

COMMONWEALTH OF AUSTRALIA

The Patents Act 1952

600341

CONVENTION APPLICATION FOR A PATENT

We, THORN EMI plc, of 4 Tenterden Street, London W1R 9AH, England, hereby apply for the grant of a Patent for an invention entitled "ELECTRICALLY RESISTIVE TRACKS" which is described in the accompanying complete specification.

APPLICATION ACCEPTED AND AMENDMENTS ALLOWED 28.5.90

This application is a Convention application and is based on the application numbered 8704467 for a patent or similar protection made in the United Kingdom on 25th February, 1987.

Our address for service is care of CALLINANS, Patent Attorneys, of 48 Bridge Road, Richmond, 3121, Victoria, Australia.

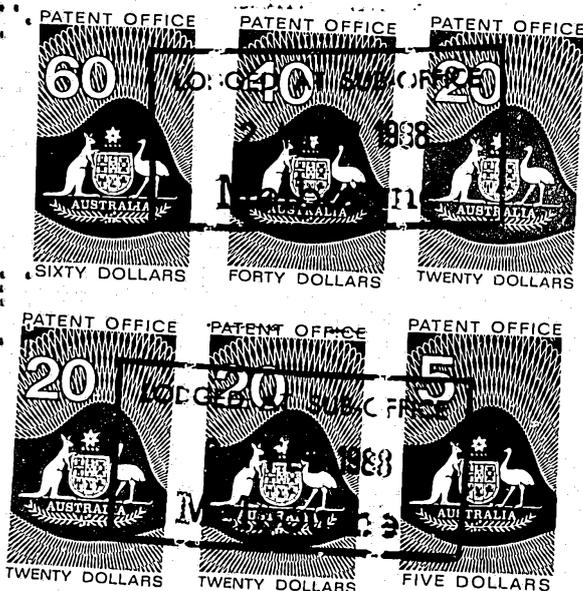
D A T E D this 24th day of February, 1988.

THORN EMI plc  
By its Patent Attorneys:  
CALLINANS

*Colin M... ..*

FEE STAMP TO VALUE OF \$...16.5... ATTACHED MAIL OFFICER.....

LODGED AT SUB-OFFICE  
24 FEB 1988  
Melbourne



To: The Commissioner of Patents.

Form 6  
Form 7

COMMONWEALTH OF AUSTRALIA  
Patents Act 1952-60

Regulation 11 (1)  
Regulation 11 (2)

Declaration in Support of  
~~(a) A Convention Application~~  
~~(b) An Application~~  
for a Patent ~~or Patent of Addition~~

In support of the ~~Application~~/Convention Application made by  
(c) THORN EMI plc

for a patent/~~patent of addition~~ for an invention entitled:

(d) "ELECTRICALLY RESISTIVE TRACKS"

I/~~We~~ (e) RICHARD ARTHUR ALEXANDER HURST

of (f) THORN EMI Patents Limited, The Quadrangle, Westmount Centre,  
Uxbridge Road, Hayes, Middlesex, England

do solemnly and sincerely declare as follows:—

1. ~~I am/we are the applicant(s) for the patent/patent of addition.~~  
X

(b) I am/~~we are~~ authorised by THORN EMI plc

the applicant for the patent/~~patent of addition~~ to make this declaration on its behalf.

2. (i) The basic application~~(s)~~ as defined by Section 141 of the Act was/~~were~~ made  
in Great Britain on the 25th day of February 19 87  
by THORN EMI plc

3. (j) ~~I am/we are the actual inventor(s) of the invention.~~  
X

(k) ~~I am/we are the actual inventor(s) of the invention referred to in the basic application.~~  
X

Simon Balderson, 64 Fleetham Gardens, Lower Earley, Reading,  
Berkshire, England.

(l)

~~of~~

is/~~are~~ the actual inventor~~(s)~~ of the invention and the facts upon which the applicant  
I am/~~we are~~/the said Company is entitled to make the application are as follows:

(m) The applicant is a person who would, if a patent were granted  
upon an application made by the said actual inventor, be  
entitled to have the patent assigned to it.

4. The basic application referred to in paragraph 2 of this Declaration was the first  
application made in a Convention country in respect of the invention the subject of the  
application.

(n) Declared at Hayes this 12<sup>th</sup> day of February 1988

SIGN

X

R.A.A. Hurst

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**(12) PATENT ABRIDGMENT (11) Document No. AU-B-12102/88**  
**(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 600341**

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(54) Title  
**HEATING ELEMENT FORMED BY A THICK FILM RESISTIVE TRACK**

International Patent Classification(s)  
(51)<sup>4</sup> **H05B 003/26 G01K 007/18 H05B 001/02 H05B 003/12**  
**H05B 003/74 H05K 001/09**

(21) Application No. : **12102/88** (22) Application Date : **24.02.88**

(30) Priority Data

(31) Number (32) Date (33) Country  
**8704467 25.02.87 GB UNITED KINGDOM**

(43) Publication Date : **01.09.88**

(44) Publication Date of Accepted Application : **09.08.90**

(71) Applicant(s)  
**THORN EMI PLC**

(72) Inventor(s)  
**SIMON BALDERSON**

(74) Attorney or Agent  
**CALLINAN LAWRIE**

(56) Prior Art Documents  
**AU 489968 63425/73 06.7**  
**US 4286377**

(57) Claim

1. A heating unit comprising an electrically insulative substrate and a heating element applied to said substrate, the substrate comprising a plate member supporting a layer of a glass ceramic material having a percentage porosity equal to or less than 2.5, the percentage porosity being defined as the porosity at a random cross-sectional plane through the layer expressed as the percentage ratio of the cross-sectional area of pores in the layer and on the plane to the cross-sectional area of the remainder of the layer on that plane, the heating unit including an electrically resistive track applied to said layer substrate, said track consisting of a thick film having in the temperature range of from 0°C to 550°C a temperature coefficient of resistance in excess of 0.006 per degree C, said thick film

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including a metal and a glass in such proportions as to provide a suitable coefficient to match that of said substrate and to permit adhesion of said track to said layer.

Australia

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Form 10

PATENTS ACT 1952

# COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE

Short Title:

Int. Cl.:

Application Number:

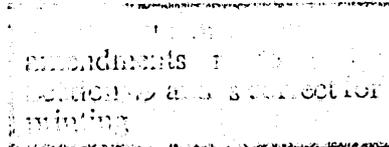
Lodged:

Complete Specification—Lodged:

Accepted:

Lapsed:

Published:



Priority:

Related Art:

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TO BE COMPLETED BY APPLICANT

Name of Applicant: THORN EMI plc

Address of Applicant: 4 Tenterden Street, London W1R 9AH, England

Actual Inventor: SIMON BALDERSON

Address for Service: CALLINANS [REDACTED] Patent Attorneys, of  
48-50 Bridge Road, Richmond, State of Victoria, Australia.

Complete Specification for the invention entitled: "ELECTRICALLY RESISTIVE TRACKS"

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

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\* Note: The description is to be typed in double spacing, pica type face, in an area not exceeding 250 mm in depth and 160 mm in width, on tough white paper of good quality and it is to be inserted inside this form.

ELECTRICALLY RESISTIVE TRACKS

This invention relates to heating elements comprising electrically resistive tracks intended to be formed on electrically insulative substrates, and it also relates to temperature sensors comprising such tracks.

5 In co-pending European Patent Application No. 0,286,216 there is described a substrate suitable for supporting such resistive tracks, and tracks in accordance with this invention are especially, though not exclusively, suitable for deposition upon substrates of the kind described in the aforementioned patent application.

10 Currently used heating devices including electric cooker hobs contain a heating element which, for a given setting, dissipates a constant power. The heat-up rate of the element from ambient temperature to its normal operating temperature is accordingly limited by the constant power output at the maximum setting.

15 The inventor has realised that for such applications, there is an advantage in providing a heating element whose power dissipation varies with temperature.

According to the present invention there is provided a heating unit comprising an electrically insulative substrate and a heating element applied to said substrate, the substrate comprising a plate member supporting a layer of a glass ceramic material having a percentage porosity equal to or less than 2.5, the percentage porosity being defined as the porosity at a random cross-sectional plane through the layer expressed as the percentage ratio of the cross-sectional area of pores in the layer and on the plane to the cross-sectional area of the remainder of the layer on that plane, the heating unit including an electrically resistive track applied to said layer substrate, said track consisting of a thick film having in the temperature of from 0° to 550° a temperature coefficient of



resistance in excess of 0.006 per degree C, said thick film including a metal and a glass in such proportion as to provide a suitable coefficient to match that of said substrate and to permit adhesion of said track to said layer.

5 The extremely high temperature co-efficient of resistance of the heating element permits the track to have a low resistance at ambient temperatures, hence allowing, on energisation of the track, a high initial current to be drawn, thus achieving rapid initial heating. This heating causes the resistance of the track to rise sharply, thus reducing the current as the normal operating temperature of the track is reached. Thus rapid heat-up and effective self regulation are  
10 achieved.

Self-regulation also is achieved in the circumstance that the heating element has been pre-set to dissipate a given power and a pan of cold water (say) is placed directly over it (probably on top of a glass ceramic layer beneath which the heating element is mounted). The pan will act as a heat sink, reducing the  
15 temperature of the element, thus causing it to draw more current and increasing the power dissipated by the element, and thus heat rapidly the contents of the pan.

In order that the invention may be clearly understood and readily carried into effect, some



embodiments thereof will now be described, by way of example only, and with reference to the accompanying drawings in which:

5 Figure 1 is a graph showing approximate variation in resistance with temperature for a thick film track for a heating element or as a temperature sensor for a heating unit in accordance with the invention;

Figure 2 shows, in plan view, a heating element in accordance with the invention on a substrate;

10 Figure 3 shows, in plan view, a heating unit comprising a heating element with a sensor track applied to a substrate;

Figure 4 shows an electrical circuit suitable for use with the sensor track of Figure 3.

15 In a preferred embodiment of the first aspect of the invention, a thick film for a heating element has a composition by weight of 80% metal powder and 20% glass powder. Thick films having a composition by weight in the range of from 50% metal/50% glass to 95% metal/5%  
20 glass may also be used for the heating element. In one preferred embodiment of the second aspect of the invention, a thick film for a temperature sensor on a heating unit has a composition by weight of 80% metal powder and 20% glass powder while in a second embodiment  
25 the composition by weight of the thick film is 50% metal powder to 50% glass powder. The sensor track may also be made from a thick film having a composition by weight in

the range of from 50% metal/50% glass to 95% metal/5% glass.

A typical, but non-limiting, glass powder used has the percentage composition by weight as below:

5	SiO <sub>2</sub>	73.39
	Al <sub>2</sub> O <sub>3</sub>	6.43
	CaO	1.29
	K <sub>2</sub> O	0.32
	Na <sub>2</sub> O	6.29
10	BaO	2.71
	B <sub>2</sub> O <sub>3</sub>	9.57

Figure 1 shows the approximate variation in resistance with temperature for a nickel thick film track having the composition by weight of 80% nickel and 20% glass. The glass used was of the aforementioned composition. As can be seen, the variation in resistance with temperature is considerable.

In general, the glass for the thick film track has a melting point of about 800°C. This enables the ink from which the track is to be made to be fired at a high temperature to ensure effective sintering of the metal without the glass bleeding out. The high melting point of the glass also provides high temperature stability. The composition of the glass is chosen so that the thermal expansion coefficient of the thick film is compatible with that of a substrate to which the track is to be applied.

The proportion of metal to glass in the thick film used affects, inter alia, the following properties:

a) The resistivity/conductivity of the thick film. This

affects the possible power dissipation of heater tracks made of the thick film and the electrical circuitry required for the temperature sensor.

b) The thermal expansion coefficient of the thick film. This should be compatible with that of a substrate to which the thick film is to be applied.

c) The adhesion of the thick film to a substrate to which the thick film is to be applied - if the proportion of metal is too high, the thick film will not adhere to the substrate.

One method of manufacturing an electrically resistive thick film track suitable for a heating element or a temperature sensor on a substrate is described hereinafter.

Nickel and glass powders of average particle size  $5\mu\text{m}$  are mixed in the required ratio with a screen printing medium, such as ESL400, in a sufficient quantity to form a thick liquid slurry with a viscosity that allows the slurry to be easily screen printed. The mixture is then passed through a triple roll mill to ensure adequate wetting of the nickel and glass powders by the screen printing medium, forming an ink. The resulting ink is screen printed in the desired pattern onto the substrate, dried at  $150^{\circ}\text{C}$  and fired at a temperature in the range of from  $750^{\circ}\text{C}$  to  $1100^{\circ}\text{C}$ . The firing procedure is preferably carried out in a nitrogen atmosphere to prevent oxidation of the metal.

A suitable pattern for the track is as shown in Figure 2 which shows a heating element 2 on a substrate 4, suitable for use as a hob unit. The heating element 2 is connected to a power supply by electrical connectors (not shown).

With respect particularly to nickel, it has been found that, when applied to a substrate comprising a metallic support plate coated with glass ceramic material, a thick film track in accordance with this invention exhibits an ability to resist perforation even if a pore in the glass ceramic coating of the substrate and closely proximate to the track should rupture, for example as a result of the electric field established between the track, which generally is run at mains voltage, and the metallic support plate, which is generally earthed, or as a result of the heat generated where the track is used as a heavy duty heating element, for a cooker hob for example.

As suggested hereinbefore, thick film tracks provided in accordance with this invention may advantageously be deposited upon substrates of the kind described in our copending European Patent application <sup>0,286,216</sup> which ~~claims priority from GB 8704468~~. This patent application describes and claims a substrate for supporting electrical components, said substrate comprising a plate member having on at least one surface a layer of a glass ceramic material wherein the



percentage porosity of the glass ceramic layer, as defined hereinafter, is equal to or less than 2.5.

By percentage porosity is meant the porosity at a random cross-sectional plane through the substrate perpendicular to the plate member expressed as the percentage ratio of the cross-sectional area of pores on the plane to the cross-sectional area of the remainder of the glass ceramic layer on that plane.

The use of a heating element in accordance with the invention lends itself to use in conjunction with an energy management system, especially where two or more units are incorporated in a hob-top or cooker, thus permitting avoidance of the possibility that two or more elements could attempt to draw surge currents simultaneously. In conjunction with an energy management system or independently, the considerable variation in resistance of the track with temperature renders it possible to use the track or tracks included in a given system as part of a bridge circuit, for example, to monitor the current temperature of the or each track.

Figure 3 shows (external connections not shown) a heating unit 10 comprising a substrate 11 bearing a heating element 12 and a temperature sensor 14, the temperature sensor being a thick film track having a high temperature coefficient of resistance as mentioned hereinbefore. Where the heating element comprises a thick film track (for example, a heating element in

accordance with said first aspect of the present invention), the heating track and sensor track may be manufactured in the same process.

To spot local hot spots, a sensor track could be arranged to closely follow the path of an associated heater track so as to cover a large area of the substrate. An area to be heated could be monitored by several sensors in the area acting as one pan-size sensor.

It is particularly necessary to provide a temperature sensor on glass ceramic substrates having a metallic support plate as electrical breakdown may occur in the glass ceramic layer when the temperature exceeds 550°C. The sensor track may also be used to regulate the temperature of the substrate and heating track using a suitable electrical circuit to compare the resistance of the sensor track with that of a variable resistor whose resistance is set to correspond to that of the required temperature.

An example of an electrical circuit suitable for use with the sensor track is shown in Figure 4, where the resistance 20 is the resistance of the sensor track 14 and the variable resistor 22 is pre-set to a resistance corresponding to the required temperature. Operational amplifiers 24, 26, to whose inverting inputs a constant voltage is applied via resistances 28, 30 having the same value, convert the resistances of the sensor track and the variable resistor to voltages which are then compared

by a third operational amplifier 32 acting as a comparator. The output of the comparator 32 switches polarity when the resistances of the sensor track and the variable resistor are the same, and accordingly when the sensor track and substrate are at the required temperature, and so can be used to switch the power supply to the heating element on the substrate when the required temperature has been reached.

After the electrically resistive tracks have been applied to the substrate, external connections are added. A suitable electrical connector for making a connection to a thick film track has a cross-sectional area suitable for the required current carrying capacity and comprises a plurality of conductive fibres braided together, each of the fibres having a diameter, preferably in the range of from  $30\mu\text{m}$  to  $300\mu\text{m}$ , so as to provide sufficient stiffness to the connector and to permit adhesion of the connector to the thick film track. The connector may be made of various metals, the most suitable metal for a particular application depending in part on the material of the thick film track to which the connector is to be adhered. Suitable metals include stainless steel, nickel and copper. The connector is adhered to the track using a glass/metal adhesive, advantageously the same conductive ink as used to form the thick film track.

The whole is then overglazed using a protecting glass or glass ceramic overglaze to protect the thick film tracks and allow high temperature stable operation.

The claims defining the invention are as follows:-

1. A heating unit comprising an electrically insulative substrate and a heating element applied to said substrate, the substrate comprising a plate member supporting a layer  
5 of a glass ceramic material having a percentage porosity equal to or less than 2.5, the percentage porosity being defined as the porosity at a random cross-sectional plane through the layer expressed as the percentage ratio of the cross-sectional area of pores in the layer and on the plane  
10 to the cross-sectional area of the remainder of the layer on that plane, the heating unit including an electrically resistive track applied to said layer substrate, said track consisting of a thick film having in the temperature range of from 0°C to 550°C a temperature coefficient of  
15 resistance in excess of 0.006 per degree C, said thick film including a metal and a glass in such proportions as to provide a suitable coefficient to match that of said substrate and to permit adhesion of said track to said layer.
- 20 2. A heating unit according to Claim 1 wherein said heating element comprises said track.
3. A heating unit according to Claim 1 wherein said track forms a temperature sensor.
4. A heating unit according to Claim 1 comprising a first  
25 and a second said track, said first track forming said heating element and said second track forming a temperature sensor.



: 12 :

5. A heating unit according to any one of the preceding claims wherein the proportion by weight of metal and glass in the thick film is in the range of from 50% metal/50% glass to 95% metal/5% glass.
- 5 6. A heating unit according to any one of the preceding claims wherein said metal comprises a transition metal or an alloy based on such a transition metal.
7. A heating unit substantially as hereinbefore described with reference to the accompanying drawings.

D A T E D this 15th Day of May, 1990.

THORN EMI plc

By their Patent Attorneys

CALLINAN LAWRIE



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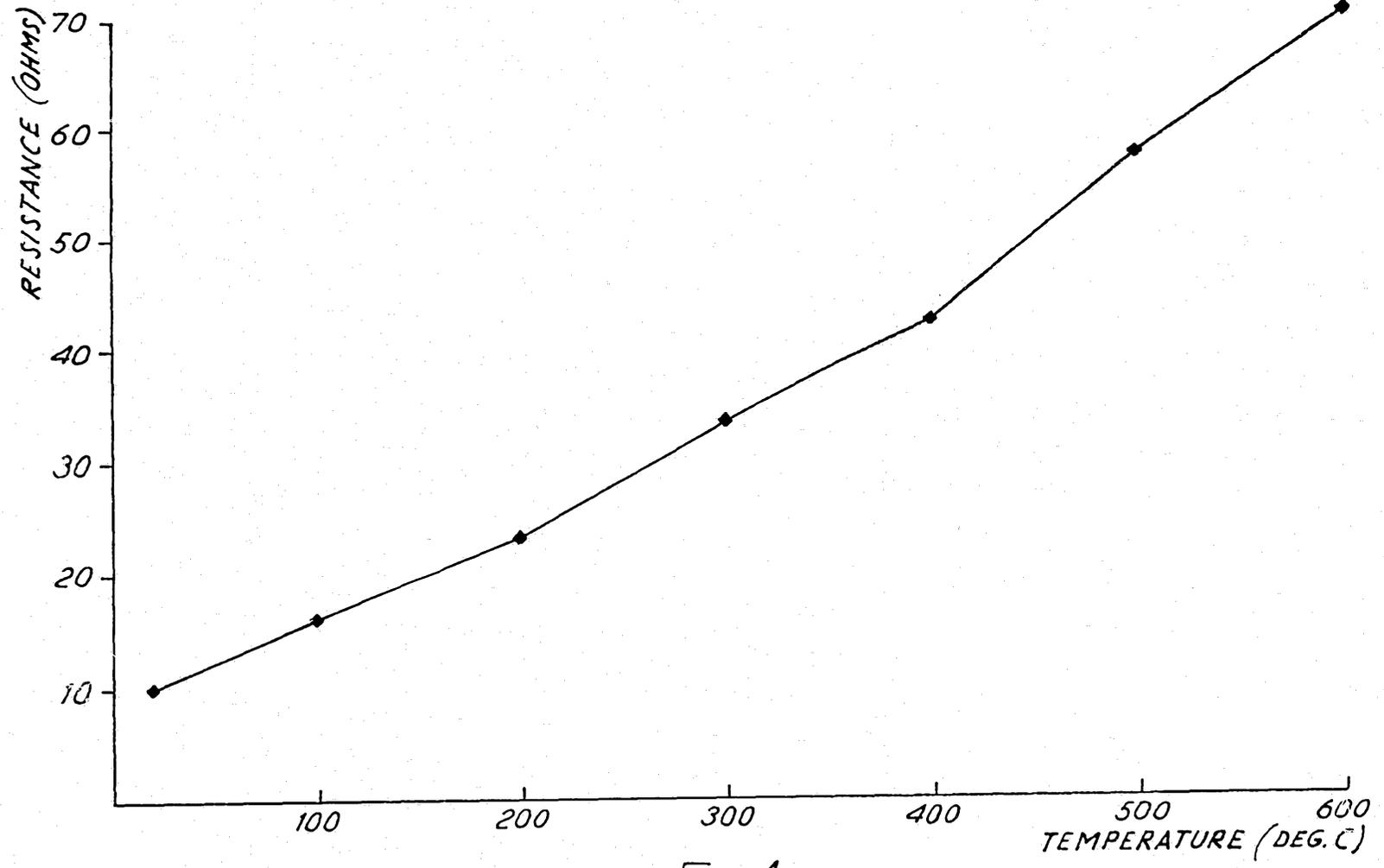


FIG. 1

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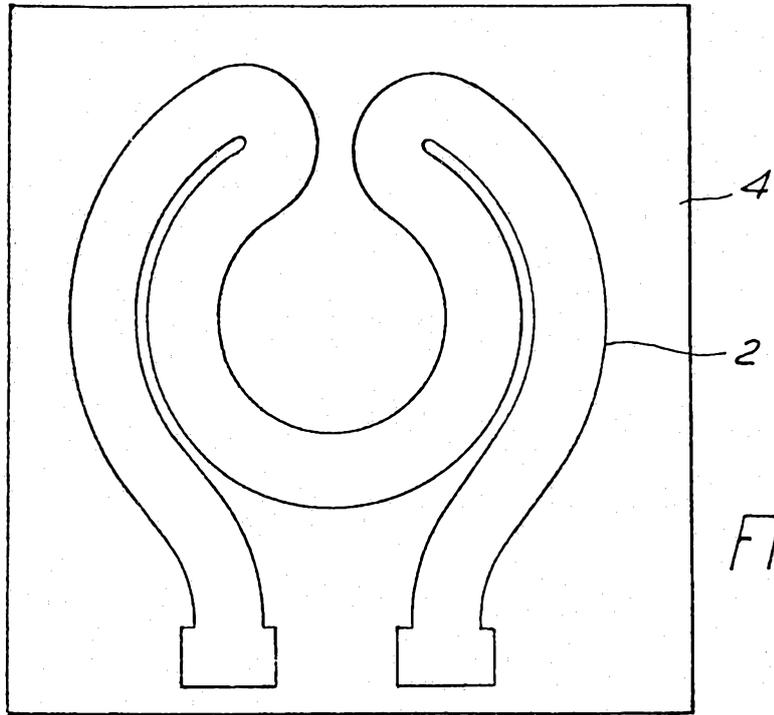


FIG. 2

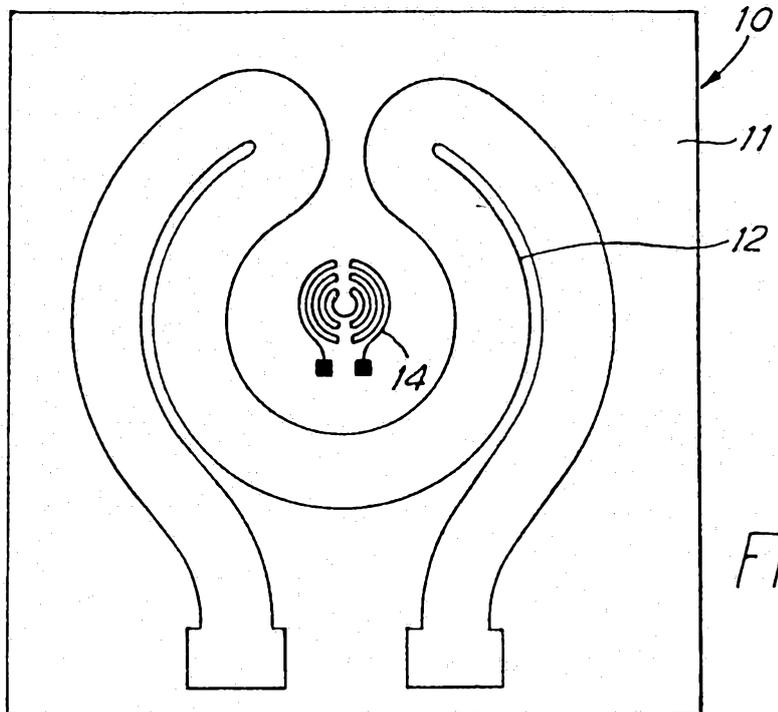


FIG. 3

27 488 12100

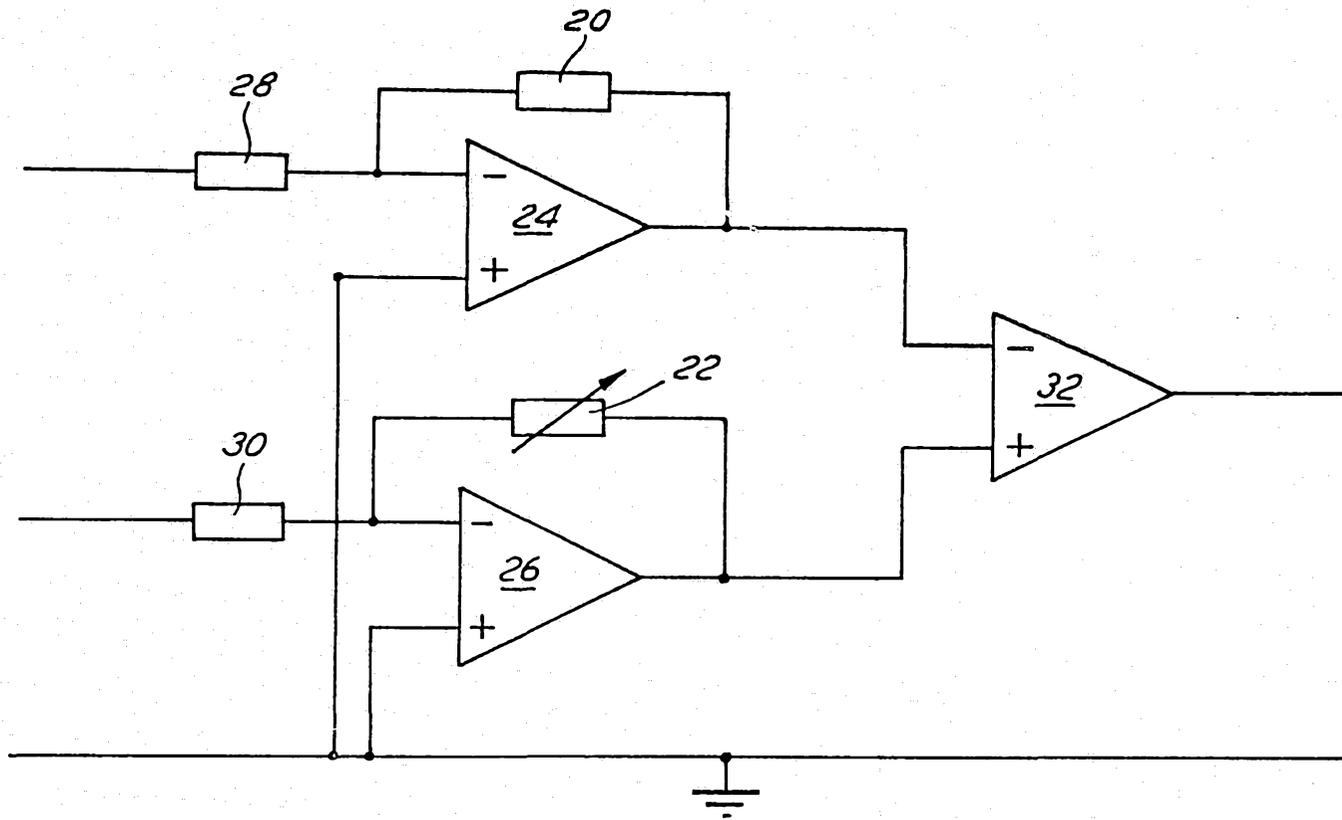


FIG. 4