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(71) Applicant *(for all designated States except US):* SPARX AB [SE/SE]; Kryptongatan 20, S-431 33 Mölndal (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : LARSSON, Ralf [SE/SE]; Gundas Gata 176, S-431 51 Mölndal (SE). BENGTSSON, Bengt-Göran [SE/SE]; Rapsvägen 43, S-460 65 Brålanda (SE).

(74) Agents: ROTH, Michel et al.; Göteborgs Patentbyrå AB, Box 5005, S-402 21 Göteborg (SE).

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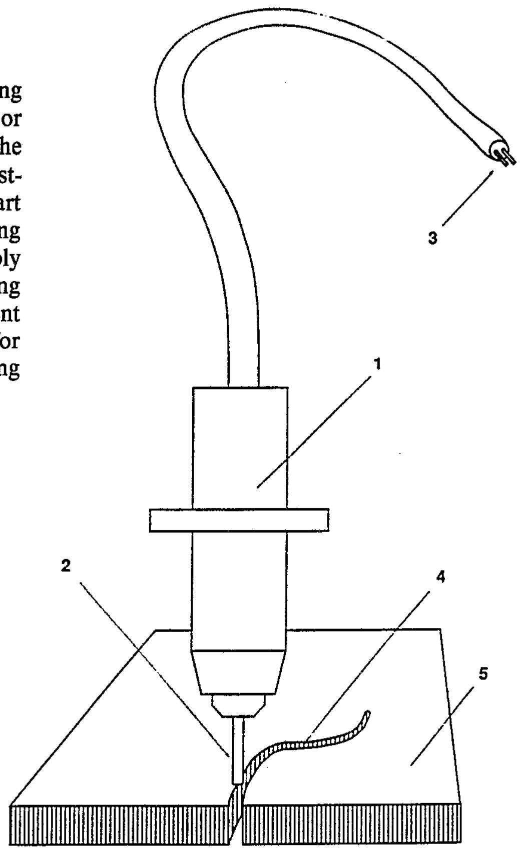
(54) Title: DEVICE FOR CUTTING MATERIAL

**(57) Abstract**

Device for cutting of materials by means of at least one cutting means, which partly is provided to be controlled by preferably a plotter or the like, partly to be heated to a temperature, which is higher than the melting temperature of the material by electric induction and/or resistance heating, and partly comprises a cutting part (30) and a holder part (31) connected thereto. The cutting part (30) is constituted by a cutting electrode formed as a substantially cylindrical pin with considerably smaller cross sectional area than the holder part (31), so that the cutting part emits substantially the whole amount of heat generated by current supplied, and that the electrode (30) is connected into a control circuit for controlling the temperature of the electrode in dependence on its cutting speed.



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# DEVICE FOR CUTTING MATERIAL

The invention refers to a device which by means of a heat generating means, glow pen, electrode, heating pin or the like, is able to cut in organic materials, such as organic tissues and thermoplastic disc or web formed sections, preferably plastics with cell structure and that said means /plastic section are movable relatively each other.

## Background of the invention

At surgical operations on organic tissue various types of heating treatments are used to transform the surface of the wound and thereby reduce the blood flow. Types similar to "soldering irons" and glowing blades of knifes are used. these are often bulky and lumbering in their design. For finer operations more and more laser heat is used as a knife which demands a relatively expensive equipment.

When cutting signs, letters etc. in cellular plastics type "frigolit" is usually used a so called hot wire saw. This consists of a resistance wire, which is clamped between the shanks of a bow. The bow shall keep the wire streched enough. The both ends of the wire are connected to an electric current source. Because of the resistance of the wire, this is heated. By adjusting the current, a temperature is set which is above the melting point of the cellular plastics. By guiding the plastic disc against the hot wire various figures may be cut out.

This technique is very hard to automate, very much depending on certain figures being provided with internal holes, which requires that one of the connections of the wire has to be released and the wire has to be pushed through the material which is going to be cut out. After the cutting the wire has to be released once again, in order to loosen the detail.

It is also difficult to automatically cut e.g. in a thin web "on line" which depends on that a fixedly mounted heating wire requires that the material moves or the reverse. In that case it might be difficult to keep the material oriented in the "free air".

Through the Swedish patent no. 461 752 it is previously known to use an electrode in the form of a glow pen, as an automatic cutting means to a X/Y-table, e.g. a usual plotter. The invention shows different embodiments of this electrode, and methods to maintain the temperature constant during varying loads.

Through the British patent GB-2163092 and the European patent EP- 0116415 devices are also known to cut in plastic material by means of heated cutting devices. In both inventions the heating of the cutting tip is carried out by first heating a heat generating means by means of resistance heating, and then transfer the heat to the cutting tip.
The drawback of these methods is that a part of the heat is lost during the heat transmission, that is from the heat generating means to the cutting tip, and the possibility to control heating of the cutting tip in relation to the cutting velocity thereby is detoriated.

The object of the invention and most important features

The object of the invention is to provide the market with an "easy to move" glow pen with possibility to use very thin cutting electrodes ( down to some tenths of a millimeter), and depending on which patterns and forms are going to be cut out and the resolution, the cutting velocity and the heat generation hve to be adapted to each other, e.g. a straight line which is cut at a high velocity demands a higher temperature in order to get the material to melt faster, and a curve which requires more careful cutting, has to be cut slower and demands less heat. In forms which contain both straight lines and curved lines the heat has to be controlled rapidly and effectively and requires that the temperature of the cutting electrode can be controlled in relation to the cutting velocity.

The invention is based on the external pin being mainly directly heated and that the electrode is either contact free or single ended connected. This implies that the invention can be used e.g. in surgery, as an easily movable pen, which serves as a "scalpel handle".

Description of the drawings

Fig. 1 shows a device in perspective view with the glow pen in elevated position.
Fig. 2 shows a device in section with tube electrode.
Fig. 3 shows a section of the tube electrode according to Fig. 2.
Fig. 4 shows a device with a cable strain- relief and cooling means.
Fig. 5 shows a device in section with U- electrode.
Fig. 6 shows a section of a U-electrode according to Fig. 5, with an isolating surface layer.
Fig. 7 shows a section of a U-electrode according to Fig. 5 with an isolating layer in between.
Fig. 8 shows a device in section with an integrated temperature sensor.
Fig. 9 shows a device where the cutting electrode is heated contact free by way of an underlying field of force.
Fig. 10 shows a device where the cutting electrode is heated contact free by way of a overlying field of force.
Fig. 11 shows a device with a cutting electrode in section, with a plated surface layer and cable connections.
Fig. 12 shows a device with a cutting electrode in section, with tubular design and cable connections.
Fig. 13 shows a device with exchangeable cable and a plotter

pen holder.

Fig. 14 shows an electric wiring diagram for maintaining constant temperature.

Fig. 15 shows a diagram over the supply current and power of the cutting electrode as a function of the cutting velocity.

Fig. 16 shows a diagram of the resistance of the cutting electrode as a function of the supply current.

## Description of embodiments

In the drawings, which show embodiments of devices according to the invention the reference designations indicate:

| | |
|---|---|
| 1 | A plotter pen holder |
| 2 | A cutting electrode |
| 3 | A connection for current supply |
| 4 | A cut out groove |
| 5 | A segment of a material disc |
| 6 | An external tubular electrode |
| 7 | An internal electrode |
| 7a | A thinner portion of an U-electrode |
| 7b | A thicker portion of an U-electrode |
| 8 | A welded contact point |
| 9 | A heat resistent electrically insulating layer |
| 10 | A flexible electric cable |
| 11 | An electric conductor |
| 12 | A cable connection |
| 13 | An attachment flange for a plotter pen holder |
| 14 | A cooling flange |
| 15 | A cable strain-relief |
| 16 | A temperature sensor |
| 17 | A connection cable for the temperature sensor |
| 18 | A cross section of a high frequency magnetic coil |
| 19 | A field line of so called "Foucault currents" |
| 20 | A heat resistent plotter table |
| 21 | A galvanic contact point |
| 22 | A tube for increasing the electric interconnection |

diameter

23 A connection terminal

24 An adapter for universal fitting in different plotter pen holders.

25 A positive current feedback circuit

30 cutting part

31 retainer part

One way in which the invention can be used makes various principles for the design and the function of the device possible. By using a X/Y - table, e.g. a flatbed plotter and that the glow pen is designed as a plotter pen, a cutting of figures can be carried out according to given computer instructions in a suitable web material. The function pen down/up may control start and stop of the cutting cycle. A general view without plotter table is shown in Fig. 1, where the cutting electrode 2 is brought to a temperature which lies above the melting point of the web material, by means of a current being applied on the terminal 3. By bringing down the plotter pen holder and move it in X/Y -direction by way of a plotter interface from a computer, the cutting electrode 2 cuts a sectior ', in the web material 5. Since only the external part c the electrode is going to be heated, this is designed with a smaller cross section or in a material having a higher resistivity than the connecting part. Within the scope of the invention this can be designed in various ways which is shown in the figures: 2,3,5,6,7, 8,11, and 12. By forming thee external electrode 6 as a tube in Fig. 2, a thin cutting electrode is obtained with possibility of single ended connection 12 of the cable 10 by way of the cables 11. In order to prevent electrical short-circuiting between the external and the internal electrode an insulating layer is applied between these e.g. by oxidation of the surface of the internal electrode. The electric circuit is closed by joining the external 6 and the internal 7 electrodes, e.g. by TIG-welding. The electrodes 6 and 7 can be connected 12 to the conductors 11 either by direct joining e.g. spotwelding or by providing the electrodes with a cable connecting device e. g. a contact shrinking sleeve as in Fig. 11 and 12. In order to prevent heat from spreading from the cutting electrode 2 to the plotter pen holder 1 as in Fig. 4 one can provide the part most adjacent to the electrode with a cooling flange 14. It is also possible to make the plotter pen holder completely in metal to obtain cooling, but a heat proof/insulating material also would work, such as e.g. a ceramic. Since the elctrode the electrode is moving very much over the cutting surface the device according to the invention can be provided with a cable strain - relief 15 to increase the length of life of the cable 10.

In Fig. 5 a U-electrode is used, where the external cutting electrode 7a is delimited to the cooler connection wire 7b by a difference in the electrical resistance. This can be achieved by the wire 7a being of smaller cross sectional area. If a round wire is used to bend a U-electrode, its cross section will not be circular. Thus two different widths could be obtained of the groove 4 cut out, depending on the cutting direction. This can be compensated by continously controlling the position of the electrode and turn it in the cutting direction. Another way is to form the U-electrode 7a with halfed cross sectional area (section B-B). in order not to make electric contact between both shanks of the U, an isolating layer can be provided on the surface of the resistance wire as in Fig. 6 before the bending, e.g. by oxidation. In Fig. 7 the insulation problem has beeen solved by inserting/applying a foil or a layer between both shanks.

The cutting electrodes are formed as a substantially cylindrical pin, that is the said electrodes 2 have the same cross sectional area in the longitudinal direction, but this cross sectional area may vary at the point where the electrodes 2 are connected to each other.

The cutting electrode has a certain power (watts) at a given supply voltage (volts). This results in a temperature which depends on the external cooling, e.g. at different cutting speeds. Since the electric resistance is changed at different temperatures, within the scope of the invention we may obtain a constant cutter electrode temperature independently of external cooling.

With reference to Fig. 14 a control circuit is shown for maintaining the cutter electrode temperature constant in a glow pin according to the present invention.

The function of the control circuit is the following:
The basic principle is that the temperature dependence of the resistance of the cutting electrode is used, which in the present case is increased resistance at elevated temperature.
In the circuit deviations from nominal resistance is measured, whereby the power supplied is increased if the resistance drops and is reduced if the resistance is increased.
A resistance $R_1$ with a known (low) value is connected in series with the cutting electrode $R_2$. An operational amplifier Op1 is coupled as a differential amplifier with the series resistance $R_1$ and the cutting electrode $R_2$ on the noninverting input of Op1 and a potentiometer P1 with the resistance $R_3$ and a resistance on the inverting input of said amplifier.
The voltage U1 at the output of OP1 is, if we assume the current I through the series combination:

$$U1 = I\,R_2 - I\,R_1 \cdot R_4/R_3 = I(R_2 - R_1 \cdot R_4/R_3)$$

For U1 = 0 the following is valid

$$R_2/R_1 = R_4/R_3$$

If $R_2$ increases, U1 increases to a positive value.
The output from the operational amplifier Op1 via a resistance $R_5$ connected to the inverting input of an operational amplifier Op2, which is contained in a PI regulator the

output voltage of which takes a constantly increasing value as long as hte input is negative and a constantly increasing value for positive input voltages.
The potentiometer P1 is set for desired cutting electrode resistance.
If the cutting electrode is cooled, the resistance $R_2$ is reduced and the output voltage from Op1 will be negative. Thus Op2 will increase the value of its output voltage. The output of Op2 controls the current I to the cutting electrode via the transistor Tr1. The current to the cuting electrode and thereby the power will increase until the resistance $R_2$ has taken the correct value.
The resistance $R_6$ in parallel with the transistor Tr1 feeds a sufficient current I in order to make Op1 able to sense if the cutting electrode is intact or not. At interruption the output of Op1 takes the supply voltage + U which leads to a rapidly falling voltage on the output of Op2 and thereby brake through of the zener diode ZD. Thus the transistor Tr2 will be conducting and the alarm relay Re will be activated.
At increased cutting speed the power supplied has to be increased proportionally to the speed. In order to be able to melt more plastic per time unit it is required that the temperature of the cutting electrode is increased with the speed. Through a positive current feedback 25 in the control circuit via a non linear element (R7, D1) a control with a transition from curve 2 to curve 3, fig. 16 can be achieved.

The graph 1 illustrated in Fig. 16 shows the resistance of the cutting electrode as a function of the supply current at still air. The graph 2 in the same figure shows the resistance of the cutting electrode as a function of the supply current at controlled to constant resistans depending on the cutting speed. the graph 3 in the same figure shows optimal resistance depending on varied cutting velocity. The figur shows graph 4 which shows the change of the set value for the cutting electrode resistance as function of the current.

In Fig. 14 OP3, OP4, $D_1$ and $R_7$ the current feedback, whereby a low pass filtering (C, $R_9$) results in a more stable control. Op3 measures the current I and adds an offset. Op4 removes all negative voltages from the output of Op3. $D_1$ and $R_7$ change the gain in Op4 over a current $I_2$ and $D_2$ and $D_3$ remove all positive voltages from the output of Op4.

Fig. 15 shows a graph where the supply current I and the power **P** of the cutting electrode are shown as a function of the cutting speed *v* .

Another way to measure the temperature can be accomplished by inserting an external temperature sensor 16 beteween the shanks of the U, as in Fig. 8.

In Fig. 9 and 10 the cutting electrode is heated by means of an external field of force 19 ( so called "Foucault currents"). In Fig. 9 the induction coil 18, placed under the plotter table 20 and in Fig. 10 it is placed above, in connection to the cutting electrode 2. By applying a high frequency AC current to the coil 18, an alternating magnetic field 19 is created which induces a current contact free in the cutting electrode 2. The resistance of the pin metal causes heating of the same.

An alternative nethod to manufacture a tube electrode compared to that in Fig. 2, is shown in Fig. 11. Here the internal electrode 7, first oxidized with an insulating layer on all surfaces except for the ends, thereafter a metallic layer has been galvanically plated, vaporized or sprayed thereon. This layer then constitutes the external electrode with a predetermined electric resistance. When a voltage is applied on the terminals 12, the current passes through the external and the internal electrode via the galvanic connection point 21. Since the internal electrode core 7 is formed with different diameters automatically a larger conduction area is obtained on the thicker part, which results in that

only the thinner part will be heated.
Instead of manufacturing an internal electrode with different diameters as in Fig. 2, in fig. 12 has been shown that the same function can be obtained by using a resistance wire 7, with even cross sectional area, and to provide it with an exteral tube. Here a variant also is shown of a cable connection 12, in which the electric conductors 11 can be connected by a shrink sleeve. As a further alternative a so called flat pin connector can be used.

Since there are a large number of different plotters and models in the market, with as many holders (13) for plotter pens, as in Fig. 13 a universal electrode adapter 24, which fits in the holders 1 which are already available for plot ter pens. The same figure also shows a design where the cable 10 has been provided with a separable connector 23.

CLAIMS

1. Device for cutting of materials by means of at least one cutting means, which partly is provided to be controlled by preferably a plotter or the like, partly to be heated to a temperature, which is higher than the melting temperature of the material by electric induction and/or resistance heating, and partly comprises a cutting part (30) and a holder part (31) connected thereto,
c h a r a c t e r i z e d  t h e r e i n,
that ther cutting part (30) is constituted by a cutting electrode formed as a substantially cylindrical pin with considerably smaller cross sectional area than the holder part (31), so that the cutting part emits substantially the whole amount of heat generated by current supplied, and that the electrode (30) is connected into a control circuit for controlling the temperature of the electrode in dependance on its cutting speed.

2. Device according to claim 1,
c h a r a c t e r i z e d  t h e r e i n,
that the cutting electrode (2) is made, e.g. coated by a material, which has higher resistance than the resistance of the connection part.

3. Device according to claim 1,
c h a r a c t e r i z e d  t h e r e i n,
that the cutting part (30) consists of a cylindrical internal electrode (7), which is electrically insulated from a coaxially provided external electrode (6), by means of a heat resistant insulating layer (9) and
that the internal electrode (7) at one of the free ends by a connection (8) is electrically joined to a circuit with the external electrode (6).

4. Device according to claim 3,
c h a r a c t e r i z e d t h e r e i n,
that said heat resistent, insulating layer (9) consists of on either of the electrodes applied oxide layer and that the external electrode consists of a galvanically plated vapored or sprayed metallic layer, which has been electrically connected with the internal electrode (7) through a galvanic connection (21) at the outer end of the electrodes.

5. Device according to claim 1,
c h a r a c t e r i z e d t h e r e i n,
that the cutting part (30) is U-formed and consists of a wire (7a) with substantially semicircular cross section, which is bent in U-form so that an essentially circular cross section is formed.

6. Device according to claim 5,
c h a r a c t e r i z e d t h e r e i n,
that a temperature sensor (16) is provided between the shanks of the U for sensing the end portion of the cutting part.

7. Device according to claim 1,
c h a r a c t e r i z e d t h e r e i n,
that the cutting part (30) is heated by means of an electromagnetic alternating field (19), which is generated from a coil (18), which is situated in the vicinity of the part e.g. above or under a working desk (20), on which the cutting of the material (5) is carried out.

8. Device according to claim 1,
c h a r a c t e r i z e d t h e r e i n,
that at least the front end (;21) the cutting part (30) is covered by a wear resistent, heat resistent material with low friction, e.g metal plating a ceramic or the like.

9. Device according to claim 1,

c h a r a c t e r i z e d t h e r e i n, that the front end (8;21) of the cutting part (30) is designed or provided with a wear member, e.g. a ball of ceramic or hard metal.

10. Circuit for measuring and controlling the temperature in a device according any of the claims 1 - 5, c h a r a c t e r i z e d t h e r e i n, that it comprises a measuring resistance with the resistance ($R_1$) connected in series with the resistance ($R_2$) of the cutting electrode (2), which resistance is thermally variable, that the resistors (R4,R2) are provided to be supplied with a current (I) from a control transistor (Tr1), the control electrode of which is connected to a PI- regulator (Op2), which is provided to give an increasing output voltage on a negative input voltage and a decreasing output voltage on a positive input voltage, the input of which is connected to the output of an amplifier coupled bridge ($R_1$, $R_2$, $R_3$, $R_4$, Op1) with the bridge condition

$$R_2/ R_1 = R_4/R_3 .$$

11. Circuit according to claim 10, c h a r a c t e r i z e d t h e r e i n, that a positive current feedback circuit (25) is provided in the control circuit, that the positive current feedback circuit (25) is intended via a nonlinear element ($D_1$,$R_7$) to provide a control, with transfer from constant resistance independently of the cutting speed, to an optimum resistance depending on a varied cutting velocity, and that a low pass filter (C, $R_9$) is provided to stabilize said control.

12. Circuit according to claim 10, c h a r a c t e r i z e d t h e r e i n, that the change in the output voltage of the differential amplifier (Op1) which occurs at interruption of the resistance ($R_2$) is used to control an interrupt and/or alarm function.

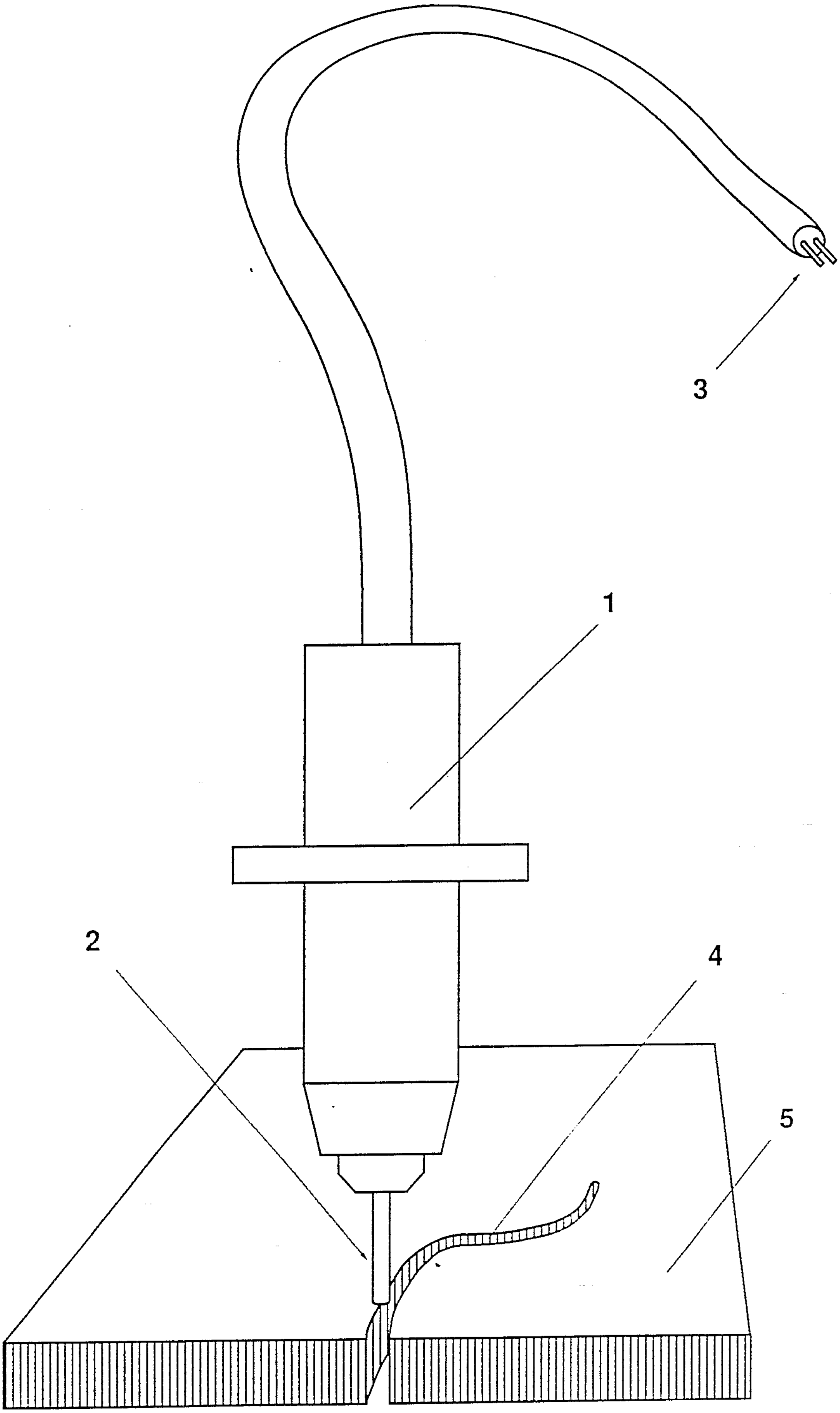



Fig. 1

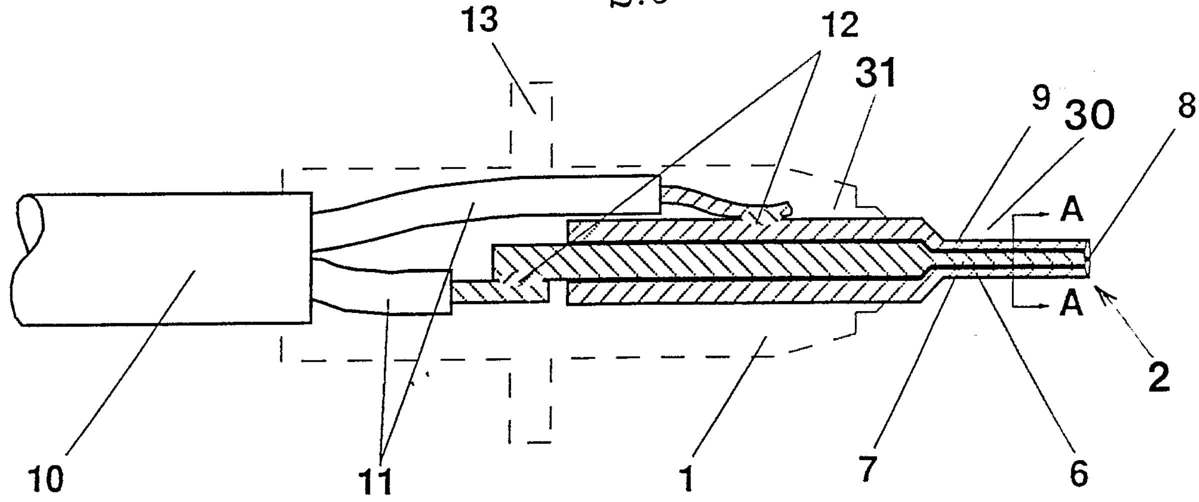



Fig. 2

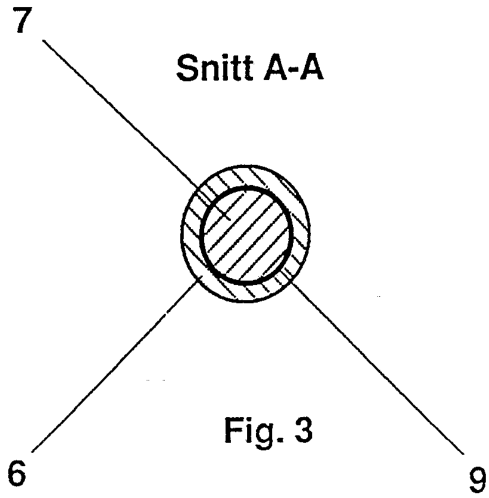



Fig. 3

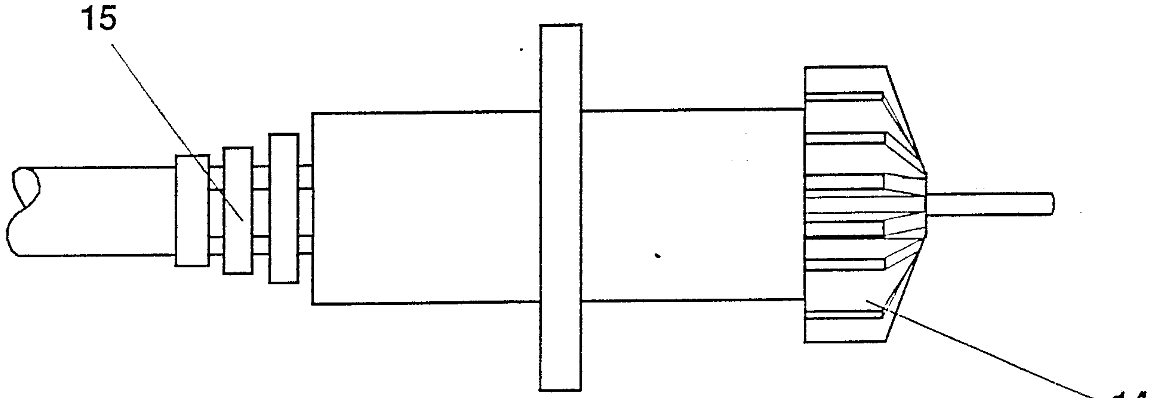



Fig. 4

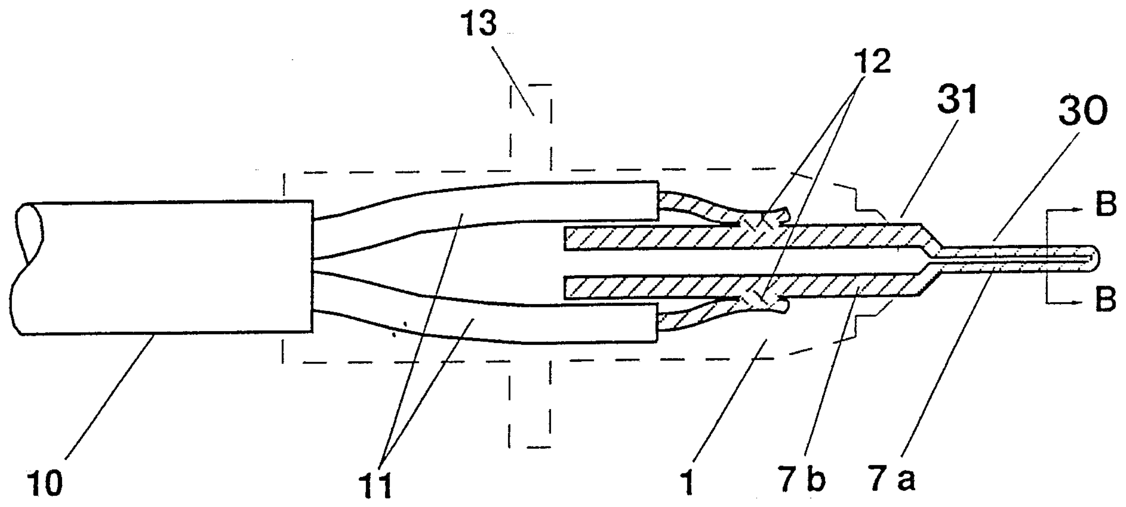



Fig. 5

Snitt B-B

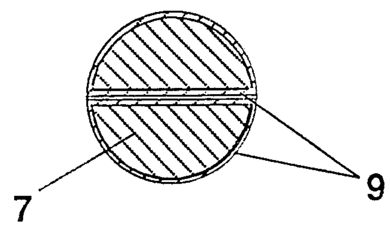



Fig. 6

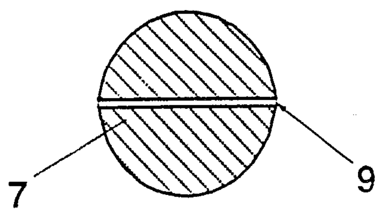



Fig. 7

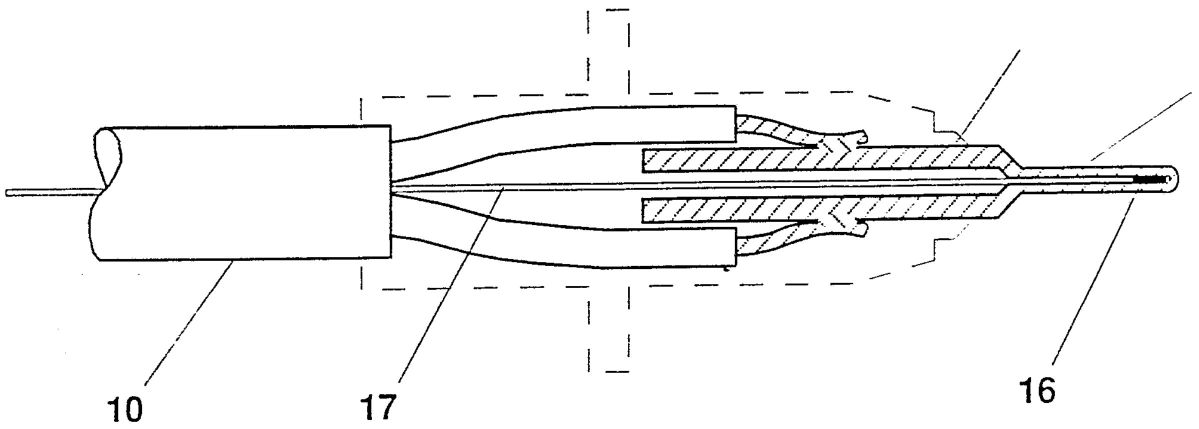



Fig. 8

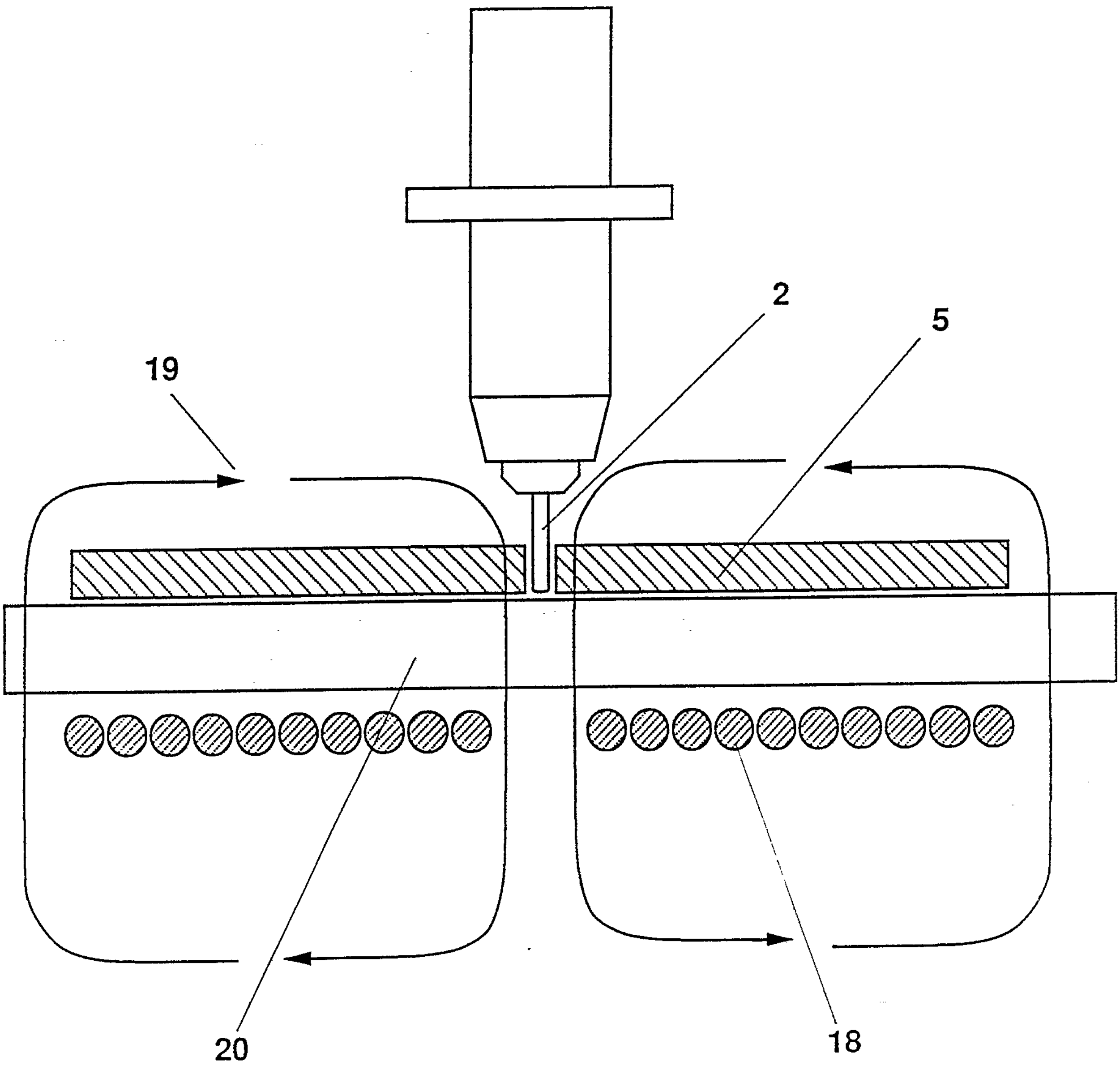



Fig. 9

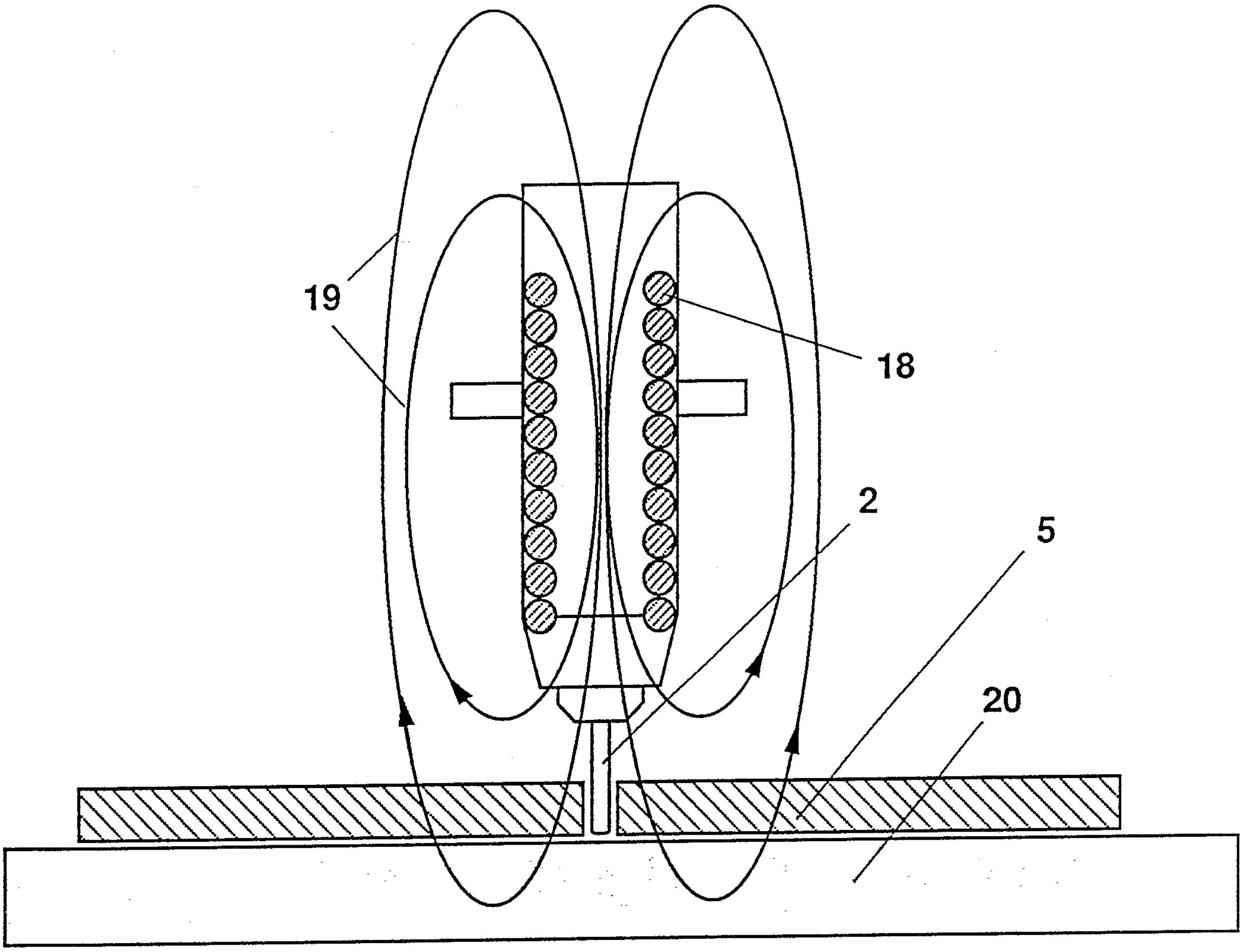



Fig. 10

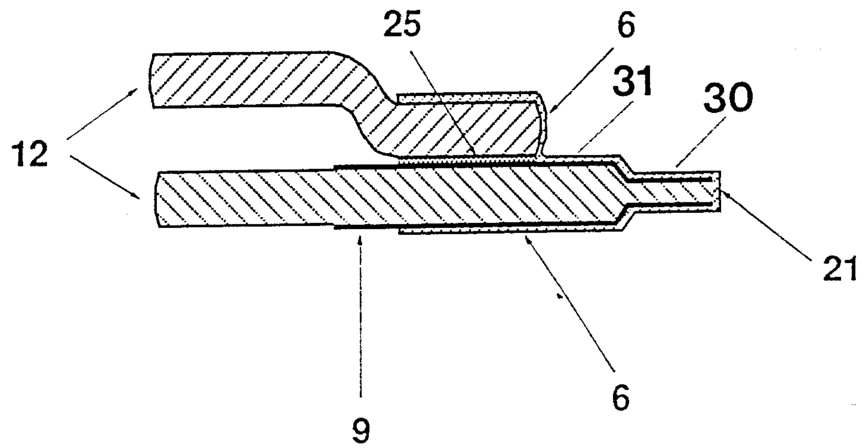



Fig. 11

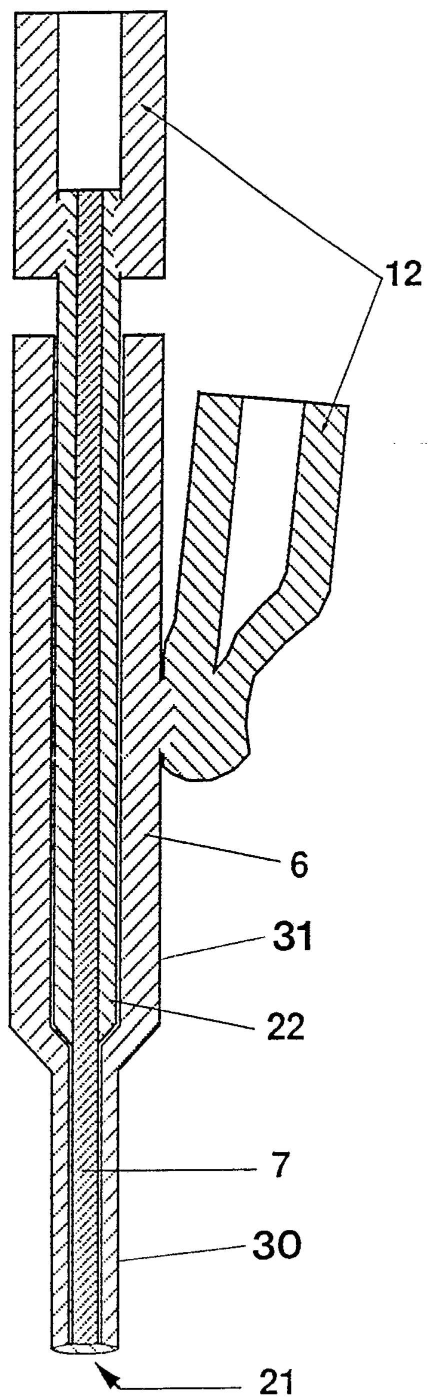



Fig. 12

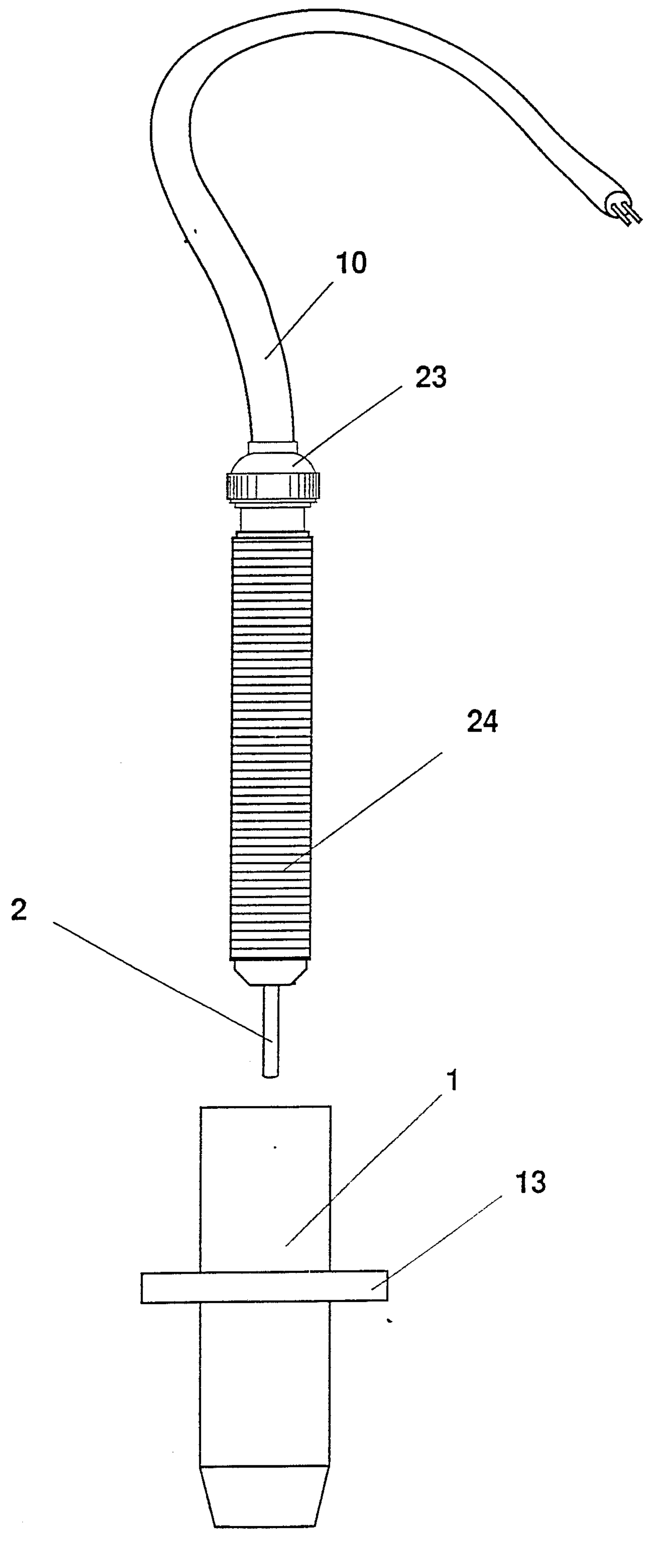
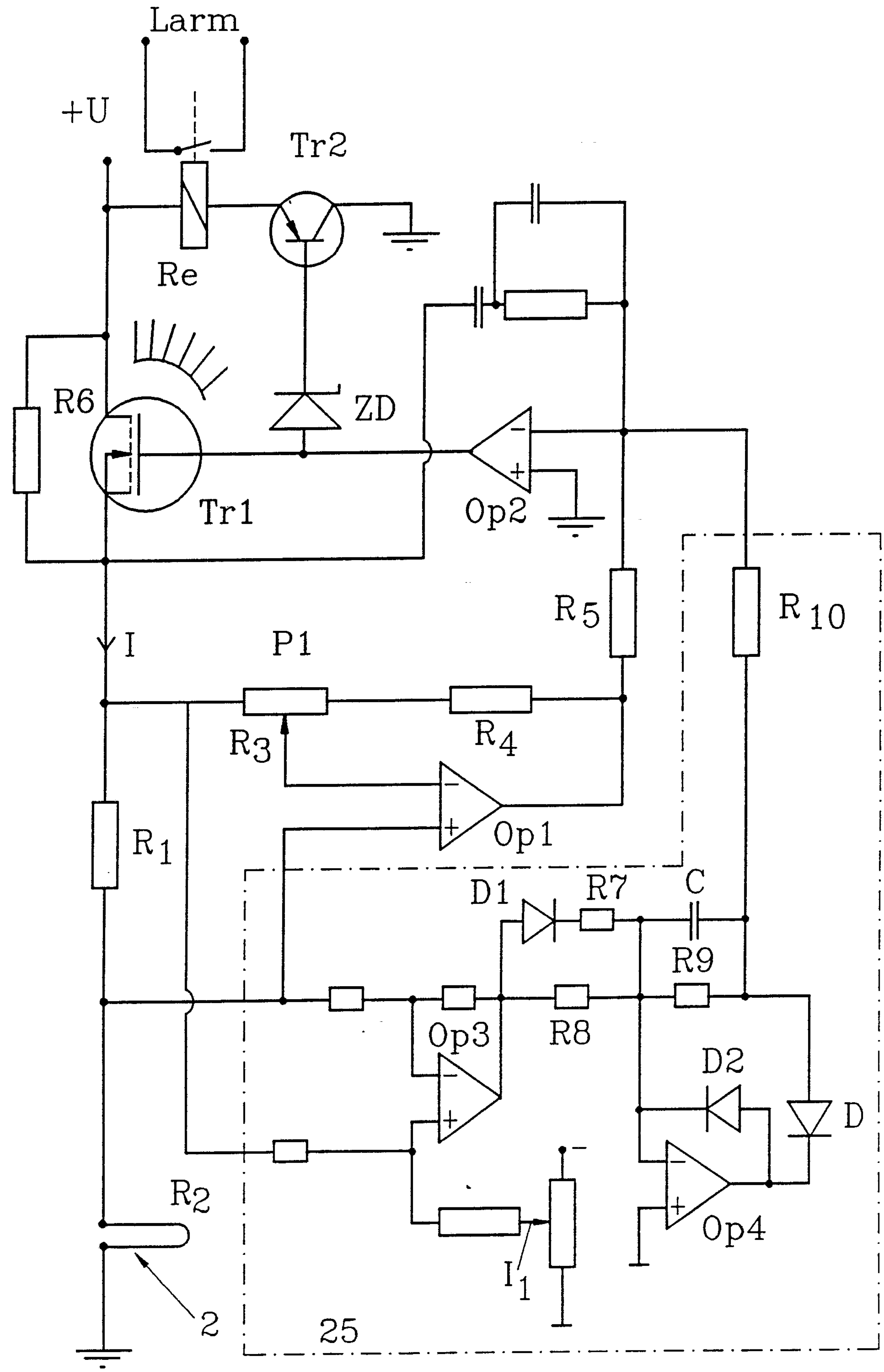



Fig. 13

FIG. 14


Larm
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Tr2
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FIG.15

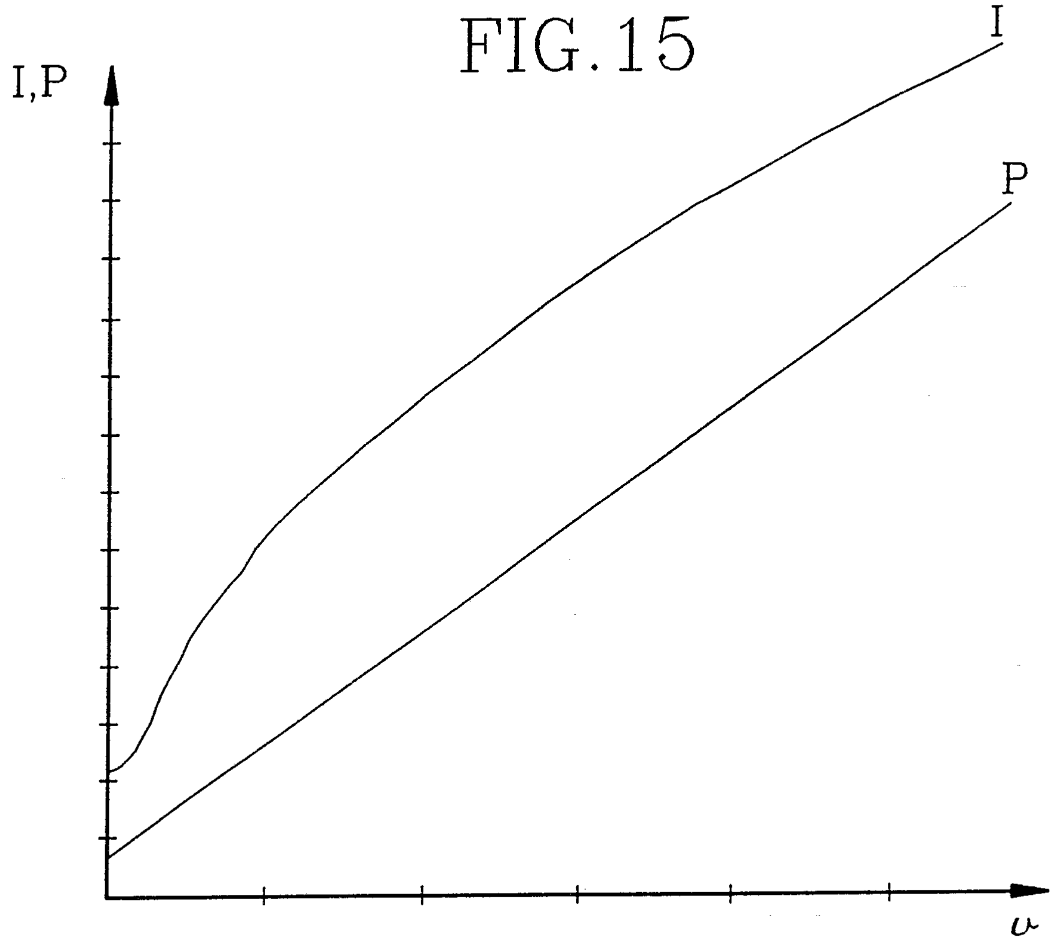
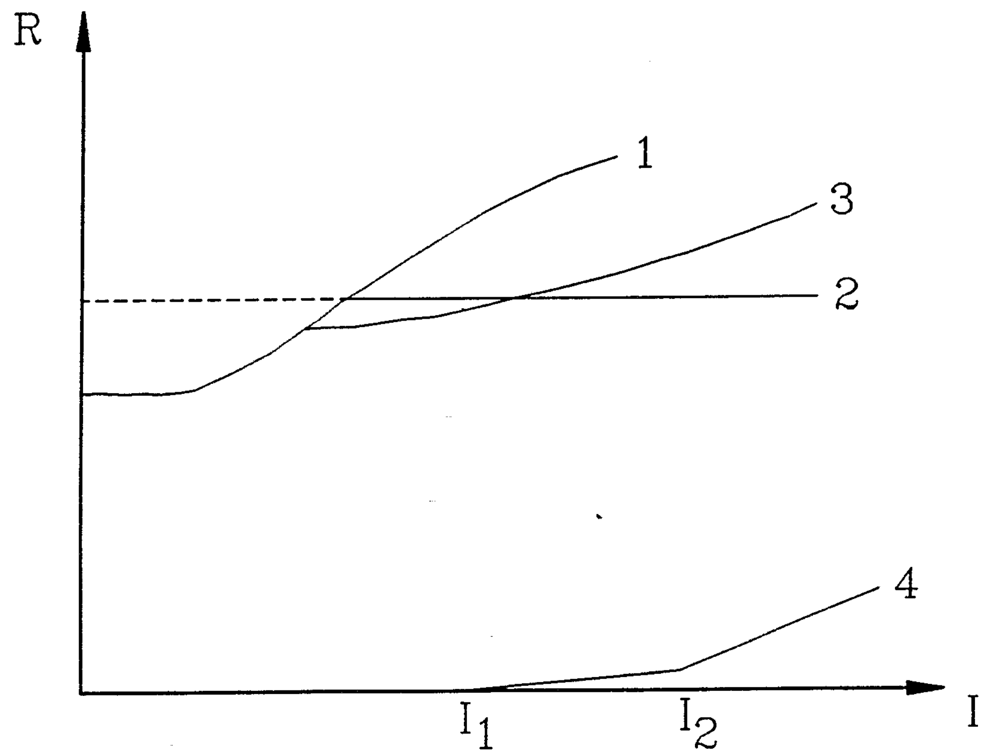



FIG.16



# INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 91/00597

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: B 26 F 3/08

## II. FIELDS SEARCHED

Minimum Documentation Searched[7]

| Classification System | Classification Symbols |
|---|---|
| IPC5 | B 26 F |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

## III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

| Category * | Citation of Document,[11] with indication, where appropriate, of the relevant passages[12] | Relevant to Claim No.[13] |
|---|---|---|
| A | EP, A2, 0116415 (PROTOCOL ENGINEERING LIMITED) 22 August 1984, see the whole document -- | 1 |
| A | GB, A, 2163092 (BRITISH AEROSPACE PUBLIC LIMITED COMPANY) 19 February 1986, see the whole document -- | 1 |
| A | FR, A1, 2425922 (LAIR JAQUES CHARLES GEORGES) 14 December 1979, see the whole document -- | 1 |

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* Special categories of cited documents: [10]

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

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

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"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

"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

## IV. CERTIFICATION

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 27th November 1991 | 1991 -12- 03 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| SWEDISH PATENT OFFICE | Björn Lindkvist |

## ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 91/00597

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 91-10-31
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document cited in search report | Publication date | Patent family member(s) | | Publication date |
|---|---|---|---|---|
| EP-A2- 0116415 | 84-08-22 | GB-A-B- | 2133780 | 84-08-01 |
| | | GB-A-B- | 2136332 | 84-09-19 |
| | | JP-A- | 59152100 | 84-08-30 |
| | | US-A- | 4594499 | 86-06-10 |
| GB-A- 2163092 | 86-02-19 | NONE | | |
| FR-A1- 2425922 | 79-12-14 | NONE | | |