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

(11) Publication number: **0 593 768 A1**

(12) EUROPEAN PATENT APPLICATION published in accordance with Art. 158(3) EPC

(21) Application number: **92915517.4**

(22) Date of filing: **26.06.92**

(86) International application number: **PCT/RU92/00131**

(87) International publication number: **WO 93/21648 (28.10.93 93/26)**

(51) Int. Cl.5: **H01J 25/50**

(30) Priority: **15.04.92 RU 5043987**

(43) Date of publication of application: **27.04.94 Bulletin 94/17**

(84) Designated Contracting States: **DE FR GB IT**

(71) Applicant: **PROIZVODSTVENNOE OBIEDINENIE "PLUTON"**
ul. Nizhnaya Syromyatnicheskaya, 11
Moscow, 107120(RU)

(72) Inventor: **KOPYLOV, Mikhail Fedorovich**
pr. Mira, 118a-102
Moscow, 129164(RU)
Inventor: **BONDARENKO, Boris Vasilievich**
ul. Tsiolkovskogo, 2-14,
Moskovskaya obl.
Dolgoprudny, 141700(RU)
Inventor: **MAKHOV, Vladimir Iliich**
korp., 406-84
Moscow, 103498(RU)
Inventor: **NAZAROV, Viktor Alexandrovich**
Zagorievsky pr., 5-2-385
Moscow, 115547(RU)

(74) Representative: **W.P. Thompson & Co.**
Coopers Building,
Church Street
Liverpool L1 3AB (GB)

(54) MAGNETRON.

(57) A magnetron comprises an anode (1) and, coaxially mounted inside it, a cathode consisting of a rod (2) with elements located on its surface and providing for primary and secondary emission. The element providing for primary emission consists of at least one flat disk (3) of an ultrathin foil of a refractory metal with a central opening in it. The element providing for secondary emission consists of at least one cylindrical bushing (4) of an emission-active metal. The external diameter of the disk (3) is larger than that of the bushing (4) by a value within the range of 0.1 to 0.2 of the value of the interelectrode gap. The end faces of the neighbouring disk (3) and bushing (4) join each other. The invention, due to the creation of the electric field intensity needed for obtaining the autoelectronic emission sufficient for excitation of the magnetron, provides for the possibility of the instant start of the magnetron without the need for first heating the cathode.

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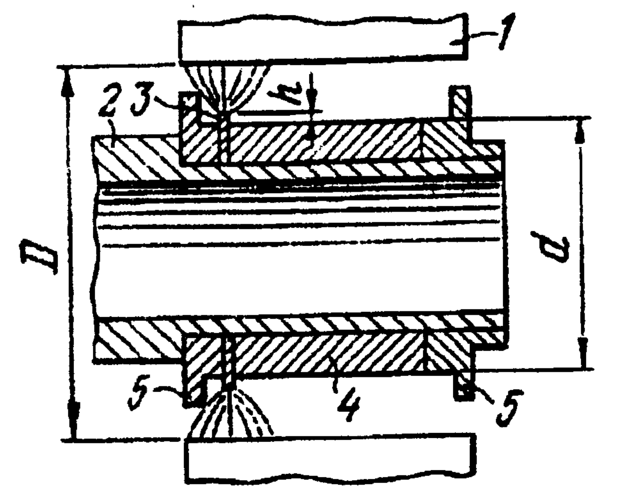

FIG.1

Technical Field

The present invention relates to microvawe electronic devices, particularly, to magnetron.

Background Art

Known in the art is a magnetron (US, A, 3109123), comprising an anode, a cathode, which has a portion of its surface made in the form of disks with sharp edges with a plurality of thin wires arranged thereon to concentrate the electric field. For the same purpose the magnetron is provided with screens of a special shape which are fed by different potentials relative to the cathode core. The magnetron without electric discharge process can not be excited only owing to the presence of sharp edges and a plurality of wires which fail to provide the necessary autoelectronic emission. Besides, it is not possible to obtain a stable field emission in the process of magnetron operation as the shape of the sharp edges changes and the so-called coefficient of shape factor is impaired, which results in the decrease of electric field intensity.

There is also known a magnetron (FR, A, 1306999) comprising an anode and a cathode arranged coaxially inside the anode and made in the form of a rod whose surface is provided with alternating elements enabling primary and secondary emissions. Besides, the elements ensuring the primary and secondary emissions in the magnetron are made on the cathode surface in the form of alternating strips of emission-active substances providing, respectively, for the primary and secondary emission.

In this case, the value of the electric field intensity is not indicated on the elements ensuring the primary emission, which is necessary for field excitation of the magnetron. Calculations of the electric field on the cathode for the millimeter and centimeter-band magnetrons with the anodic voltage ranging from units of kilovolts to several dozens of kilovolts testify that the value of the electric field intensity does not exceed $5 \cdot 10^5$ V/cm, whereas the value of the electric field intensity required for the field emission should be in the order of 10^7 V/cm at minimal efficiency of the emitting element. So, the electric field intensity of $5 \cdot 10^5$ V/cm is not sufficient for the cold emission and, therefore, a coating in the form of stripes or rings, parallel or perpendicular to the cathode axis and intended for the emission of electrons, can not ensure the field emission necessary for initiating the magnetron. The presence of two different coatings ensuring the emission of electrons in a cold state and the secondary electron emission can not be stable during the time of the magnetron operation as the active substance is transferred from the cathode to the anode and vice versa and, as a result, a homogeneous mixed coating is formed all over the surface of the cathode. So, the field (cold) excitation of the magnetron is not ensured. In the case of probable field excitation of the magnetron caused by electric discharge processes, the cathode surface coated with emission-active substances rapidly deteriorates as a result of its bombardment by negative ions. Thus, the given magnetron does not ensure an instantaneous firing (with the first pulse) without preliminary heading-up the cathode and without transmission of an input (exciting) signal and can not be reliable and durable.

Disclosure of the Invention

The invention resides in providing a magnetron whose design and production technology, as well as respective selection of compatible materials of the elements ensuring the primary and secondary emission would allow instantaneous firing (with the first pulse) without preliminary heating-up of the cathode, increasing the service life and improving reliability of the magnetron proper and of the switching device in which the magnetron operates, owing to the provision of the electric field intensity, necessary for obtaining the field emission sufficient in value for exciting the magnetron.

The foregoing object is attained by that in a magnetron comprising an anode and a cathode installed coaxially inside the anode and made in the form of a cylindrical rod with alternating primary-emission and secondary-emission elements arranged on its surface, according to the invention, the primary-emission and the secondary-emission elements are made, respectively, in the form of at least one flat disk manufactured from a superfine foil of a refractory metal and provided with a central hole, and at least of one cylindrical bush manufactured from an emission-active material, installed coaxially, the external diameter of the flat disk exceeding that of the cylindrical bushing by a value of 0.1 to 0.2 the value of the interelectrode gap, and the end faces of the adjacent disk and cylindrical bushing adjoin each other.

Such an arrangement of the flat disk with respect to the cylindrical bush ensures sufficiently high concentration of the electric field on the disk edge owing to coefficient β of the shape-factor and reliable excitetion of the magnetron. The central hole provided in the flat disk and coaxial installation of the disk and cylindrical bush provides for a uniform projection of the primary-emission element over the surface of the secondary emission element all around the circumference. If the external diameters of the primary-emission elements are made larger than those of the secondary-emission elements by a value greater than 0.2 the interelectrode gap value, the primary-emission element finds itself outside the space charge cloud and deteriorates. Besides, an unstable operation of the magnetron in the form of sparking takes place. If the projecting portion of the primary-emission element is less than 0.1 the value of the interelectrode gap, the preset value of the electric field intensity required for obtaining the field emission can not be ensured.

Thus, the embodiment of the primary-emission and secondary emission elements in the predetermined form and from the predetermined materials, and the provision of the electric field intensity necessary for obtaining the field emission sufficient in value, ensure the magnetron excitation and its instantaneous firing (with the first pulse) without preliminary heating-up of the cathode, increase of the magnetrom service life and improved reliability, as well as reliable operation of the transmitting device in which the magnetron is utilized.

It is advantageous that the primary-emission element should be made in the form of five flat disks and the secondary-emission element, in the form of four cylindrical bushes manufactured from an emission-active material.

The presence of a great number of flat discs decreases the distance between them and reduces the electric field intensity due to mutual shunting of adjacent flat disks.

It is expedient that the end faces of each cylindrical bush be in the form of a truncated cone whose smaller base adjoins the end face of the respective flat disk and the greater base diameter serves as the external diameter of the cylindrical bush.

As the secondary-emission elements adjoin on two sides the end faces of the primary-emission elements, an annular groove is formed with the end faces made in the form of a truncated cone. The annular groove decreases the screening effect of the secondary-emission element, thus increasing the electric field intensity.

It is also advantageous that the end faces of the adjacent flat disk and cylindrical bush should adjoin each other through a flat cylindrical protective washer made of a thin refractory metal foil, the thickness of the flat cylindrical protective washer being at least five to ten times greater than that of the flat disk.

The presence of protective washers makes it possible to eliminate deterioration of the primary-emission elements caused by mechanical and chemical effect on them of the secondary-emission elements. In this case, the protective washer manufactured from a superfine foil of a recractory metal, whose thickness is at least five to ten times greater than the thickness of the flat disk, ensures reliable protection of the disk against deterioration due to physicochemical processes taking place at the point of contact of the flat disk and the cylindrical bush.

It is advantageous that the primary-emission element should be manufactured from one of refractory metals, such as Ta, Nb and W.

The use of one of refractory metals Ta, Nb, W for manufacturing the primary-emission element makes it possible to stabilize the field emission.

It is advantageous that the primary-emission element should be manufactured from tungsten-and-tantalum alloy.

The use of alloys of refractory metals for the primary-emission elements makes it possible to stabilize the field emission and ensure their stable shapes.

The present invention makes it possible to attain an instantaneous initiating (with the first pulse) of the magnetron without preliminary heating-up of the cathode, to increase the service life of the magnetron and improve its reliability, as well as reliability of the transmitting device in which the magnetron operates owing to the provision of the electric field intensity necessary for obtaining the field emission sufficient in its value for the magnetron excitation. The claimed invention allows creating filamentless magnetrons with the field excitation in two- and three-centimeter and millimeter bands for high-frequency pulses of different power. These magnetrons are characterized by their instantaneous settling (first pulse readiness), high reliability and durability exceeding ten thousand hours, a possibility of fast change from the small pulse ratio mode to the great pulse ratio mode and vice versa, a high economical efficiency due to the absence of the power consumption in the filament circuit. The use of such magnetrons in transmitting devices makes it possible to essentially simplify their circuits and decrease their overall dimensions and weight, since approximately fifty radio components are excluded from their circuits.

Brief Description of Drawings

The invention will now be described further with reference to specific embodiments thereof, taken in conjuction with the accompanying drawings wherein:

Figure 1 is a general view of a magnetron, its working part, comprising one primary-emission element and one secondary-emission element, a longitudinal sectional view according to the invention;

Figure 2 is a general view of a magnetron, its working part, comprising one flat disk and two cylindrical bushes, a longitudinal sectional view;

Figure 3 is a general view of a magnetron, its working part, comprising five flat disks and four cylindrical bushes, a longitudinal sectional view;

Figure 4 is a view of a magnetron section illustrating the components of the elements ensuring the secondary emission, whose end faces are shaped as a truncated cone, a longitudinal sectional view;

Figure 5 is a view of a magnetron section illustrating one flat disk and the components of two secondary-emission elements whose end faces have the shape of a truncated cone, and protective washers, a longitudinal sectional view;

Figure 6 is a general view of a magnetron, its working part, comprising three flat disks and two cylindrical bushes adjoining each other through protective washers, a longitudinal sectional view.

Preferred Embodiment of the Invention

The magnetron, its working part, comprises an anode 1 (Figure 1) and a cathode installed coaxially inside the anode and made in the form of a cylindrical hollow rod 2 with primary-emission and secondary-emission elements, arranged on its surface, their end faces adjoining each other. A primary-emission element is made in the form of at least one flat disk 3 provided with a central hole and made of a superfine foil of a refractory metal. In the given case, the primary-emission element is made in the form of one flat disk 3 having the thickness ranging from fractions of micron to several microns and manufactured by stamping or electroerosion method. A secondary-emission element is made in the form of at least one cylindrical bush 4 manufactured from an emission-active material and installed coaxially with the disk 3 and rod 2. In the given case, the secondary-emission element is made in the form of one cylindrical bush 4. Used as secondary-emission elements may be impregnated cathodes and also the cathodes based on metal alloys including platinum group metals, such as Pt, Ir, Os, Ru, Rh, Pd with admixtures of activators in the form of one or several elements of alkali-earth metals (Ba, Sr, Ca). Two focusing screens 5 are arranged on, and coaxially with the hollow cylindrical rod 2, which may be made of molybdenum or other refractory metal or their alloys. One focusing screen 5 is installed on the side of the cylindrical bush 4 and the other focusing screen 5 is located on the side of the flat disk 3.

The external diameter of the disk 3 is greater than that of the cylindrical bush 4 by the value ranging from 0.1 to 0.2 the value of the interelectrode gap.

Figure 1 also illustrates:

h- the height of projection of the primary-emission element edge over the surface of the secondary-emission element;

d - the external diameter of the secondary-emission element;

D - the diameter of the anode 1.

Schematically shown by dotted lines is the electric field concentration on the thin edge of disk 3.

Used as a functional section of the primary-emission element is its thin edge projecting over the surface of the secondary-emission element by height h. The height h is determined proceeding from the condition that it should be equal to or less than the effective size of the synchronous space charge cloud in the magnetron over the surface of the cylindrical bush 4 made of an emission-active material, and is expressed by the formula:

$$h \leq \frac{d}{2}\left(\sqrt{\frac{1}{1-2\frac{\omega_1}{\omega_2}}}-1\right) \qquad (1)$$

where d is the external diameter of the secondary-emission element;

ω_1 and ω_2 are the angular synchronous and cyclotron frequencies, respectively, with

$$\omega_1 = 2\pi\frac{f_0}{n}$$

where f_o is the generated frequency,

n is the number of the oscillation mode (for the "π"- type $n = \frac{N}{2}$ where N is quantity of magnetron resonators), and

$\omega_2 = \frac{e}{m} B,$

where e and m are, respectively, the charge and mass of the free electron and

B is the induction of the static magnetic field.

Values h in magnetrons of different designs usually constitute from 0.1 to 0.2 the value of the interelectrode cap which is equal to

$$\frac{D - d}{2}$$

where D is the diameter of the magnetron anode and d - the external diameter of the secondary-emission element.

The design of the magnetron working part illustrated in Figure 2 is similar to that illustrated in Figure 1, the only difference being that the magnetron shown in Figure 2 comprises two secondary-emission elements whose end faces adjoin the end faces of the disk 3. Besides, the focusing screens 5 are installed on the side of the other end faces of the secondary-emission elements.

Illustrated in Figure 3 is the working part of the magnetron comprising five flat disks 3 and four cylindrical bushes 4 whose design is similar to that of the working part of the magnetron shown in Figure 1. The only difference consists in that one focusing screen 5 (Figure 3) is installed on the side of the last disk 3. So, the primary-emission element can be made of several disks 3 depending on the type and design of the magnetron and also on the excitation current value. In the case when several disks 3 are installed, minimal distance between them, with a purpose of reducing their mutual screening, is determined as

$\ell = (4 - 6)\ h \qquad (2),$

where h is the height of the projecting edge of the disk 3 whose value is found from the formula (1). If this condition is observed, the starting current can be reduced by no more than 10% its maximum value representing a sum of currents of separate disks 3 without consideration of their mutual screening. The presence of five and more disks 3, if the longitudinal sizes of the anode 1 and, consequently, of the cathode allow this, makes it possible to essentially improve the reliability of the magnetron field excitation.

Shown in Figure 4 is a section of the magnetron working part demonstrating the end faces of the cylindrical bush 4 made in the form of a truncated cone whose smaller base adjoins the end face of the disk 3. In this case, the diameter of the cone greater base is an external diameter of the bush 4.

Figure 5 illustrates a section of the magnetron working part whose design is similar to that of the section shown in Figure 4. The only difference consists in that the end faces of the adjacent flat disks 3 (Figure 5) and bushes 4 adjoin each other through the flat cylindrical protective washer 6, each washer 6 being made of a thin foil of a refractory metal. The thickness of the washer 6 exceeds that of the disk 3 at least five to ten times. The washers 6 are made preferably of 15- to 30 μm thick tungsten.

The design of the magnetron working part illustrated in Figure 6 is similar to that of the magnetron working part shown in Figure 1. The only difference consists in that the magnetron represented in Figure 6 comprises three disks 3, two bushes 4 and four washers 6. Besides, the screens 5 are installed on the side of the first and the last disks 3 and the washers 6 are installed between the adjacent disk 3 and bush 4. The washers 6 are installed with a purpose of protecting the disks 3 from possible deterioration as a result of chemical and physical interaction with the material of the bushes 4. For example, if a tantalum foil is used as a primary-emission element and a palladium-barium alloy, as a secondary-emission element, the protective washer 6 made of tungsten can be installed.

The present magnetron operates as follows.

An anodic voltage is applied between the single-wire lead-in and the magnetron body (the lead-in and body are not shown in figures). The magnetron excitation current is ensured by the field emission from the primary-emission element edge directed towards the anode 1.

The field emission is caused by the strong electric field created by the applied anodic voltage (the difference in potentials between the cathode and anode 1). The electrons emitted by said element, accelerating and changing the direction of their movement under the action of the microwave electromagnetic field, get partially on the secondary-emission element and expell the secondary electrons which in their turn, multiplying in an avalanch-like manner, ensure the main operating currant of the magnetron.

Operation of the magnetrons shown in Figures 2 to 6 is similar to that of the magnetrons illustrated in Figure 1.

Thus, the present invention makes it possible to ensure an instantaneous starting of the magnetron with the first pulse without preliminary heating-up of the cathode owing to the provision of the electric field intensity required for obtaining the field emission sufficient in its value for excitation of the magnetron.

Industrial Applicability

The present invention can be used in radars, aircraft, sea ships, spacecraft, rockets, etc.

Claims

1. A magnetron comprising an anode (1) and a cathode installed coaxially in the anode and made in the form of a cylindrical rod (2) provided with alternating primary-emission and secondary-emission elements arranged on it, characterized in that the primary-emission and secondary-emission elements are made, respectively, in the form of at least one flat disk (3) manufactured from super-fine foil of a refractory metal and provided with a central hole, and at least of one cylindrical bush (4) of an emission-active material, installed coaxially so that the external diameter of the flat disk (3) exceeds the external diameter of the cylindrical bush (4) by a value ranging from 0.1 to 0.2 the interelectrode gap value and the end faces of the adjacent flat disk (3) and cylindrical bush (4) adjoin each other.

2. A magnetron, as claimed in Claim 1, **characterized** in that the primary-emission element is made in the form of five flat disks (3), and the secondary-emission element is made in the form of four cylindrical bushes (4).

3. A magnetron as claimed in any of Claims 1 and 2, characterized in that the end faces of each cylindrical bush (4) are shaped as a truncated cone whose smaller base adjoins the end face of the corresponding flat disk (3) and the diameter of the greater base is the external diameter of the cylindrical bush (4).

4. A magnetron as claimed in any Claims 1 and 2, **characterized** in that the end faces of the adjacent flat disk (3) and cylindrical bush (4) adjoin each other through a flat cylindrical protective washer (6) made of a fine foil of a refractory metal, with the thickness of the flat cylindrical protective washer (6) being at least five to ten times greater than the thickness of the flat disk (5).

5. A magnetron as claimed in Claim 3, **characterized** in that the end faces of the adjacent flat disk (3) and cylindrical bush (4) border on each other through the flat cylindrical protective washer (6) made of a fine foil of a refractory metal, and the thickness of the flat cylindrical protective washer (6) is at least five to ten times greater than the thickness of the flat disk (3).

6. A magnetron as claimed in any of Claims 1 and 2, **characterized** in that the primary-emission element is made of one of refractory metals, such as tantalum, niobium or tungsten.

7. A magnetron as claimed in Claim 3, **characterized** in that the primary-emission element is made of one of refractory metals, such as tantalum, niobium or tungsten.

8. A magnetron as claimed in Claim 4, **characterized** in that the primary-emission element is made of one of refractory metals, such as tantalum, niobium or tungsten.

9. A magnetron as claimed in any Claims 1, 2, 5, 7, 8, **characterized** in that the primary-emission element is made of tungsten-and-tantalum alloy.

10. A magnetron as claimed in Claim 3, **characterized** in that the primary-emission element is made of tungsten-and-tantalum alloy.

11. A magnetron as claimed in Claim 4, characterized in that the primary-emission element is made of tungsten-and-tantalum alloy.

12. A magnetron as claimed in Claim 6, **characterized** in that the primary-emission element is made of a tungsten-and-tantalum alloy.

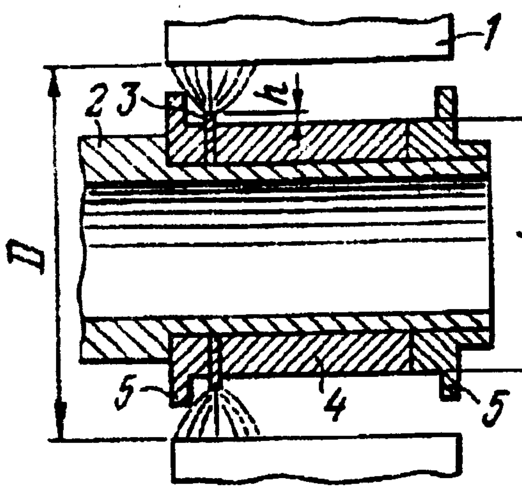

FIG.1

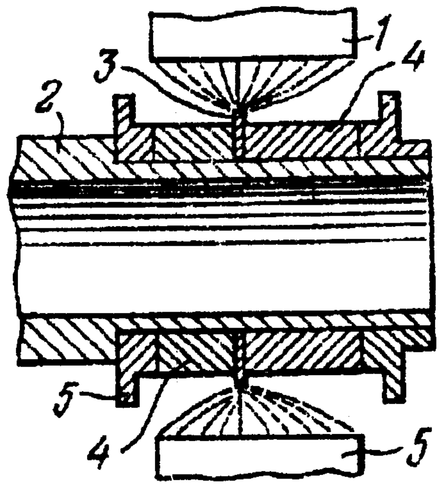

FIG.2

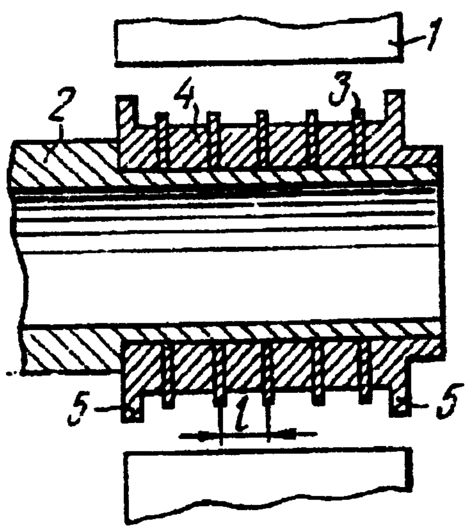

FIG.3

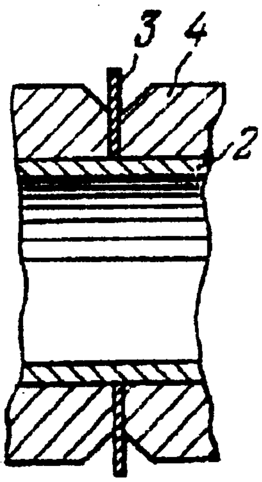

FIG.4

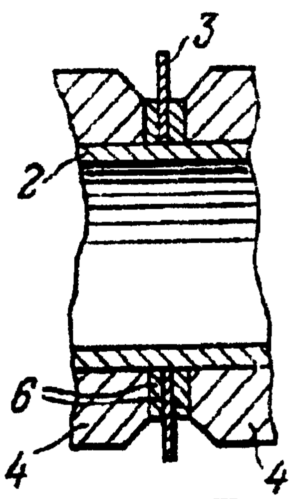

FIG.5

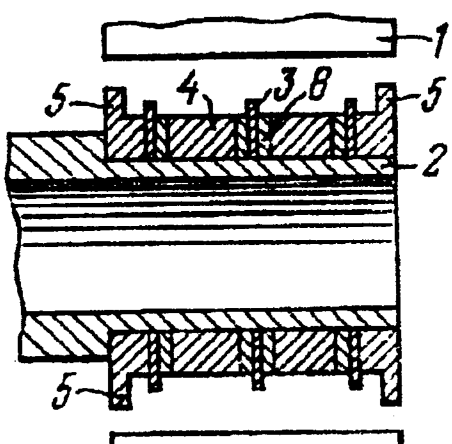

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 92/00131

A. CLASSIFICATION OF SUBJECT MATTER

IPC^5 H 01 J 25/50

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)

IPC^5 H 01 J 25/00, 25/02, 25/34, 25/50-25/55

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4380717 (ENGLISH ELECTRIC VALVE COMPANY LIMITED) 19 April 1983 (19.04.83), the abstract	1-12
A	US, A, 3297901 (LITTON INDUSTRIES, INC), 10 January 1967 (10.01.67)	1,2
A	DE, A, 1441243 (RAYTHEON COMPANY) 9 July 1970 (09.07.70), the claims, figures 1,2	1,2
A	FR, A1, 2539554 (VARIAN ASSOCIATES, INC) 20 July 1984 (20.07.84) figures 1-3	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"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	Date of mailing of the international search report
26 November 1992(26.11.92)	22 December 1992 (22.12.92)
Name and mailing address of the ISA/ RU	Authorized officer
Facsimile No.	Telephone No.