

Description

Technical Field

[0001] This patent disclosure relates generally to a temperature measurement arrangement of a cooling circuit and a related method in which a sensing device may monitor a surface temperature in a cooling circuit, detect nucleate boiling or control the boiling state of a liquid coolant circulating in the cooling circuit.

Background

[0002] This patent disclosure relates generally to the field of cooling systems for high-temperature generating apparatuses, such as vehicle engines, and to the field of low pressure, low temperature boiling systems, for instance in air conditioning (HVAC) and heating ventilation systems. During operation of the engine, the engine may be kept in operative mode by using a cooling circuit wherein a liquid coolant circulates inside the cooling circuit. A liquid coolant circulating inside the cooling circuit may transport the heat away from a heat source in order to prevent overheating of the engine.

[0003] It is often desirable to prevent or control a nucleate boiling state of the liquid coolant in the cooling circuit, which may enhance the cooling effect significantly. However, an effect known as "film boiling" may occur when bubbles merge and a coolant vapour layer forms at the heated surface. This coolant vapour layer separates the liquid coolant from the heated surface and can act as an insulator. At the point where film boiling initiates, thermal exchange between the surface of the cooling circuit and the coolant inside the circuit may rapidly decrease. The temperature of the heated surface in the region where film boiling occurs may thus escalate to a temperature multiple times higher than the saturation temperature of the coolant. This effect may result in a surface temperature high enough to cause damage to or failure of the heated surface material or structure.

[0004] It is known that thermal exchange may be increased by providing cavities in a surface of the cooling system in contact with the liquid coolant. At a certain wall superheat temperature, bubbles may form and depart from the cavities and transport the heat away from the surface of the cooling system.

[0005] Additionally, in order to control the nucleate boiling state, the cooling system may be influenced to alter the rate of nucleate boiling. This may be done by activation of external ventilation units to reduce coolant temperature, increasing the speed of the coolant flow for transporting the heat away from the heat source, or any other suitable procedures to alter the boiling state.

[0006] In order to control the cooling system, a sensor may be used to measure the temperature of the cooling circuit wall to detect bubble departure. In case a measured temperature exceeds a pre-defined alerting value, measures could be taken to prevent any damage to the

cooling system, including derating or stopping the engine until it has cooled down or activating additional cooling systems, e.g. a fan unit, for providing further cooling.

[0007] Although known sensor arrangements may provide temperature indication, they may not measure the temperature accurately, may not provide information quickly enough or measure the temperature at a suitable location to fully control a nucleate boiling state.

[0008] There is a desire to precisely measure the temperature of the cooling circuit heated surface during bubble formation and departure and to identify when nucleate boiling occurs, so as to maintain the circuit in a controlled nucleate boiling state.

[0009] There is also a need for a nucleate boiling sensor arrangement which is adapted to react quickly, preferably in real-time, to keep a liquid coolant in a nucleation boiling state

Brief Summary of the Invention

[0010] This patent disclosure relates generally to a nucleate boiling sensor arrangement for liquid cooling systems, comprising a sensor positioned in a support structure; and at least one nucleation cavity in a support structure, said nucleation cavity having a zone of bubble formation, a portion of the sensor positioned at the zone of bubble formation so as to detect initiation of a nucleate boiling state.

[0011] According to another aspect of the present disclosure, a method of measuring a nucleate boiling temperature of a surface having at least one nucleation cavity in liquid cooling systems, comprising the steps of positioning a portion of a sensor at a zone of bubble formation of at least one cavity and monitoring a temperature at said zone of bubble formation to detect initiation of nucleate boiling state.

[0012] Yet in another aspect of the present disclosure, the disclosure describes a nucleate boiling sensor arrangement adapted to measure a temperature of said liquid coolant in a same plane spanned by said surface.

Brief Description of the Drawings

[0013] The foregoing and other features and advantages of the present disclosure will be more fully understood from the following description of various embodiments, when read together with the accompanying drawings, in which:

Fig. 1 is an illustration of a zone of bubble formation of a cavity according to the present disclosure;

Fig. 2 is a sectional view of a first embodiment of a controlled nucleate boiling sensor of a controlled nucleate boiling sensor arrangement according to the present disclosure;

Fig. 3 is a sectional view of a first embodiment of a controlled nucleate boiling sensor arrangement according to the present disclosure;

Fig. 4 is a sectional view of a second embodiment of the controlled nucleate boiling sensor arrangement according to the present disclosure;
 Fig. 5 is a sectional view of a third embodiment of the controlled nucleate boiling sensor arrangement according to the present disclosure;
 Fig. 6 is a sectional view of a fourth embodiment of the controlled nucleate boiling sensor arrangement according to the present disclosure;
 Fig. 7 is an isometric view of a second embodiment of the controlled nucleate boiling sensor of a controlled nucleate boiling sensor arrangement according to the present disclosure;
 Fig. 8 is an isometric view of a third embodiment of the controlled nucleate boiling sensor of a controlled nucleate boiling sensor arrangement according to the present disclosure; and
 Fig. 9 is a side cross section view of a fourth embodiment of the controlled nucleate boiling sensor of a controlled nucleate boiling sensor arrangement according to the present disclosure.

Detailed Description

[0014] This disclosure generally relates to a controlled nucleate boiling sensor arrangement for liquid cooling systems. Particularly, it relates to a sensor arrangement and process for accurate detection of initiation of a nucleate boiling state and monitoring thereof.

[0015] Fig. 1 illustrates a cavity 12 which may be located in a liquid cooling system for instance in a cooling circuit of a vehicle. Cavity 12 may be formed within a support structure 18 of the cooling circuit. At a nucleate boiling state bubbles may form in cavity 12 and depart therefrom. A bubble may form within a zone of bubble formation 13 prior to bubble departure. The zone of bubble formation 13 includes the hollow of the cavity 12 and the proximate region around the aperture of cavity 12 on surface 11. In the absence of a bubble said areas may be in contact with a coolant liquid that may circulate through the coolant circuit. During bubble formation and prior to bubble departure said areas may be contact with the vapour of the bubble. Monitoring the temperature at the zone of bubble formation 13 provides an accurate gauge of bubble formation to thereby accurately detect changes in the boiling state.

[0016] In an embodiment the zone of bubble formation 13 may include the periphery 14 around the cavity 12 in support structure 18. Temperature changes within the cavity 12 may be accurately detected within the periphery 14.

[0017] In another embodiment having a plurality of cavities 12 each cavity may have a zone of bubble formation 13 such that the plurality of zones may merge to form a single combined zone of bubble formation 13.

[0018] Fig. 2 illustrates a first embodiment of a controlled nucleate boiling sensor for a controlled nucleate boiling sensor arrangement according to the present disclosure.

A sensor 2 may be constituted by three sections. A first section 3 having the largest diameter of the sensor may be in contact with the liquid coolant. In direct contact with the first section 3 may be a second section 4, which has a smaller diameter than the first section 3. Attached to the second section 4 may be a third section 5. A connection element 6 may be connected to third section 5. The connection element 6 enables the sensor 2 to be electrically connected to a control system for further processing of the measurements taken by the sensor 2.

[0019] Section 3 may be formed in any suitable shape. In an embodiment, first section 3 may have a generally cylindrical shape. First section 3 may comprise an external layer which may include a junction 7 and an insulation shield 10. Insulation shield 10 may be thermally or electrically insulating. At an end, first section 3 may be connected to second section 4 and, in an embodiment, at the other end the first section 3 may comprise the junction 7. Junction 7 may be a thin plate and may be in contact with a surface or a substance, for instance a coolant liquid, for monitoring the temperature thereof. The first section 3 may be enclosed on its entire circumference by an insulation shield 10. The insulation shield 10 may protect the sensor from damage when the sensor is installed into the surface of the cooling circuit. The insulation shield 10 may also act as a fastening element when mounted into surface of the cooling circuit. The insulation shield 10 may be slightly larger in diameter in respect to a hole 16 into which sensor 2 is to be installed so as to press fit the sensor 2 into the hole 16. The outer surface of the insulation shield 10 may also have a structure to further provide for a tight fit, such as threads or a knurled structure.

[0020] The first section 3 may be constituted by two different conducting materials 8 and 9, for instance metals. The first material 9 may occupy the entire volume of section 3 except for an annular centre area. The centre area may be constituted by a second material 8. The first 8 and second 9 material may aid in monitoring a surface or a substance through a portion of sensor 2 based on a thermoelectric effect between the two materials.

[0021] Sensor 2 may detect initiation of a nucleate boiling state at the zone of bubble formation 13 or a combined zone of bubble formation. In an embodiment, initiation of a nucleate boiling state may be detected through a portion of sensor 2. The portion of sensor 2 may be junction 7 or a portion of junction 7.

[0022] Fig. 3 illustrates a first embodiment of a controlled nucleate boiling sensor arrangement 1 for measuring a temperature in a cooling circuit. In such an arrangement a sensor 2 may be inserted into the support structure 18 of a cooling circuit. The sensor may be inserted in a hole 16 provided in the support structure 18 of a cooling circuit. The hole 16 may be shaped to accommodate sensor 2. The hole 16 may be sized so as to accommodate the sensor 2 in a press-fit manner. The mounting of the sensor 2 may be achieved by pressing it into the hole 16 with force so that the sensor 2 may be arranged so as to be substantially part of the support structure 18. In an em-

bodiment, hole 16 may be provided with threading for receiving and mounting sensor 2. The hole 16 may have a closed end which may be located in support structure 18. A plurality of cavities 12 may be formed in the support structure 18 extending into the surface 11. The closed end 33 of the hole 16 may be positioned in the periphery 14. The periphery 14 may include a border 35. The border 35 may lie between the closed end 33 and the bottom of the cavities 12. A suitable metal may constitute the support structure 18. Any suitable form-shaping process, such as laser treatment or stamping or any other suitable forming process may be used to obtain the cavity 12 or the plurality of cavities 12.

[0023] In operative position the sensor 2 may be inserted in the hole 16 and junction 7 of the sensor 2 may abut the closed end 33. The junction 7 may be within the periphery 14. Surface 11 may be substantially plane in the region wherein cavities 12 may not be present. A liquid coolant 34 may be in contact with the surface 11 and the interior of the cavities 12. A bubble 15 may form at the zone of bubble formation 13 and bubble departure may signal that a state of nucleate boiling is reached. The sensor 2 abutting the border 35 may accurately monitor the periphery 14 within the zone of bubble formation and thereby detect initiating of the nucleate boiling state. The material used for the parts of a cooling system must be suitable to withstand heat and must be corrosion-resistant due to the contact with the liquid coolant. Certain metals, like steel and aluminium fulfil these requirements. Certain polymers or any other material having similar characteristics as the metal described above can be used.

[0024] Fig. 4 illustrates a second embodiment of the controlled nucleate boiling sensor arrangement 1 comprising the sensor 2 in an operative position wherein the sensor 2 may be mounted in the coolant circuit.

[0025] The sensor arrangement 1 may include the sensor 2, which may be mounted in a hole 16 of a support structure 18 of a cooling circuit. The hole 16 may be sized so as to accommodate the sensor 2 in a press-fit manner. The mounting of the sensor 2 may be achieved by pressing it into the hole 16 with force so that the sensor 2 may be arranged so as to be substantially part of the support structure 18. Surface 11 of support structure 18 may be flush with junction 7. By press-fitting the sensor into the support structure 18 of the cooling system no coolant, which circulates at the surface 11 of the support structure 18, may escape from the cooling system through the region of abutment between junction 7 and surface 11.

[0026] The support structure 18 may have a plurality of cavities 12 on the surface 11. Each of the cavities 12 may be shaped to be substantially cylindrical with an opening at the surface 11. In an embodiment, each of the opening may have a diameter which may be lesser in magnitude than the depth of the cavities 12

[0027] The plurality of cavities 12 may be spaced apart from the junction 7 so as to form a cluster 17 of cavities 12. Within the cluster 17 the cavities 12 may be arranged

randomly or in regular distances from each other at the surface 11 of the support structure 18.

[0028] In a nucleate boiling state of the coolant, a bubble 15 may form in the zone of bubble formation 13. The junction 7 may be positioned so that at least a part of the bubble 15 may contact the junction 7 of the sensor 2. The junction 7 may be adapted to monitor the temperature of the coolant at surface 11 and detect initiation of nucleate boiling, i.e. when one or more bubbles 15 start departing from the cavities 12. The junction 7 may also be in contact with the fluid coolant, vapour of a forming bubble or residual vapour of a departed bubble for measuring the actual temperature at that location.

[0029] Fig. 5 illustrates a third embodiment of the controlled nucleate boiling sensor arrangement comprising the sensor 2 according to the disclosure. In this embodiment, the sensor 2 may be arranged below the cavities 12 of the support structure 18 of the cooling circuit. Cavities 12 may extend through support structure 18 to a hole 16 for receiving sensor 2. The junction 7 of the sensor 2 may be arranged so as to be in immediate contact with the bottom of cavities 12 wherein junction 7 may form a bottom surface 19 of the cavities 12. The bottom surface 19 may be in direct contact with the zone of bubble formation 13 and with the fluid coolant, vapour of a forming bubble or residual vapour of a departed bubble for measuring the actual temperature at that location. The plurality of cavities 12 present in the surface 11 of the support structure 18 may be arranged in regular distances to each other.

[0030] Fig. 6 illustrates a fourth embodiment of the controlled nucleate boiling sensor arrangement. The controlled nucleate boiling sensor 2 may be positioned at the zone of bubble formation 13 of a single cavity. In another embodiment, the junction 7 of the sensor 2 may form the bottom surface 19 of a single cavity.

[0031] Fig. 7 illustrates a second embodiment of the controlled nucleate boiling sensor. A sensor 20, which may comprise two-parts. One part may be first section 21, which may be substantially cylindrical and may have an edge 27 at one end. At the other end of first section 21 may be a junction 23 covering a part of the sensor 20, which may be in contact with a liquid coolant during operation of the sensor 20. At the surface 26 of the junction 23 may be a cavities 24 dispersed thereon.

[0032] Fig. 8 illustrates a third embodiment of the controlled nucleate boiling sensor. At the surface 26 of the sensor 20 may be a plurality of clusters 28 comprising cavities 24.

[0033] Sensor 20 may fit into a hole 16 of support structure 18. Sensor 20 may detect initiation of a nucleate boiling state at the zone of bubble formation 13 of cavity 24 or at the combined zone of bubble formation. Initiation of a nucleate boiling state may be detected through a portion of sensor 20. The portion of sensor 20 may be junction 23 or a portion of junction 23.

[0034] The cluster 28 may be arranged so as to build a regular pattern having the equal distances to each other

or may be arranged in a random configuration. During initiation of nucleate boiling a bubble 25 may build up at a cluster 28 so as to cover at least a portion of the cluster 28 or cavity 24 at the surface 26. Junction 12 may be adapted to measure a temperature when the bubble 25 begins to depart from the surface 26. The junction 23 may be in direct contact with zones of the bubble formation of the cavities 24 or the combined zone of bubble formation of the cavities. The junction 23 may also be in contact with the fluid coolant, vapour of a forming bubble or residual vapour of a departed bubble for measuring the actual temperature at that location.

[0035] An accurate temperature measurement may not be possible if junction 23 is damaged or cavities 24 are corroded. In such an event sensor 20 may be exchanged with a new junction 23.

[0036] Fig. 9 illustrates a fourth embodiment of the controlled nucleate boiling sensor. Sensor 40 may comprise a first section 41. First section 41 may comprise a surface 42. Surface 42 may comprise a cavity 43 or a plurality of cavities 43. The cavities may be arranged in clusters. Cavities may be formed by machining into first section 41.

[0037] First section 41 may comprise a junction 44 positioned below the cavity 43. The junction may be embedded in first section 41 and may be positioned up to 1mm from the surface 42. The junction 44 may be in direct contact with zones of the bubble formation of the cavity 43 or the combined zone of bubble formation of a plurality of cavities 43.

[0038] Sensor 40 may detect initiation of a nucleate boiling state at the zone of bubble formation 13 of cavity 43. Initiation of a nucleate boiling state may be detected through a portion of sensor 40. The portion of sensor 40 may be junction 44 or a portion of junction 44.

[0039] In an embodiment, the layer of first section 41 provided on junction 44 may be removably mounted to the sensor 40. The layer of first section 41 may be welded, screwed or pressed on the sensor 40.

[0040] Sensor 40 may be mounted into a hole 16 of support structure 18 by press-fitting or by threading.

[0041] Existing coolant systems may be easily upgraded with a nucleate boiling sensor arrangement according to the present disclosure.

Industrial Applicability

[0042] This disclosure describes a controlled nucleate boiling sensor arrangement, wherein the controlled nucleate boiling sensor is arranged in close vicinity to the nucleation cavities and in direct contact with a bubble forming at said cavities.

[0043] The industrial applicability of the controlled nucleate boiling sensor manufactured as part of a cooling system or temperature controlled process or as an add-on element as described herein will be readily appreciated from the foregoing discussion. In case a sensor breaks or the cavities corrode, the sensor with the cavities thereon can easily be replaced keeping maintenance low

and downtime of the machine to a minimum. The present disclosure is applicable to cooling systems for, but not limited to, internal combustion engines.

[0044] Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein.

[0045] Where reference signs follow technical features mentioned in any claim, the reference signs have been included for the sole purpose of increasing the intelligibility of the claims. Neither the reference signs nor their absence have any limiting effect on the technical features as described above or on the scope of any claim elements.

[0046] One skilled in the art will realize the invention may be embodied in other specific forms without departing from the invention or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the invention described herein. The scope of the invention is thus indicated by the appended claims, rather than by the foregoing description. Moreover, all changes that come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

Claims

1. A controlled nucleate boiling sensor arrangement (1) for liquid cooling systems, comprising:
 - a sensor (2, 20, 40) positioned in a support structure (18); and
 - at least one nucleation cavity (12, 24, 43) having a zone of bubble formation (13); wherein at least a portion of the sensor (2, 20) is positioned at the zone of bubble formation (13).
2. The controlled nucleate boiling sensor arrangement according to claim 1, wherein said portion of said sensor (2, 20, 40) is flush with a surface (11) of support structure (18).
3. The controlled nucleate boiling sensor arrangement according to claim 2, wherein said support structure (18) includes a hole (16) for accommodating the sensor (2, 20, 40).
4. The controlled nucleate boiling sensor arrangement according to claims 2 or 3, wherein the nucleation cavity (12) is spaced apart from the portion of sensor (2) and positioned on said support structure (18).
5. The controlled nucleate boiling sensor arrangement according to claims 1, 2 or 3, wherein the nucleation

cavity is formed on the portion of sensor (20, 40).

6. The controlled nucleate boiling sensor arrangement according to claim 5, wherein said the portion of sensor (20) is removably mounted on a first section (21). 5
7. The controlled nucleate boiling sensor arrangement according to claim 1, wherein said the portion of sensor (2, 20, 40) is positioned at the base of the nucleation cavity (12, 24, 43). 10
8. The controlled nucleate boiling sensor arrangement according to any one of the preceding claims comprising a plurality of nucleation cavities. 15
9. The controlled nucleate boiling sensor arrangement according to claim 8, wherein the plurality of cavities (24) are grouped in clusters (28).
10. The controlled nucleate boiling sensor arrangement according to any one of the preceding claims wherein the portion of said sensor is junction (7, 23, 44). 20
11. A method of measuring a nucleate boiling temperature of a surface (11, 26, 42) having at least one nucleation cavity in liquid cooling systems, comprising the steps of: 25
 - positioning at least portion of a sensor (2, 20, 49) at a zone of bubble formation (13) of at least one cavity (12, 24, 43); and 30
 - monitoring a temperature at said zone of bubble formation (13).
12. The method of measuring a nucleate boiling temperature of a surface (11, 26, 42) in liquid cooling systems according to claim 11, wherein said portion of sensor is arranged so as to substantially form part of a support structure (18). 35 40
13. The method of claim 11 wherein the nucleation cavity (12) is spaced apart from the portion of sensor (2).
14. The method of claim 11 wherein the nucleation cavity (12) is integral with the portion of sensor (2). 45

50

55

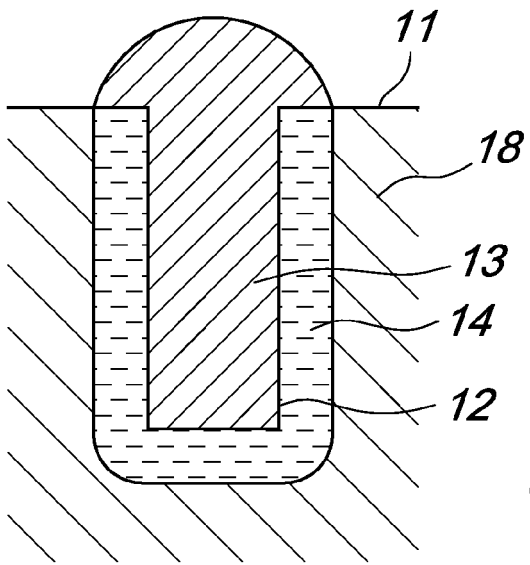


Fig. 1

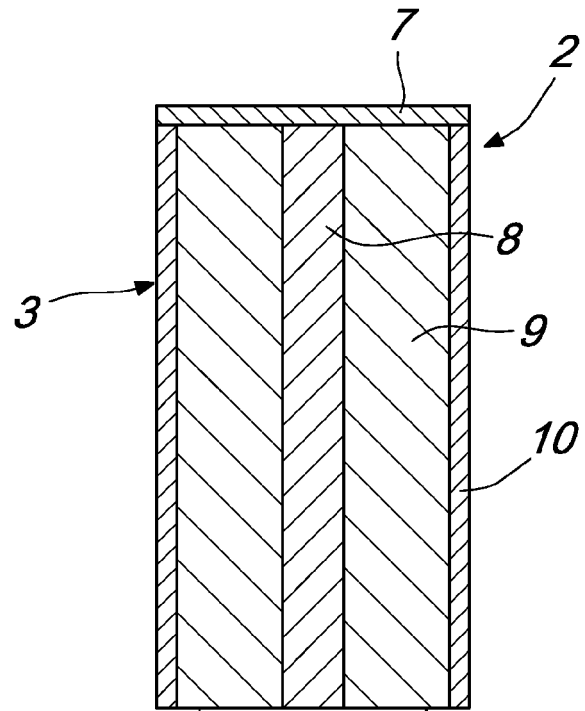
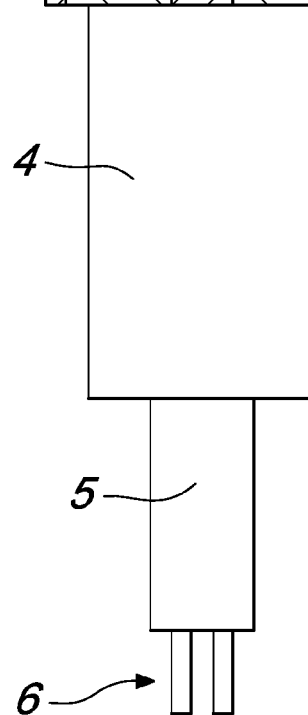
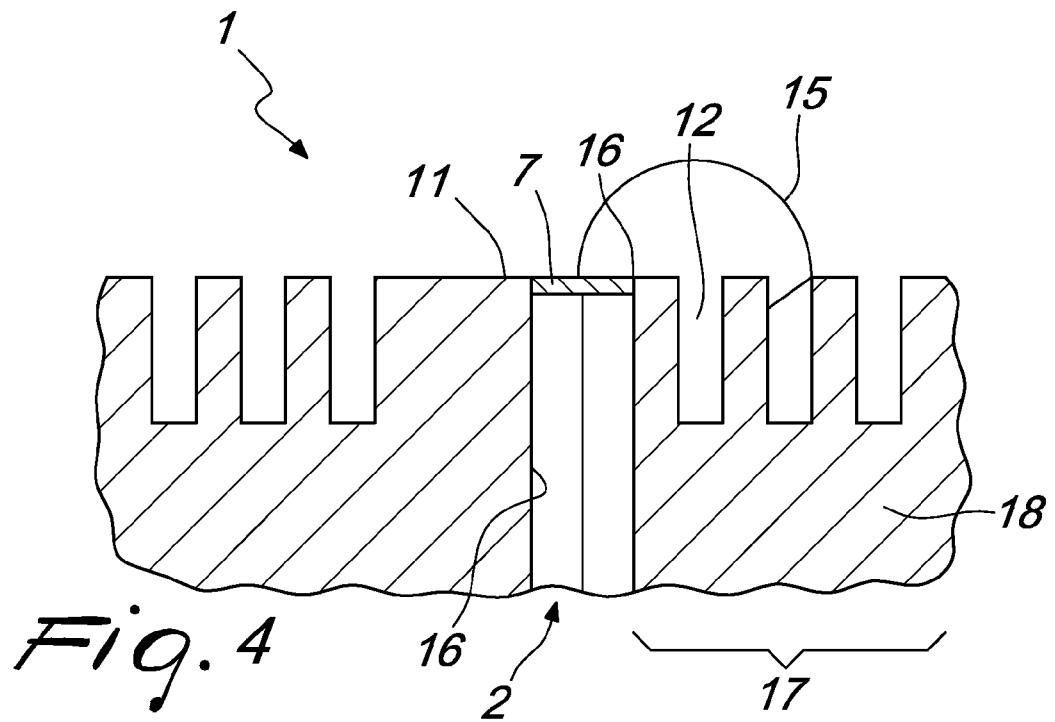
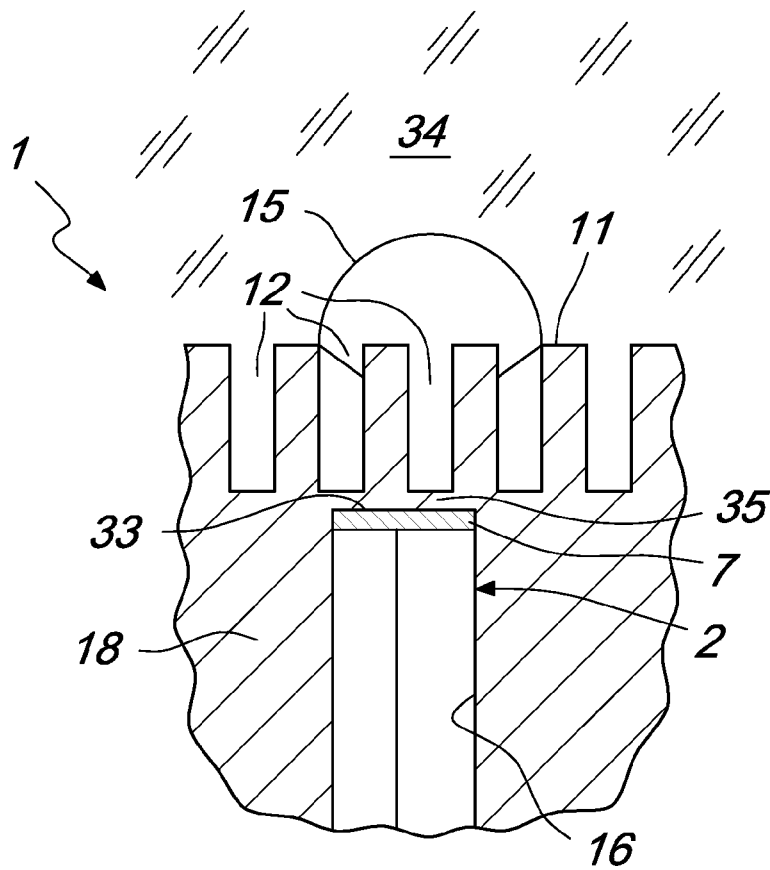
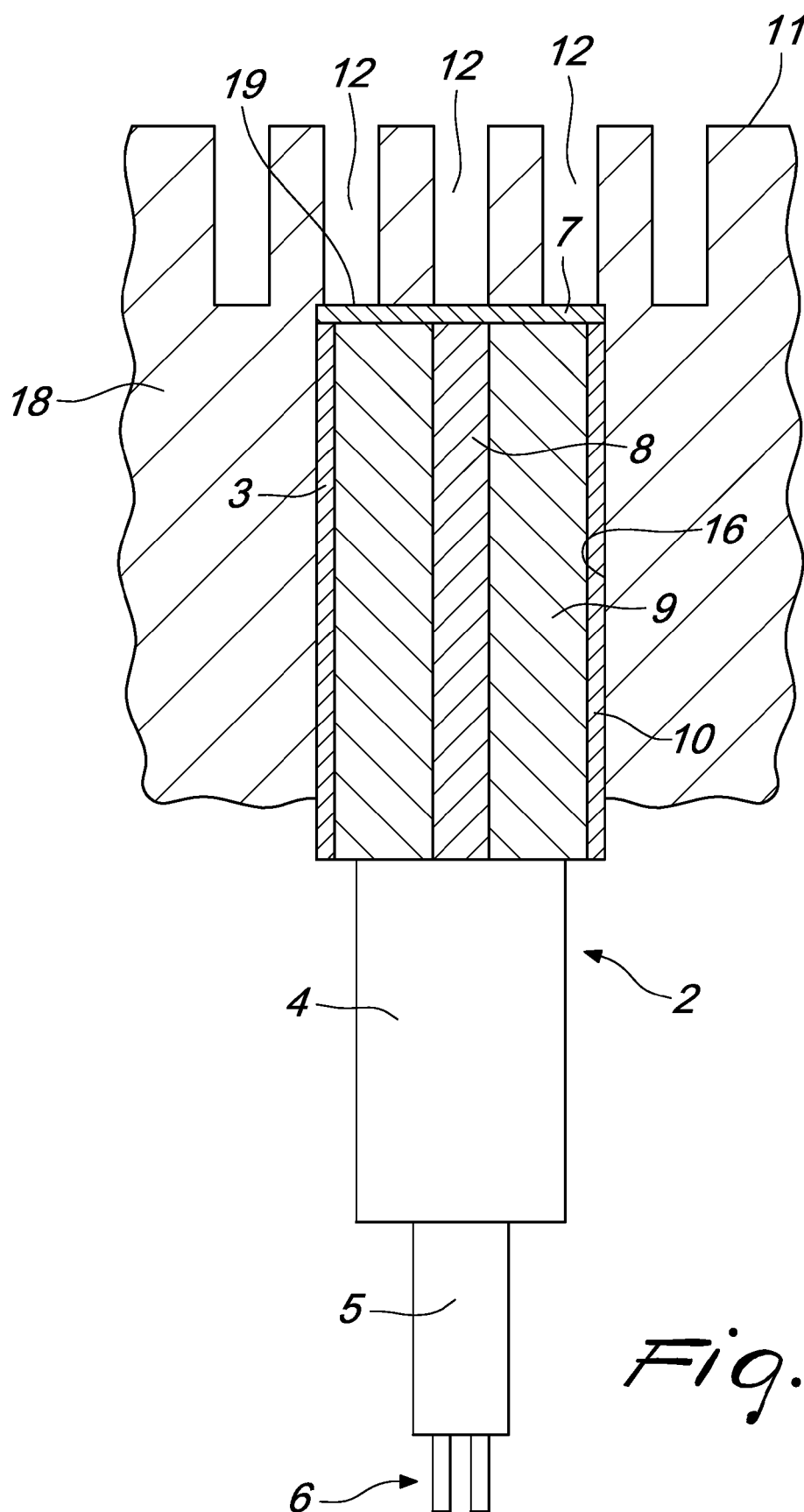


Fig. 2







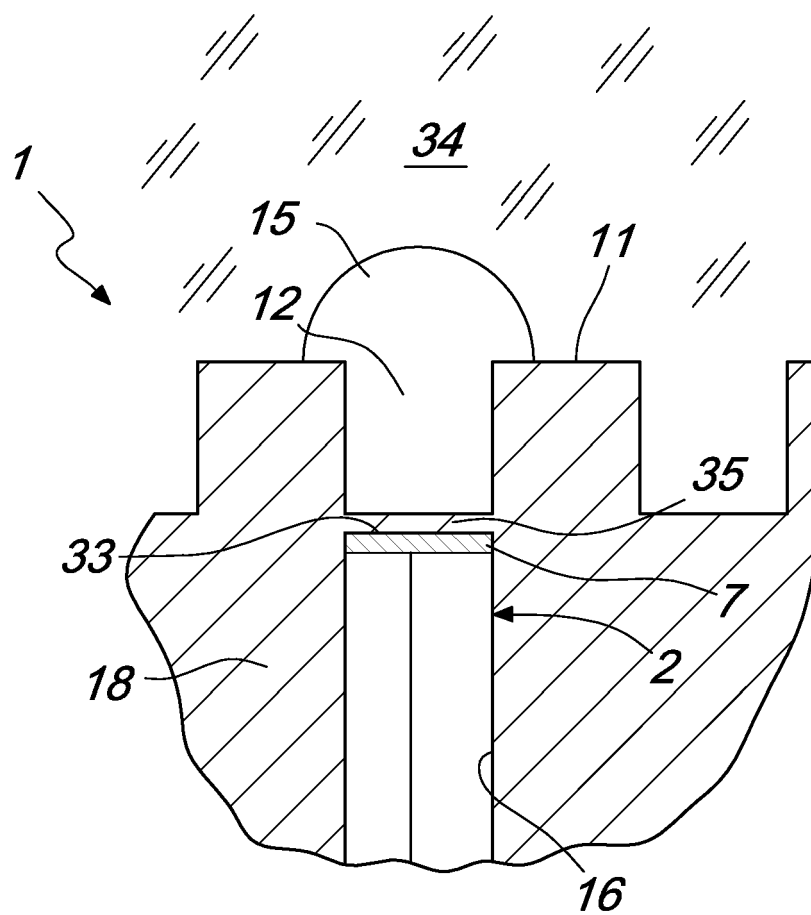


Fig. 6

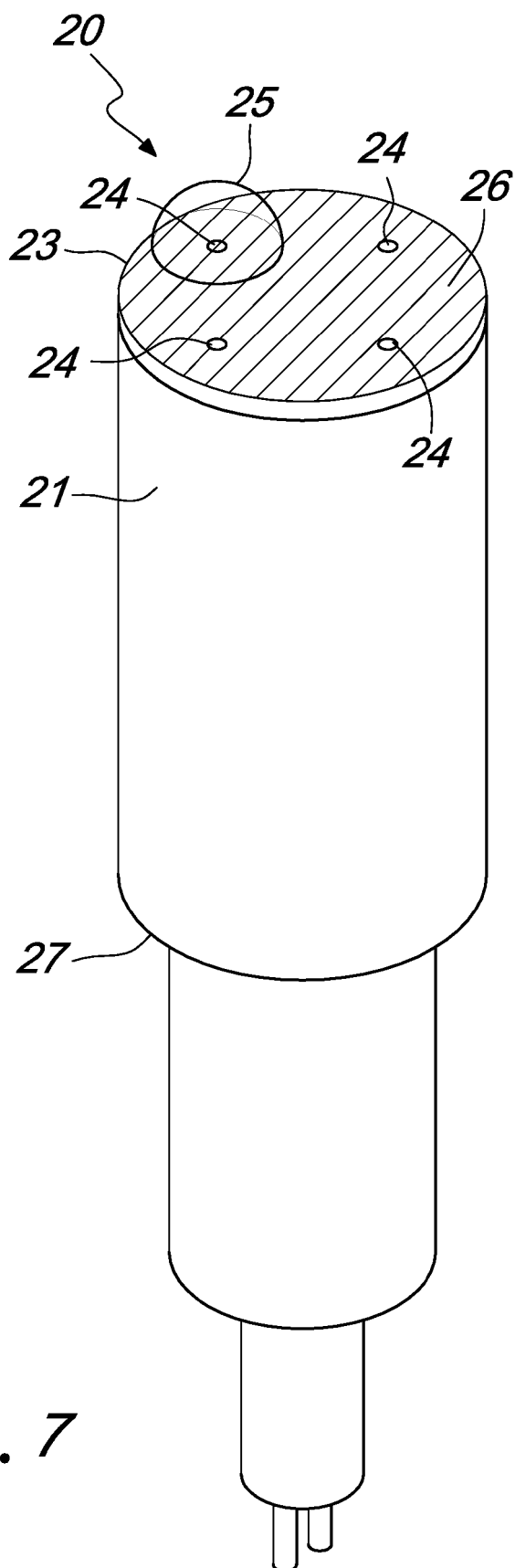


Fig. 7

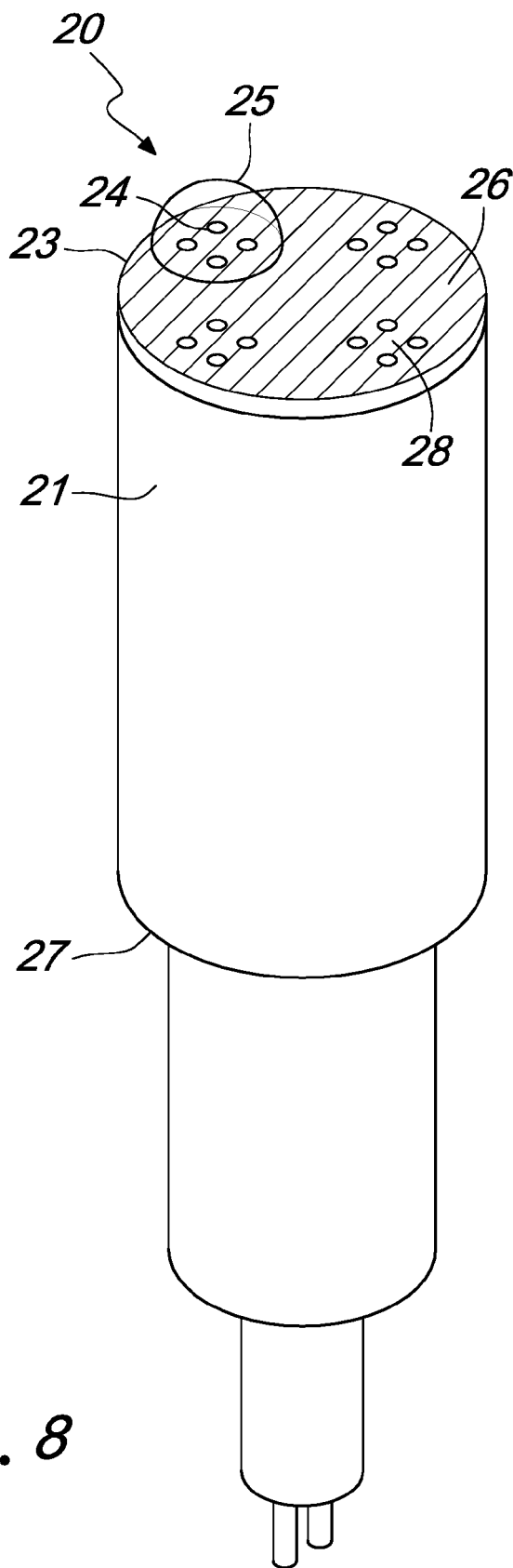


Fig. 8

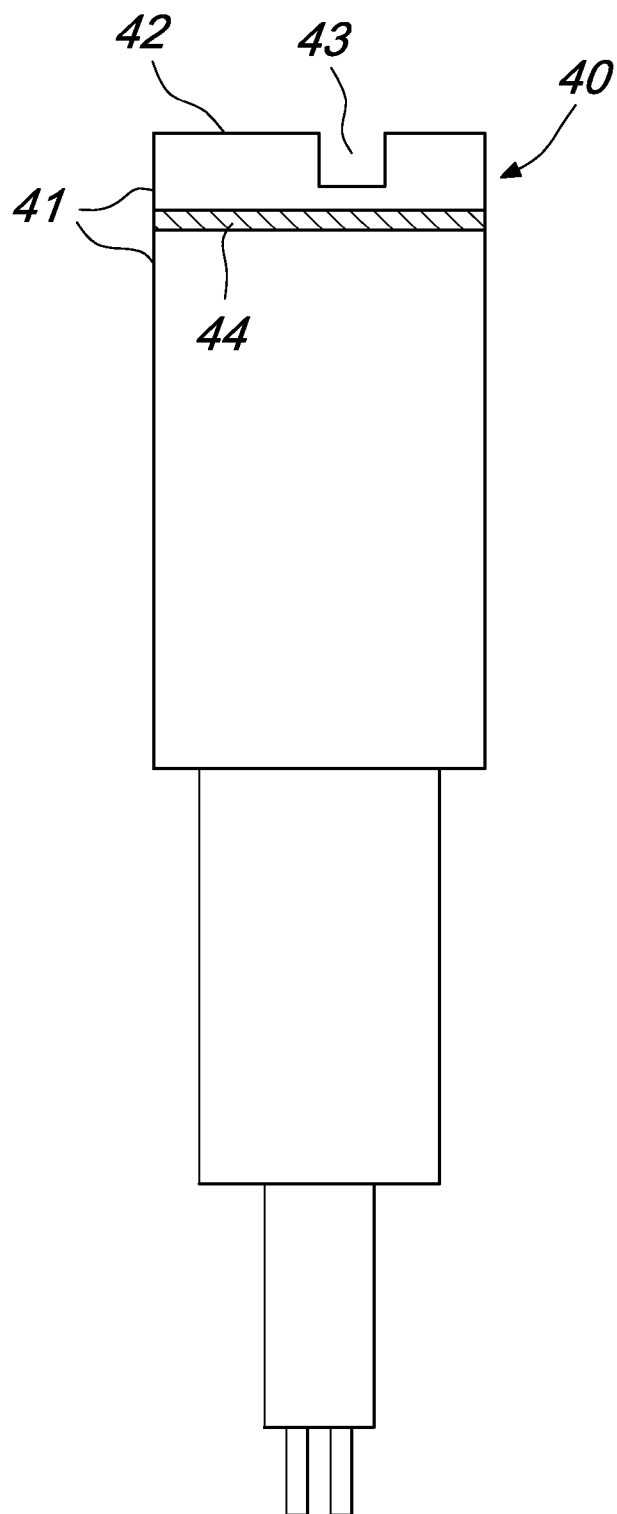


Fig. 9



EUROPEAN SEARCH REPORT

Application Number
EP 08 16 6816

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 02 115755 A (TOKYO SHIBAURA ELECTRIC CO) 27 April 1990 (1990-04-27) * abstract * * figures *	1,11	INV. F01P11/16
A	WO 03/038251 A1 (BOSCH GMBH ROBERT [DE]; SCHMITT MANFRED [DE]; GERUNDT OLIVER [DE]; WIN) 8 May 2003 (2003-05-08) * page 16, paragraph 2 * * figure 4 *	1,11	
A	US 2002/049015 A1 (SUZUKI AKITAKA [JP] ET AL) 25 April 2002 (2002-04-25) * paragraph [0063] * * figure 7 *	1,11	
A	DE 41 13 294 C1 (FA CARL FREUDENBERG) 17 June 1992 (1992-06-17) * abstract * * figure 2 *	1,11	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01P
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 10 August 2009	Examiner Matray, J
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			

2
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 16 6816

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.

10-08-2009

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 2115755	A	27-04-1990	NONE	

WO 03038251	A1	08-05-2003	DE 10153486 A1	08-05-2003
			EP 1440228 A1	28-07-2004
			JP 2005507047 T	10-03-2005

US 2002049015	A1	25-04-2002	JP 3942691 B2	11-07-2007
			JP 11005596 A	12-01-1999

DE 4113294	C1	17-06-1992	EP 0510302 A2	28-10-1992
			JP 5133251 A	28-05-1993
			JP 7072506 B	02-08-1995
			US 5201840 A	13-04-1993
