



(51) International Patent Classification:

G01K 1/14 (2006.01) G01K 7/02 (2006.01)

(21) International Application Number:

PCT/GB2019/051789

(22) International Filing Date:

25 June 2019 (25.06.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1810832.4 02 July 2018 (02.07.2018) GB

(71) Applicant: BAE SYSTEMS PLC [GB/GB]; 6 Carlton Gardens, London SW1Y 5AD (GB).

(72) Inventors: SCHOLES, Derek; BAE Systems Maritime Submarines, Barrow-in-Furness Lancashire LA14 1AF (GB). FAULDER, Benjamin; BAE Systems Maritime Sub-

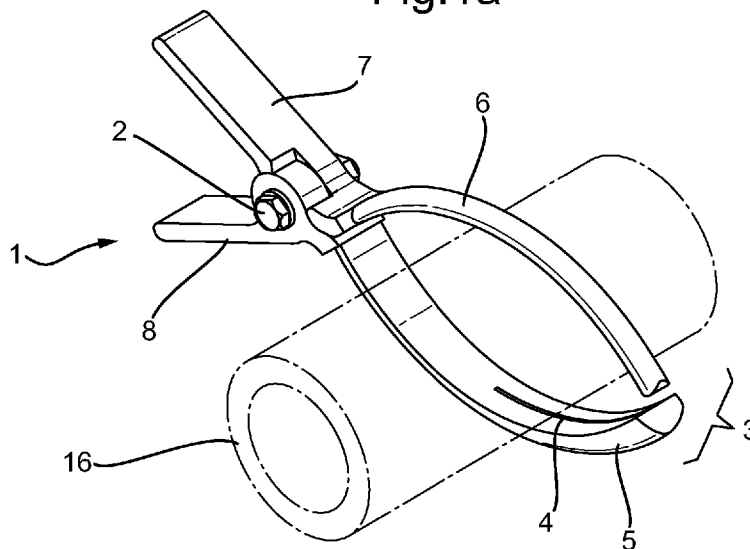
marines, Barrow-in-Furness Lancashire LA14 1AF (GB). HAMBLING, Stuart; BAE Systems Maritime Submarines, Barrow-in-Furness Lancashire LA14 1AF (GB).

(74) Agent: BAE SYSTEMS PLC, GROUP IP DEPT; Farnborough Aerospace Centre, Farnborough Hampshire GU14 6YU (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) Title: THERMOCOUPLE CLAMP

Fig.1a



(57) Abstract: The present invention relates to a thermocouple clamp, suitable for clamping a thermocouple in direct contact with a body to be thermally monitored. There is disclosed a thermocouple clamp suitable for clamping to a body to be thermally monitored, comprising two clamping surfaces, wherein the two clamping surfaces are selected from a material which is thermally matched to the body to be thermally monitored, a retaining means operating on said two clamping surfaces to fixedly clamp onto said body to be thermally monitored, wherein at least one of the two clamping surfaces comprises a recess which comprises a thermocouple located therein, wherein the recess has a cross section which is re-entrant such that said recess retains the thermocouple and causes the thermocouple to be at least flush with at least one clamping surface, as well as the surface of the body to be thermally monitored such that during use, the thermocouple is held in thermal contact with said body to be thermally monitored.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

- 1 -

THERMOCOUPLE CLAMP

The present invention relates to a thermocouple clamp, suitable for clamping a thermocouple to a body to be thermally monitored.

5 Thermocouples are routinely used to measure the temperature or heat flow through a body to be thermally monitored. They are cheap and effective; however they need to be retained in thermal contact with the body to be monitored.

According to a first aspect of the invention there is provided a
10 thermocouple clamp suitable for clamping to a body to be thermally monitored, comprising two clamping surfaces, wherein the two clamping surfaces are selected from a material which is thermally matched to the body to be thermally monitored, a retaining means operating on said two clamping surfaces to fixedly
15 clamp onto said body to be thermally monitored, wherein at least one of the two clamping surfaces comprises a recess which comprises a thermocouple located therein, wherein the recess has a cross section which is re-entrant such that said recess retains the thermocouple and causes the thermocouple to be at least flush with at least one clamping surface, as well as the surface of the body to be thermally monitored such that during use, the thermocouple is held in
20 thermal contact with said body to be thermally monitored.

In a further arrangement, both of the at least two clamping surfaces comprise the thermocouple. The thermocouples may be independently selected, and may operate over the same or different temperatures ranges.

25 The thermocouple clamp may be made from any suitable material, such as for example, metal, polymer, or ceramic.

The body to be thermally monitored may be any item that is to be heated or cooled and monitored, preferably a pipe, tube or rod. In a highly preferred
30 arrangement the material of the body to be thermally monitored may be metal or metal alloy.

- 2 -

Metal pipes that are to be heated, such as those that are to be / have been welded together, may be heated by any means, such as electrical, gas flame, induction etc. The approximate temperature of the metal pipe may be determined by colour comparison with the naked eye, (on heating) through the black, red, cherry, yellow, white, or more accurately, by using pyrometers, infrared cameras and/or thermocouples. The use of gas flames provides very facile yet efficient method for industrial scale heating of body to be thermally monitored. However, the gas flame typically causes an oxide layer to form on the surface of said body during heating. The formation of the said surface oxide layer has been found to cause erroneous temperature results with infrared detectors whilst crudely heating with a gas flame [rather than a controlled furnace environment]. The use of pyrometers, IR cameras, may therefore not be suitable for providing reliable and/or accurate temperatures on a metal body to be heated, by a gas flame.

Thermocouples may typically be connected directly to a metal body to be monitored and are largely unaffected by the build-up of an oxide layer with respect to its thermal monitoring capacity. The use of gas flames to heat metal pipes have shown that an unprotected thermocouple tip is exposed to significant thermal energy and provides misleading, unreliable thermal monitoring that may not represent the temperature of the pipe by a significant margin.

The thermocouple must have direct thermal contact with the body to be monitored in order to accurately represent the temperature (or change in temperature) of the body with a minimal time lag to equilibrate its temperature.

The recess has a cross section which is re-entrant such that said recess retains the thermocouple and permits part of the thermocouple to be at least flush with the surface of said clamping surface. Where the thermocouple is at least flush it ensures that as the clamping surface comprising the thermocouple is clamped and therefore held onto the body to be thermally monitored, it forces direct thermal / mechanical contact between the thermocouple and the body to

- 3 -

be monitored. The recess may be fashioned such that the thermocouple protrudes from the surface of the clamping surface.

The two clamping surfaces may be selected from any material, preferably
5 the clamping surface material may be thermally matched to the material of said
body to be thermally monitored, more preferably the clamping surface material
is substantially the same material as the body to be thermally monitored,
wherein the thermally matched material may not comprise a metal with melting
temperature below 400°C. Care should be taken with the selection of metal with
10 respect to the metals melting point and the temperature range over which the
said body is to be thermally monitored. The avoidance of the use of a metal
with a low melting point with respect to the thermal monitoring range is
desirable as the metal may readily reach its liquid phase and flow onto/into the
body subject to thermal monitoring, wherein the liquid metal [from the melted
15 clamp material] may act as a contaminate, which may affect the physical and
chemical properties of the body to be thermally monitored. That is to say that
the material used to manufacture the thermocouple clamps shall be selected
such that there is no adverse effect to the body to be thermally monitored.

20 In a highly preferred arrangement for the thermal monitoring of the annealing
temperature for 90/10 CuNi pipework the thermally matched material may be
and additive layer manufacture (ALM) binder-jet-sintered composite metal using
a 300 or 400 series stainless steel primary alloy structure infiltrated (by
approximately 30%) with either 90/10 CuNi alloy or pure copper. The ALM
25 deposition process provides a “green” product, which is a deposited metal in a
polymer lattice. The polymer is removed and may be sintered, or displaced / in-
filled with the melt of other materials.

The thermal matching of the clamping surface with the body to be thermally
30 monitored, may be further improved wherein the clamping surface which
comprises the thermocouple may have a thickness in the range of 20% of the
thickness of the body to be thermally monitored. The cross-section of the

- 4 -

clamping surface may be any shape, with a thickness which is in the range of 20% of the thickness of the body to be thermally monitored, more preferably 10% of the thickness more preferably substantially equal. Preferably the clamping surface is semi-circular in cross section, with a radius which is in the
5 range of 20% of the thickness of the body to be thermally monitored, more preferably 10% of the thickness more preferably substantially equal.

The thermal matching of the clamping surface, which comprises the thermocouple, with the body to be thermally monitored, allows the body to be
10 thermally monitored and the clamping surface to be heated or cooled at the same rate, and thereby allow the thermocouple to be heated or cooled at the same rate.

The at least one clamping surface that comprises the thermocouple may be
15 thermally matched to the body to be thermally monitored.

The clamping surface's cross section does not require contact across its width with the entire body to be thermally monitored. Preferably, the semi-circular cross section has a diameter or chord which extends away from the body to be thermally monitored, preferably the diameter or chord that extends
20 away is curved, such that substantially only the thermocouple and the re-entrant part of the clamping surface are in thermal contact with the body to be thermally monitored.

It has been found that without any thermal mass [protection] surrounding
25 the thermocouple tip to balance the heat gradient during direct flame impingement heating, the relatively small volume of the thermocouple tip can get white hot within a relatively short time period (if directly exposed to a gas flame) whilst insufficient time for heating of the body may have occurred. This is especially significant where bodies are large diameter pipes with pipe wall
30 thickness of several millimetres.

- 5 -

In one arrangement the recess may be a blind cavity such that the thermocouple may not extend beyond the end of one of the two clamping surfaces. Preferably the blind cavity ensures that the end portion (sensing portion) of the thermocouple does not extend beyond the point of contact with
5 the body to be thermally monitored.

It may be convenient to remove the thermocouple from the clamping surface, when the clamp is still clamped in place on the body to be thermally monitored, such as if the thermocouple fails, or a new temperature range has
10 been reached. In one arrangement the clamping surface may comprise a through-hole, such that the thermocouple is fed through said through-hole and into the recess. Further the use of the blind cavity ensures that if the thermocouple is replaced, in situ, the replacement thermocouple cannot be introduced beyond the blind cavity. It ensures that the replacement
15 thermocouple is located in the same place in the recess as the original thermocouple to ensure reproducibility of temperature measurements/results.

In the prior art fixing methods, thermocouples may be taped, fixed by conductive adhesive, welded or wound onto a body to be thermally monitored. The disadvantage of the use of spot welding to the body to be thermally
20 monitored is that the weld material may be a source of contamination but generally problematic to fully remove said weld material from the body to be thermally monitored.

The use of the thermocouple clamp allows removal of the clamp, or
25 where a through hole is used the thermocouple may be removed and replaced without removing the clamp.

The thermocouple clamp, may be reversibly engaged with the body to be thermally monitored, to allow facile removal or relocation of the clamp. The two clamping surfaces may preferably be held in a closed position by the retaining
30 means, said retaining means may be a resilient bias, screw thread, over-centre locking action mechanism. The resilient bias may in the form of a spring which may be arranged to force the two clamping surfaces together. The screw thread

- 6 -

may be a G-clamp or vice type arrangement. The over-centre locking mechanism may be that of locking pliers, i.e. mole grips.

In a preferred arrangement said two clamping surfaces comprise a first
5 clamp surface and a second clamp surface, which are pivotally connected, by a
pivot, and are biased to a closed clamped position by the resilient bias, such
that they form a sprung plier, sprung peg or sprung scissor-like arrangement.
Preferably the clamp is in the form of a peg, scissor, plier configuration, such
that each of said first and second clamp surfaces comprises an elongate portion
10 extending away from said clamping surface to provide an operating handle,
such that said pivot is located between the handle and said clamping surface.

The resilient bias in this pivoted arrangement may be a torsion spring,
such that the torsion spring forces the first and second clamping surfaces
15 together. The resilient bias may be overcome by squeezing the handles towards
each other, to move the at least two clamping surfaces apart, and allowing
release of the at least two clamping surfaces away from the body to be
thermally monitored.

20 The body to be thermally monitored may have a surface which is flat,
curved, or tubular. The at least one of the first and second clamping surfaces
may have an arcuate portion, or may be arcuate along the entire clamping
surface. The arcuate portion or arcuate clamping surface provides a facile
means of clamping to tubes or rods. Where the thermocouple clamp comprises
25 only one arcuate clamping surface, preferably it is the arcuate portion that
comprises the thermocouple.

The at least two clamping surfaces may comprise a texture to provide
further grip. The texture may be protrusions, grooves, ie a gripping jaw.

30

So that the invention may be well understood, embodiments thereof shall now
be described with reference to the following figures, of which:

- 7 -

Figures 1a, 1b and 1c, show a thermocouple clamp

Figures 2a and 2b show a thermocouple in the clamp of fig 1

Figure 3 shows a tube held in a thermocouple clamp.

5

Turning to figures 1a, 1b, and 1c, there is provided a thermocouple clamp 1, with two clamping surfaces 3, which can clamp onto a body to be thermally monitored 16. The two clamping surfaces 3, are formed from a first clamping surface 6, and second clamping surface 5, which comprises a recess 4, which can accept a thermocouple (not shown). The at least two clamping surfaces 3, are pivotally mounted on a pivot 2, and extending beyond the pivot are handles 7, 8, which when squeezed together open up the at least two clamping surfaces 3. The at least two clamping surfaces 3 are biased to the closed position by a resilient bias means (not shown), to clamp on a body to be thermally monitored 16.

In figure 1b, the second clamping surface 5, shows the recess 4, and a through-hole 9, which extends through the entire clamping surface 5, to allow the thermocouple to be threaded therethrough. The recess 4, terminates in a blind cavity 13, such that the thermocouple may not extend beyond the end of the second clamping surface 5. To ensure that the tip of the thermocouple is in direct thermal contact with the body to be thermally monitored, preferably the tip is located in the region 14, where the arcuate 15 portion of the clamping surface 5, will engage with the body to be thermally monitored.

In figure 1c, the cross-section A—A shows the re-entrant shaped recess 11, where the walls extend inwardly and retain the thermocouple 10 therein. The re-entrant recess 11, is such that the thermocouple 10 is caused to be at least flush with the surface 12, such that it will be in thermal contact with the body to be thermally monitored.

- 8 -

Turning to figure 2a and 2b, there is shown a thermocouple clamp 21, with the thermocouple 20 being fed through a through hole which starts from the handle portion rather than the top of one of the two clamping surfaces 23. The two clamping surfaces 23, are pivoted about a sprung screw thread pivot 22.

5 The spring tension located therein (not shown) causes the two clamping surfaces 23 together. Figure 2b, provides a close up to show the thermocouple in the re-entrant cavity 24.

Turning to fig 3, there is provided a thermocouple clamp arrangement 31,

10 with a body to be thermally monitored 34 in the form of a pipe 36, with a wall thickness t_1 . The pipe 36 has a thermocouple clamp (Fig 1) 1, located thereon, with first clamping surface 35a and second clamping surface 35b. The clamping surface 35a comprises a thermocouple 30, located in the re-entrant cavity, such that the thermocouple 30 is in direct thermal contact with the pipe 36. The

15 second clamping surface may also have a further thermocouple, or empty recess cavity, or may be a blank with no cavity, just surface clamping material. For clarity the first and second clamping surfaces 35a, 35b, are only schematically shown (not to scale) in cross-section A---A. A gas flame 37, is used to heat up the pipe 36, typically around the entire circumference of the

20 pipe 36. To ensure that the thermocouple is raised in temperature in a uniform manner with the pipe 36, the radius R_1 of the first clamping surface is preferably within the range of from +/- 20% of the thickness t_1 of the body being thermally monitored [i.e. the pipe wall thickness in this example].

CLAIMS

1. A thermocouple clamp suitable for clamping to a body to be thermally monitored, comprising two clamping surfaces, wherein the two clamping surfaces are selected from a material which is thermally matched to the body to be thermally monitored, a retaining means operating on said two clamping surfaces to fixedly clamp onto said body to be thermally monitored, wherein at least one of the two clamping surfaces comprises a recess which comprises a thermocouple located therein, wherein the recess has a cross section which is re-entrant such that said recess retains the thermocouple and causes the thermocouple to be at least flush with at least one clamping surface, as well as the surface of the body to be thermally monitored, such that during use, the thermocouple is held in thermal contact with said body to be thermally monitored.
2. A thermocouple clamp according to claim 1, wherein the body to be thermally monitored is a pipe, tube or rod.
3. A thermocouple clamp according to claim 1 or claim 2, wherein the material which is thermally matched to said body to be thermally monitored is substantially the same material as the body to be thermally monitored, wherein the thermally matched material may not comprise a metal with melting temperature below 400°C.
4. A thermocouple clamp according to claim 3, wherein the thermally matched material is an ALM binder jet sintered stainless steel alloy, with an infill of copper or alloy thereof
5. A thermocouple clamp according to any one of the preceding claims, wherein the clamping surface is semi-circular in cross section, with a radius which is in the range of 20% of the thickness of the body to be thermally monitored.
6. A thermocouple clamp according to claim 5, wherein the semi-circular cross section has a diameter which extends away from the body to be thermally monitored.
7. A thermocouple clamp according to claim 6, wherein the diameter that extends away is curved.

- 10 -

- 5
8. A thermocouple clamp according to any one of the preceding claims wherein the retaining means is a resilient bias, screw thread, or over-centre locking action.
- 10
9. A thermocouple clamp according to any one of the preceding claims, wherein said two clamping surfaces comprise a first clamp surface and a second clamp surface, which are pivotally connected, by a pivot, and are biased to a closed clamped position by the resilient bias.
- 15
10. A thermocouple clamp according to any one of claim 9, wherein each of said first and second clamp surfaces comprises an elongate portion extending away from said clamping surface to provide an operating handle, such that said pivot is located between the handle and said clamping surface.
- 20
11. A thermocouple clamp according to any one of the preceding claims, wherein the clamping surface which comprises the recess comprises a through-hole, such that the thermocouple is fed through said through-hole and into the recess.
- 25
12. A thermocouple clamp according to any one of the preceding claims wherein the at least two clamping surfaces are arcuate.
- 30
13. A method of monitoring the temperature of a metal body to be heated by a gas flame, comprising the steps of locating one or more thermocouple clamps, according to any one of the proceeding claims, around said metal body, applying the gas flame, and measuring the temperature of the metal body with said thermocouple.

1/3

Fig.1a

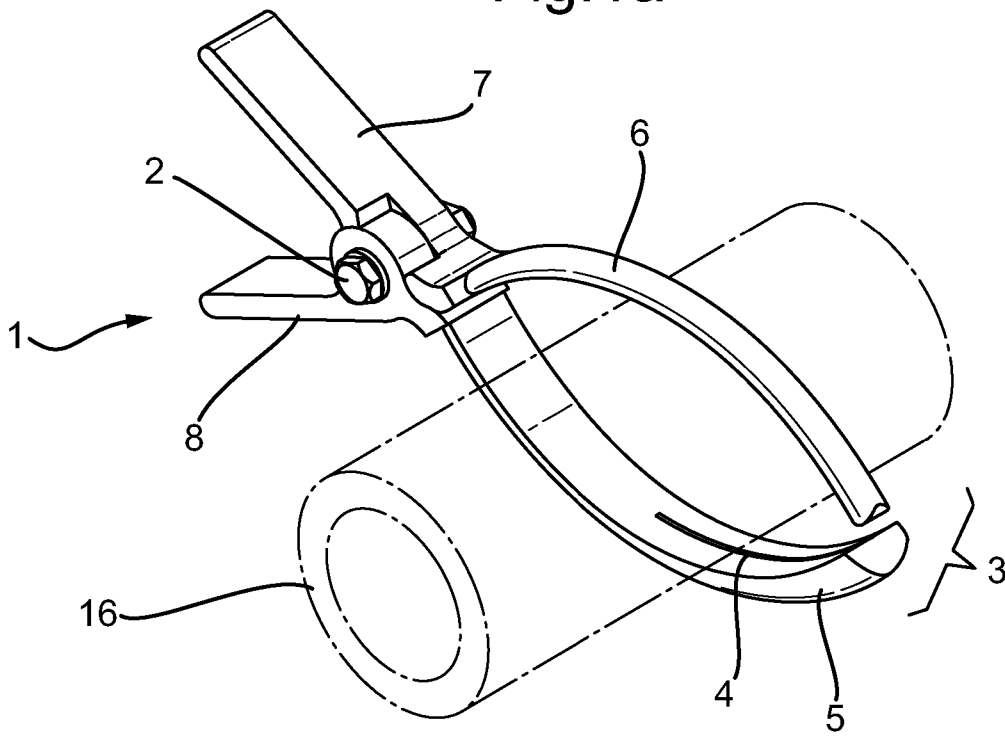


Fig.1b

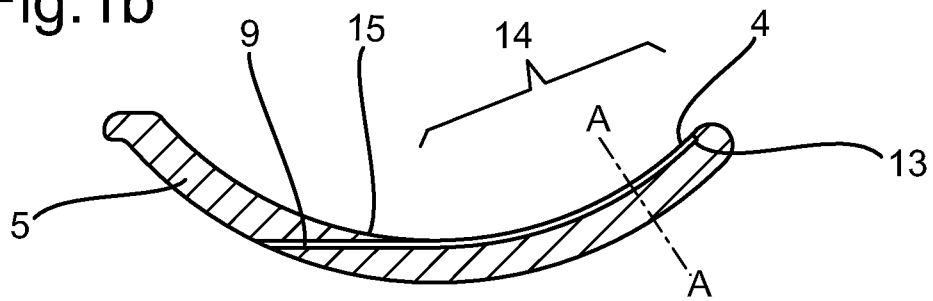
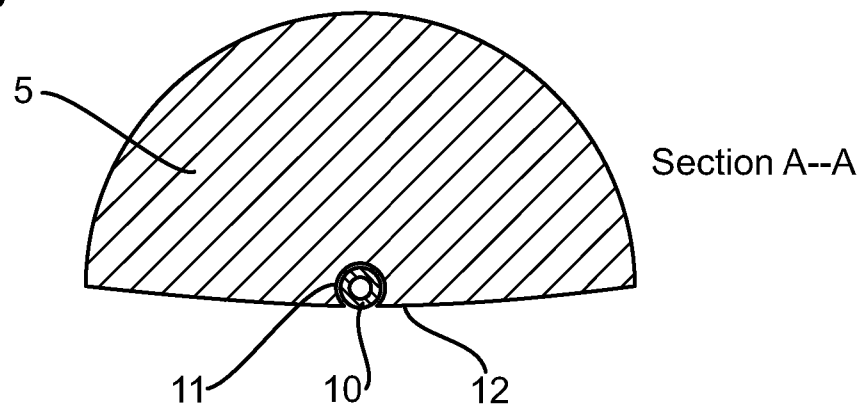


Fig.1c



2/3

Fig. 2a

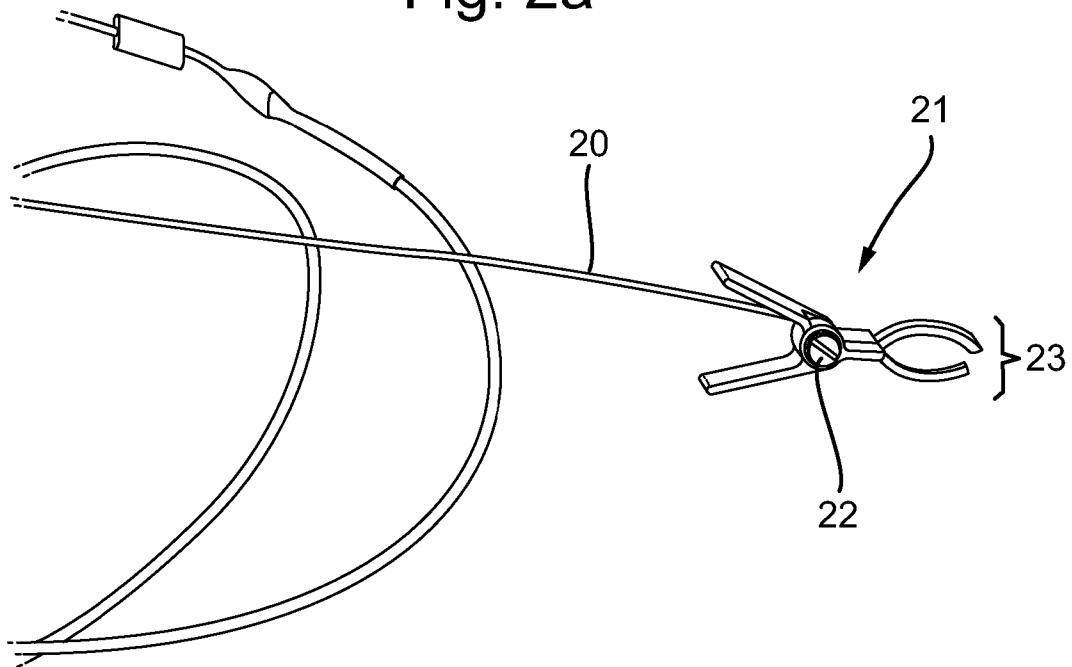
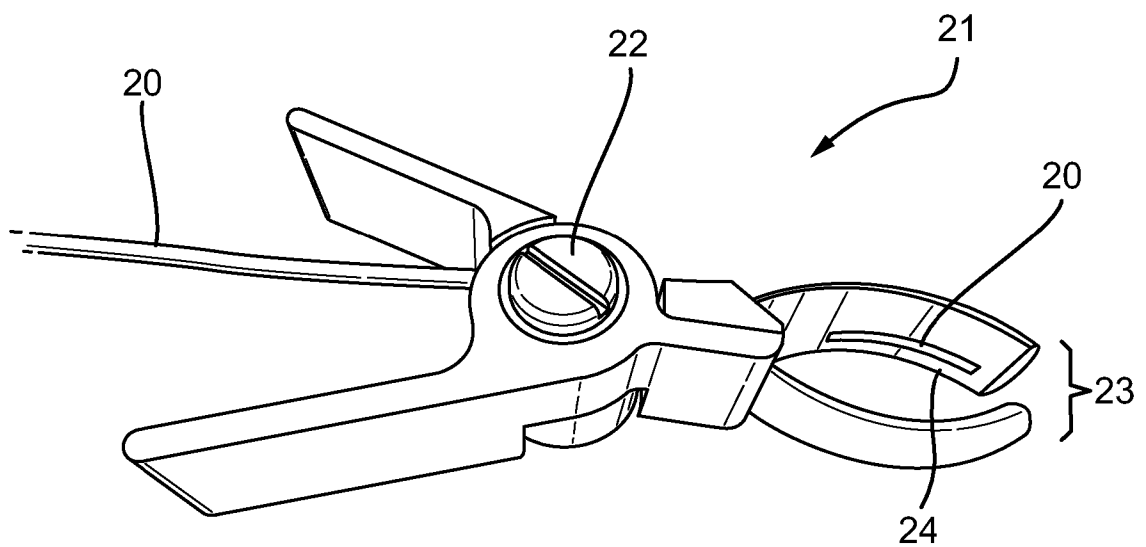
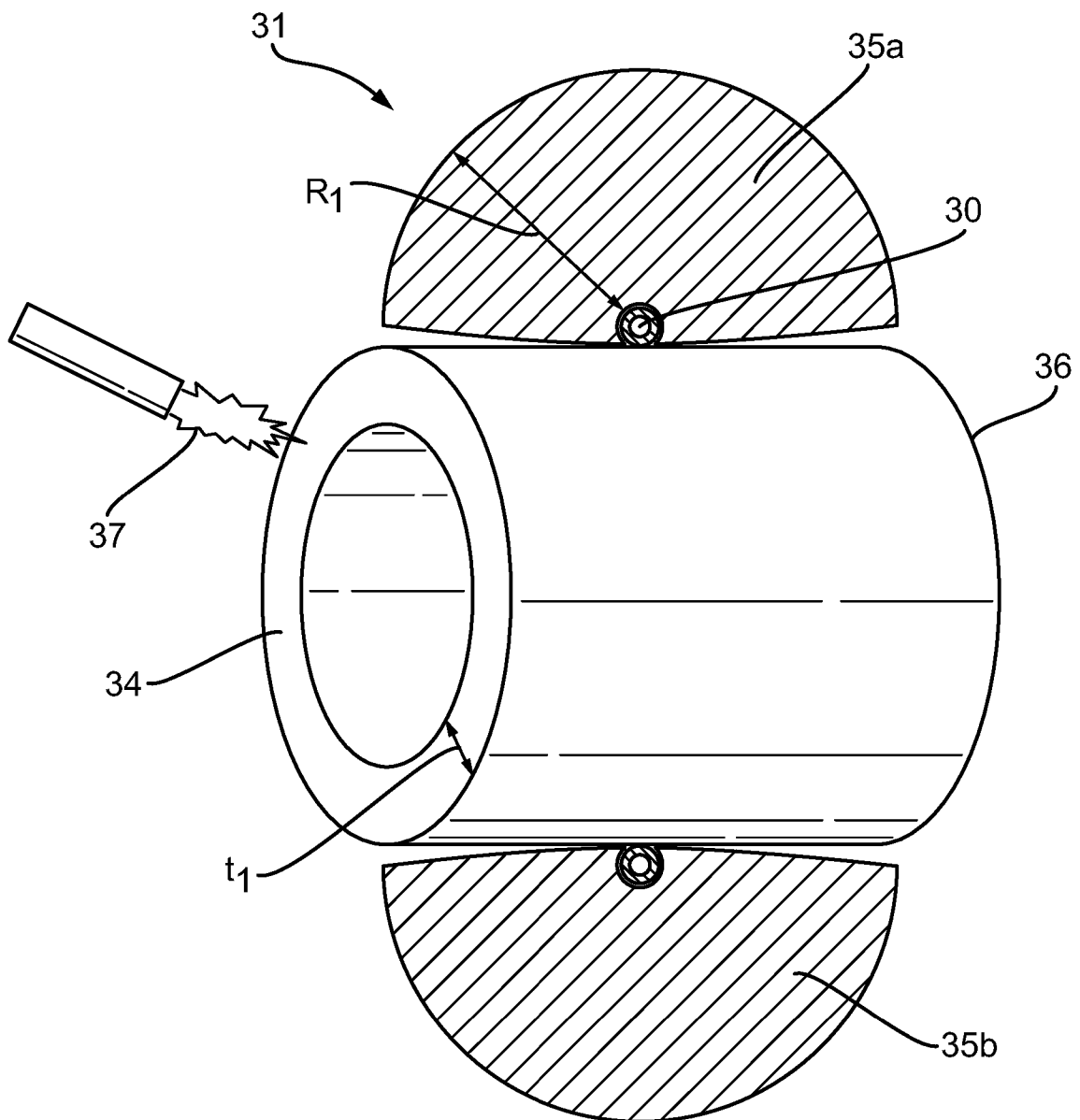


Fig. 2b



3/3

Fig. 3



INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2019/051789

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01K1/14 G01K7/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 201 955 164 U (TCL AIR CONDITIONER ZHONGSHAN) 31 August 2011 (2011-08-31) figures	1-12
X	US 2017/268934 A1 (HARJU REY [US] ET AL) 21 September 2017 (2017-09-21) abstract; figures 3-7 paragraphs [0025] - [0029]	1-4, 8-10, 12 13
X	US 5 620 255 A (COOK III WALTER R [US]) 15 April 1997 (1997-04-15) abstract; figures 4,5 column 4, lines 20-39	13
A		1
A	JP H06 137955 A (FURUKAWA ELECTRIC CO LTD) 20 May 1994 (1994-05-20) abstract; figures 1,2	1,13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 September 2019

Date of mailing of the international search report

26/09/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

de Bakker, Michiel

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2019/051789

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
CN 201955164	U	31-08-2011	NONE	
US 2017268934	A1	21-09-2017	NONE	
US 5620255	A	15-04-1997	US 5441344 A US 5620255 A	15-08-1995 15-04-1997
JP H06137955	A	20-05-1994	NONE	