



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.11.2000 Bulletin 2000/45

(51) Int Cl.7: **B06B 1/06, B08B 3/12**

(21) Application number: **99810540.7**

(22) Date of filing: **18.06.1999**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**
Designated Extension States:
AL LT LV MK RO SI

• **Islan Suntex Corporation**
Kyungki-do (KR)

(72) Inventors:
• **Miodrag Prokic**
2400 Le Locle (CH)
• **Lee, Hee-Myoung**
Kunpo-shi, Kyungki-do (KR)

(30) Priority: **03.05.1999 KR 9915913**

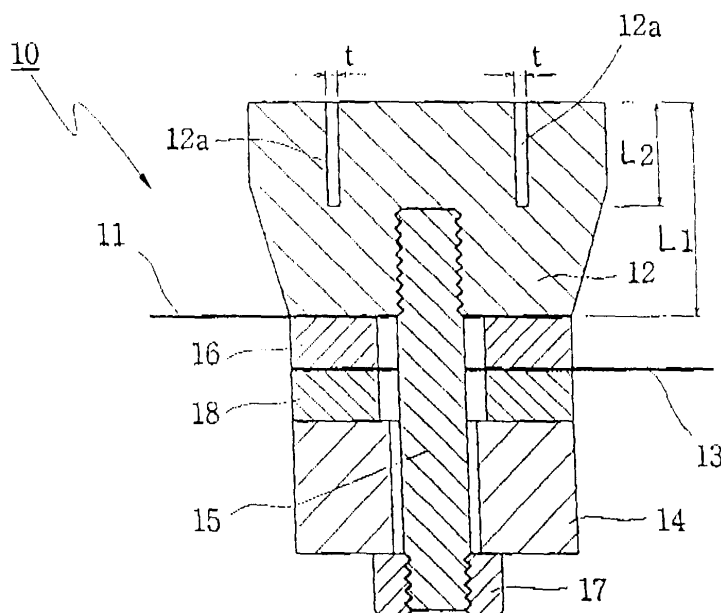
(71) Applicants:
• **Miodrag Prokic**
2400 Le Locle (CH)

(54) **Ultrasonic transducer**

(57) The present invention deals with an ultrasonic transducer mounted on the bottom or side surface of the cleaning tank of an ultrasonic cleaner. The ultrasonic transducer of the present invention includes: piezoelectric ceramics, electrodes for applying power to the piezoelectric ceramics, masses to be vibrated by the piezoelectric ceramics, a fastening means with a stud and

a nut, and the front mass with various geometry vertical slits on its upper surface. The front mass has the recesses (vertical slits) on its top surface in order to improve the longitudinal mechanical quality factor ("Q_{meff}") of piezoelectric ceramics determining the cleaning efficiency of the ultrasonic cleaner. Preferably, the width of the recesses is 1 ~ 2 mm and the depth is 1/3 ~ 1/2 of the longitudinal length of the front mass.

FIG. 1



DescriptionFIELD OF THE INVENTION

[0001] The present invention relates to an ultrasonic transducer mounted onto the bottom or side surface of a cleaning tank of an ultrasonic cleaner. Specifically, the present invention is an ultrasonic transducer including a front mass with slits on its top surface in order to improve the mechanical quality factor ("Q_{meff}") of piezoelectric ceramics, which in turn determines the cleaning efficiency of the ultrasonic cleaner.

BACKGROUND OF THE INVENTION

[0002] Ultrasonic transducers use piezoelectric or magnetostrictive effect converting AC energy over 20 kHz into mechanical energy of the same frequency. Such ultrasonic transducers are especially suitable for ultrasonic cleaning, high-power plastic welding, machining and liquid atomizing.

[0003] Moreover, the conventional ultrasonic transducer for cleaning is provided with the typical cleaning tank (or container) disclosed in US Patents No. 5,641,228 and 5,722,444. If power is applied to the ultrasonic transducer, then the cleaning liquid in the cleaning tank vibrates radially and longitudinally from the center of the ultrasonic transducer mounted on the cleaning tank, thus effecting the cleaning. Generally, the cleaning efficiency of the ultrasonic cleaner is determined by the mechanical quality factor ("Q_{meff}"), dealing with the longitudinal mode vibrations of piezoelectric transducers. The output power of the ultrasonic cleaner diminishes because the vibrations of piezoelectric ceramics are split in the longitudinal and radial mode vibrations. Besides, the longitudinal mode vibrations are attenuated by interference with the radial mode vibrations.

[0004] Furthermore, said radial mode vibrations cause erosion of the radiating rigid plate disclosed in US Patent No. 5,722,444 and the bottom wall of the cleaning container disclosed in US Patent No. 5,641,228.

SUMMARY OF THE INVENTION

[0005] The purpose of the present invention therefore is to present an ultrasonic transducer which improves the mechanical quality factor ("Q_{meff}") of piezoelectric ceramics determining the cleaning efficiency of an ultrasonic cleaner.

[0006] In order to attain the above-mentioned objectives, the ultrasonic transducer is equipped with: an ultrasonic transducer mounted on the bottom or side surface of a cleaning tank of an ultrasonic cleaner, consisting of:

- a pair of piezoelectric ceramic rings having a hole
- a pair of electrodes positioned at the top surface of the upper piezoelectric ceramic and interposed between the upper and the lower piezoelectric ceramic respectively, which also form a through hole
- a front mass positioned at the top surface of the upper electrode, having a lower thread hole at the lower surface, and having an upper thread hole of the upper surface. They are fastened with the stud fixed to the bottom or side surface of the ultrasonic cleaner cleaning tank, where the front mass has various shape and geometry, vertical slits on the upper surface for improving mechanical quality factor of the piezoelectric ceramics.
- a back mass positioned at the bottom surface of the lower electrode having a through hole
- a means for fastening respective piezoelectric ceramics, electrodes, front and back mass.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The above objectives and advantages of the present invention will become more apparent when described in detail with reference to the attached drawings:

FIG. 1 is a cross-sectional view of an adhesive mounting type ultrasonic transducer according to one shape of the present invention;

FIG. 2 is a plane view of an ultrasonic transducer of FIG. 1;

FIG. 3a through 3f are plane views of ultrasonic transducers according to different forms of the present invention, similar to FIG. 1;

FIG. 4 is a cross-sectional view of a bolting mounting type ultrasonic transducer

FIG. 5 is a plane view of an ultrasonic transducer of FIG. 4;

FIG. 6a through 6c are plane views of ultrasonic transducers according to different shapes of the present invention, similar to FIG. 4 and 5;

FIG. 7a and FIG. 7b are graphs showing wide-band resonant characteristics of a bolting type ultrasonic transducer;

FIG. 8 is a vertical cross-sectional view of the ultrasonic transducer in FIG. 1 mounted on a cleaning tank; and FIG. 9 is a vertical cross-sectional view of the ultrasonic transducer in FIG. 4 mounted on a cleaning tank.

DETAILED DESCRIPTION OF THE PREFERRED SHAPES

[0008] FIG. 1 to 9 illustrate the preferred shape of the ultrasonic transducer according to the present invention. Referring to FIG. 1, an adhesive mounting type ultrasonic transducer 10 includes piezoelectric ceramics 16,18; electrodes 11,13 for applying power to the piezoelectric ceramics 16,18; masses 12,14 to be vibrated by the piezoelectric ceramics 16,18; and a fastening means having a stud 15 and a nut 17.

[0009] The piezoelectric ceramics 16,18 and the electrodes 11,13 respectively have a through hole. The upper electrode 11 is positioned at the top surface of the upper piezoelectric ceramic 16, and the lower electrode 13 is interposed between the upper piezoelectric ceramic 16 and the lower piezoelectric ceramic 18.

[0010] The front mass 12 has slits 12a at the top surface in order to improve the longitudinal mechanical quality factor ("Q_{meff}") of the piezoelectric ceramics 16,18 determining the cleaning efficiency of the ultrasonic cleaner and having a central thread hole at the lower surface. Specifically, the width (t) of the slits 12a is 1 ~ 2 mm and the depth (L2) is 1/3 ~ 1/2 of the longitudinal length (L1) of the front mass 12.

[0011] A fastening means is a stud 15 with threads on both ends and a nut 17. The upper electrode 11, the upper piezoelectric ceramic 16, the lower electrode 13, the lower piezoelectric ceramic 18 and the lower mass 14 are assembled into a sandwich type transducer by the stud 15 and the nut 17, and connected to the front mass 12.

[0012] It is important that the outer surface of the stud 15 should not be in contact with the inner surface of through holes of the piezoelectric ceramics 16,18, the electrodes 11,13 and the lower mass 14. Furthermore, it is preferable that the outer surface of the piezoelectric ceramics 16,18 be coated by insulating coatings.

[0013] In FIG. 1 and 2, the upper mass 12 has a cylindrical shape and its upper section is larger than the lower section. The slits 12a are lattice shaped formed vertically and horizontally through the upper surface of the front, radiating mass 12. Besides, the vertical and the horizontal slits 12a are positioned at the same distance (α) from the center of the front mass 12. Furthermore, respective intersections of the slits 12a are positioned inside the circumference (hidden line) of the lower surface of the front mass 12.

[0014] In FIG. 3a to 3f, ultrasonic transducers include front masses 22,32,42 respectively, corresponding to various shaped recesses 22a,32a,42a at its upper surface. No further detailed description about the structure of the FIG. 3a to 3f is provided because the respective structures are equal to the structure of FIG. 1 and 2. except for the shape of the recesses (slits) 22a,32a,42a.

[0015] In FIG. 3a, the recesses 22a formed at the upper surface of the front mass 22 are slots in the shape of the sides of an equilateral triangle ($\theta_1 = \theta_2 = \theta_3$), and respective apexes of the recesses 22a are positioned at the edge of the upper surface of the front mass 22.

[0016] In FIG. 3b, the recesses 32a formed at the upper surface of the front mass 32 are cross-shaped slits; an intersection of the recesses 32a is positioned at the center of the upper surface of the front mass 32.

[0017] In FIG. 3c, the recesses 42a formed at the upper surface of the front mass 42 are a large number of holes, and are formed at respective circumferences of concentric circles; the center of the concentric circles is the center of the front mass. Here, the unexplained numbers 21,23,31,33,41,43 are electrodes and d is the width of the recesses (slits).

[0018] In FIG. 3d to 3f, ultrasonic transducers include front masses 52,62,72 of a regular rectangular shape.

[0019] In FIG. 3d, the recesses 52a formed at the upper surface of the front mass 52 are lattice shaped slots and are formed vertically and horizontally through the upper surface of the front mass 52. The vertical and horizontal recesses 52a are positioned at the same distance (β) from the edge of the front mass 12. Consequently, the areas divided by recesses 52a are the same ($S_1=S_2=S_3=S_4=S_5=S_6=S_7=S_8=S_9$).

[0020] In FIG. 3e, the recesses 62a formed at the upper surface of the front mass 62 are slots of rhomboid shape and respective apexes of recesses 62a are positioned at the edge of the upper surface of the front mass.

[0021] In FIG. 3f, the recesses 72a at the top surface of the front mass 72 are a large number of holes, formed at random on the upper surface of the front mass 72. The unexplained numbers 51,53,61,63,71,73 are electrodes and d is the width of the recesses.

[0022] In FIG. 4 and 5, the bolting type ultrasonic transducer 80 includes a front mass 82 forming a thread hole 89 at its upper surface. Here, no further detailed descriptions are provided about the structure of FIG. 4 and 5, because they are equal to the structures of FIG. 1 and 2, except for the thread hole 89 for fastening.

[0023] In FIG. 6a to 6c, the bolting type ultrasonic transducers include the front mass 92,102,112 forming the thread hole 99,109,119 at its upper surface. Here also, no further detailed descriptions are given about the respective structure of FIG. 6a to 6c, because their structures are the same as the corresponding structures of FIG 3a, 3d and 3e, except for the thread hole 99,109,119 for fastening.

[0024] Unexplained numbers 91,93,101,103,111,113 are electrodes and 92a, 102a, 112a are recesses.

[0025] When electric acoustic characteristics of the ultrasonic transducer with recesses were compared to the ultrasonic transducer without recesses, the results were as follows (table 1).

Test Conditions

[0026]

- (1) Instruments: Model No. 4194A made by Hewlett Packard (Gain Phase Impedance Analyzer)
- (2) Piezoelectric Ceramics: SONOX P4 and SONOX P8 made by Iloechst Ceramtec Company in Germany
- (3) Front Mass: a bolting type front mass of FIG. 4 and 5; and a conventional front mass without recesses
The dimensions of the front mass are as follows:

- (a) upper and lower diameter (outer): 64 mm and 51 mm,
- (b) longitudinal length: 23 mm, (c) the depth of recess: 12 mm, and
- (d) the inside diameter of a through hole and a thread hole: 10 mm.

- (4) Load: Air Load and Hand Load under normal temperature

TABLE 1.

CONVERTER parameter	Example 1	Example 2	Example 3	Example 4
Cp=Cs=Cin[nF]; (1kHz)	5.62	5.66	4.39	4.39
tgD[0.001]; (1kHz)	3.76	3.20	2.36	2.36
Rp[MOhm.]; (1kHz)	7.68	7.68	16.26	16.00
Rs[Ohm.]; (1kHz)	103.25	98.34	86.75	86.00
Cop[nF]	5.08	5.03	3.96	3.81
C1[nF]	0.98	0.95	0.79	0.80
L1[mH]	25.49	25.37	31.74	30.30
R1[Ohm.]	12.34	9.78	11.72	9.51
Qm1	423.39	529.59	550.57	645.97
Zmin.[Ohm.]	11.93	9.92	11.78	9.64
Phase Angle[°]	0.00	0.00	0.00	0.00
f1[Hz]	31860.75	32467.00	31768.75	32267.00
Zmax[KOhm.]	75.82	84.06	109.41	160.60
Phase Angle[°]	0.00	0.00	0.00	0.00
f2[Hz]	34804.75	35390.00	34801.50	35517.00
Cos[nF]	6.06	5.98	4.76	4.62
C2[nF]	32.71	33.72	25.37	23.05
L2[uH]	640.32	599.58	824.96	871.58
R2[Kohm.]	74.12	84.40	108.81	177.77
Qm2	530.19	632.93	601.59	914.24
P-Anglemax,[°] f1<f<f2	87.61	88.00	87.94	88.70
Phase Anglemín,[°]	-88.38	-89.00	-88.51	-89.70
H-loaded: Zmin.[Ohm.]	137.75	60.61	258.58	89.10
H-loaded: Zmax,[KOhm.]	3.67	9.30	3.49	9.78

TABLE 1. (continued)

CONVERTER parameter	Example 1	Example 2	Example 3	Example 4
H-loaded: Anglemax,[°]	48.65	71.00	40.50	69.00
Qmeff	473.42	578.96	574.99	768.49

[0027] Examples 1 and 3 are the conventional ultrasonic transducers without recesses, and examples 2 and 4 are the present ultrasonic transducers with recesses. Moreover, Examples 1, 2 and Examples 3, 4 are assembled with the SONOX P4 and the SONOX P8, respectively.

[0028] Generally, the efficiency of an ultrasonic transducer is determined by the mechanical quality factor ("Qmeff"). In Table 1, the respective value of mechanical quality factor of the Examples is 473.42 (Example 1), 578.96 (Example 2), 574.49 (Example 3) and 768.49 (Example 4). Consequently, the Examples 2 and 4 of the present invention improved by 20 ~ 25% of the value of the mechanical quality factor in comparison with the value of the mechanical quality factor for Examples 1 and 3.

[0029] Also, referring to the resonant impedance R1 in Table 1, Examples 2 and 4 are considerably reduced in comparison with Examples 1 and 3.

[0030] In conclusion, it is deemed that the recesses formed on the upper surface of the front mass significantly improve the value of the mechanical quality factor.

[0031] Furthermore, Example 4 in FIG. 7 shows noticeable vibration characteristics at 121.840 kHz Harmonic Resonant Frequency and at 32.402 kHz Fundamental Resonant Frequency. Therefore, an ultrasonic transducer with the front mass as in the present invention has an excellent cleaning efficiency because the Fundamental Resonant Frequency and the Harmonic Resonant Frequency coincide in cleaning.

[0032] In FIG. 8 and 9, ultrasonic transducers 10, 80 in FIG. 1 and 4 are mounted onto the cleaning tank TK filled with the cleaning liquid L. The adhesive mounting type ultrasonic 10 is strongly attached to the bottom surface of the cleaning tank TK, because the adhesive penetrates into the recesses 12a. The bolting type ultrasonic 80 is fastened by the stud C fixed onto the bottom surface of the cleaning tank TK.

[0033] The above-mentioned present invention has several advantages and characteristics, as follows.

(1) Cleaning efficiency and aspect of vibrations of the ultrasonic cleaner are uniform and improved because the interference of radial and planar vibrations diminished.

(2) Acoustic matching of the present invention is good because acoustic load impedance of front mass is reduced. Because the acoustic load is expressed as "density $\times$ the speed of sound", the density of the front mass is reduced proportionally to its area of recesses.

[0034] Consequently, the acoustic matching of the front mass reduced density is very good.

(3) An adhesive mounting type ultrasonic is strongly attached to the bottom surface of the cleaning tank, because the adhesive penetrates into the recesses.

(4) The present invention offers excellent cleaning efficiency because the Fundamental Resonant Frequency and the Harmonic Resonant Frequency coincide in cleaning.

[0035] The present invention has been shown and described with reference to its particular types, so that it will be understood by people skilled in this area. Various changes in form and details may be effected without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

1. An ultrasonic transducer mounted on the bottom or side surface of the cleaning tank of an ultrasonic cleaner, comprising:

- a pair of piezoelectric ceramics having a through hole
- a pair of electrodes positioned at the top surface of the upper piezoelectric ceramic and interposed between the upper and the lower piezoelectric ceramic, respectively, having a through hole
- a front mass positioned at the top surface of the upper electrode and forming a thread hole, where the front mass has various shape and geometry recesses (vertical slits) at its upper surface to improve longitudinal mechanical quality factor of the piezoelectric ceramics which determines the cleaning efficiency of the ultra-

sonic cleaner

- a back mass positioned at the bottom surface of the lower electrode and having a through hole, and
- a means for fastening piezoelectric ceramics, electrodes, the front and the back mass.

2. An ultrasonic transducer as in claim 1, where the front mass is of a cylindrical shape, the recesses of lattice shape formed vertically and horizontally through the top surface of the front mass; the intersections of the recesses are positioned inside the circumference of the lower surface of the front mass, the width of the recesses is 1 ~ 2 mm and their depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

3. An ultrasonic transducer as in claim 2, where the intersections are positioned at the same distance from the center of the front mass.

4. An ultrasonic transducer as in claim 1, where the front mass is of a cylindrical shape, the recesses are slots of an equilateral triangle shape, respective apexes of the recesses are positioned at the circumference of the upper surface of the front mass, the width of the recesses is 1 ~ 2 mm and their depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

5. An ultrasonic transducer as in claim 1, where the front mass is of a cylindrical shape, the recesses are cross shaped formed at the top surface of the front mass, the width of the recesses is 1 ~ 2 mm and their depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

6. An ultrasonic transducer as in claim 1, where the front mass is of a cylindrical shape, the recesses in the shape of a hole are formed at respective circumferences of concentric circles, the center of the concentric circles is the center of the front mass, the width of the recesses is 1 ~ 2 mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

7. An ultrasonic transducer as in claim 1, where the front mass is of a rectangular shape, the recesses of lattice shape are formed vertically and horizontally through the top surface of the front mass. the areas divided by recesses are equal, the width of the recesses is 1 ~ 2 mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

8. An ultrasonic transducer as in claim 1, where the front mass is of a rectangular shape, the recesses are slots of a rhomboid shape, respective apexes of the recesses are positioned at the edge of the top surface of the front mass, the width of the recesses is 1 ~ 2 mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

9. An ultrasonic transducer as in claim 1, where the front mass is of a rectangular shape, the recesses in the shape of a hole formed at the circumference of concentric circles, the center of the concentric circles is the center of the front mass, the width of the recesses is 1 ~ 2 mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

10. An ultrasonic transducer mounted onto a bottom or side surface of a cleaning tank of an ultrasonic cleaner, comprising:

- a pair of piezoelectric ceramics having a through hole
- a pair of electrodes positioned at the top surface of the upper piezoelectric ceramic and interposed between the upper and the lower piezoelectric ceramic respectively, which have a through hole
- a front mass positioned at the top surface of the upper electrode, having a lower thread hole at the lower surface, and having an upper thread hole of the upper surface, fastened by the stud downwardly fixed to the bottom or side surface of the cleaning tank of the ultrasonic cleaner, where the front mass has various recesses at its top surface in order to improve the mechanical quality factor of the piezoelectric ceramics determining the cleaning efficiency of the ultrasonic cleaner
- a back mass positioned at the bottom surface of the lower electrode having a through hole, and
- a means for fastening the piezoelectric ceramics, electrodes, front and back mass.

11. An ultrasonic transducer as in claim 10, where the front mass is of a cylindrical shape, the recesses of lattice shape are formed vertically and horizontally through the top surface of the front mass, the intersections of the recesses are positioned between the circumference of the lower surface of the front mass and the upper thread hole, the width of the recesses is 1 ~ 2 mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

12. An ultrasonic transducer as in claim 11, where the intersections are positioned at the equal distance from the center

of the front mass.

5 **13.** An ultrasonic transducer as in claim 10, where the front mass is of a cylindrical shape, the recesses are slots of an equilateral triangle, respective apexes of the recesses are positioned at the circumference of the top surface of the front mass, the width of the recesses is $1 \sim 2$ mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

10 **14.** An ultrasonic transducer as in claim 10, where the front mass is of a rectangular shape, the recesses of lattice shape formed vertically and horizontally through the top surface of the front mass, the areas divided by recesses are equal, the width of the recesses is $1 \sim 2$ mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

15 **15.** An ultrasonic transducer as in claim 10, where the front mass is of a rectangular shape, the recesses are slots of rhomboid shape, respective apexes of the recesses are positioned at the edge of the top surface of the front mass, the width of the recesses is $1 \sim 2$ mm and the depth is $1/3 \sim 1/2$ of longitudinal length of the front mass.

FIG. 1

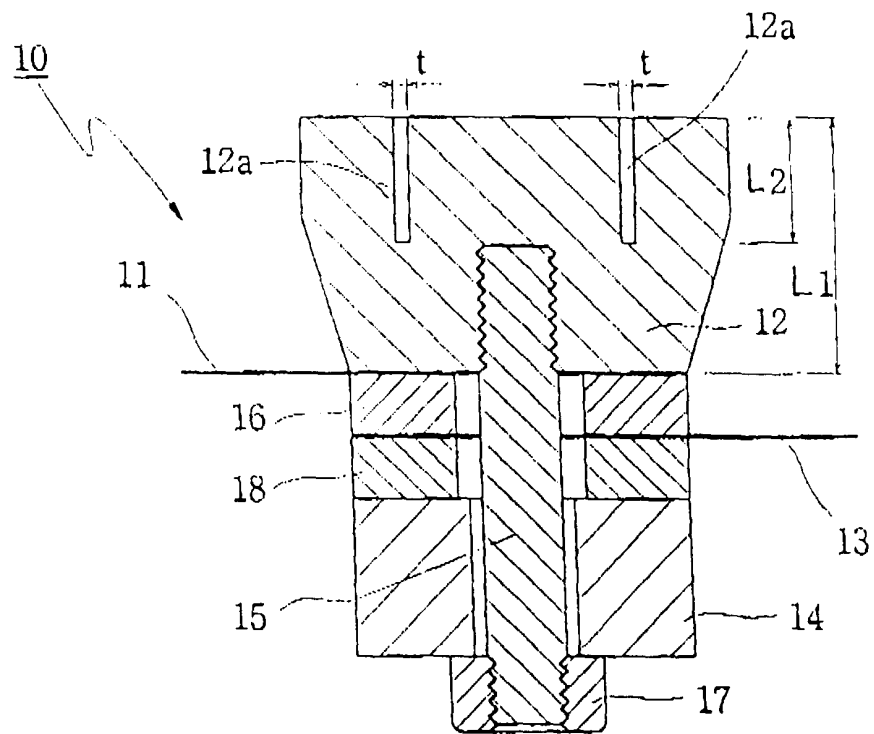


FIG. 2

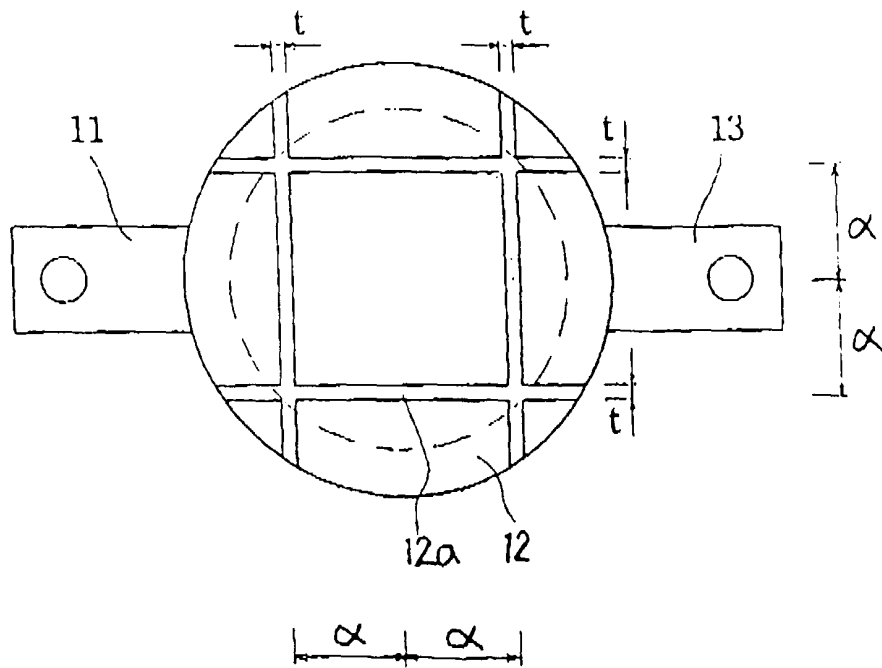


FIG. 3a

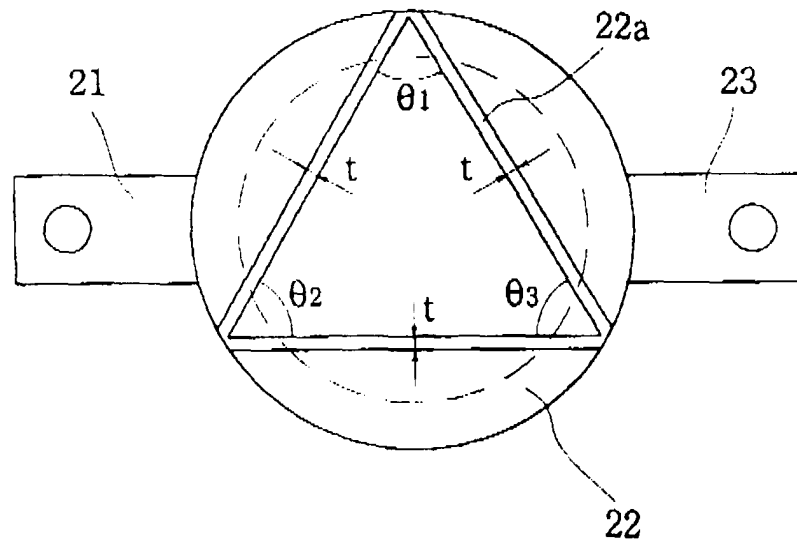


FIG. 3b

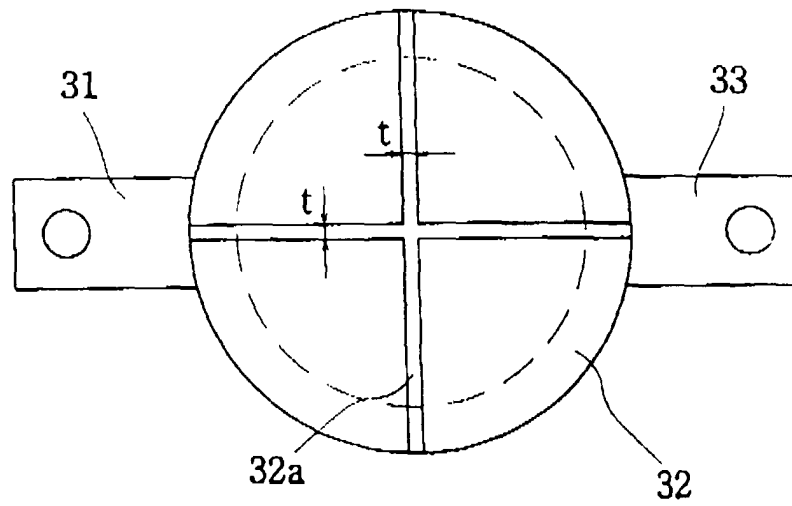


FIG. 3c

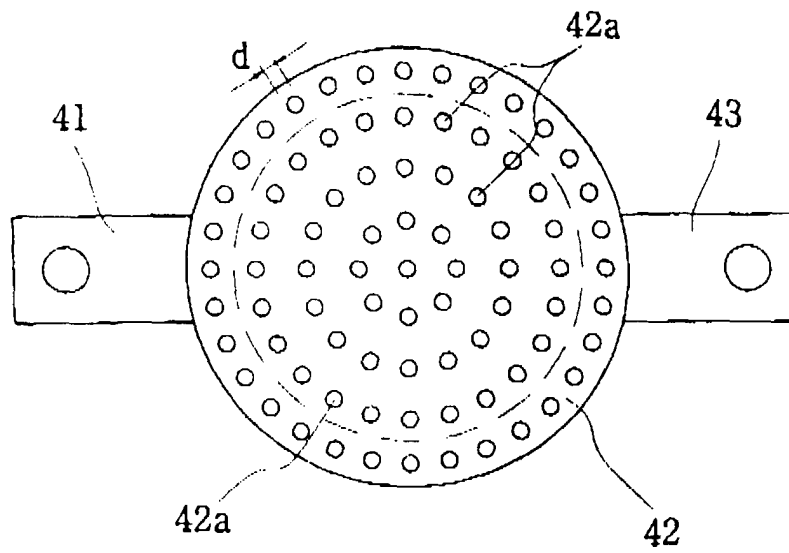


FIG. 3d

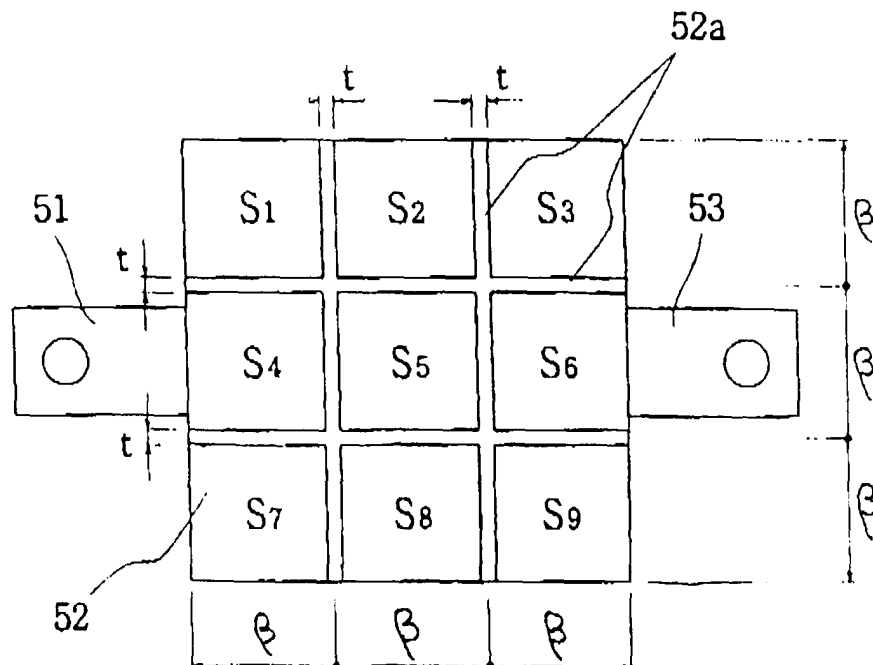


FIG. 3e

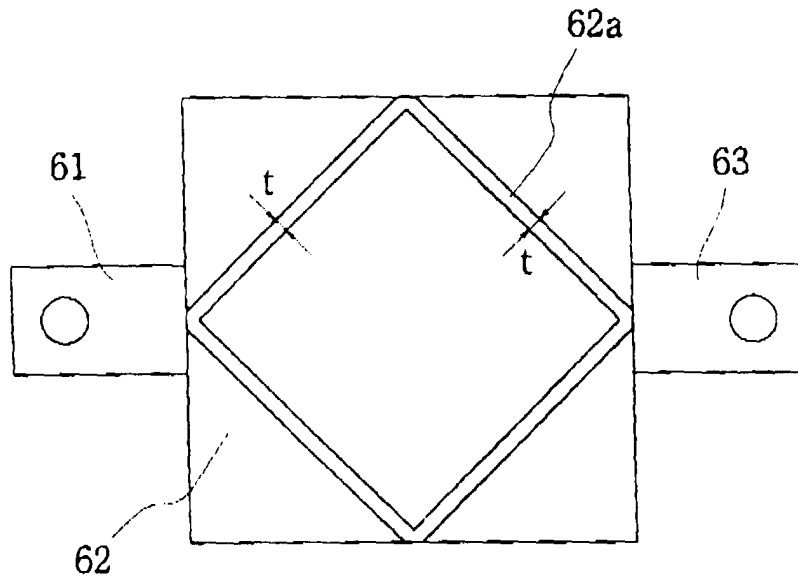


FIG. 3f

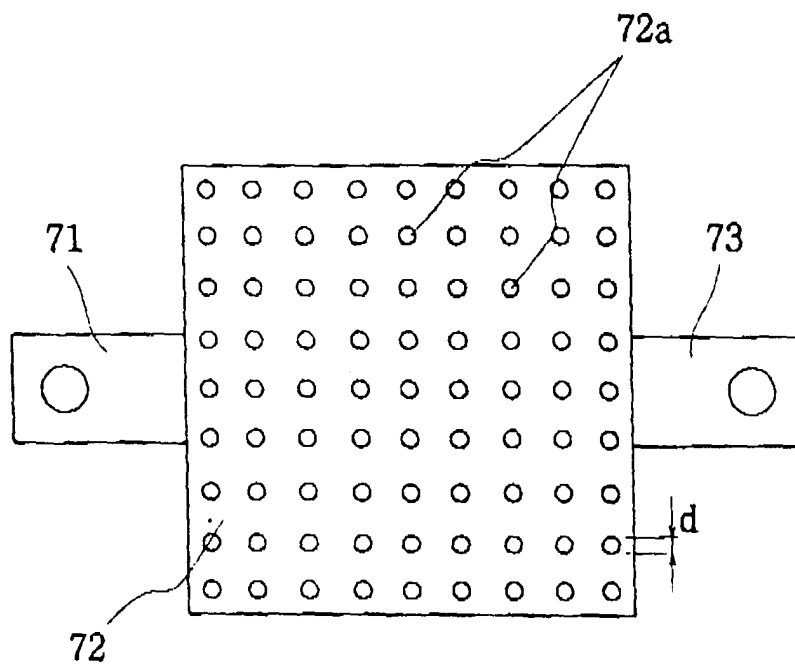


FIG. 4

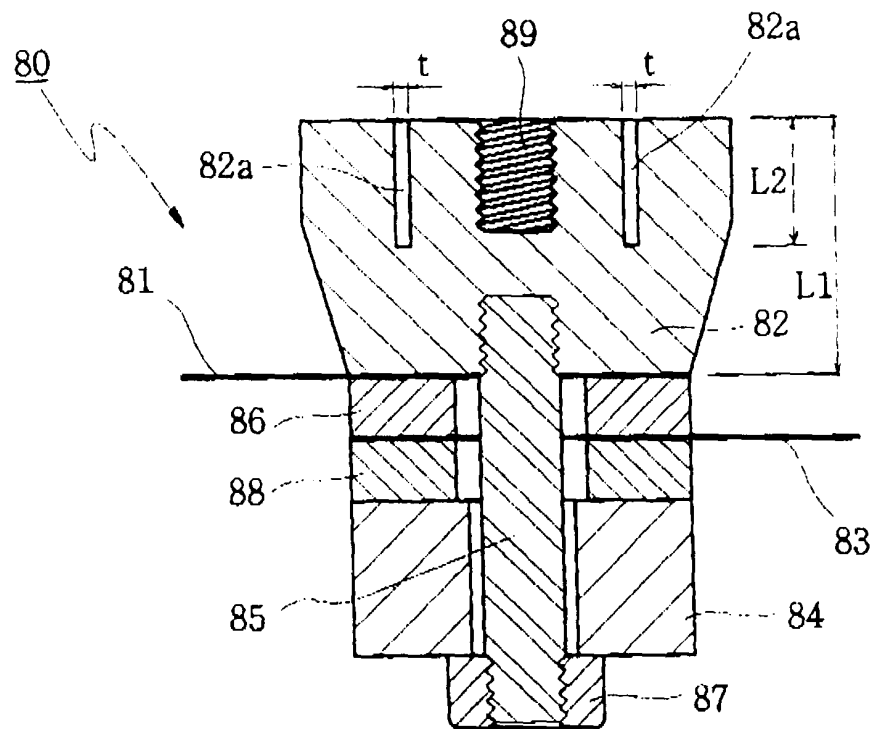


FIG. 5

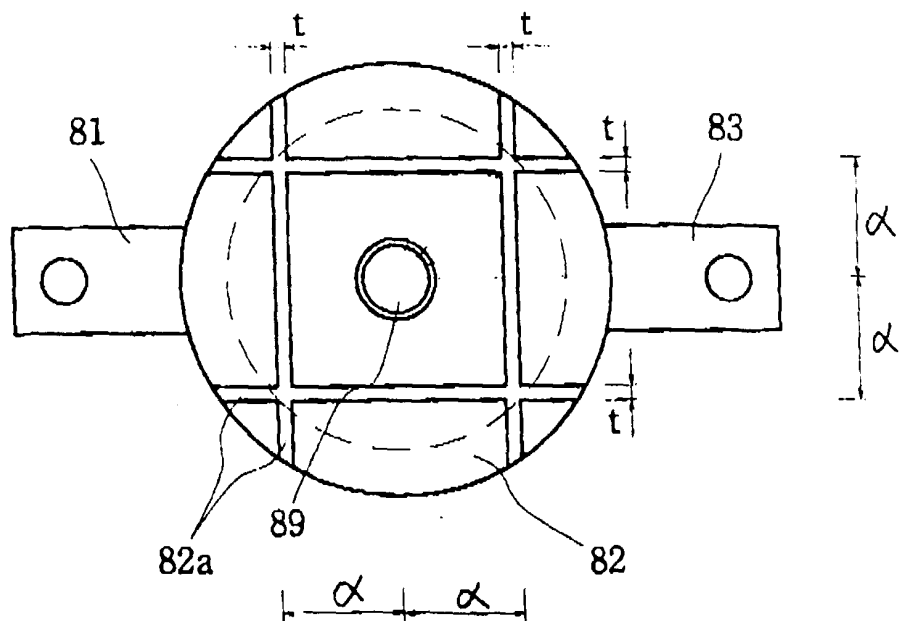


FIG. 6a

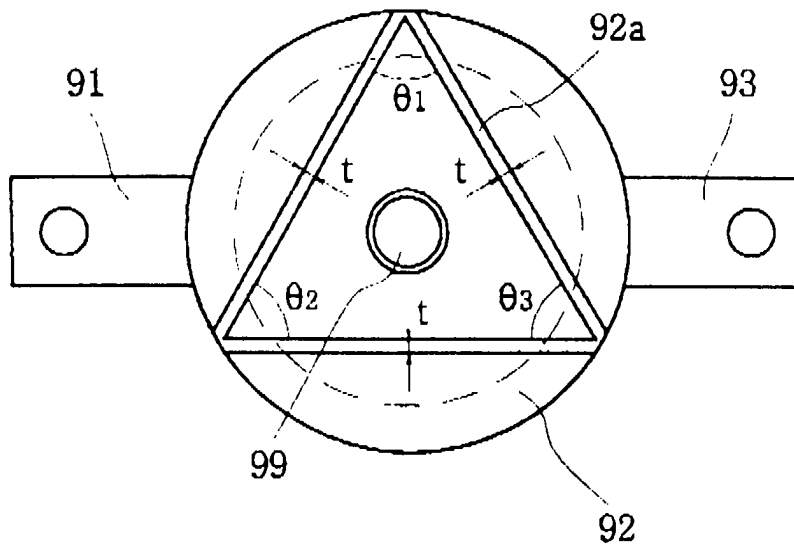


FIG. 6b

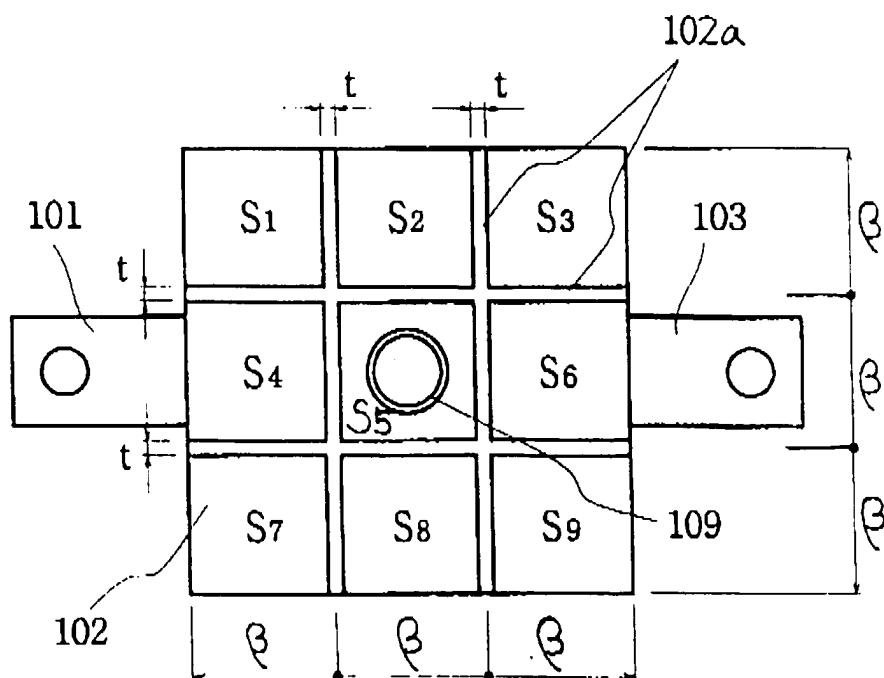


FIG. 6c

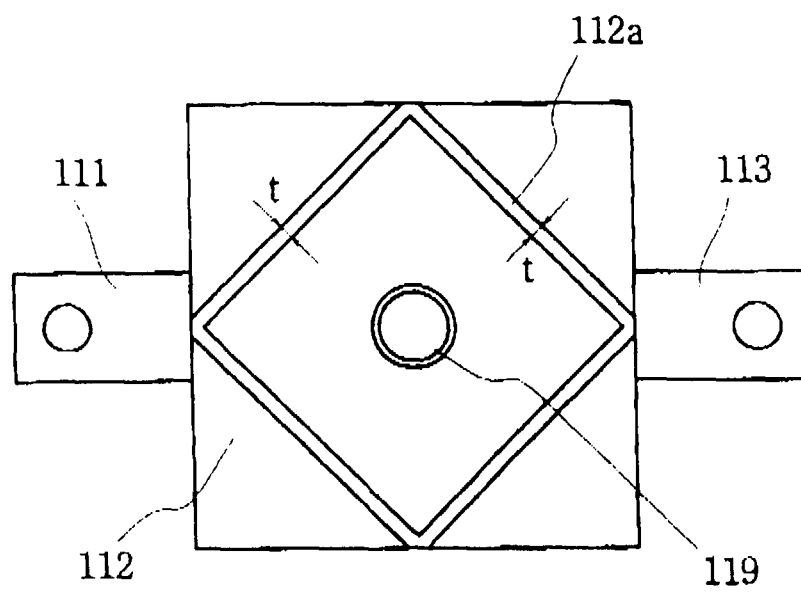
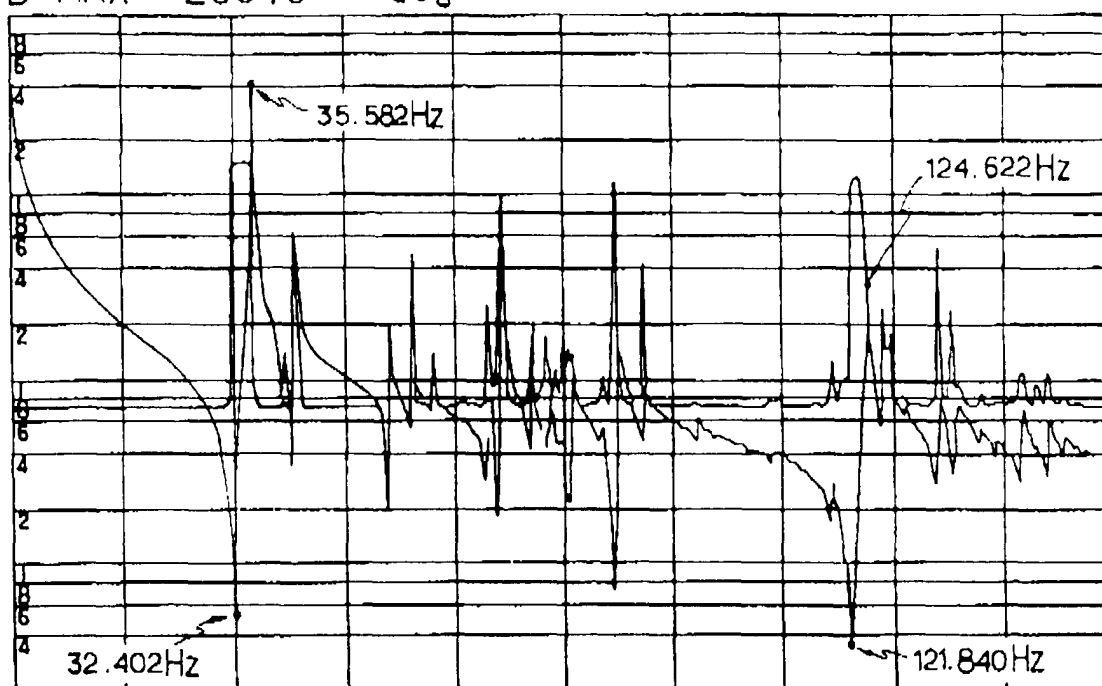


FIG. 7a

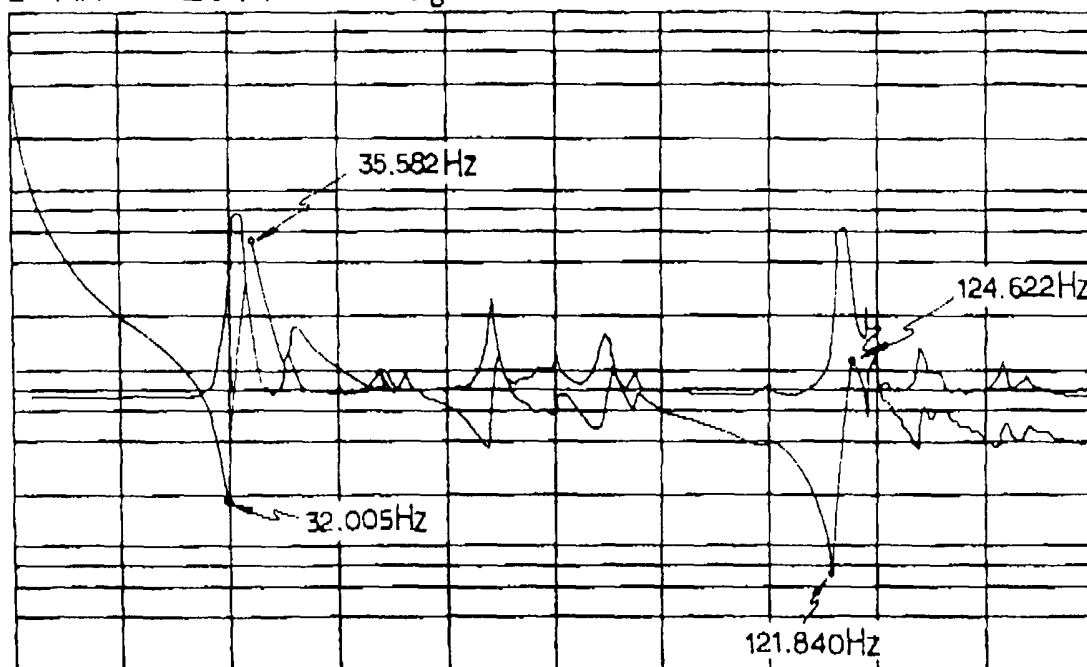
A: Z B:
A: MAX 100.0 K
B: MAX 200.0 deg



A MIN 20.00 START 1 000.000 Hz
B/DIV 50.00 deg STOP 160 000.000 Hz
STOP= 160000.000 HZ
AVERAGING TIME = 4

FIG. 7b

A: Z B:
A MAX 100.0 K
B MAX 200.0 deg



A MIN 20.00 START 1 000.000 Hz
B/DIV 50.00 deg STOP 160 000.000 Hz
STOP= 160000.000 Hz

FIG. 8

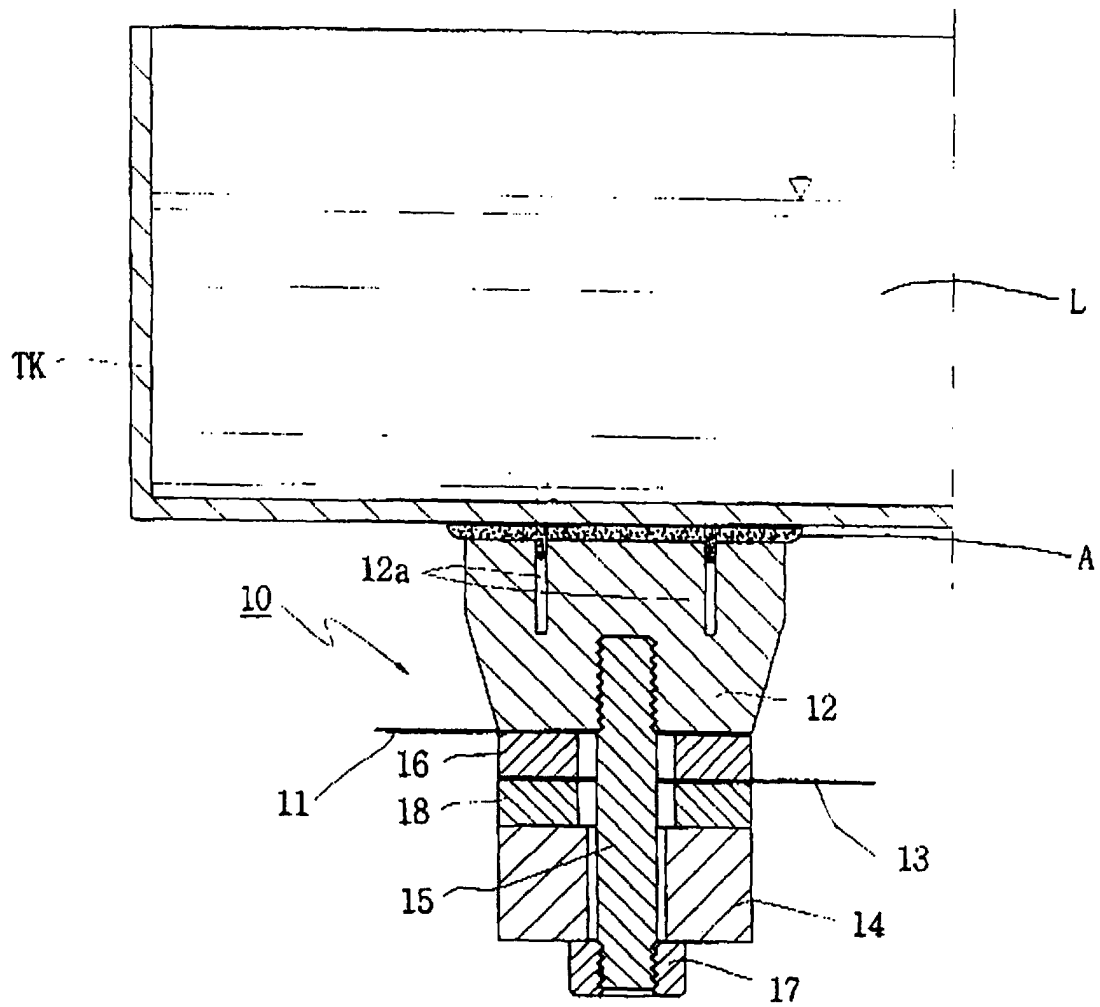


FIG. 9

