, also defines a larger volume for receipt of more molten alloy, which increases material costs. One way in which the skirt length can be defined is in relation to the overall length of the mandrel 3 since the length of the mandrel 3 typically defines the total volume of alloy material which is initially supported on the assembly before deployment (as shown in Figure 3) and which can therefore be used to form the seal. The skirt 2 may be at least around 10 to 20 % of the total length of the mandrel 3, or may be longer, such as at least around 30 to 40 % of the total length of the mandrel 3.

Commonly, wells to be sealed contain a liquid, such as water. This is advantageous since this water can be used to cool the molten bismuth alloy as it slumps into the gap between the skirt 2 and the well casing 1. If the water level is not at the optimum sealing level then further water can be introduced into the well so as to raise the water level to an appropriate level to assist in forming the seal at the optimum level. As the molten bismuth alloy slumps into the gap at the lower end of the assembly around the outside of the skirt 2 it contacts the water within the well and rapidly forms a solidified skin, in a similar way to that which occurs in undersea volcanic lava flows, exhibiting pahoehoe flow. The skin may initially re-melt or deform, but has sufficient structural integrity after a very short period of time to prevent rapid mass flow, and will rapidly solidify as cooling of the alloy continues until such time as a strong and reliable lower crust is formed. The underside of the solidified alloy contacting the water within the well is likely to be irregular but due to the pahoehoe nature of the alloy's flow the layer of alloy above the crust should have a more uniform structure and thereby provide a reliable seal against the wall of the well casing 1, as the remainder of the molten alloy solidifies within the volume higher up the mandrel 3.

It may be advantageous to use an assembly incorporating a relatively long skirt 2, for example, a skirt 2 that is around 50 to 100 % of the length of the mandrel 3 so that the skirt 2, which is generally formed of a relatively cheap material like concrete or plastic, can be submerged into the water within the well to a sufficient depth to ensure that the skirt 2 and the wall of the well casing 1 define an appropriate volume for receipt of the molten alloy taking into account the balance of cost against seal strength described above. Longer skirts 2 may be advantageous since they provide greater flexibility during deployment to ensure that the seal can be formed at the optimum position and at an acceptable cost. Longer skirts 2 also would not typically have a significant bearing on the total cost of the assembly because they are generally produced very cheaply using low cost raw materials, such as cast concrete (as in Figures 1 to 6) or moulded plastic (as in Figure 7). A further benefit is that a single, or a pre-specified range, of assemblies can be produced in large quantities but that will still suit a wide range of different applications.

The skirt 2 can be solid, for example a solid block of concrete, which may include fibre reinforcement, cast on to one or more supporting members attached to the lower end of the mandrel 3 as shown in Figures 1 to 6, or a solid block of plastic adhered to the lower end of the mandrel 3 as shown in Figure 7. Alternatively, the skirt 2 can be hollow or tubular so as to define an internal cavity for receipt of a coolant, such as water already resident within the well. In this way, the outer wall of the skirt 2 is cooler than if the skirt 2 is a solid block of material, and so in this way, the hollow skirt 2 can increase the rate of cooling of molten material flowing into the space defined between the skirt 2 and the wall of the well casing 1.

In addition to the above, in the embodiment depicted in Figures 1 to 6, the frustoconical head 7 is able to serve as a wedge that drives into the expanded bismuth alloy plug and, in doing so, forces the plug against the casing wall 1 improving the integrity of the seal. The seal is further enhanced by the fins 8 which serve three purposes. Firstly the fins 8 aid in forcing the expanding metal against the casing 1 by minimising axial and promoting lateral expansion. Secondly the fins 8 aid the transfer of heat from the heater element 11 to the bismuth alloy. Thirdly the fins 8 aid in reducing creep of the bismuth alloy plug up hole.

The fins 8 are a loose sliding fit within the well casing 1 and therefore relatively small gaps are defined between the casing and the peripheral edges of the fins 8 (and the peripheral edge of the head 7). This gap is generally referred to as the "drift". When the molten metal cools and solidifies, it expands. In the absence of the fins 8, much of this expansion would simply result in molten metal flowing upwards in the axial direction. This would not contribute to the formation of a plug tightly compressed within the casing. The fins 8 reduce this flow, hence improving the security of the plug.

The effect of the fins 8 is increased by introducing a coolant into the carrier body defined by the mandrel 3 after the plug material has been melted. Coolant can be delivered to the mandrel 3 in any convenient manner. For example, simply by ensuring that the casing above the plug is filled with water is generally sufficient providing that the water can penetrate into the mandrel 3 after heating of the plug. Alternatively, a body of coolant can be provided which is released a predetermined period after heating. Introduction of the coolant will cause material adjacent the mandrel 3 to

solidify before material further from the mandrel 3, and thereafter cooling will be accelerated around the fins 8. As a result molten material in the gaps between the peripheries of the fins 8 and the casing 1 will solidify relatively rapidly, before a substantial portion of the melted material has a chance to solidify. The material that is still molten at this stage is, as a result, effectively trapped between the seal formed around the lower end of the assembly around the skirt 2, the head 7 which is acting like a wedge, and the fins 8. As this trapped material cools and solidifies, the resultant expansion contributes to the application of pressure to the casing 1 so as to provide a very tight plug and a reliable seal.

Once the plug has been formed, the fins 8 offer substantial resistance to creep of the plug material past the fins 8 given the relatively narrow gaps around the peripheral edges of the fins 8. This gap can be further reduced in magnitude by arranging for it to be obstructed by devices which are embedded in the plug. For example grooves in the peripheral edges of the fins 8 may receive a double-turn ring of a memory metal such that when heated as a result of melting of the plug material the ring springs outwards so as to obstruct the gap between the peripheral edge of the fins 8 and the casing 1. Alternatively, the double turn ring can be replaced with a C-shaped ring formed of a memory metal simply pre-sprung but initially restrained so as to be held within the groove around the periphery of each fin 8, the spring being released as a result of heating of the assembly. The body of material located between the fins 8 could have embedded within it particulates such as balls which will move into the gaps adjacent the fins 8 when the material is melted. For example, "floating" balls of steel or aluminium and "sinking" balls of, for example, tungsten so that when the material is melted the floating balls move upwards adjacent the upper fin 8 and the sinking balls sink downwards adjacent the lower fin 8. The axially facing surfaces of the fins 8 could be frustoconical to encourage migration of the balls into the gaps adjacent the peripheral edges of the fins 8. It would be possible in some applications to rely upon magnetism, for example by embedding magnetised particles within the material to be melted, the magnetised particles migrating towards the gaps around the peripheral edges of the fins 8 as soon as the material is melted. It would also be possible to use magnetism in other ways to displace gap-obstructing components. For example, magnetic C-rings could be constrained in a position such that, after melting of the plug material and consequent release of the constraint, the C-rings are displaced into a

position in which they obstruct the gaps. In one arrangement, in which the carrier is non-magnetic, C-shaped horseshoe magnets could be positioned such that each extends around 120° of the edge of a fin 8, the magnets being arranged end to end with opposed polarities and embedded in the plug material adjacent the fin 8. When the plug material melts, the rings will be pushed apart by repulsive magnetic forces. Arms could be pivotally mounted on the mandrel 3 at points spaced at an interval of 120° , each of the arms supporting a blocking member which is moveable outwards towards the periphery of an adjacent fin 8, the blocking member being dimensioned and located so that when brought to a position adjacent the fin 8 it blocks approximately $1/3$ of the circumference of the gap around the periphery of that fin 8. Each of the fins 8 could support a peripheral skirt extending in the axial direction from the outer edge of the fin. That peripheral skirt would be embedded in the plug after it has solidified. Creep of the plug material towards the gap around the fin 8 would carry the skirt with it, causing the skirt to flare outwards, thereby blocking the gap.

It will be appreciated that the formation of a plug as described above has a wide range of applications, such as sealing passageways in nuclear waste containers or securing objects, such as cables, components of bridges or the like, to carriers anchored to a solid base such as a rock.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An apparatus for forming a plug in a passageway, the apparatus comprising
 - a. a carrier which in use is lowered into the passageway, the carrier comprising an elongate body of a material resistant to creep which supports first and second spaced apart portions and a hollow skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway;
 - b. a second body of material supported on the carrier, said second body of material having a melting point which is higher than a temperature within the passageway and which expands as the second body of material solidifies; and
 - c. means for melting the second body of material such that melted material fills a space defined between the first and second portions, and flows into the clearance defined between the skirt and the passageway.
2. The apparatus according to claim 1, wherein the spaced apart portions are dimensioned to define respective gaps between said portions and the passageway, means being provided to obstruct said gaps formed between the portions and the passageway, the obstructing means being displaced into the gaps as a result of melting of the second body of material or as a result of creep of material after the second body of material has been melted and solidified.
3. The apparatus according to claim 1 or 2, wherein the spaced apart portions are defined by fins extending radially outwards from the elongate body.
4. The apparatus according to claim 1, 2 or 3, wherein the elongate body is tubular.
5. The apparatus according to claim 4, wherein the tubular body receives a heater element.

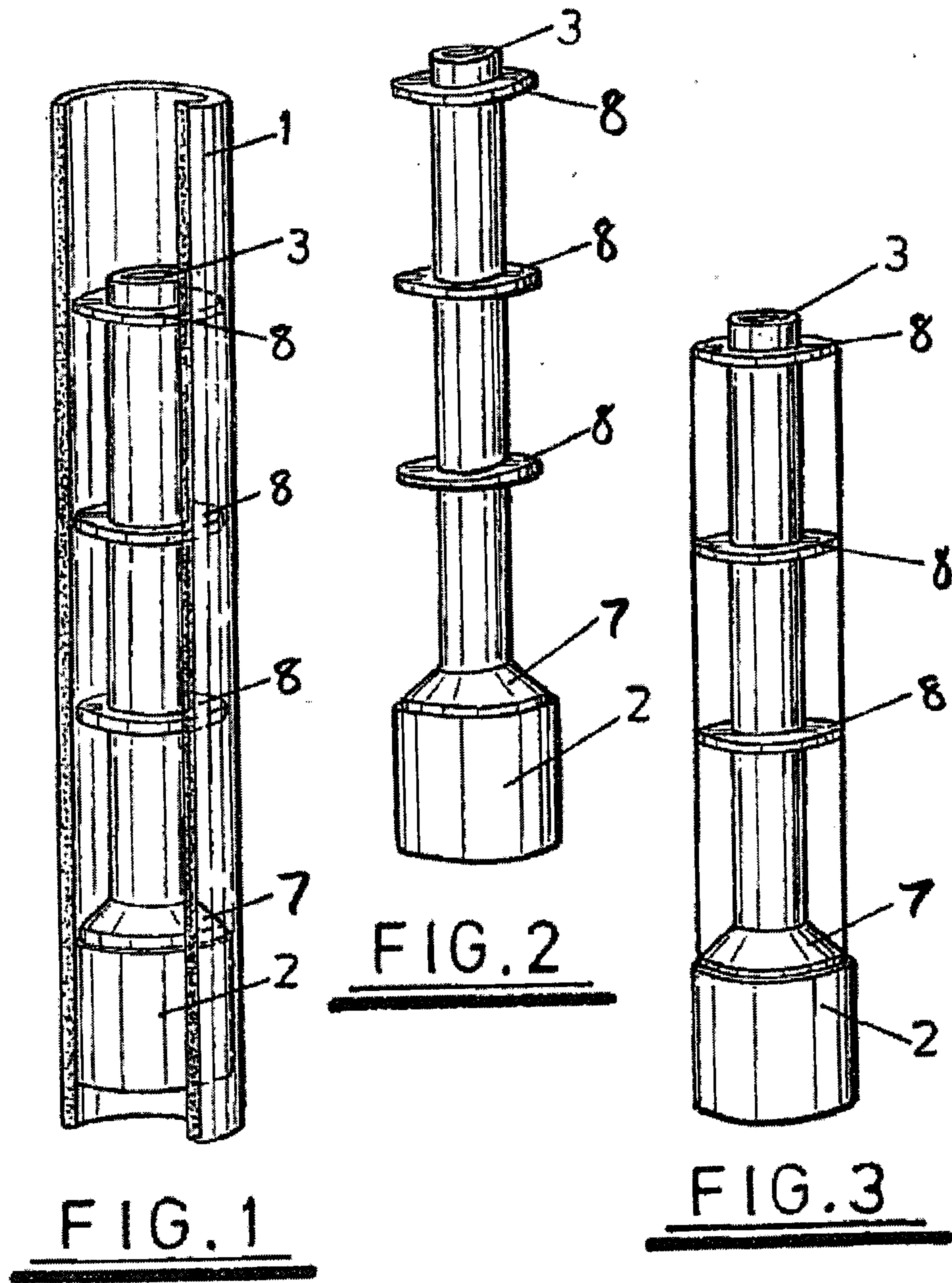
6. The apparatus according to any one of claims 1 to 5, wherein the skirt is tubular and defines an opening at its lower end.
7. The apparatus according to claim 6, wherein the clearance comprises an annular clearance.
8. The apparatus according to any one of claims 1 to 7, wherein a diameter of the skirt is at least 50 % of an inner diameter of the passageway, at least 60 % of the inner diameter of the passageway, or 75 to 90 % of the inner diameter of the passageway.
9. The apparatus according to any one of claims 1 to 8, wherein the skirt is formed from a material comprising cement, fibre reinforced cement, concrete, fibre reinforced concrete, rubber, plastic or any combination thereof.
10. The apparatus according to any one of claims 1 to 9, wherein the skirt is cast or moulded onto a supporting member attached to the lower end of the carrier.
11. The apparatus according to any one of claims 1 to 9, wherein the skirt is attached to the lower end of the carrier by an adhesive and/or suitable fixing.
12. The apparatus according to any one of claims 1 to 11, wherein the passageway is a well.
13. A method for forming a plug in a passageway, wherein the method comprises
 - a. placing a carrier in the passageway, the carrier defining an elongate body of material resistant to creep which supports at least two spaced apart portions and a hollow skirt that extends axially from a lower end of the carrier, the skirt being dimensioned to define a clearance between the skirt and the passageway;
 - b. melting in the passageway a second body of material the melting point of which is higher than a temperature within the passageway and which expands as the second body of material solidifies such that melted material fills a space defined between the spaced apart portions and

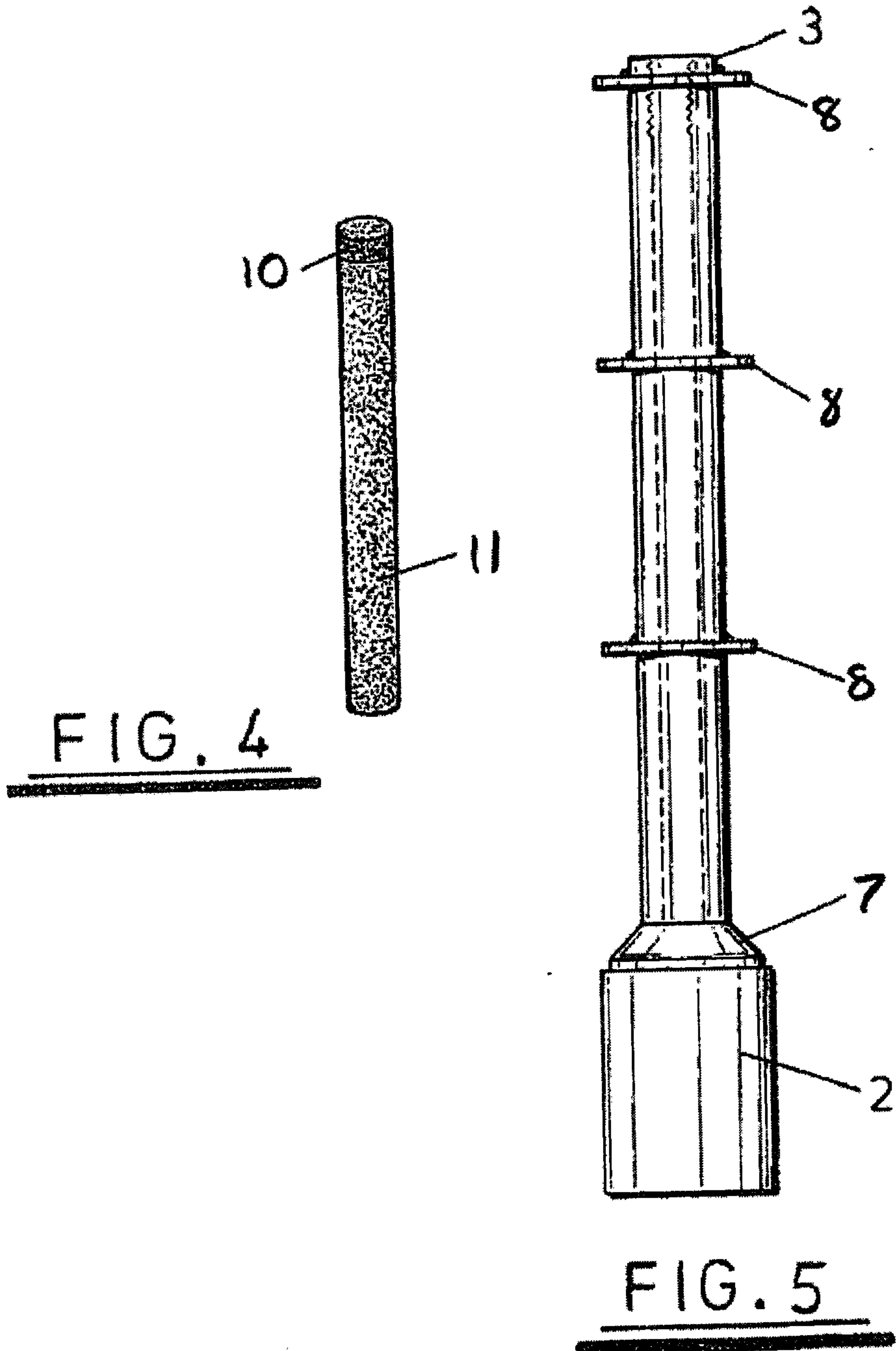
flows into the clearance defined between the skirt and the passageway;
and

- c. causing and/or allowing the melted material in the clearance to rapidly cool and solidify.

- 14. The method according to claim 13, wherein the method further comprises cooling the carrier such that molten material adjacent the spaced apart portions solidifies before the melted material between the spaced apart portions that is spaced from the carrier.
- 15. The method according to claim 13 or 14, wherein the carrier comprises an elongate tubular body from which the spaced apart portions project, and the carrier is cooled by introducing coolant into the tubular body.
- 16. The method according to claim 13, 14 or 15, wherein the method further comprises submerging the carrier and associated skirt within a liquid within the passageway.
- 17. The method according to claim 16, wherein said liquid is water.
- 18. The method according to any one of claims 13 to 17, wherein the passageway is a well.

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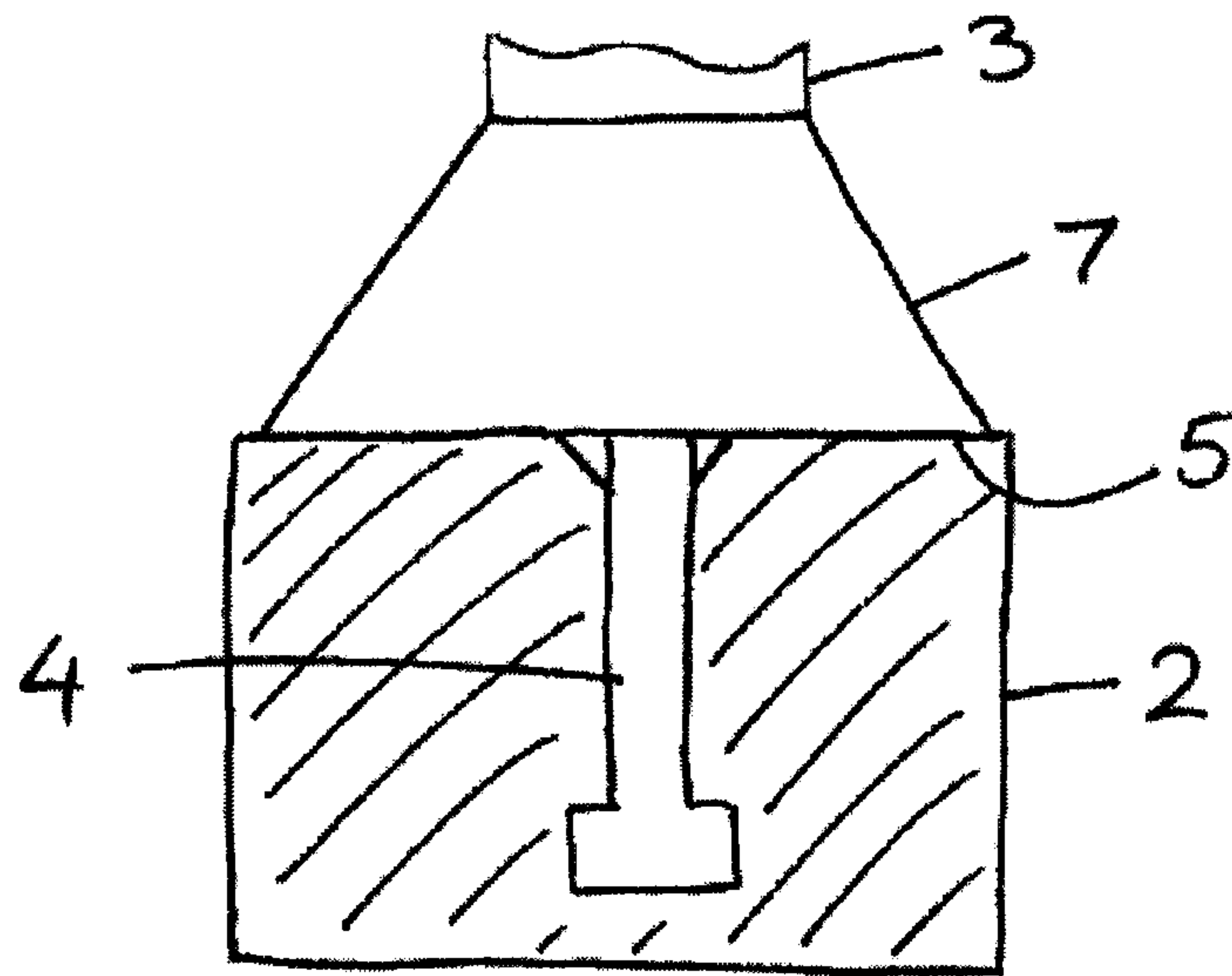


FIG. 6

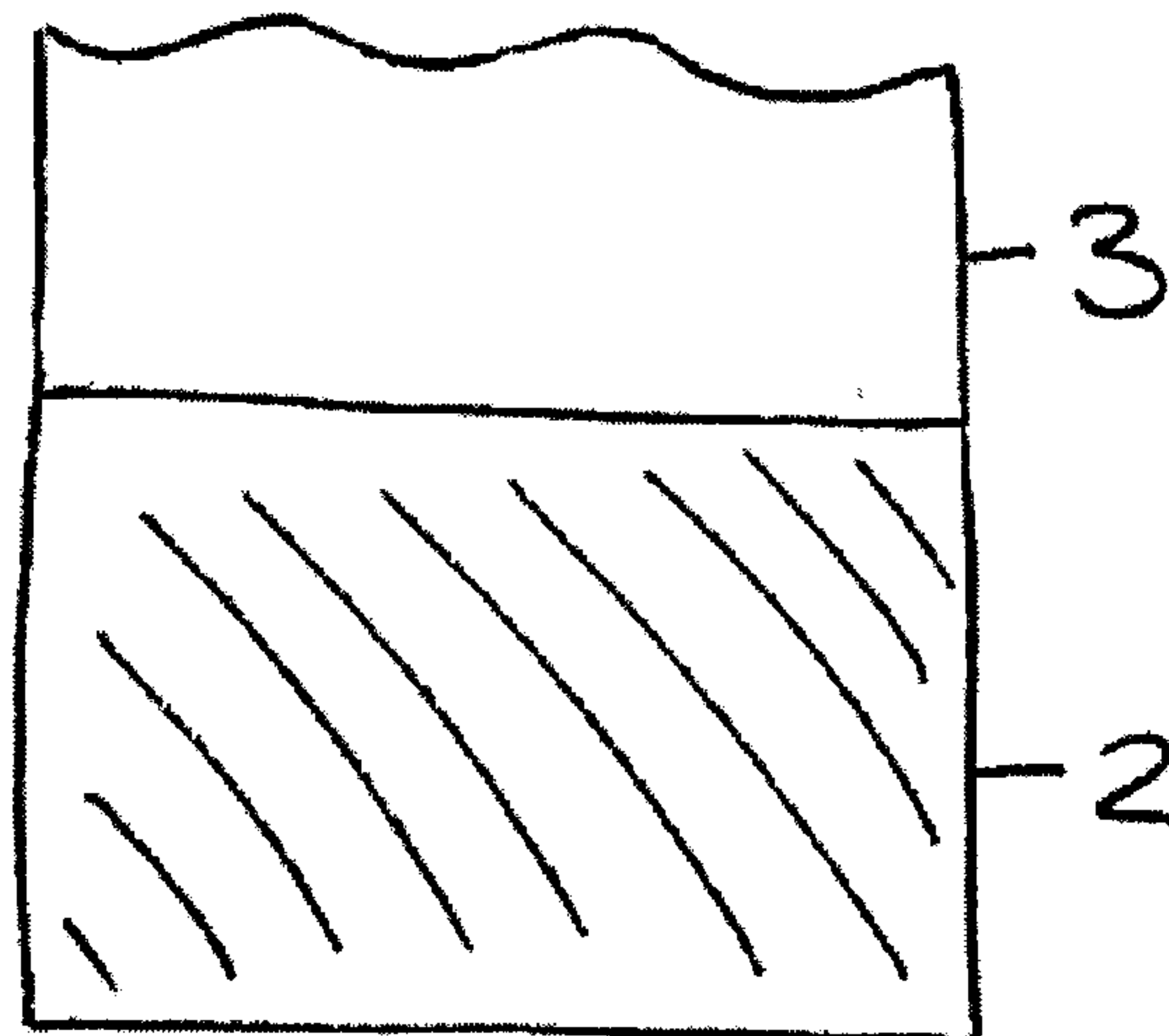


FIG. 7

