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METHOD AND DEVICE FOR MEASURING THE TEMPERATURE OF A MOLTEN METAL BATH

ABSTRACT

5 The invention relates to a method for measuring a temperature of a molten metal bath (2) by means of an optical fibre (3) surrounded by a cover (4). The optical fibre (3) is immersed in the molten bath (2) and the radiation absorbed by the optical fibre (3) in
10 the molten bath (2) is fed to a detector (13), wherein the optical fibre (3) is heated when immersed in the molten bath (2). The heating curve of the optical fibre (3) has at least one point $P(t_0, T_0)$, wherein the increase ΔT_1 in the temperature T of the optical fibre (3) over the time Δt in a first time interval $t_0 - \Delta t$ up to the temperature T_0 is smaller than the increase ΔT_2 in the temperature of the optical fibre (3) over the time Δt in an immediately
15 following second time interval $t_0 + \Delta t$.

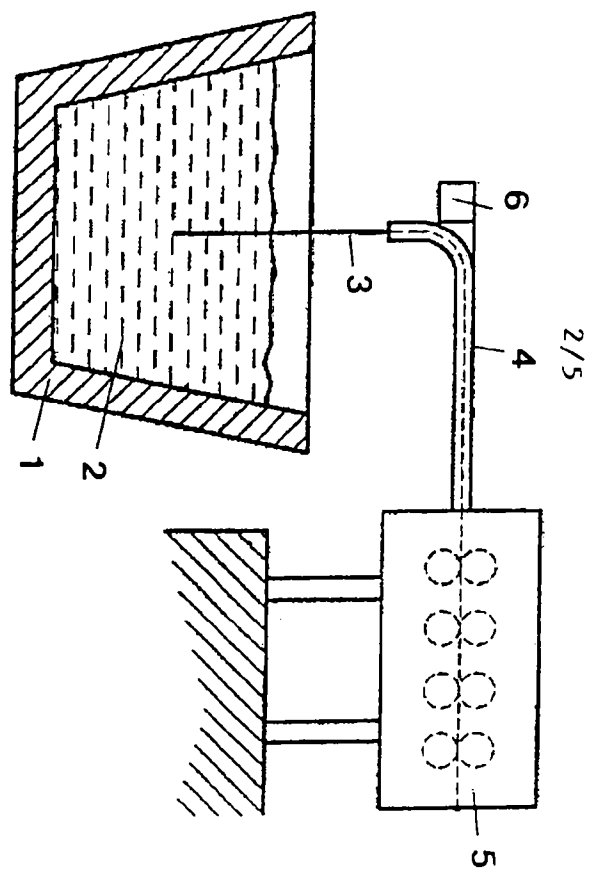


Fig. 2

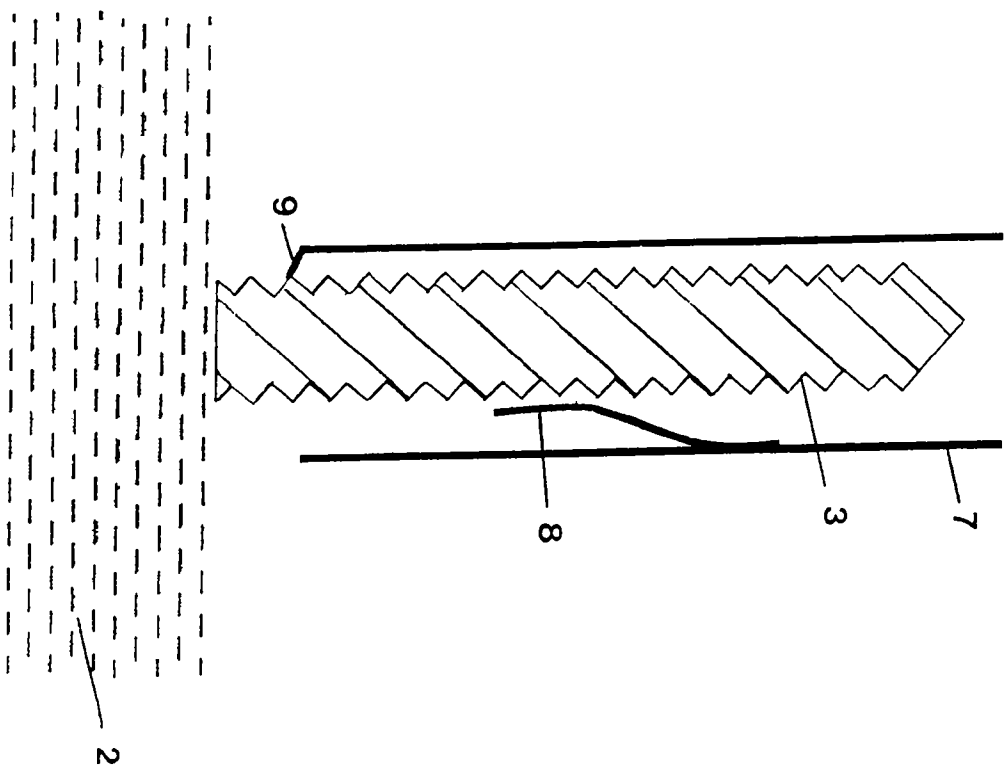


Fig. 3

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COMPLETE SPECIFICATION

FOR A STANDARD PATENT

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Invention Title:	Method and device for measuring the temperature of a molten metal bath

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

METHOD AND DEVICE FOR MEASURING THE
TEMPERATURE OF A MOLTEN METAL BATH

5 The invention relates to a method for measuring a parameter, in particular a temperature, of a molten bath, in particular a molten metal bath, by means of an optical fibre, surrounded by a cover, the optical fibre being immersed in the molten bath and the radiation absorbed by the optical fibre in the molten bath being fed to a detector, wherein the optical fibre is heated when immersed in the molten bath. Furthermore, the invention relates to a device for measuring a parameter, in particular a temperature, of a molten bath, in particular a molten metal bath, with an optical fibre having a cover and a detector connected to the fibre, wherein the cover surrounds the fibre in a plurality of layers. Parameters in the sense of the invention may also be, for example, the height of the bath or the composition, in other words the proportion of components. It is also possible to measure in other molten baths, such as molten salt, cryolite or glass baths.

15 A method of this kind is known, for example, from JP 11118607. This describes how an optical fibre is used for measuring temperature in molten metal baths. The optical fibre is unwound from a spool and fed to the molten metal bath through a feed pipe. The radiation absorbed by the optical fibre is evaluated by a detector. Corresponding optical fibres are known, for example, from JP 10176954. The fibre described there is surrounded at a distance by a metal tube. Arranged round the tube is a tube made of an insulating material, which in turn is surrounded by an outer metal tube. This structure prevents the inner metal tube from melting too quickly. The tube made of an insulating material contains carbon particles, so the inner metal tube does not melt until the corresponding tube portion is immersed in the molten metal bath. The fibre is immersed in the molten metal bath and tracked at a previously determined speed, so that it is possible to continue measuring even if the tip of the fibre is destroyed. A similar optical fibre for measuring temperature is disclosed in JP 7151918. Here the optical fibre is surrounded by a protective metal tube surrounded by a layer of plastics material.

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Furthermore, multi-layered wires are known, which are used in steelworks to introduce doping substances selectively into the molten steel bath (for example in DE 199 16 235, DE 37 12 619, DE 196 23 194, US 6,770,366).

It is the object of the present invention to substantially overcome or ameliorate one or more of the disadvantages of the prior art.

The optical fibre is by nature heated when it is immersed in the molten bath or when it approaches the molten bath or the layer of slag above it (for example on molten steel baths). The heating relates in particular to the tip or the immersion end of the optical fibre. The optical fibre, the light-conducting element of which is usually quartz glass, has to be regularly replaced where the tip is concerned, for example, in molten steel baths, as quartz glass cannot withstand the high temperatures of the molten steel bath for long.

According to a first aspect, the present invention provides a method for measuring a parameter of a molten bath by means of an optical fibre, surrounded by a cover, the optical fibre being immersed in the molten bath and the radiation absorbed by the optical fibre in the molten bath being fed to a detector, wherein the optical fibre is heated when immersed in the molten bath, the heating curve of the optical fibre having at least one point $P(t_0, T_0)$, wherein the increase ΔT_1 in the temperature T of the optical fibre over the time Δt in a first time interval $t_0 - \Delta t$ up to the temperature T_0 is smaller than the increase ΔT_2 in the temperature of the optical fibre over the time Δt in an immediately following second time interval $t_0 + \Delta t$.

A temperature course of this kind means that from a particular point in time onwards the heating curve in principle has a bend (quasi discontinuity), at which the heating speed considerably increases compared with the previous course. It has been proved that a mechanical movement of the optical fibre or its immediate environment takes place, the magnitude of which depends on the size of the change in the heating speed and the shortness of the corresponding time interval. The greater the change in the heating speed and the smaller the time interval Δt is, the greater is the mechanical movement of the fibre or its immediate environment at the time of this quasi erratic change in the heating curve. This movement assists the immersion of the optical fibre in the molten bath and the replacing of the tip of the optical fibre, which is practically

pushed off by the suddenly arising movement (vibration), so a new end of the glass fibre, not yet damaged by high temperatures, can be tracked.

The increase ΔT_2 in the temperature T after the second time interval $t_0 + \Delta t$ is preferably at least 5 times, preferably at least 10 times, in particular at least 20 times as large as the increase ΔT_1 in the temperature in the first time interval $t_0 - \Delta t$. In particular
5 preferred is a 50 times, or even better 100 times greater increase in the temperature in the second time interval. The duration Δt of the two time intervals may be at the most 500 ms, preferably at the most 200 ms long.

It is preferred that the temperature T_0 of the optical fibre allocated to the point in
10 time t_0 between the two time intervals is a maximum of 600°C , preferably a maximum of 200°C , in particular preferably a maximum of 100°C . The temperature of the actual optical fibre in the narrower sense, in other words the temperature of the quartz glass should be considered in this. The lower this temperature T_0 , on which the change in the heating speed is based, the stronger and more effective this change can be.

15 The speed at which the optical fibre is immersed in the molten metal bath or fed thereto corresponds to the speed at which the vitreous structure of its tip is destroyed, so new glass fibre material is constantly fed which is suitable for receiving and passing on radiation, without radiation losses arising owing to a destroyed fibre structure.

According to a second aspect, the present invention provides a device for
20 measuring a parameter of a molten bath with an optical fibre, having a cover, and a detector connected to the fibre, wherein the cover surrounds the fibre in a plurality of layers, one layer comprising a metal tube and an intermediate layer arranged beneath it comprising a powder or a fibrous or granular material, wherein the material of the intermediate layer surrounds the fibre in a plurality of pieces.

25 The preferred feature according to which the material of the intermediate layer surrounds the fibre in a plurality of separate parts means in the sense of the invention that the construction in multiple parts exists in the operating state, in other words during or after immersion in the molten bath to be measured. In this case there are temperatures of at least 1000°C , preferably at least 1400°C . In this state, a binding agent preferably used
30 during manufacture between the parts of the intermediate layer may dissolve or burn, so

the individual parts do not or largely no longer adhere to one another. The parts may form either small particles or else large cohesive units, such as conglomerates or, for example, shells arranged round the fibre. The material of the intermediate layer may not therefore be rigid overall but at least to a limited extent movable in itself.

5 An intermediate layer of this kind is heated during the immersion of the optical fibre in the molten metal bath or a layer of slag above it, the combination of a metal tube and an intermediate layer arranged beneath it made of a powder or a fibrous or granular material results in this material of the intermediate layer suddenly expanding greatly during heating, from a particular point onwards, in a heating curve with the presence of
10 gases, namely if the metal tube is heated so much that it can no longer withstand the pressure which arises inside the metal tube because of the expansion of the gases of the intermediate layer conditional on heat. In this case, fast rising stresses form inside the metal tube, until it suddenly cracks or is destroyed in some other way, so the cover of the optical fibre moves away from the fibre practically explosively. The device according to
15 the invention during or after the destruction of the metal tube, may very quickly disintegrate the intermediate layer as a layer, its parts preferably moving away from the fibre. In this way, on the one hand the optical fibre is very quickly and suddenly exposed to the molten metal bath at its immersed end and on the other hand the advance of the tip of the optical fibre into the molten metal bath is made considerably easier.

20 The intermediate layer is preferably formed of silicon dioxide, aluminium oxide or a material fireproof to a molten steel bath or an inert material. The material of the intermediate layer may not be rigid in itself, but the individual material particles are movable in respect of one another, so that on the one hand the cover with the optical fibre is as flexible as possible and on the other hand the erratic nature of the bursting or
25 releasing of this material is guaranteed. The cover may have an outer layer of metal, in particular of zinc, of ceramic paper, cardboard or plastics material.

The cover preferably has a vibrator or a vibrator is preferably arranged on or next to the cover, to improve the release of the material of the cover from the optical fibre or the removal (breaking off) of the destroyed tip of the optical fibre. The vibrator may also
30 be formed by the material of the intermediate layer, as it has been proved that the particles

of the material of the intermediate layer move towards one another on heating, this movement taking place partially erratically, so vibrations arise within this material or within the intermediate layer.

The vibrator may be formed of a material forming gas between 100°C and 1700°C (e.g. plastics material or other material which burns or gives off gas in this temperature range). It can also be appropriate that arranged between the vibrator and the cover there is an intermediate space which is smaller than the oscillation amplitude of the vibrator. In particular if the vibrator is arranged outside the cover, it acts mechanically on the cover periodically, so the vibration may be optimally transmitted by these beats. Another option may be that the outside of the cover has irregularities arranged in succession in the longitudinal direction, into which an obstacle arranged next to the cover, in particular on a fibre guiding device, acts, so when the optical fibre is advanced a vibration is generated.

Additionally the optical fibre may be surrounded by a metal sleeve as an inner layer. The layers of the cover may be arranged directly against one another in each case, the layer on the inside preferably resting directly against the optical fibre. The metal tube of the cover and also the metal sleeve are preferably made of steel, in particular if the device is used for measuring in a molten steel bath or a molten iron bath. Preferably the melting point of the material of the metal tube or the metal sleeve should correspond to the melting point of the molten metal bath to be measured.

The device according to the invention preferably has a cover for the quartz glass fibre which on immersion into the molten metal bath is discontinuously destroyed. In this way the optical fibre is kept for a relatively long time at a very low temperature and from a particular temperature onwards the fibre is preferably heated erratically to the equilibrium temperature in the molten metal bath, so the measurement can then take place very quickly before the optical fibre or its end immersed in the molten metal bath is destroyed. Preferably by continuously tracking the fibre into the molten bath at the same speed at which its immersed end is destroyed, there may be usable fibre material available in the molten metal bath for measuring. Preferably the tip of the fibre is continuously destroyed, so the erosion face of the fibre is practically stationary. For this, the fibre or its

immersion end may reach the bath temperature at the moment its degradation begins (this so-called critical speed is in this case therefore identical to the erosion speed at which the erosion face of the fibre moves). If the erosion speed is lower than the critical speed, the fibre may be destroyed before it reaches the bath temperature.

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

 Fig. 1 shows a heating curve for a method according to one embodiment of the invention, features of the heating curve being mentioned in the introductory portion of the description;

10 Fig. 2 shows a schematic illustration of a device according to one embodiment of the invention;

Fig. 3 shows the illustration of a mechanical vibration option for the device;

5 Figs. 4a to 4c show schematic illustrations of the device according to different embodiments of the invention, each with detector;

Figs. 5a to 5d are cross-sections of various embodiments of a fibre with a cover for the device; and

10 Fig. 6 shows a detailed illustration of the fibre in cross-section.

In Fig. 1 the temperature/time course is illustrated for the immersion of an optical fibre in a molten steel bath according to the method according to the invention. The immersion speed of the quartz glass fibre with cover in the molten steel bath is equal to its
15 destruction speed (erosion speed), so the erosion face is quasi stationary in the molten metal bath. This speed corresponds to the critical speed, so the optical fibre on the destruction face has reached the bath temperature.

The quartz glass fibre itself inside its covering has only a very small increase in
20 temperature over a long period of time. At a particular point in time its cover is suddenly removed, so its temperature increases in a short time very steeply until it reaches the equilibrium temperature in the molten steel bath.

In Fig. 2 a melting tub 1 with a steel molten bath 2 is illustrated. An optical fibre
25 arrangement 3 is immersed in this. The optical fibre arrangement 3 has, above the molten metal bath, an outer covering 4, which serves for easier propulsion by a propulsion device 5. At the end of the covering 4 facing the molten steel bath 2 a vibrator 6 is arranged, which beats on the covering 4 at short intervals, so the cover of the quartz glass fibre is suddenly destroyed by the vibration generated, as soon as it has reached a
30 predetermined temperature. At this point the temperature of the outer steel cover is

already very high, the powder arranged between the quartz glass fibre and the outer steel cover or the gas contained in the intermediate layer has greatly expanded and, assisted by the mechanical effect of the vibrator 6, explodes the steel cover which is under thermo-mechanical stresses in any case. As a result the quartz glass fibre is immediately exposed
5 to the temperature of the molten steel bath, so it heats up extremely quickly to the equilibrium temperature. The intermediate layer is formed of silicon dioxide powder or aluminium oxide powder.

Fig. 3 shows an optical fibre arrangement 3 with a cover which has on its outside
10 irregularities arranged in succession in the longitudinal direction. The optical fibre arrangement 3 is guided by a guide sleeve 7, which has inside it a support element 8, along which the optical fibre arrangement 3 is guided. On the side of the optical fibre arrangement 3 opposite the support element 8 an edge of the guide sleeve 7 is tangent-
bent inwards, so at this point it forms an obstacle 9. This obstacle 9 engages in the
15 irregularities, so the optical fibre arrangement 3 is constantly vibrated during its advance movement.

Fig. 4a shows an optical fibre arrangement 3, in which the fibre 10, a quartz glass fibre, is surrounded by a steel tube 11. Inside the steel tube 11 is arranged an intermediate layer
20 12 made of aluminium oxide powder. The quartz glass fibre 10 is connected to a detector 13 at its end facing away from the immersion end of the optical fibre. In Fig. 4b a similar arrangement is illustrated and here the quartz glass fibre 10 is surrounded by a metal sleeve 14. Cooling gas can be conducted through the metal sleeve 14, which is guided out of the steel tube 11 at the detector-side end of the optical fibre arrangement 3,
25 so the quartz glass fibre 10 is additionally cooled. Fig. 4c shows an arrangement, likewise similar to Fig. 4a, of an optical fibre 3. The intermediate space between the steel tube 11 and the quartz glass fibre 10 is divided into a plurality of chambers with the aid of cardboard discs 15 arranged perpendicular to the optical fibre 10. The cardboard discs 15 serve on the one hand to stabilise the intermediate layer 12. They stabilise in particular
30 the powder of the intermediate layer 12 during the destruction of the optical fibre

arrangement 3, running in the longitudinal direction. On the other hand during the burning of the cardboard discs 15, taking place because of the heating, an additional discontinuity/disruption is generated, which contributes to exposing the quartz glass fibre 10 quickly to the molten metal bath, so it heats up very quickly after the destruction of the cover.

In Figs. 5a to 5d several options are illustrated for stabilising the quartz glass fibre 10 in the centre of the cover of the optical fibre arrangement 3. According to Fig. 5a the steel tube 11 is bent in such a way that it forms in one piece a concentrically arranged inner tube 16, which is connected to the outer steel tube 11 by a web 17 running along the cover. The outer steel tube 11 is welded together at a seam point 18 and has a wall thickness of approximately 0.5 mm. The quartz glass fibre 10 is arranged in the inner tube 16. In the embodiment according to Fig. 5b the quartz glass fibre 10 is arranged centrally in the material of the intermediate layer 12. Fig. 5c shows a further embodiment of the optical fibre arrangement 3, similar to Fig. 5a. Here, though, the steel tube 11 is composed of two halves, in each case jointly forming two webs 17, by which the quartz glass fibre 10 is centrally locked. The embodiment according to Fig. 5d is similarly constructed. It additionally has a second outer steel tube 19, which holds together the steel tube 11 formed from two shells. The wall of the two steel tubes 11, 19 can be reduced correspondingly in respect of the other embodiments and amounts in each case to approximately 0.25 mm. A single welding at the seam point 20 is required.

Fig. 6 shows a fibre cross-section in detail. The quartz glass fibre 10 is surrounded at a minimal distance by a steel casing 21, so different expansions of the two materials on heating are possible and the quartz glass fibre 10 is nevertheless stabilised. Between the steel casing 21 and the steel tube 11 is arranged an intermediate layer 12 made of aluminium oxide particles. The steel tube 11 is rolled from a metal sheet and closed by a fold 23.

The claims defining the invention are as follows:

1. A method for measuring a parameter of a molten bath by means of an optical fibre, surrounded by a cover, the optical fibre being immersed in the molten bath and the radiation absorbed by the optical fibre in the molten bath being fed to a detector, wherein the optical fibre is heated when immersed in the molten bath, the heating curve of the optical fibre having at least one point $P(t_0, T_0)$, wherein the increase ΔT_1 in the temperature T of the optical fibre over the time Δt in a first time interval $t_0 - \Delta t$ up to the temperature T_0 is smaller than the increase ΔT_2 in the temperature of the optical fibre over the time Δt in an immediately following second time interval $t_0 + \Delta t$.
2. The method according to claim 1, wherein the parameter is a temperature.
3. The method according to claim 1 or 2, wherein the molten bath comprises a molten metal bath.
4. The method according to claim 1, 2 or 3, wherein the increase ΔT_2 in the temperature in the second time interval $t_0 + \Delta t$ is at least 5 times as large as the increase ΔT_1 in the temperature in the first time interval $t_0 - \Delta t$.
5. The method according to claim 4, wherein the increase ΔT_2 in the temperature in the second time interval $t_0 + \Delta t$ is at least 10 times as large as the increase ΔT_1 in the temperature in the first time interval $t_0 - \Delta t$.
6. The method according to claim 5, wherein the increase ΔT_2 in the temperature in the second time interval $t_0 + \Delta t$ is at least 20 times as large as the increase ΔT_1 in the temperature in the first time interval $t_0 - \Delta t$.
7. The method according to claim 6, wherein the increase ΔT_2 in the temperature in the second time interval $t_0 + \Delta t$ is at least 50 times as large as the increase ΔT_1 in the

temperature in the first time interval $t_0 - \Delta t$.

8. The method according to claim 7, wherein the increase ΔT_2 in the temperature in the second time interval $t_0 + \Delta t$ is at least 100 times as large as the increase ΔT_1 in the temperature in the first time interval $t_0 - \Delta t$.

9. The method according to any preceding claim, wherein the time Δt is at the most 500 ms long.

10. The method according to claim 9, wherein the time Δt is at the most 200 ms long.

11. The method according to any preceding claim, wherein the temperature T_0 of the optical fibre allocated to the point of time t_0 between the two time intervals amounts to a maximum of 600°C.

12. The method according to claim 11, wherein the temperature T_0 of the optical fibre allocated to the point of time t_0 between the two time intervals amounts to a maximum of 200°C.

13. A device for measuring a parameter of a molten bath with an optical fibre, having a cover, and a detector connected to the fibre, wherein the cover surrounds the fibre in a plurality of layers, one layer comprising a metal tube and an intermediate layer arranged beneath it comprising a powder or a fibrous or granular material, wherein the material of the intermediate layer surrounds the fibre in a plurality of pieces.

14. The device according to claim 13, wherein the parameter is a temperature.

15. The device according to claim 13 or 14, wherein the molten bath comprises a molten metal bath.

16. The device according to claim 13, 14 or 15, wherein the intermediate layer comprises an inert material, silicon dioxide, aluminium oxide or a material fireproof to a molten bath.
- 5 17. The device according to any one of claims 13 to 16, wherein an outer layer comprises metal, ceramic paper, cardboard or plastics material.
18. The device according to claim 17, wherein the metal comprises zinc.
- 10 19. The device according to any one of claims 13 to 18, wherein the cover has a vibrator or a vibrator is arranged on or next to the cover.
20. The device according to claim 19, wherein the vibrator comprises a material which forms gas between 100°C and 1700°C.
- 15 21. The device according to claim 19 or 20, wherein an intermediate space is arranged between the vibrator and the cover which is smaller than an oscillation amplitude of the vibrator.
- 20 22. The device according to claim 19, 20 or 21, wherein the outside of the cover has irregularities arranged in succession in the longitudinal direction, into which an obstacle arranged next to the cover, in particular on a fibre guide arrangement, engages.
23. The device according to any one of claims 13 to 22, wherein the optical fibre is
25 surrounded by a metal sleeve as an inner layer.
24. The device according to any one of claims 13 to 23, wherein the layers of the cover are arranged directly against one another.
- 30 25. The device according to claim 24, wherein the layer on the inside rests directly

against the optical fibre.

5 26. A method for measuring a parameter of a molten bath substantially as
hereinbefore described with reference to any one of Figures 1 to 3, 4a to 4c, 5a to 5d and
6.

10 27. A device for measuring a parameter of a molten bath constructed
substantially as hereinbefore described with reference to any one of Figures 2, 3, 4a to 4c,
5a to 5d and 6.

Dated 24 April 2007

Heraeus Electro-Nite International N.V.

15 **Patent Attorneys for the Applicant/Nominated Person**
SPRUSON & FERGUSON

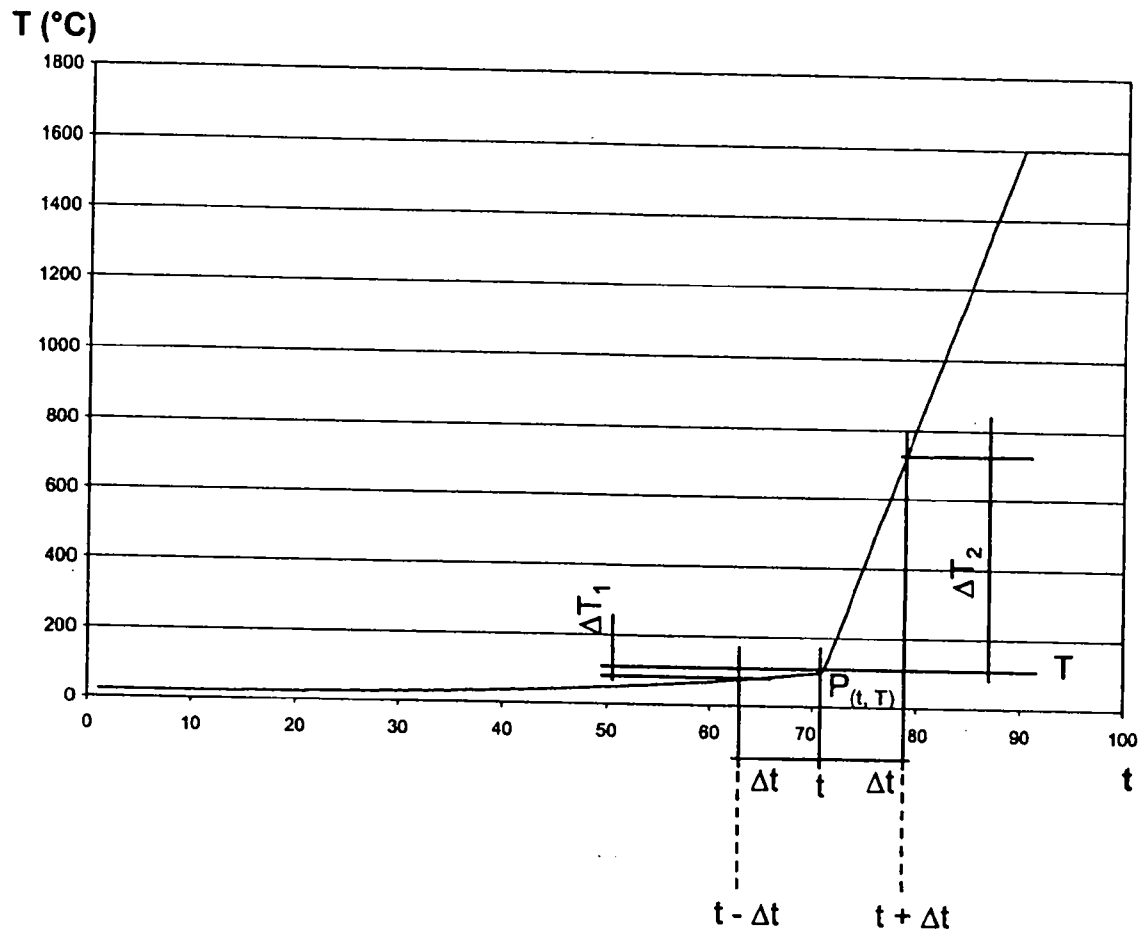
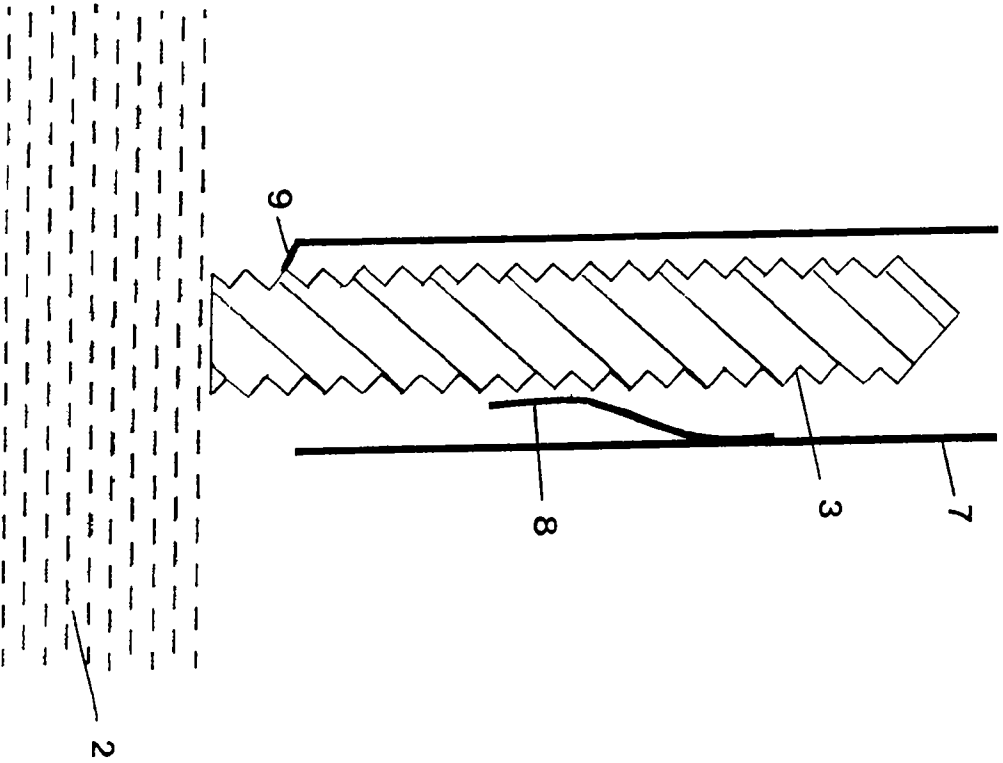
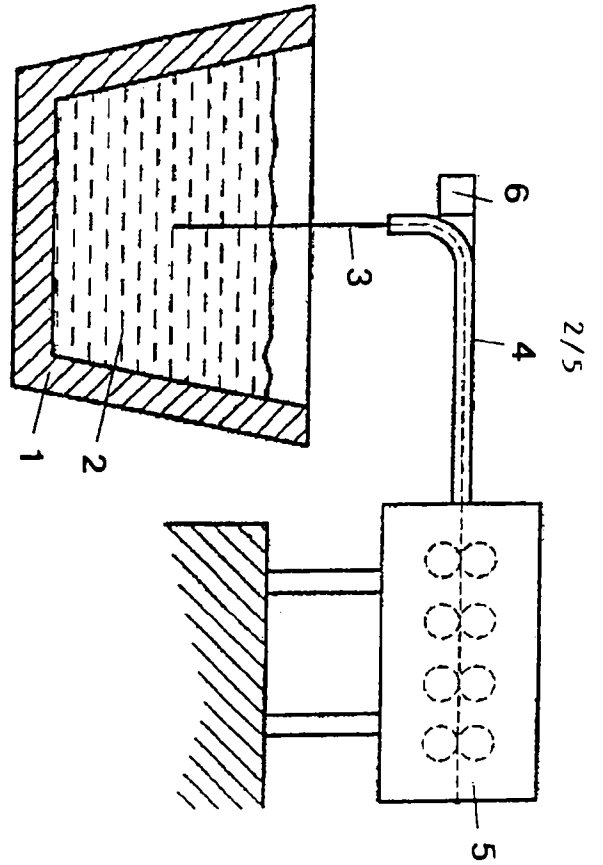


Fig. 1



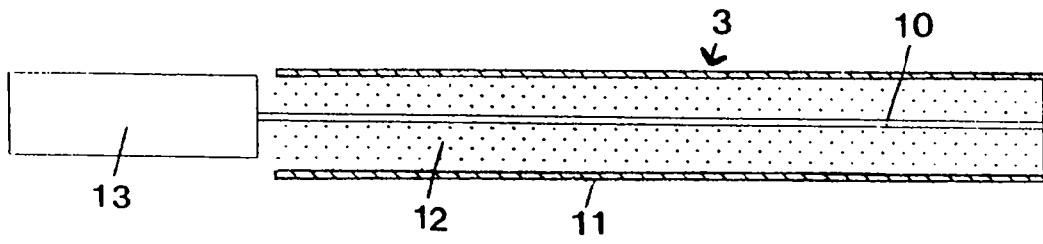


Fig. 4a

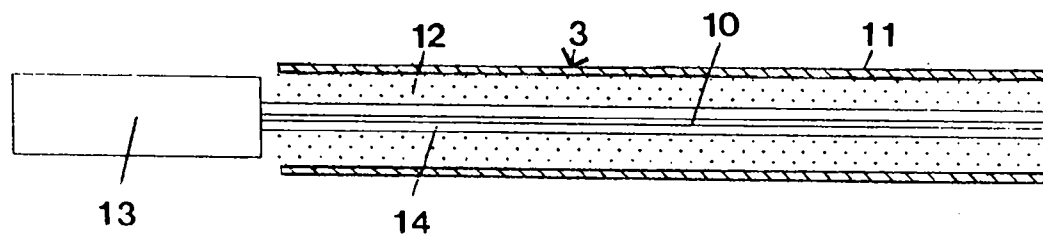


Fig. 4b

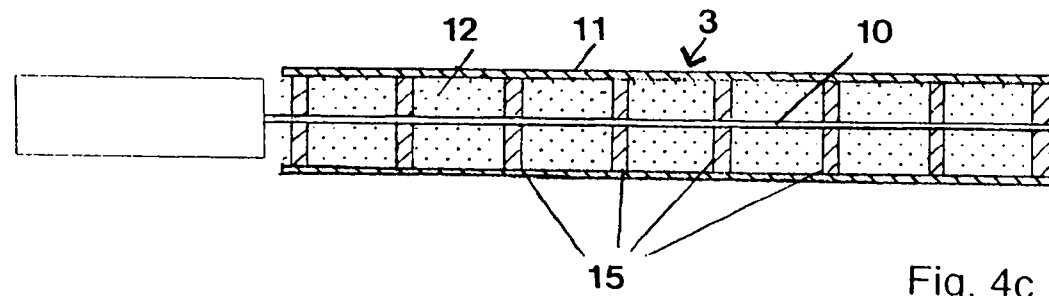


Fig. 4c

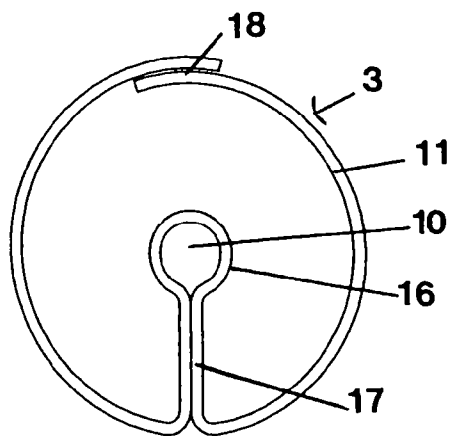


Fig. 5a

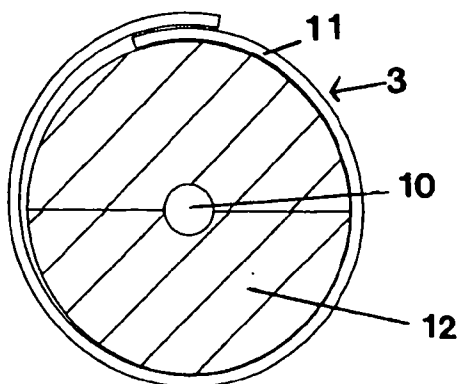


Fig. 5b

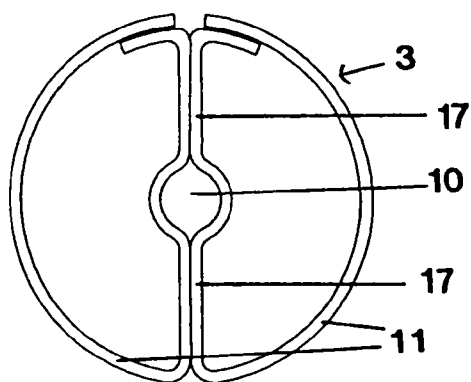


Fig. 5c

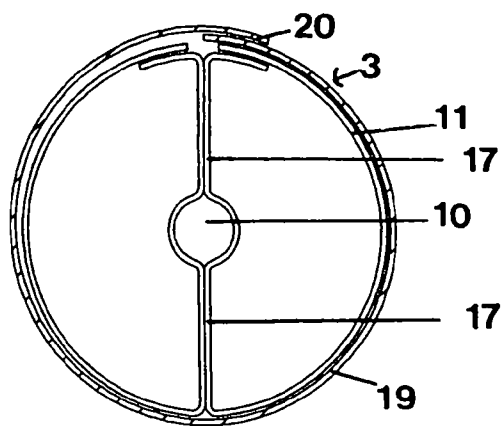


Fig. 5d

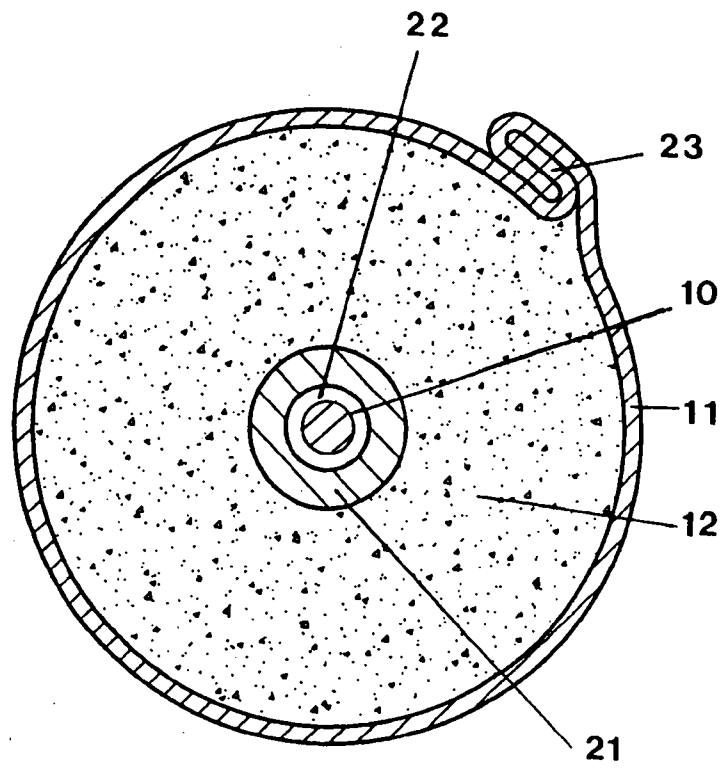


Fig. 6