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(71) Applicant: **FOR.E.M. S.p.A.**
Via Archimede 22/24
I-20041 Agrate Brianza (Milano)(IT)

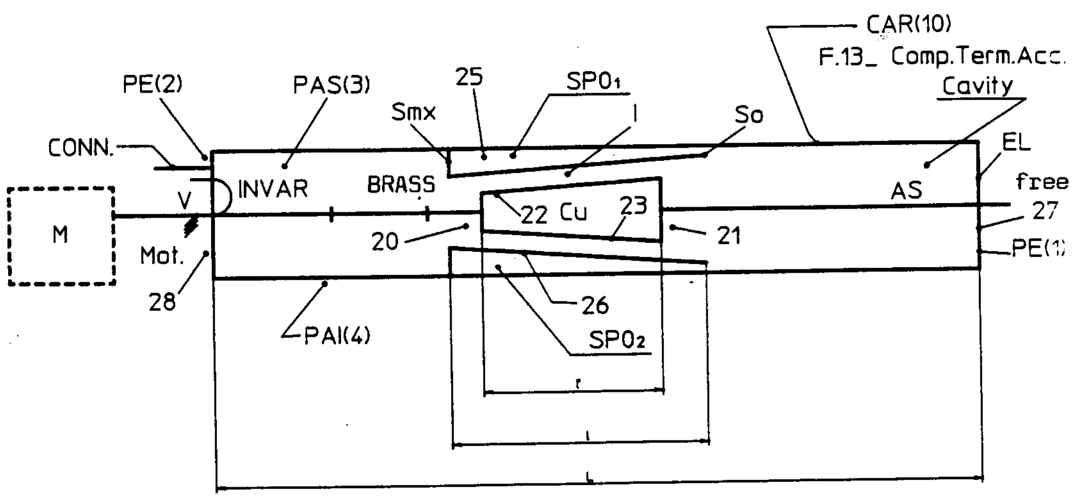
(72) Inventor: **Bandera, Mario**
Via Garibaldi 4
I-20040 Carnate(IT)
Inventor: **Tansini, Vittorio**
Via Postumia 30
I-20153 Milano(IT)
Inventor: **Sala, Antonio**
Via G. di Vittorio 13
I-20041 Agrate Brianza(IT)

(74) Representative: **Incollingo, Italo**
Piazzale Lavater, 3
I-20129 Milano (IT)

(54) Thermal compensation of wave guide resonant cavities.

(57) In a wave guide resonant cavity (CAR) formed of f.i. six walls, at least one of which (PE (2)) carries input and output connectors (CON. I, CON.U) and coupling loops (LO), a variable capacity (Cv) is created by displacement of a nucleus or wedge (Cu) on a rodshaped support (AS) which extends along the cavity whole major axis and is free to expand at one end (PE (1)). The maximum value of capacity (Cv) is reached at the maximum displacement of the wedge (Cu) towards said wall (PE(2)) carrying connectors and loops.

Fig.2



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The present invention refers to a method and system for the compensation of wave guide resonant cavites, more particularly to a system for the compensation of the thermal effects on the cavity characteristics and for the conservation of the band-width at varying tuning frequencies.

The invention comprises the microwave resonant cavities so obtained, with compensation of the resonance frequency and also of the magnetic coupling and of the band-width.

PRIOR ART

The wave guide cavities are largely used as resonators and filters when the microwave signal powers are high and cannot therefore involve dielectric containing cavities.

It is known that thermal excursions can cause deleterious effects on the working and on the characteristics of resonant cavities and affect the resonant frequency in an prohibitive measure. The problem is so important that the manufacturers have to use special materials with very low thermal coefficients, which are however very expensive and often are very difficult to be machined and/or formed. The well known alloys INVAR and SUPER-INVAR are to be recalled among the various precious materials. To restrict the use of such expensive materials, compensation systems have been suggested which can be adopted in combination with poor materials so to maintain the excursions of the resonant frequency and of the band-width within acceptable (even if not entirely satisfactory) limits.

For instance, one of these systems foresees the use (especially in the dielectric cavities) of several materials with different thermal expansion coefficients, located however in such a way to cause a compensation of the expansions.

Just to fix the ideas, one of the most immediate solutions of the prior art is represented in fig. 1 which is a schematic and partial cross-section showing a wave guide cavity CAR (10) delimited by major longitudinal upper PAS (3) and lower PAI (4) walls at a distance H from each other, and by minor transversal and walls PE (1) and PE (2) at a distance L.

The resonant cavity CAR is tuned wilh the help of a variable capacity Cv formed of a rod AS which can assume a variable penetration. At increasing penetration P and therefore capacity Cv, decreases the cavity tuning frequency Fs.

The rod penetration P is regulated by means of a screw VI which is fixed through a bolt D to a cylinder CI soldered to the cavity CAR (10). The thermal compensation is based on the difference between the expansion linear coefficient of the rod AS and of the support cylinder CI. At increasing temperature, as the cylinder undergoes an expansion higher than that of the rod AS, the end of this rod reduces its penetration into the cavity causing a decrease of the capacity of Cv and therefore a tuning frequency increase which compensates the natural decrease caused by the cavity linear dimension increase.

The above frequency compensation can be perfect at one frequency but can be maintained with acceptable characteristic only in one frequency restricted band because of the strong non-linearity between the tuning frequencies Fs and the rod penetrations P into the cavity. Indeed when the frequency decreases, at a parity of frequency variations ΔF, correspond always minor introductions P of the rod; all this causes an over compensation at the lower frequencies and a subcompensation at the higher frequencies.

An other inconvenience of the above described system resides in the big encumbrance of the cylinder/rod device which has a body outside the wave guide cavity. Moreover said tuning system is not able to develop a frequency variable action on the cavity coupling elements because the mutual distance does not vary at the different frequencies. This concept will be better clarified in the course of the invention description .

First object of the present invention is to provide a method and system which do not show the above mentioned drawbacks and allow the obtainement of an optimal and easy tuning and of a contemporaneous compensation concerning not only the resonant frequency but also the band width and the coupling.

An other object is to provide wave guide resonant cavities with a compensation device having a body moving along the longitudinal axis and substantially within protuberances projecting from the cavity major walls, and an organ of support and control of the translation and position of said body over said protuberances, said organ extending on substantially the whole internal length of the cavity and imparting displacements to said body only on the basis of its thermal variations.

These and other objects are reached with a variable capacity obtained trough longitudinal displacements. In a simple advantageous and therefore preferred embodiment, the system according to the invention comprises:

a) stationary means provided on and projecting from at least one of the cavity major walls, said means having a longitudinal extension "l" which is small over the length "L" of said major walls;

b) means movable over said means a) projecting from said walls;

c) means which extend on the whole length L within the cavity and carry said movable means b) imparting them displacements proportional to their thermal excursion; and

d) means to form a fixed stationary constraint at one end of said means c) -

In one embodiment of the invention, the means a) projecting from the two major faces towards the cavity internal space have a thickness variable from Smx to So over a length "l", and the means b) have a major base in correspondence to the minimal thickness So and a minor base in correspondence to the maximal thickness (Smx), the distance between said major and minor bases being equal to "l".

In a preferred embodiment of the invention, the means a) have the form of a pole shoe and the means b) nave the form of a cylinder showing therefore a constant diameter on the length "l".

The various features and advantages of the invention will better appear from the following description of the non-limitative embodiments shown in the accompanying drawings, in which:

- figures 2 and 10 are schematic frontal views of the wave guide cavity embodying the compensator according to the invention;
- fig. 3 is a top view of the cavity of fig. 2;
- figures 4, 7 and 7A are equivalent schemes of the cavity incorporating the compensator;
- fig. 4A is a diagram;
- fig. 5 is a front view similar to that of fig. 2 but restricted to a compensation system portion shown on an enlarged scale;
- fig. 6 is an equivalent scheme of the prior art solution;
- figures 8 and 8A are plan respectively cross section views of a compensator formed of rectangular elements, and
- fig. 11 is a lateral view of a double cavity with two compensators of the type of fig. 10.

In the drawings the reference CAR (10) indicates a resonant cavity in the form of a wave guide, schematically defined by two minor end walls PE(1), PE(2) and two major upper PAS(3) and lower PAI(4) walls; to one of the two end walls, f.i. to PE(2) are associated the input and output connectors CON I (6) respect. CON U (5) with the relevant loops LO I(7), LO U (8).

In the central zone of the cavity CAR (10) is located the compensation system according to the invention COMP(11) (figures 2,3,8A, 10 and 11), which generally comprises:

a) at least one, preferably two (as shown in the figures 2,8A, 10 and 11) protuberancies, thickenings or projections SPO_1, SPO_2 provided on the two major faces PA(3) and PAS (2) and having a longitudinal extension "l" small over the length L of said major faces or walls;

b) a wedge Cu, CUC and CUC' respectively in the figures 2, 10 and 11 which is movably inserted between said protuberances and has a length "l'" equal or different from "l";

c) a rod AS extending on the whole length L and carrying fixedly the wedge Cu, and

d) a constraint V at one end of road AS which cannot move at this end whereas at the other end EL it is free to undergo dimensional excursions under the effect of thermal variations.

In fig. 2 the wedge Cu and the projections SPOi are trapezoidal but they can be parallelepiped f.i. rectangular as in figures 8 and 8A or cylindrical as in the figures 10 and 11. In fig. 2 said wedge Cu has a terminal minor face 20 f.i. in correspondence to the maximal projection Smx and a terminal major face 21 in correspondence to the terminal protrusion So; the wedge has its two major surfaces 22 and 23 extending parallel to the major faces 25 and 26 of projections SPO_1 and SPO_2 over a length "l". In figures 8 and 8A wedge Cu is parallelepiped wilh equal faces 20 and 21; accordingly also the SPO_1 and SPO_2 have an equal height. In fig 10 the wedge CUC is a cylinder body; the SPO_1 and SPO_2 have the shape of a pole shoe.

A rod AS carries Cu, said rod being free at the end EL (passing thus through the wall PE(1)) but being blocked at the end 28 where it can be activated manually or wilh the help of a motor for tuning purposes. An air gap I exists between walls 22 and 23 of wedge Cu and the facing walls 25 and 26 of the projections SPO_1 and SPO_2.

Referring to the equivalent scheme of fig. 4, cavity CAR (10) has a resonant frequency which, in a resonator of the $\lambda/2$ type and in the absence of compensator COMP, occurs at $L = \lambda/2$ where L is the length of CAR.

The compensator COMP corresponds to an additional capacity Cv which is clearly variable with the displacement of wedge Cu between protruberances SPO_1 and SPO_2, i.e. with the variation of the gap I (fig.5). If this gap I is Io in the position 1) of fig 5, it will assume values $Ii > Io$ as Cu is displaced by rod AS rightwards f.i. to the position 2 in said fig.5.

By varying gap I, vary the capacity Cv of compensator COMP and the capacity equivalent length "Le" in the sense that at increasing I (desplacement of Cu to the right) decreases Le because of the capacity Cv decrease. Let us consider the situation in the absence of compensator COMP: with increasing temperatures the resonant cavity CAR would expand by itself, i.e. its length $L = \lambda/2$ would increase and its resonant frequency Fr would decrease. By adopting compensator COMP and setting it, according to the invention, in such a way that to a natural increase ΔL of the length L and thus to a capacity reduction $-\Delta C$ caused by a temperature increase ΔT, corresponds a displacement of Cu rightwards and thus a gap increase ΔI

and consequently a reduction - ΔCv of the additional capacity such as to compensate the cavity thermal and dimensional variations wilh simple and effective means.

In the diagram of fig. 4A, curve 1 shows the natural behaviour of cavity CAR in the absence of compensation: at increasing temperature T (on the abscissa) L increases and accordingly the resonant frequency FR decreases (curve 2).

If now at increasing temperatures the rod AS desplaces the wedge Cu rightwards, i.e. gap I increases and decreases the capacity Cv added by compensator COMP with consequent frequency increase (curve 1), one succeeds in compensating substantially constantly the resonance frequency FR (curve 3) on which the wave guide cavity had been tuned.

Moreover the compensator according to the invention produces further surprising advantages. As known in the devices with movable elements it is important that the magnetc coupling between loops LOI, LOU and cavity be not altered. However in the compensation absence, when the resonant frequency decreases, the loop magnetic coupling and the resonator band-width decreases. One of the drawbacks of the prior art f.i. of the type of fig. 1, is that even if a compensator having a rod AS with variable penetration is able to increase or decrease capacity Cv and therefore decrease or increase the tuning frequency, it is however not able to produce any influence on the coupling degree.

This is due to the fact that rod AS is and remains always in a fixed position f.i. over the walls PE(1) and PE (2); i.e. the rod can move upwards or downwards along its axis Z-Z (fig. 6) but can not move perpendicularly to Z-Z. This limitation is schematically shown in fig. 6 where capacity Cv is indicated as a variable capacity but it cannot change its longitudinal position f.i. it cannot move in the position P indicated with dotted line.

According to an important feature of the invention, the value of the variable capacity is maximal (and thus the resonant frequency is minimal) just when the loop coupling must be increased and thus the distance of said capacity Cv from the loops LO is to be minimized so to have a coupling increased proportionally to the frequency decrease.

In fig. 7A the maximal capacity Cmx is shown just at a minimum distance Dmin from loop LO whereby the natural coupling decrease due to the frequency decrease is compensated by this. In fig. 7 also the other limit case is shown in which the minimal capacity Cmin is obtained at the maximal distance Dmax of wedge Cu from the end wall PE-(2) carrying the loops. As to this minimal capacity Cmin corresponds a resonance maximal frequency and thus a high natural coupling, the compensator wedge Cu is moved rightwards so to decrease its coupling with the loops and to compensate the coupling increase.

Consequently also the band-width is compensated and maintained substantially constant at varying frequency. Moreover these two beneficial surprising effects of the tuning frequency thermal compensation and of the coupling and band-widh compensation at varying resonant frequency do not have negative consequences on the insertion loss: indeed the whole compensator has big dimensions (especially over the conventional screws of fig. 1) and is flown by low density currents to which corresponds a negligible loss.

Besides the critical feature of the compensation of the coupling and of the band-width due to the approaching/departing of the compensator wedge from the loops, the invention has also involved the overcoming of a technical prejudice. Fig 9 schows the curve of the electric field between the walls of the cavity resonant in the most used mode TE 101. It is a half sinusoidal curve with a central maximum. This central position corresponds therefore to the maximal efficiency of the capacity inserted in the cavity and is thus normally adopted when it is desired to vary the frequency with a variable capacity placed in a fixed position.

If on the contrary the tuning is to be varied with a constant capacity placed in a position variable along the major length , the most convenient position is that nearest to the end walls because there occurs the major variation of the frequency.

Further in this position the maximal linearity in the correspondence between the capacity position and the tuning frequency occurs because the electric field sinusoidal characteristic is nearly linear in the proximity of zero. If the capacity is placed in the cavity center, no cavity tuning frequency variations correspond to the position variations because the electric field varies there too slowly. A frequency variation is obtainable also in this position if on the cavity walls are provided projections as in fig. 2 or wedges as in fig 8 or pole shoes as in figures 10 and 11. The corresponding nucleus to be moved must have the form of a prism, a wedge or a cylinder in said three cases to have a sufficiently linear tuning at varying position.

From the above it appears clearly that it is possible to tune the cavity with good linearity by placing the mobile wedge in any position. Consequently, at a substantial parity of linearity on the whole length it is possible and advantageous to choose the critical position to which corresponds the minor band-width variation at varying frequency.

By appropriately selecting the linear thermal expansion coefficient (s) of the control rod (f.i. by making the rod with material gradients e.g. in IN-

VAR on a length portion and in brass on an other length portion as in figures 2,3 and 10), it is possible to obtain a thermal compensation with a very wide frequency band thanks to the linearity made possible by the criterion chosen to vary the tuning.

To the advantage of the tunability band increase togheter with good thermal compensation must be added the other advantage of the minor encumbrance f.i. over fig. 1 because of the absolute absence of outer organs as the whole compensation system namely the rod and the relevant wedge are inside the cavity. As anticipated, in figures 10 and 11 a diplexer is shown with two compensators in which the protuberances SPO_1, SPO_2, resp. $SPO_{1'}$, and $SPO_{2'}$, have the shape of pole shoes and the wedges CUC are cylinders.

The important advantage is that, for small as for big rotations (generally casually occurrring during transportation after setting in the manufacture facilites) of rod AS around its longitudinal axis X-X (arrow F) the air gap between CUC and the polar shoe remains constant and therefore also the electric characteristics of the cavity are independent from the angular position of CUC over the pole shoe.

Claims

1. Method for the thermal compensation of resonant cavities in form of wave guides, closed and defined by at least six walls, on at least one PE(2) of which are provided connectors (CON) and relevant coupling loops (LOI, LOU), characterized in that along the whole major longitudinal extension (L) of the cavity (CAR) a rodshaped element (AS) is placed which is fre of constraints at one (EL) of its ends and shows on its minor extension (l') gradients of thickness, composition and capacitative coupling with at least one of said cavity forming walls.

2. Method according to claim 1, characterized in that further analogous gradients are generated also on the cavity longitudinal walls, substantially in correspondence of said minor extension (l').

3. System of the thermal compensation of resonant cavities in form of wave guides, comprising at least:
   i) two walls (PAS_3, PAI_4) which are parallel and symmetrical over the longitudinal axis of the cavity and have a length L and a transversal distance H;
   ii) two end walls (PE_1. PE_2);
   iii) input and output connectors (CON I, CON U) with relevant loops LOI, LOU of coupling with the cavity, charaterized in that on an extension "l" lower than L, a variable capacity is created by moving longitudinally a nucleus or wedge over portions of said walls, said wedge undergoing longitudinal translations under the action of the thermal variations of a support element extending on the whole length L, the maximum value of said capacity being obtained with the maximum displacement of said nucleus towards the wall carrying the coupling loops associated to said connectors.

4. System according to claim 3, characterized in that the nucleus is parallelepiped and the longitudinal walls are provided with protuberances projecting inside the cavity.

5. System according to claim 3, characterized in that the wedge is cylindrical and the protuberances projecting from the walls have the shape of a pole shoe.

6. System according to claim 3, characterized by:
   a) means provided on and projecting from two major, each other facing, cavity forming walls which protrude inside the cavity with a thickness variable from a maximum Smx to a minimum So thickness value on a length portion "l" generally small over the length L of the major walls;
   b) means inserted between said projecting means having a trapezoidal form with a major base corresponding to said protuberance minimal thickness (So) and a minor base corresponding to the maximal protuberance (Smx) of means a), the distance between said major and minor bases being substantially equal to "l";
   c) means to carry and guide longitudinally means b) between means a) so to vary the gap (l) between said means a), and
   d) means to form a fixed stationary constraint at one end of means c) which are free, i.e. not constrained at the other end.

7. System according to claim 6, charaterized in that the means a) are ribs with variable projection to the cavity inside, and the means b) have the form of a trapezoidal wedge with minor base in correspondence to the maximum projection points of a) and with major base in correspondence to the minimal projections, and means c) have the form of a rod.

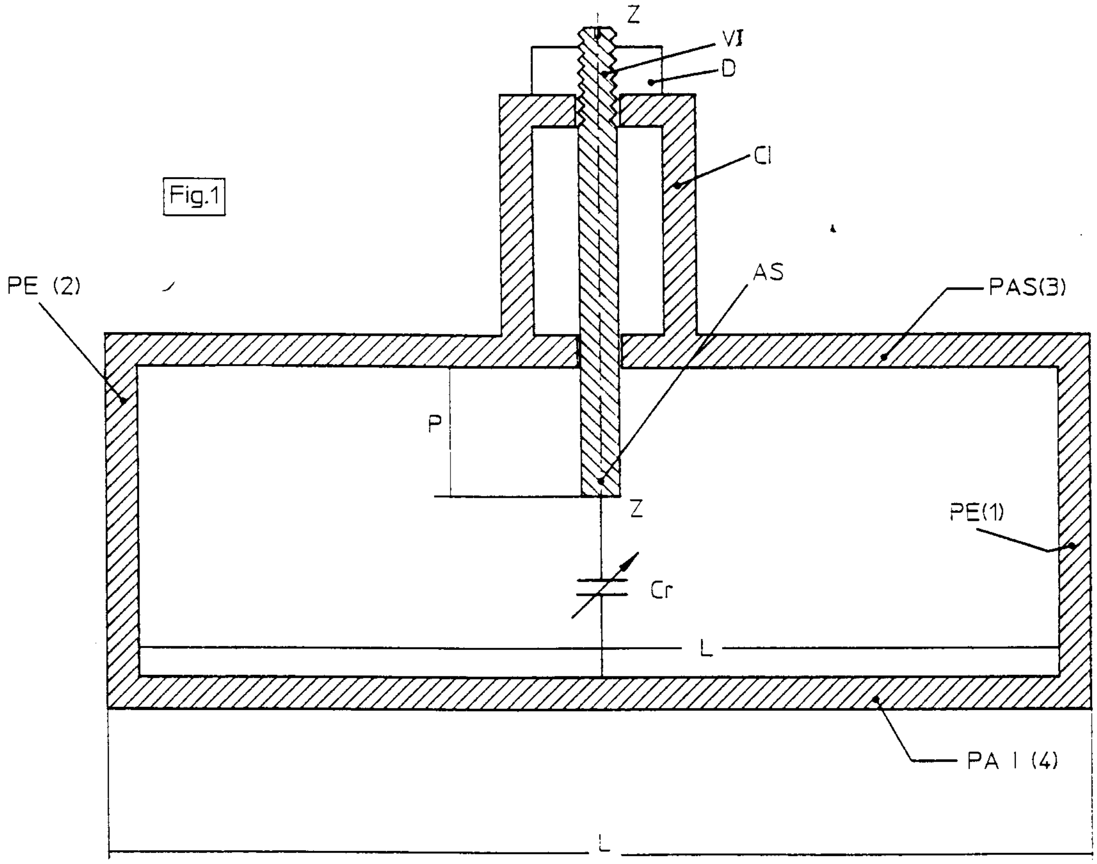
8. System according to claim 3,4,5 or 6, characterized by additional means (manual or motor) placed at the terminal d).

9. System according to at least one of claims 3 to 8, wherein the cavity is substantially made of not precious material of thermal expansion low coefficient.

10. System according to claims 3, 4, 5 or 6, wherein the projecting ribs, the wedge and/or the rod are also made of not precious materials having equal or different thermal expansion coefficients.

11. System according to at least one of the claims from 3 to 10, characterized in that the displacement of the nucleus or wedge is carried out in such a way that said wedge is brought near the wall carrying connectors and loops when said additional capacity is high (the temperature is low) increasing thereby the coupling between loops and cavity, and is taken away from said wall when said additional capacity is minimal.

Fig.1



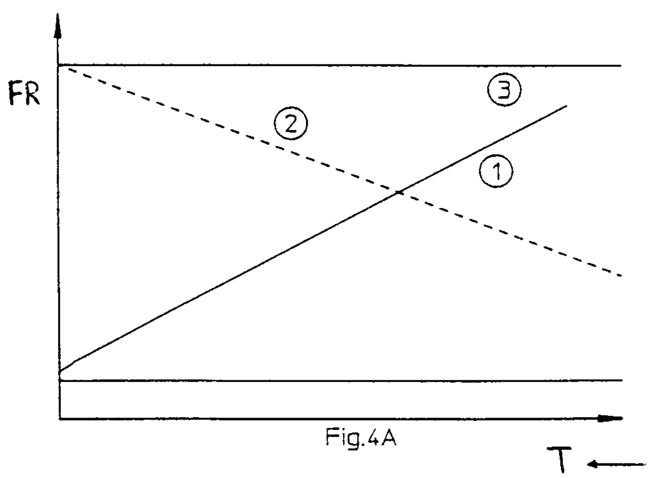


Fig.4A

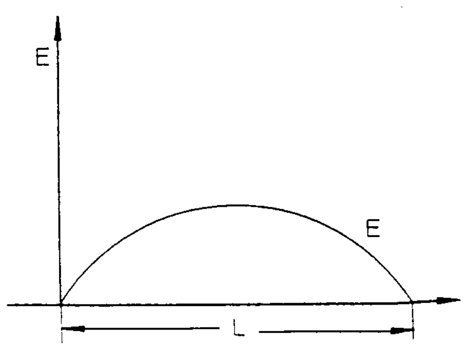


Fig.9

Fig.2

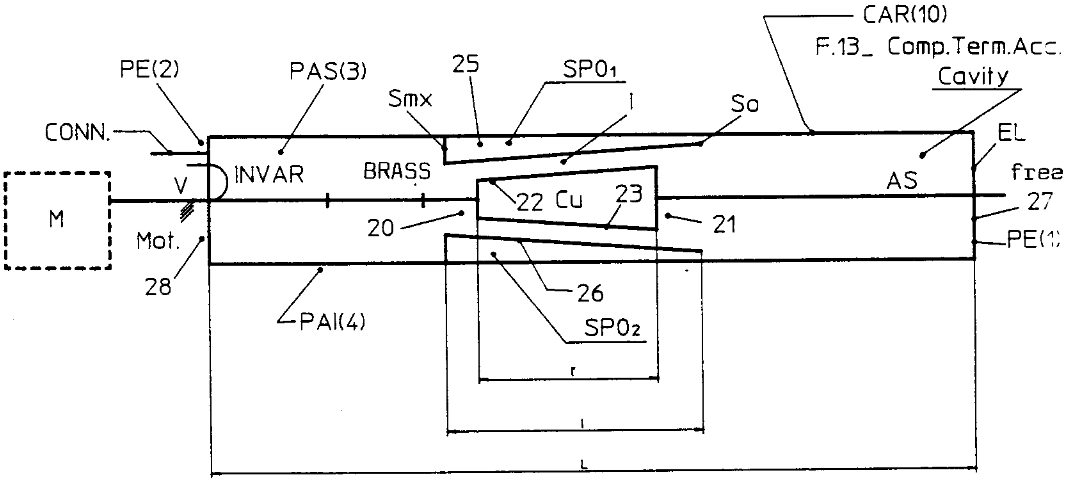


Fig.3

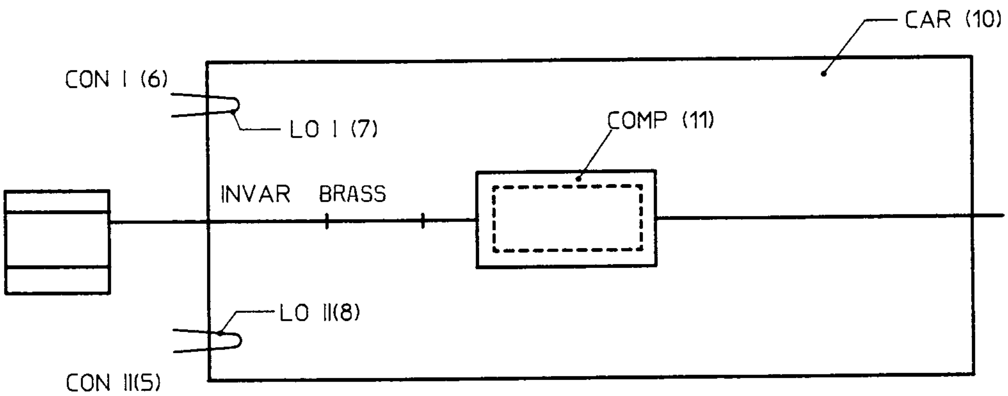


Fig.4

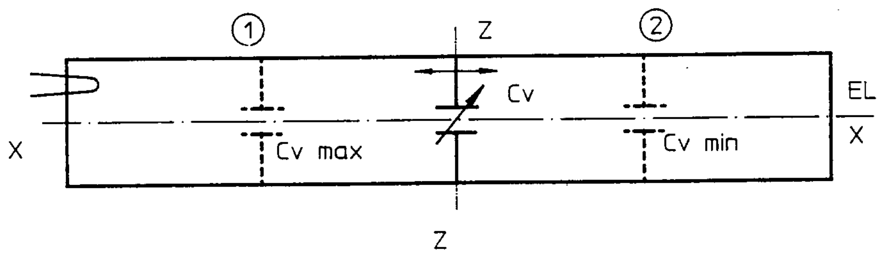


Fig.5

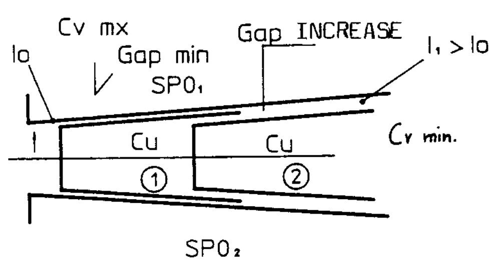


Fig.6

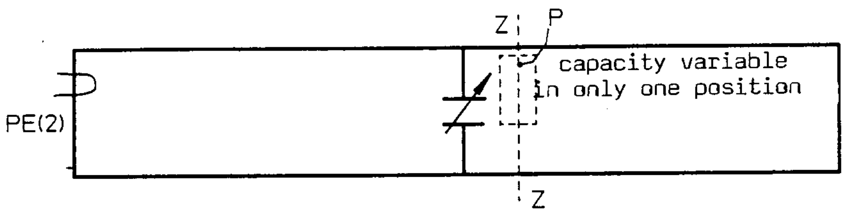


Fig.7A

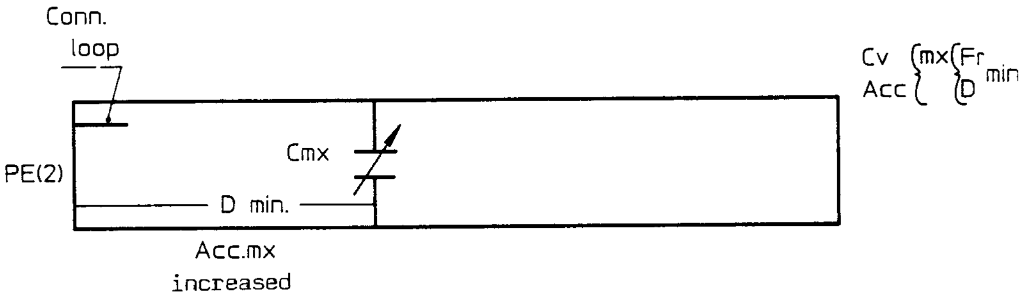


Fig.7

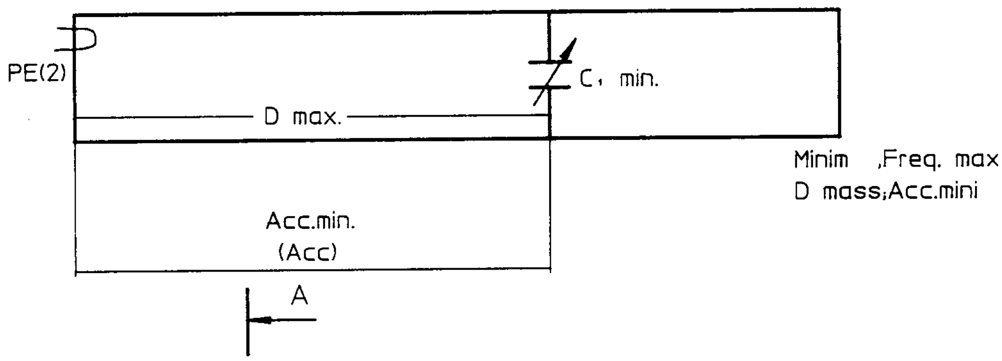
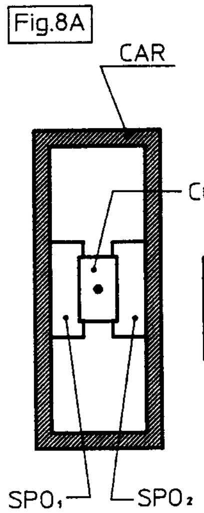


Fig.8A



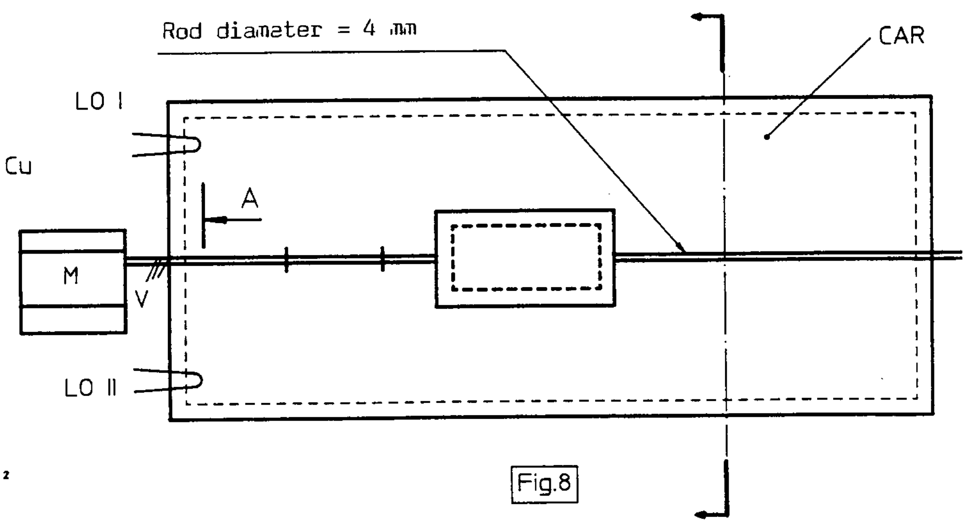


Fig.8

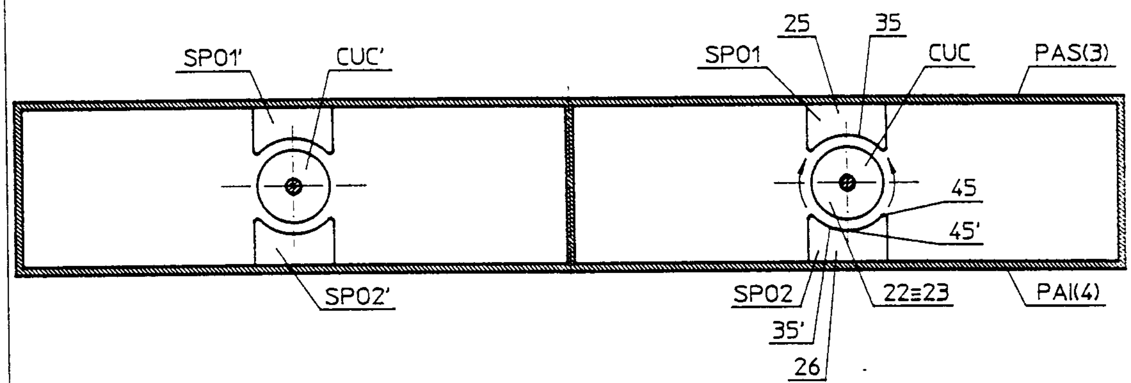

SPO1'
CUC'
SPO2'
25
35
SPO1
CUC
PAS(3)
45
45'
SPO2
22≡23
PAI(4)
35'
26

Fig.11

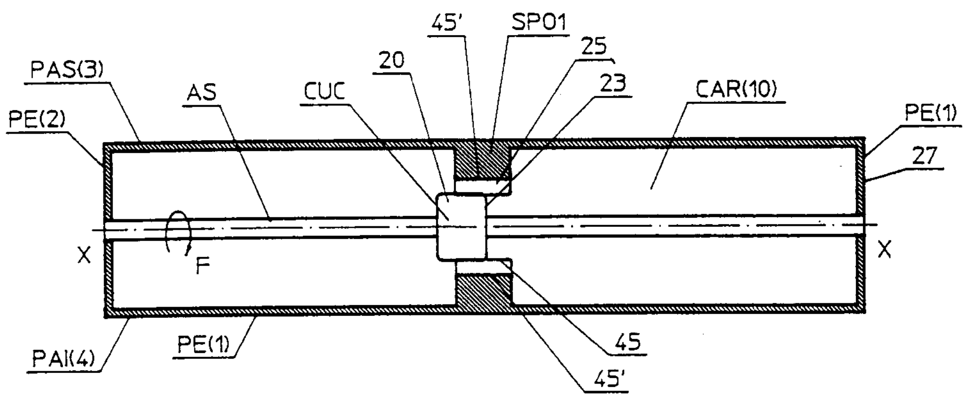

45'
SPO1
25
20
23
PAS(3)
AS
CUC
CAR(10)
PE(2)
PE(1)
27
X
F
X
PAI(4)
PE(1)
45
45'

Fig.10