(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 290 928**
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **88107093.2**

(51) Int. Cl.4: **H01F 21/00**

(22) Date of filing: **03.05.88**

(30) Priority: **15.05.87 US 50721**

(43) Date of publication of application:
17.11.88 Bulletin 88/46

(84) Designated Contracting States:
DE FR GB

(71) Applicant: **Siemens Aktiengesellschaft Berlin und München**
Wittelsbacherplatz 2
D-8000 München 2(DE)

(72) Inventor: **Mc Kenna, Gilbert Walter**
805 Winthrop Avenue
Revere Massachusetts 02151(US)
Inventor: **Weedon, Hans Joergen**
1A Daniels Street Court
Salem Massachusetts 01970(US)

(54) **Radiofrequency tuning inductor.**

(57) A radio frequency tuning inductor provides a helical inductor coil, a cylindrically shaped ground positioned within the coil and coaxially with respect thereto for adjusting the inductance thereof, a conductor located coaxially within the ground and forming a coaxial transmission line in combination therewith, and an electrical coupling of the conductor to the coil at an adjustable position along the coil. In a preferred embodiment, the electrical coupling includes a sleeve located around the conductor and axially slideable with respect thereto, a wiper extending radially outward from the sleeve for electrically contacting the coil, and a member for electrically coupling the sleeve to the conductor.

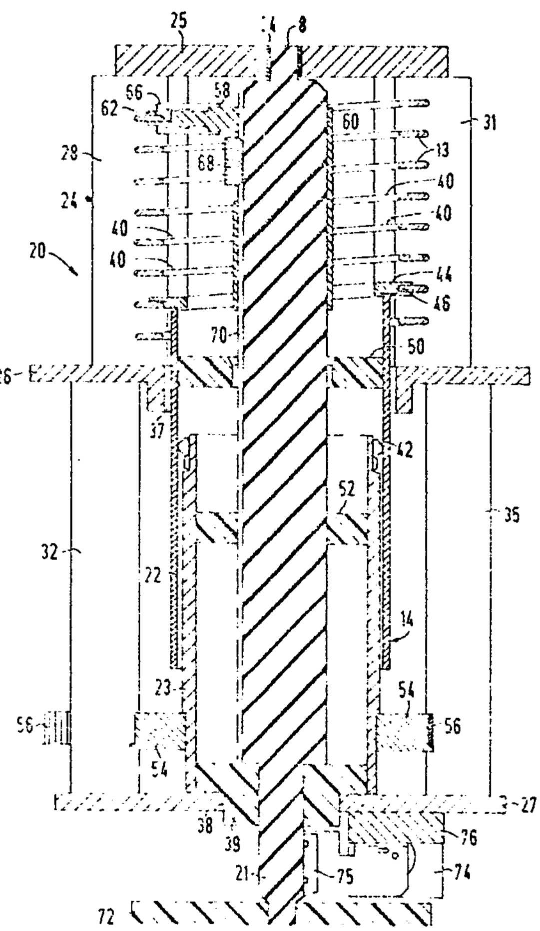

FIG 2

EP 0 290 928 A1

RADIO FREQUENCY TUNING INDUCTOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to radio frequency tuning inductors and, in particular, to such inductors which are operable up to 100 MHz.

Statement of the Prior art

Different types of radio frequency tuning inductors vary greatly in accordance with their many varied applications throughout the entire field of radio frequency electronics. One of these various applications includes tuning the output inductance of radio frequency power amplifiers. High-power, radio frequency amplification is typically performed by vacuum tubes which are constructed with electrodes. These electrodes exhibit a large amount of inter-electrode capacitance at frequencies often encountered in radio frequency amplification. As the signal frequency increases, so does the effect of inter-electrode capacitance, which correspondingly interferes with the output power of the amplifier. Placing a tuned inductor in series with the output of the amplifier creates a resonant circuit at a tuned frequency which counteracts the inter-electrode capacitance at that frequency. Making the inductor tunable to different inductances allows the resulting resonant circuit to be tuned to different frequencies to thereby counteract the capacitive reactance over the tunable range of the resonant circuit. This enables the amplifier to perform more efficiently.

Generally, the use of amplifier output tuning inductors is well known. The constraints on previously known tuning inductors of this type are as follows: the bandwidth over which any particular coil can tune; the power losses to heating caused by low unloaded Q and imperfect matching of the tuned inductor to the power amplifier inter-electrode capacitance; the upper frequency limit for which a tunable coil can be constructed and still maintain good Q; and further losses in coupling the output of the tuning inductor.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a radio frequency tuning inductor which operates a high frequencies with a large tunable bandwidth excellent Q over the entire tunable range, and minimized losses in coupling the output thereof. The inductor of the present invention comprises a helical inductor coil, a cylindrically shaped grounding means positioned within the coil and coaxially with respect thereto for adjusting the inductance thereof, a conductor located coaxially within the grounding means and forming a coaxial transmission line in combination therewith, and means for electrically coupling the conductor to the coil at an adjustable position along the coil.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustratively described in relation to the accompanying drawings of which:

Fig. 1 is a circuit diagram of a radio frequency power amplifier using a tuning inductor as specified in the present application;

Fig. 2 is a front sectional view of a tuning inductor constructed in accordance with one embodiment of the present invention;

Fig. 3 is a partially sectioned, front view of the tuning inductor of Fig. 2;

Fig. 4 is a partially sectioned, right side view of the inductor of Figs. 2 and 3;

Fig. 5 is a sectioned view of the inductor of Fig. 3 taken along viewlines 5-5;

Fig. 6 is a sectioned view of the inductor of Fig. 3 taken along viewlines 6-6; and

Fig. 7 is a sectioned view of the inductor of Fig. 3 taken along viewlines 7-7.

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a typical radio frequency power amplifying circuit 1 having an amplifying vacuum tetrode 2. Tetrode 2 includes a plate electrode 3, a screen electrode 4, a grid electrode 5 and a filament cathode 6. Filament cathode 6 is powered by a signal source 7 for purposes of heating. Grid electrode 5 receives an input radio frequency signal for amplification, which signal is represented by signal source 8. Screen grid 4 receives a control voltage signal (not shown). Plate electrode 3 is coupled through a radio frequency blocking inductor 9 to a positive plate voltage source 10. In addition to inductor 9, a capacitor 11 coupled between the plate electrode end of inductor 9 and ground, blocks radio frequency signals from reaching the positive voltage source 10. The amplified radio frequency signal is coupled from the plate 3 by a D.C. blocking capacitor 12 to the tuning inductor 13 which is the subject of the present invention. Tuning inductor 13 includes an adjustable ground 14 and an adjustable signal tap 15. The signal tap 15 is connected to the center conductor 21 of a coaxial conductor 16 for transmission of the amplified radio frequency signal. Adjustment of the ground 14 enables the variation of the inductance of coil 13 to thereby counteract interelectrode capacitance within the tetrode 2 as represented by the phantom capacitors 17 and 18 shown therein.

Fig. 2 shows a tuning inductor 20 having a helical inductor coil 13, a cylindrical grounding means 14 and a central conductor 21. The helical inductor coil 13 is constructed of solid copper and includes approximately 8 turns having a diameter of approximately 6 inches (15.2 cm). The cylindrical grounding means 14 is composed of a pair of cylindrical telescoping sections 22 and 23. Section 22 is adjustable with respect to the helical inductor coil 13 and is used to short out or ground an adjustable portion of coil 13 to thereby change the inductance thereof.

The center conductor 21 forms a coaxial transmission line in cooperation with the cylindrical grounding means 14 and thereby minimizes power losses in transferring radio frequency power from the coil.

The components described are mounted on a support structure 24 generally including a plurality of circular or annular plates 25, 26 and 27 and a plurality of stand-off members 28 through 35 interconnecting the plates 25-27. Plate 22 is circular having a center opening 36 for receiving one end of the conductor 21. Plate 26 is annular for allowing the grounding means 14 and the conductor 21 to pass through a central opening 37 and serves the function of making electrical contact with the cylindrical grounding means 14 with a minimal support function. Plate 27 may either be described as circular having a central opening 38 or as annular and having a smaller central opening 38 than plate 26. The plates 25-27 are all constructed from electric conducting metal. Stand-off members 28-31 separate plates 25 and 26. They are made of an electrically insulating material and are rectangular in cross-section. Stand-off members 29 and 30 are shown in Fig. 3. Stand-off members 31-35 are used to attach plates 26 and 27. They are circular in cross-section and members 33 and 34 are shown in Fig. 3.

Inductor coil 13 is mounted in slots 40 formed in each of the members 28-31. The upper end of coil 13 (not shown) is intended for coupling to the D.C. blocking capacitor 12 of Fig. 1. The lower end (not shown) is physically and electrically coupled to plate 26 as a ground.

Cylindrical section 23 is rotatably mounted by means of a spacer 39 to the plate 37. Telescoping section 22 fits around the outside of section 23 with a slidable electrical contacting connection 42. The end 43 of section 22, the position of which determines the inductance of coil 13, is engagable with the coil 13 for both electrical contacting and support purposes. The end 43 of section 22 is constituted by an outwardly extending flange 44 which is physically and electrically attached to section 22 as described in reference to Fig. 7. The flange 44 is helical in shape to match the shape of inductor 13 and extends for approximately one turn of the inductor 13. The extension of flange 44 between adjacent turns of coil 13 provides a certain amount of shielding between the first grounded turn and the last ungrounded turn of coil 13.

The central conductor 21 is rotably mounted in opening 34 and is electrically isolated from plate 22 by means of an insulator 48. The other end of conductor 21 is rotatably mounted in opening 38 and is electrically isolated from plate 27 by the insulating properties of spacer 39. The proper separation and spacing between the grounding means 14 and the center conductor 21 are maintained by a pair of spacers 50 and 52. Spacer 50 maintains the spacing between the movable section 22 of grounding means 14 and the center conductor 21, and spacer 52 maintains the spacing between rotatable section 23 and the center conductor 21. The proper spacing helps to maintain the electrical characteristics of the coaxial transmission line formed by the grounding means 14 and the center conductor 21.

The rotatable section 23 further has attached thereto a pulley 54 which may be rotated by a drive belt 56 to rotate grounding means 14. Thus the belt 56 may be used to cause rotation of section 23 which rotation is transmitted to section 22 by means described below. This rotation causes adjustment of the position of the flange 44 along the axial length of coil 13. Thereby, the amount of coil 13 which is grounded by grounding means 14 may be varied by rotation of grounding means 14 by the belt 56.

The upper end of the center conductor 21 shows means for electrically coupling the conductor 21 to the coil at an adjustable position along the coil. Means 58 generally includes a sleeve 60 located around the conductor 21 and axially slideable with respect thereto, wiper means 62 extending radially outward from the sleeve 60 for electrically contacting the coil 13 and a further member 64 (in Fig. 4) for electrically connecting the sleeve 60 to the center conductor 21. Wiper means 62 further includes a follower 66 for maintaining the position of wiper means 62 to maintain electrical contact between wiper means 62 and the coil 13. Further affixed to the sleeve 60 is a slot key 68 which slideably engages a slot 70 located in a straight line along the side of conductor 21. The sleeve 60 along with the slot key 68 are axially slideable along the conductor 21. Slot key 68 and slot 70 cause any rotational force on the conductor 21 to be transferred to the sleeve 60 to thereby cause the wiper means 62 to be adjustable to different portions of the coil 13. The follower 66 mains the wiper means 62 in electrical contact with the coil 13 during adjustment of the wiper means therealong with the axial force generated from such adjustment being transmitted by follower 66 to the sleeve 60 to thereby cause axial movement of sleeve 60 along conductor 21. By this means rotation of conductor 21 may be used to adjust the position of wiper means 62 along the coil 13. To this end, a pulley 72 is attached to the lower end of conductor 21 to enable rotation thereof via a belt (non shown) similar to the belt 56.

Lastly shown in Fig. 2 is an electrical connector 74 for coupling amplified radio frequency signals from the center conductor 21 to other locations. Connector 74 is mounted to plate 27 by means of an insulating block 76 and includes a pair of finger contacts 75, only one of which is partially shown.

Fig. 3 is essentially the same view as Fig. 2 with much of the device left unsectioned and the sleeve 60 along with wiper means 62 being rotated along the coil 13 to face the viewer. Additionally shown is an end piece 78 for the coil 13, which end piece 78 is electrically insulating except for an electrical connecting stud 80 for coupling to the D.C. blocking capacitor 12 of Fig. 1. Further shown in Fig. 3 is a block 82 and screw 84 arrangement which is used to secure the lower end 86 of coil 13 to the plate 26.

Further shown are a multiplicity of fan or iris springs 88 which are attached to the movable section 22 of grounding means 14 along their vertically oriented edges 90 and which extend partially radialy and partially angularly to form a flexible and more complete ground between the plate 26, the grounding means 14 and shorted portions of the coil 13 located below the flange 44.

Section 22 is shown to have a slot key which engages a slot 94 located in section 23. By this means, rotation of section 23 is transmitted to section 22. Additional finger contacts 96 are shown making additional grounding contact between the section 23 and the plate 27. The front of connector 74 is shown having a second pair of finger contacts 98 for coupling to the center conductor 21.

Fig. 4 is a right side view of the inductor 20 of Fig. 3. It shows the finger contacts 64 which extend through an opening 100 in sleeve 60 to contact the center conductor 21. Also shown is a coaxial connector 102 which is coupled to the electrical connector 74 and thereby to finger contacts 75 and 98 for transmitting radio frequency power from the conductor 21 to other locations.

Fig. 5 shows a downward view of the apparatus of Fig. 3 taken along viewlines 5-5. This view shows the arrangement of the iris or fan springs 88 in extending radially and angularly outward from the section 22 of grounding means 14. The outward pressure of these springs maintains electrical contact with portions of the coil 13 adjacent thereto and also with the opening 37 in plate 26.

Fig. 6 is a downward view along the section lines 6-6 in Fig. 3 showing the top of the helical flange 44 as it would partially shield the first grounded turn of coil 13. Also shown is a set of finger contacts 104 located on top of the highest portion of the helical flange for making some extra grounding contact with the highest portion of the coil 13 to be grounded.

Fig. 7 is an upwardly looking sectional view of the apparatus of Fig. 3 taken along viewlines 7-7 and showing the underside of the flange 44. Also shown located between the bottom surface 45 of flange 44 and the section 22 of grounding means 14 are a series of additional finger contacts 106 through 110, a plurality of smaller teflon blocks 112, and three larger teflon blocks 114. Finger contacts 106 and 107 are located at opposing ends of the helical flange with contact 106 being on the opposite side of the coil 13 from finger contacts 104 of Figs. 3 and 6. Additional contacts 108-110 are equi-angularly spaced around the helical flange 44. Finger contacts 106-110 receive radio frequency current from the coil 13 and cause it to be conducted down the outside surface of section 22 to ground.

As mentioned above, the flange 44 and section 22 are driven up and down along the coil 13 through rotation of the grounding means 14 and engagement of the flange 44 with the helical coil 13. This physical engagement which drives section 22 axially along the coil is performed by the teflon blocks 112 and 114. The smaller blocks 114 are located on the underside of the flange 44 to physically slide along the top of the first turn of coil 13 which is to be grounded. The larger blocks 114 engage the underside of coil 13 as well as the top side and serve to push the section 22 down in response to proper rotation thereof.

CONCLUSION

The tuning inductor embodying the present invention exhibits very low power losses even at frequencies in the neighborhood of 100 MHz. This performance is achieved over a very wide operting range of 10 to 90 MHz. The very high Q achieved by the inductor gives reduced power losses and improved efficiency even at elevated frequencies.

Claims

1. A radio frequency tuning inductor comprising:

a helical inductor coil;

a cylindrically shaped grounding means positioned within the coil and coaxially with respect thereto for adjusting the inductance thereof;

a conductor located coaxially within the grounding means and forming a coaxial transmission line in combination therewith; and

means for electrically coupling the conductor to the coil at an adjustable position along the coil.

2. The inductor of claim 1, wherein the cylindrical grounding means are adapted to electrically contact an adjustable amount of the inductor coil.

3. The inductor of claim 2, wherein the cylindrical grounding means includes one end thereof which is axially adjustable along the coil.

4. The inductor of claim 3, wherein the coil includes a plurality of adjacent turns and further wherein the adjustable end of the grounding means includes a helical flange which extends radially outwardly between adjacent turns of the coil.

5. The inductor of claim 2, wherein the cylindrical grounding means includes means for making electrical contact between the grounding means and turns of the coil adjacent thereto.

6. The inductor of claim 3, wherein the cylindrical grounding means includes a pair of telescoping cylindrical sections one of which is axially adjustable with respect to the coil, and includes the one end of the grounding means, and the other of which is axially fixed with respect to the coil.

7. The inductor of claim 1, wherein the means for coupling includes a sleeve located around the conductor and axially slideable with respect thereto, wiper means extending radially outward from the sleeve for electrically contacting the coil, and means for electrically coupling the sleeve to the conductor.

8. The inductor of claim 7, wherein the means for coupling includes follower means attached to the wiper means for maintaining the wiper means in a position to maintain the electrical contact with the coil.

9. The inductor of claim 8, wherein the follower means engages the inductor coil.

10. The inductor of claim 8, wherein the sleeve includes means for transmitting rotational force from the conductor to the sleeve for allowing adjustment of the wiper means with respect to the inductor coil.

87 P 7447 E

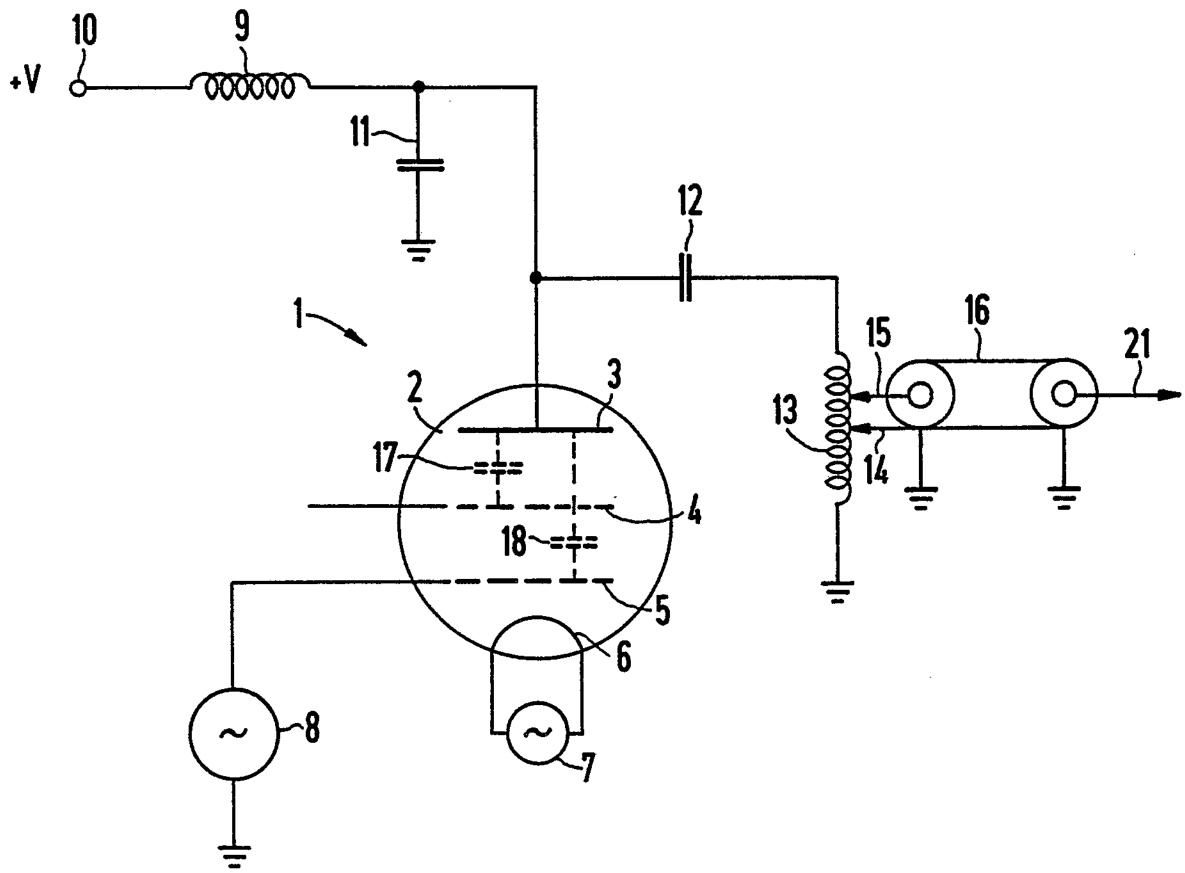

FIG 1

87 P 7447 E

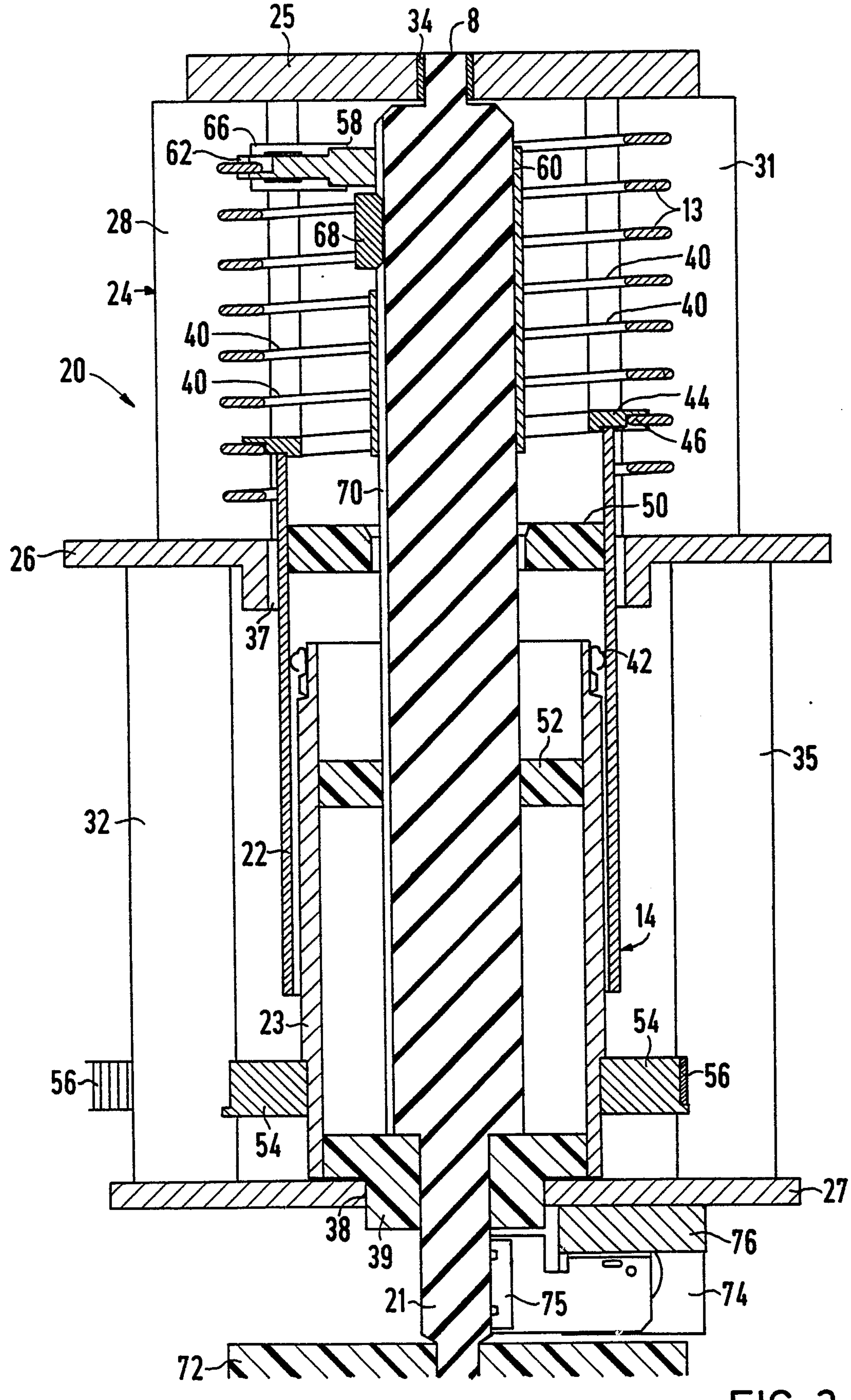

FIG 2

87 P 7447 E

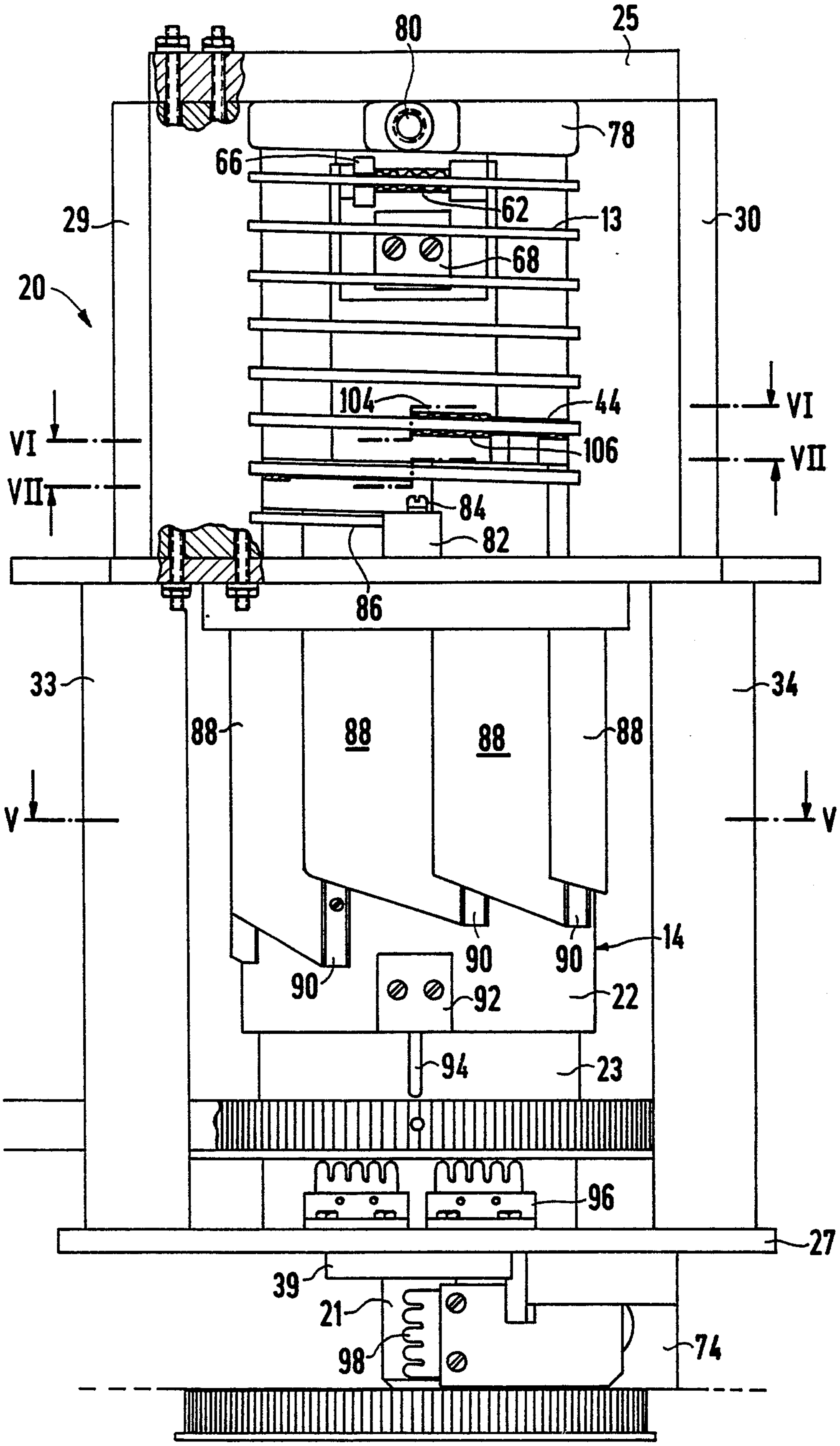

FIG 3

87 P 7447 E

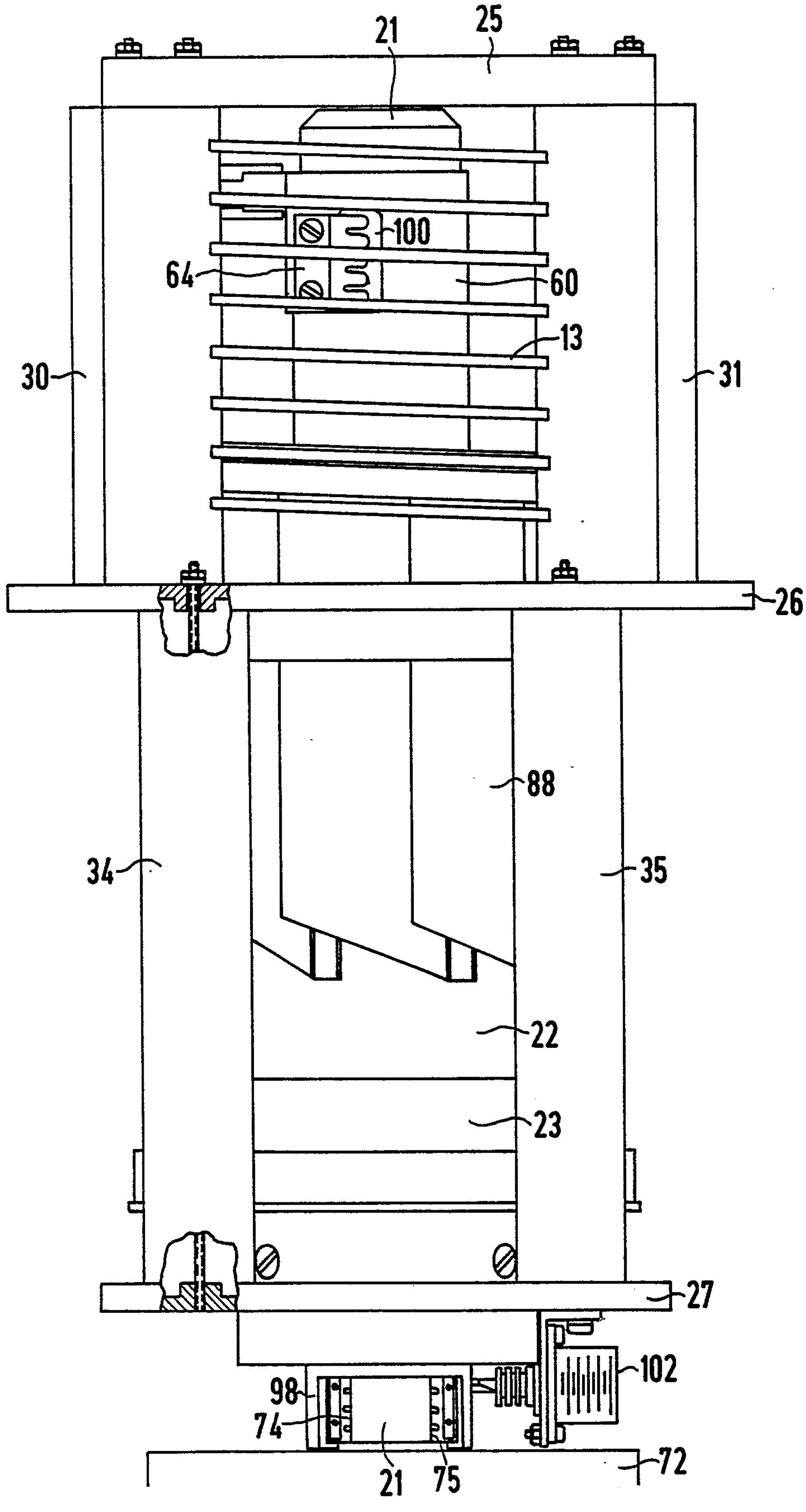

FIG 4

87 P 7447 E

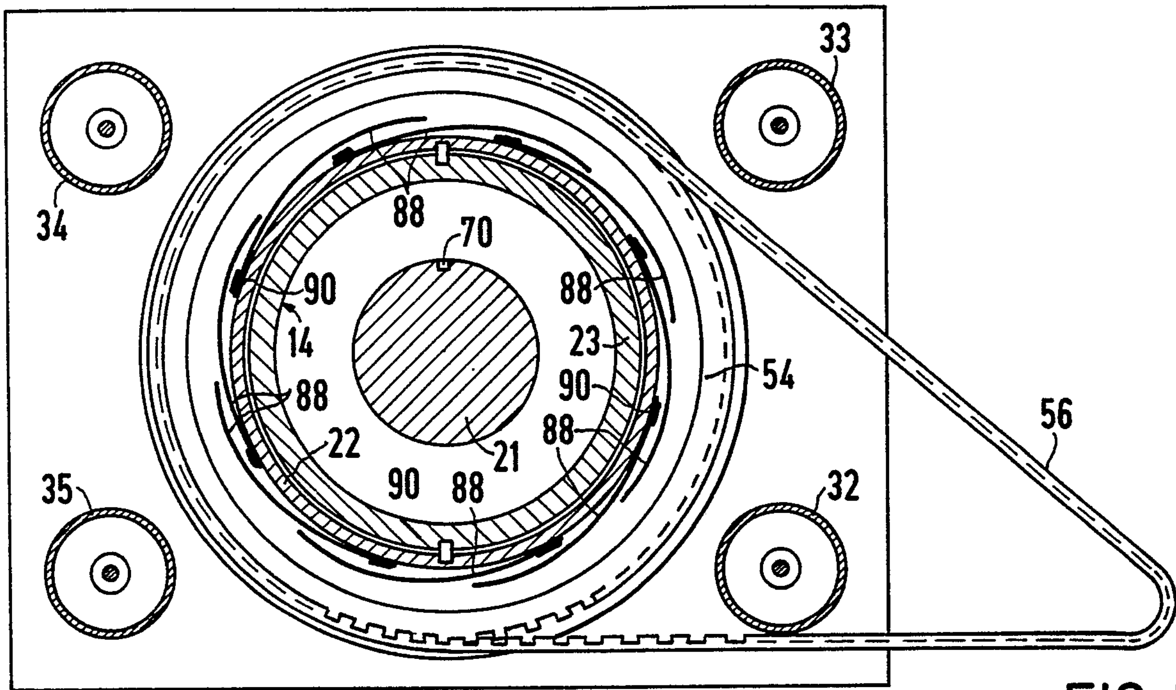

FIG 5

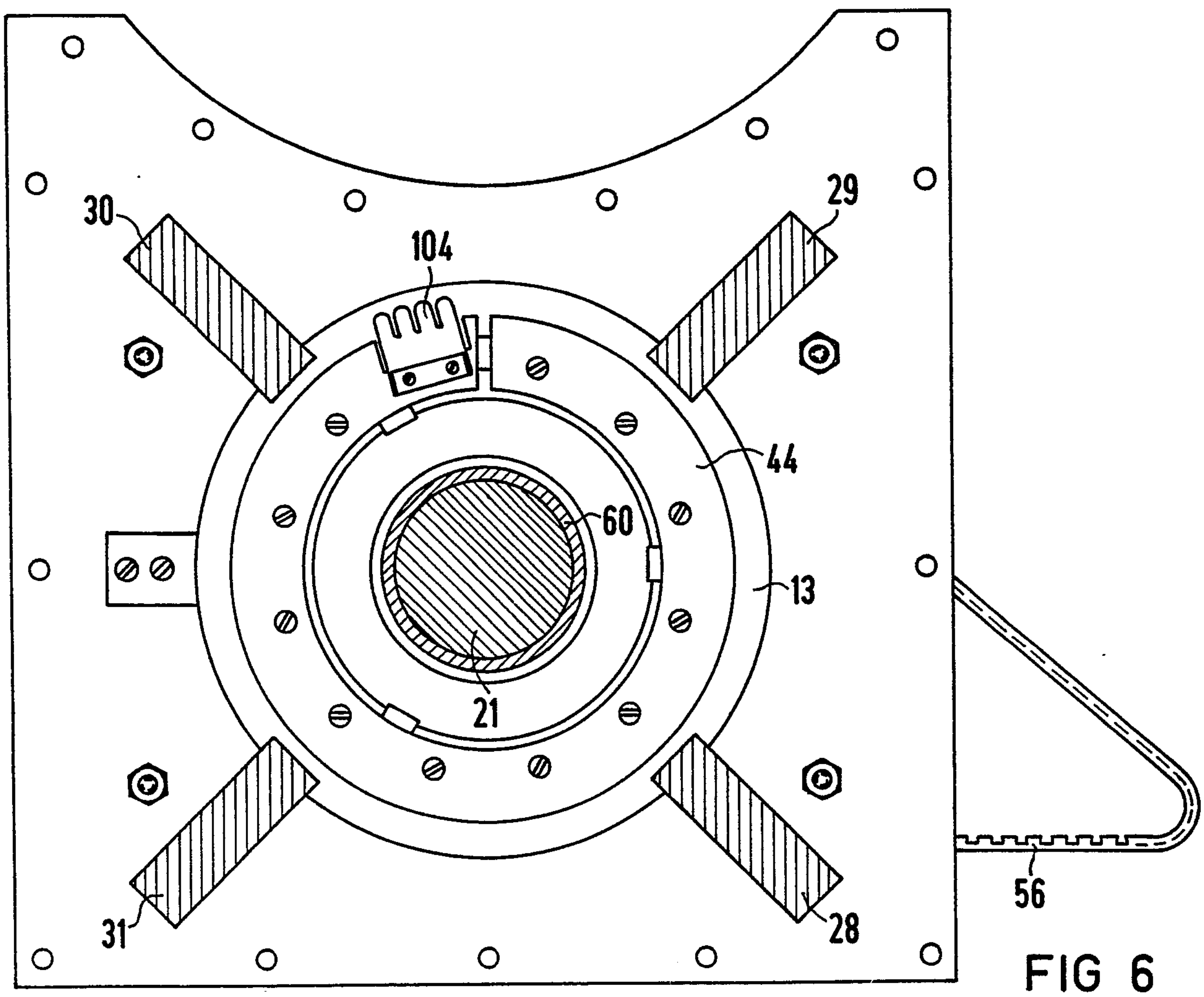

FIG 6

87 P 7447 E

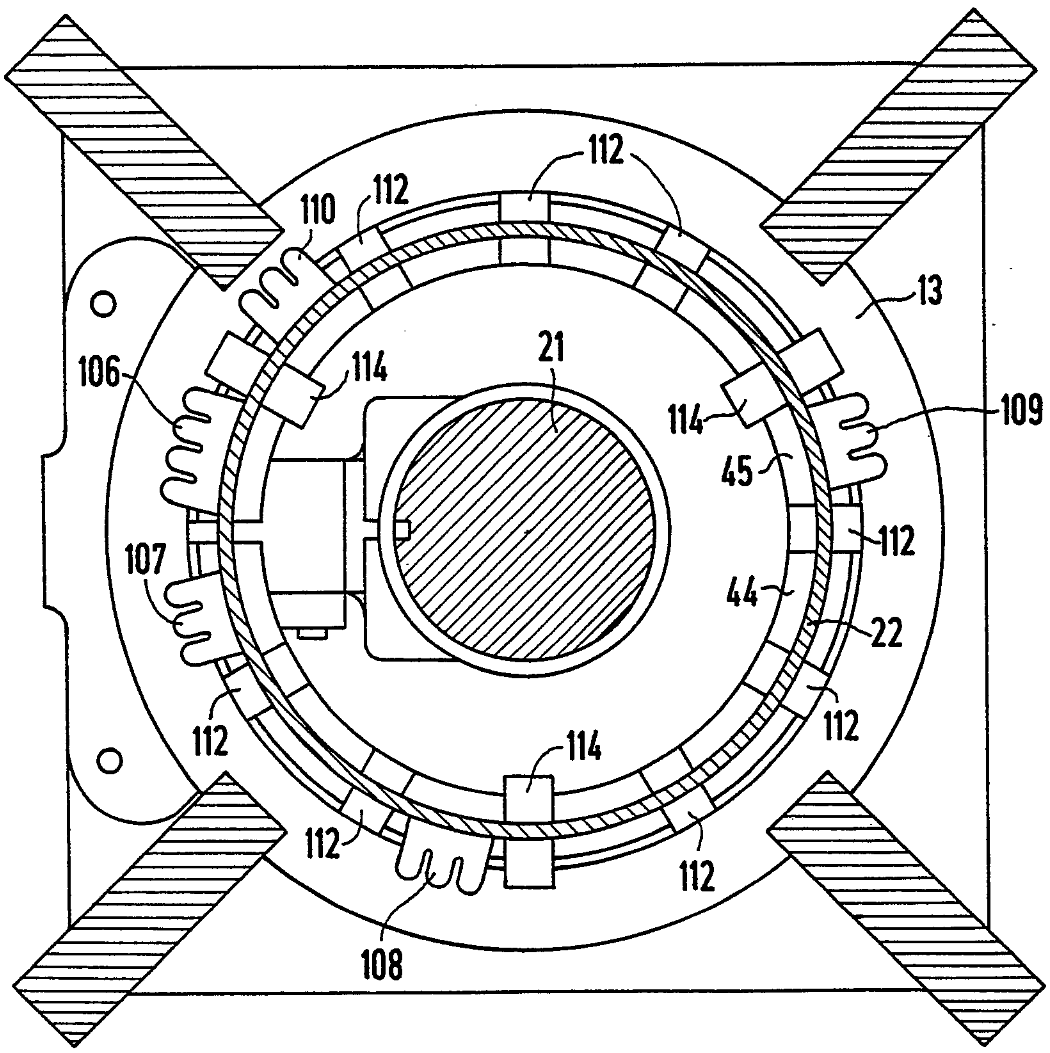

FIG 7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 10 7093

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-1 969 746 (GEBHARD) * Page 2, lines 31-131; figure 1 * ---	1	H 01 F 21/00
A	FR-A- 904 098 (PHILIPS) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			H 01 F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16-07-1988	BIJN E.A.

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

EPO FORM 1503 03.82 (P0401)