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(54) Multiple cone electroacoustic transducer

(57) A loudspeaker comprises a motor stator (12) defining an air gap (32). The stator provides a magnetic field in the air gap. A former (14) supports a voice coil (30) through which current to be transduced into audio is to be passed in the air gap. A first diaphragm (34) is fixed to the former at a first position a first distance (38) from the front plate (20) of the stator along the length of the former. The first diaphragm has a first outer perimeter (56). A first compliance (54) for permitting relative movement between the first outer perimeter and an outer frame (16) couples the first outer perimeter to the frame (16). A first opening (40) in the frame vents air from a first face (44) of the first diaphragm. A second opening (46) in the frame vents air from a second face (48) of the first diaphragm. A second diaphragm (134) is fixed to the former at a second position a second distance (138) from the front plate (20) of the stator greater than the first distance along the length of the former. The second diaphragm has a second outer perimeter (156). A second compliance (154) permitting relative movement between the second outer perimeter and the frame couples the second outer perimeter to the frame. A third opening (140) in the frame vents air from a first face (144) of the second diaphragm. A first partition (64) disposed between the second face of the first diaphragm and the first face of the second diaphragm provides a fourth opening (66) through which the former extends. The fourth opening lies between the first and second positions.

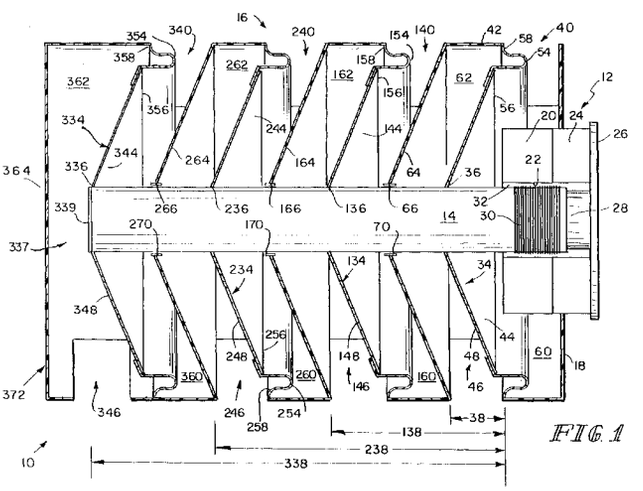

FIG. 1

EP 0 771 133 A1

Description

Background of the Invention

This invention relates to loudspeaker construction.

Various loudspeaker constructions are known. There are, for example the configurations illustrated and described in U.S. Patents: 4,118,605; 4,567,959; 4,590,333; 4,908,601; 5,097,513; 5,119,431; 5,295,194; and, 5,327,985.

Configurations specifically designed to move the large volumes of air required by woofer, subwoofer and sub-subwoofer applications are also known. There are, for example, the systems illustrated and described in U. S. Patents: 4,531,025; 4,757,547; 4,763,358; 5,140,641; 5,313,127; and, 5,317,642.

Summary of the Invention

According to the invention, a loudspeaker comprises a motor stator defining an air gap. The stator provides a magnetic field in the air gap. A former supports a voice coil through which current to be transduced into audio is to be passed in the air gap. A first diaphragm is fixed to the former at a first position a first distance along the length of the former. The first diaphragm has a first outer perimeter. A first compliance for permitting relative movement between the first outer perimeter and frame couples the first outer perimeter to the frame. A first opening in the frame vents air from a first face of the first diaphragm. A second opening in the frame vents air from a second face of the first diaphragm. A second diaphragm is fixed to the former at a second position a second distance greater than the first distance along the length of the former. The second diaphragm has a second outer perimeter. A second compliance permitting relative movement between the second outer perimeter and frame couples the second outer perimeter to the frame. A third opening in the frame vents air from a first face of the second diaphragm. A first partition disposed between the second face of the first diaphragm and the first face of the second diaphragm provides a fourth opening through which the former extends. The fourth opening lies between the first and second positions.

According to an illustrative embodiment, a first spider movably couples the former to the first partition around the fourth opening.

Further according to illustrative embodiments a fifth opening in the frame vents air from a second face of the second diaphragm.

Additionally according to illustrative embodiments, a third diaphragm is fixed to the former at a third position a third distance greater than the second distance along the length of the former. The third diaphragm has a third outer perimeter. A third compliance permitting relative movement between the third outer perimeter and frame couples the third outer perimeter to the frame. A second partition providing a sixth opening through which the former extends is disposed between the second face of the second diaphragm and the first face of the third diaphragm.

Adcording to an illustrative embodiment, a second spider movably couples the former to the second partition around the sixth opening.

Further according to illustrative embodiments, the frame comprises a first end closure providing the first opening. A first housing portion having a first configuration provides the second opening and the first partition. A first housing portion having a second configuration provides the third opening. A second housing portion having the first configuration provides the fifth opening and the second partition. A second housing portion having the second configuration provides a seventh opening for venting air from a first face of the third diaphragm.

Additionally according to illustrative embodiments, a third housing portion having the first configuration provides an eighth opening for venting air from a second side of the third diaphragm and a third partition defining a ninth opening through which the former extends.

Additionally according to an illustrative embodiment, a third spider movably couples the former to the third partition around the ninth opening.

According to illustrative embodiments, the frame further comprises a third housing portion having the second configuration. A fourth diaphragm is fixed to the former at a fourth position a fourth distance greater than the third distance along the length of the former. The fourth diaphragm has a fourth outer perimeter. A fourth compliance permitting relative movement between the fourth outer perimeter and frame couples the fourth outer perimeter to the frame. The third housing portion having the second configuration defines a tenth opening for venting air from a first side of the fourth diaphragm.

Further according to illustrative embodiments of the invention, the frame further comprises a second end closure defining an eleventh opening for venting air from a second side of the fourth diaphragm.

Additionally according to illustrative embodiments, the first opening, the third opening, the seventh opening and the tenth opening all open generally in a first common direction and the second opening, the fifth opening, the eighth opening and the eleventh opening all open generally in a second common direction generally opposite to the first direction.

According to illustrative embodiments, the frame further includes mounting flanges extending generally outwardly from the frame between at least one of the first, third, seventh and tenth openings on the one hand and the second, fifth, eighth and eleventh openings on the other hand. The flanges permit mounting of the frame in a baffle with the first, third, seventh and tenth openings opening on a first side of the baffle and the second, fifth, eighth and eleventh openings opening on a second side of the baffle opposite the first side of the baffle.

Additionally according to illustrative embodiments,

the first end closure further comprises means for mounting the motor stator in the frame.

Brief Description of the Drawings

The invention may best be understood by referring to the following description and accompanying drawings which illustrate the invention. In the drawings:

Fig. 1 illustrates conceptually and schematically a longitudinal sectional view of an embodiment of the invention;
Fig. 2 illustrates an exploded longitudinal perspective view of an embodiment of the invention; and
Fig. 3 illustrates a fragmentary perspective view of the embodiment of Fig. 2 mounted in a baffle.

Detailed Description of the Drawings

Referring now to Fig. 1, an audio transducer 10 for such applications as a mid range loudspeaker, woofer loudspeaker, subwoofer loudspeaker or sub-subwoofer loudspeaker includes a motor 12, a generally right circular cylindrical coil former 14 and a generally right circular cylindrical frame 16. The motor 12 is fixed to one end wall 18 of the frame 16. Motor 12 includes a front plate 20 providing a generally right circular cylindrical outer pole 22, an annular permanent magnet 24 and a back plate 26 providing a generally right circular cylindrical center pole 28. Coil former 14 supports a voice coil 30 in the air gap 32 defined between poles 22 and 28.

In accordance with the invention the coil former 14 extends substantially beyond air gap 32. While coil former 14 is illustrated as continuing for its full length as a generally right circular cylindrical tube, it is to be understood that other configurations of coil former 14 outside of air gap 32 can be employed in practicing the invention. For example, coil former 14 at some distance outside of air gap 32 can assume the shape of a substantially reduced cross-section right circular cylindrical rod or other reduced or enlarged cross sectional shape, such as square, rectangular, elliptical, and so on.

In any event, a first diaphragm 34 of a stiff, light weight material is fixed at its apex 36 to coil former 14 at a distance 38 from front plate 20. A vent 40 is provided through the generally right circular cylindrical sidewall 42 of frame 16 for air moved by a first face 44 of first diaphragm 34 during the voice coil 30 excursion in air gap 32 in response to excitation of voice coil 30 by a current to be transduced into audio. A vent 46 is provided through sidewall 42 of frame 16 for air moved by a second face 48 of first diaphragm 34 during the voice coil 30 excursion in air gap 32. Terminals 50, 52 are provided for the application of current to voice coil 30. The sidewall 42 of frame 16 need not be circular. Other configurations would serve equally well. For example, and not by way of limitation, elliptical and rectangular transducer frame configurations are known in the art. See, for example, U.S. Patents 4,554,414 and 1,913,645. Such frame configurations are also contemplated by the present invention.

A compliance 54 extends from the outer perimeter 56 of first diaphragm 34 and couples perimeter 56 to sidewall 42 at 58. Compliance 54 is attached at its perimetrally inner extent to perimeter 56 and at its perimetrally outer extent at 58 to support first diaphragm 34 for relatively free reciprocating motion longitudinally of frame 16. Compliance 54 also seals the chamber 60 defined in part by the first face 44 of first diaphragm 34 from the chamber 62 defined in part by the second face 48 of first diaphragm 34. This prevents cancellation effects adjacent the outer perimeter 56 of first diaphragm 34.

Beyond the second face 48 of first diaphragm 34, a partition 64 extends across frame 16 generally transversely to the longitudinal extents of coil former 14 and frame 16. Partition 64 in part defines chamber 62. Partition 64 is provided with a voice coil former opening 66 through which voice coil former 14 passes beyond the attachment 36 of voice coil former 14 to first diaphragm 34. A low-friction sliding seal 70 is provided between coil former 14 and opening 66 so that movement of coil former 14 in response to current flow in voice coil 30 is not substantially impaired by seal 70.

A second diaphragm 134 is fixed at its apex 136 to coil former 14 at a distance 138 from front plate 20. A vent 140 is provided through sidewall 42 for air moved by a first face 144 of second diaphragm 134 during voice coil 30 excursion in air gap 32. A vent 146 is provided through sidewall 42 for air moved by a second face 148 of second diaphragm 134 during voice coil 30 excursion in air gap 32. A compliance 154 extends from the outer perimeter 156 of second diaphragm 134 and couples perimeter 156 to sidewall 42 at 158. Compliance 154 is attached at its perimetrally inner extent to perimeter 156 and at its perimetrally outer extent at 158 to support second diaphragm 134 for relatively free reciprocating motion longitudinally of frame 16. Compliance 154 seals the chamber 160 defined between the first face 144 of second diaphragm 134 and partition 64 from the chamber 162 defined between the second face 148 of diaphragm 134 and a partition 164. Partition 164 extends across frame 16 generally transversely to the longitudinal extents of coil former 14 and frame 16. Partition 164 is provided with a coil former opening 166 through which coil former 14 passes beyond the attachment 136 of coil former 14 to second diaphragm 134. A low friction sliding seal 170 is provided between coil former 14 and opening 166 so that movement of coil former 14 in response to current flow in voice coil 30 is not substantially impaired by seal 170.

A third diaphragm 234 is fixed at its apex 236 to coil former 14 at a distance 238 from front plate 20. A vent 240 is provided through sidewall 42 for air moved by a first face 244 of third diaphragm 234 during voice coil

30 excursion in air gap 32. A vent 246 is provided through sidewall 42 for air moved by a second face 248 of second diaphragm 234 during voice coil 30 excursion in air gap 32. A compliance 254 extends from the outer perimeter 256 of third diaphragm 234 and couples perimeter 256 to sidewall 42 at 258. Compliance 254 is attached at its perimetrally inner extent to perimeter 256 and at its perimetrally outer extent at 258 to support second diaphragm 234 for relatively free reciprocating motion longitudinally of frame 16. Compliance 254 seals the chamber 260 defined between the first face 244 of diaphragm 234 and partition 164 from the chamber 262 defined between the second face 248 of third diaphragm 234 and a third partition 264. Third partition 264 extends across frame 16 generally transversely to the longitudinal extents of coil former 14 and frame 16. Partition 264 is provided with a coil former opening 266 through which coil former 14 passes beyond the attachment 236 of coil former 14 to second diaphragm 234. A low friction sliding seal 270 is provided between coil former 14 and opening 266 so that movement of coil former 14 in response to current flow in voice coil 30 is not substantially impaired by seal 270.

A fourth diaphragm 334 is fixed at its apex 336 to the remote end 337 of coil former 14 at a fourth distance 338 from front plate 20. End 337 is provided with a dust cap 339. A vent 340 is provided through sidewall 42 for air moved by a first face 344 of fourth diaphragm 334 during voice coil 30 excursion in air gap 32. A vent 346 is provided through sidewall 42 for air moved by a second face 348 of fourth diaphragm 334 during voice coil 30 excursion in air gap 32. A compliance 354 extends from the outer perimeter 356 of fourth diaphragm 334 and couples perimeter 356 to sidewall 42 at 358. Compliance 354 is attached at its perimetrally inner extent to perimeter 356 and at its perimetrally outer extent at 358 to support fourth diaphragm 334 for relatively free reciprocating motion longitudinally of frame 16. Compliance 354 seals the chamber 360 defined between the first face 344 of fourth diaphragm 334 and partition 264 from the chamber 362 defined between the second face 348 of fourth diaphragm 334 and an end closure 364.

End closure 364 and/or vent 346 can be omitted from frame 16. If the end 372 of frame 16 is left open, however, cancellation effects between the open end and vents 40, 46, 140, 146, 240, 246 and 340 may be aggravated, depending upon the mounting orientation of frame 16. While horns are not illustrated, vents 40, 46, 140, 146, 240, 246, 340 and/or 346 can, if desired, be loaded via horns of any conventional configuration either formed integrally with side wall 42 or made separately and attached to side wall 42.

A realization of the transducer 10 of Fig. 1 is illustrated in Fig. 2. The elements of the transducer illustrated in Fig. 2 which perform the functions of the transducer illustrated in Fig. 1 are referred to by the same reference numbers, and the detailed description of Fig. 1 can be referred to for the explanation of those functions. The transducer 10 illustrated in Fig. 2 is made up of a stack of rings of two different basic configurations. Rings 380 provide the ports 140, 240, 340. Rings 382 provide the ports 46, 146, 246 and the partitions 64, 164, 264. A ring 384, like rings 380 except that it is provided with a region 386 for locating the motor assembly 20, 24, 26, provides port 40. Rather than being provided with sliding seals 66, 70, 166, 170, 266, and 270, more or less conventional dampers 388 are mounted to extend between respective partitions 64, 164, 264 and the adjacent surface of coil former 14. Rings 380, 382, 384 and end closure 364 can be constructed from, for example, filled or unfilled resin and their adjacent edges 390 joined adhesively, ultrasonically, by longitudinally extending bolts, or otherwise, with the outer extents 58, 158, 258, 358 of compliances 54, 154, 254, 354, respectively, captured therebetween during assembly. In this way, a transducer 10 having any desired number of diaphragms 34, 134, 234, 334, ..., rings 380 and rings 382 can be built up in a "stack." The transducer 10 can be custom tailored to the desired transducer 10 characteristics.

Undesirable cancellation effects can be reduced substantially by any number of mounting techniques, one of which is illustrated with reference to Figs. 2-3. Each ring 380, 382, 384 and end closure 364 is provided with outwardly extending, flat mounting flanges 394. Some or all of the flanges 394 are provided with mounting holes 396. A rectangular opening 398 having substantially the external dimensions of transducer 10 excepting flanges 394 is provided in a baffle 400 such as, for example, a rear package tray or rear seat back of a passenger vehicle. Ports 40, 140, 240, 340 are oriented to vent into the passenger compartment of the vehicle. Ports 46, 146, 246, 346 are oriented to vent into the trunk of the vehicle. Transducer 10 is mounted to baffle 400, for example, by fasteners of any desired type through mounting holes 396 and baffle 400.

It should be understood that, although a four-diaphragm, or four stage, transducer has been illustrated and described, any number of stages, either more or fewer than the illustrated four, can be incorporated into the transducer to provide the desired volume of air movement and/or other transducer characteristics. Further, and as previously mentioned, although a transducer having a circular cross section transverse to its longitudinal extent is illustrated, any desired cross section and indeed any desired cross sectional area within the limits of other acoustical constraints can be implemented into a transducer constructed according to the present invention. It should also be understood that the coil former 14 can be extended into the area of end closure 364 and provided with another voice coil wound in the opposite manner to voice coil 30. Another motor stator of the same or substantially the same or similar configuration to motor stator 20, 24, 26 can be provided on the inside of end closure 364 with this additional voice coil suspended in the air gap of the additional motor stator. The two voice coils can then be driven with the same

program material signal to provide twice the acceleration of diaphragms 34, 134, 234, 334 as taught by the above identified U.S. Patent 5,119,431.

Claims

1. A loudspeaker comprising a motor stator defining an air gap, the stator providing a magnetic field in the air gap, a voice coil through which current to be transduced into audio is to be passed, a former for supporting the voice coil in the air gap, a first diaphragm fixed to the former at a first position a first distance along the length of the former, the first diaphragm having a first outer perimeter, a first compliance for coupling the first outer perimeter to the frame, the first compliance permitting relative movement between the first outer perimeter and frame, a first opening in the frame for venting air from a first face of the first diaphragm, a second opening in the frame for venting air from a second face of the first diaphragm, a second diaphragm fixed to the former at a second position a second distance greater than the first distance along the length of the former, the second diaphragm having a second outer perimeter, a second compliance for coupling the second outer perimeter to the frame, the second compliance permitting relative movement between the second outer perimeter and frame, a third opening in the frame for venting air from a first face of the second diaphragm, and a first partition disposed between the second face of the first diaphragm and the first face of the second diaphragm, the first partition providing a fourth opening through which the former extends, the fourth opening lying between the first and second positions.

2. The apparatus of claim 1 and further comprising a first spider for movably coupling the former to the first partition around the fourth opening.

3. The loudspeaker of claim 1 further comprising a fifth opening in the frame for venting air from a second face of the second diaphragm.

4. The loudspeaker of claim 3 further comprising a third diaphragm fixed to the former at a third position a third distance greater than the second distance along the length of the former, the third diaphragm having a third outer perimeter, a third compliance for coupling the third outer perimeter to the frame, the third compliance permitting relative movement between the third outer perimeter and frame, and a second partition disposed between the second face of the second diaphragm and the first face of the third diaphragm, the second partition defining a sixth opening through which the former extends.

5. The apparatus of claim 4 and further comprising a second spider for movably coupling the former to the second partition around the sixth opening.

6. The apparatus of claim 4 wherein the frame comprises a first end closure providing the first opening, a first housing portion having a first configuration providing the second opening and the first partition, a first housing portion having a second configuration providing the third opening, a second housing portion having the first configuration providing the fifth opening and the second partition, and a second housing portion having the second configuration defining a seventh opening for venting air from a first face of the third diaphragm.

7. The apparatus of claim 6 and further comprising a third housing portion having the first configuration providing an eighth opening for venting air from a second side of the third diaphragm and a third partition defining a ninth opening through which the former extends.

8. The apparatus of claim 7 further comprising a third spider for movably coupling the former to the third partition around the ninth opening.

9. The apparatus of claim 7 wherein the frame further comprises a third housing portion having the second Configuration, a fourth diaphragm fixed to the former at a fourth position a fourth distance greater than the third distance along the length of the former, the fourth diaphragm having a fourth outer perimeter, a fourth compliance for coupling the fourth outer perimeter to the frame, the fourth compliance permitting relative movement between the fourth outer perimeter and frame, the third housing portion having the second configuration defining a tenth opening for venting air from a first side of the fourth diaphragm.

10. The apparatus of claim 9 wherein the frame further comprises a second end closure defining an eleventh opening for venting air from a second side of the fourth diaphragm.

11. The apparatus of claim 10 wherein the first opening, the third opening, the seventh opening and the tenth opening all open generally in a first common direction and the second opening, the fifth opening, the eighth opening and the eleventh opening all open generally in a second common direction generally opposite to the first direction.

12. The apparatus of claim 11 wherein the frame further includes mounting flanges extending generally outwardly from the frame between at least one of the first, third, seventh and tenth openings on the one

hand and the second, fifth, eighth and eleventh openings on the other hand to permit mounting of the frame in a baffle with the first, third, seventh and tenth openings opening on a first side of the baffle and the second, fifth, eighth and eleventh openings opening on a second side of the baffle opposite the first side of the baffle.

13. The apparatus of claim 6, 7, 8, 9, 10 11 or 12 wherein the first end closure further comprises means for mounting the motor stator in the frame.

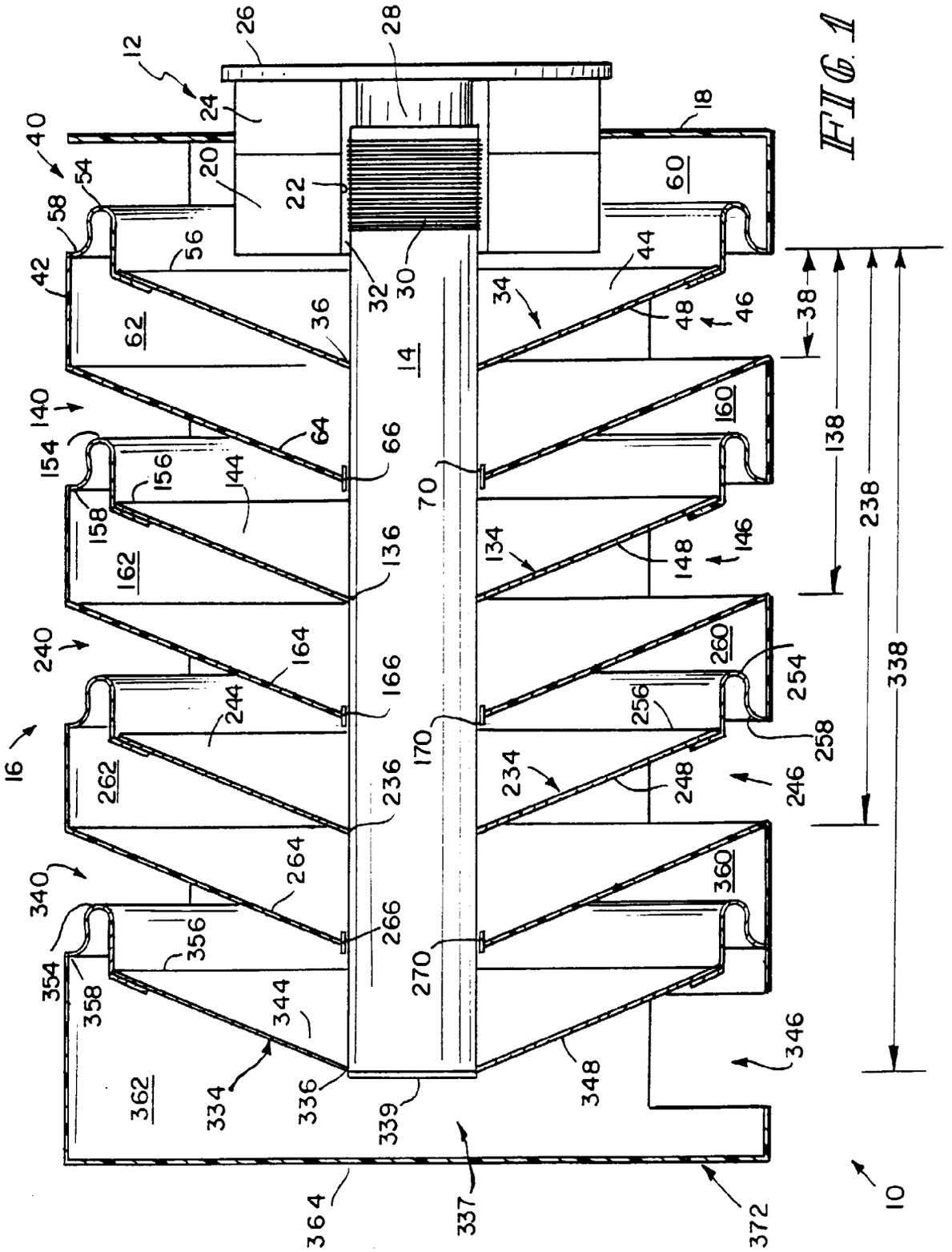
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FIG. 1

FIG. 2

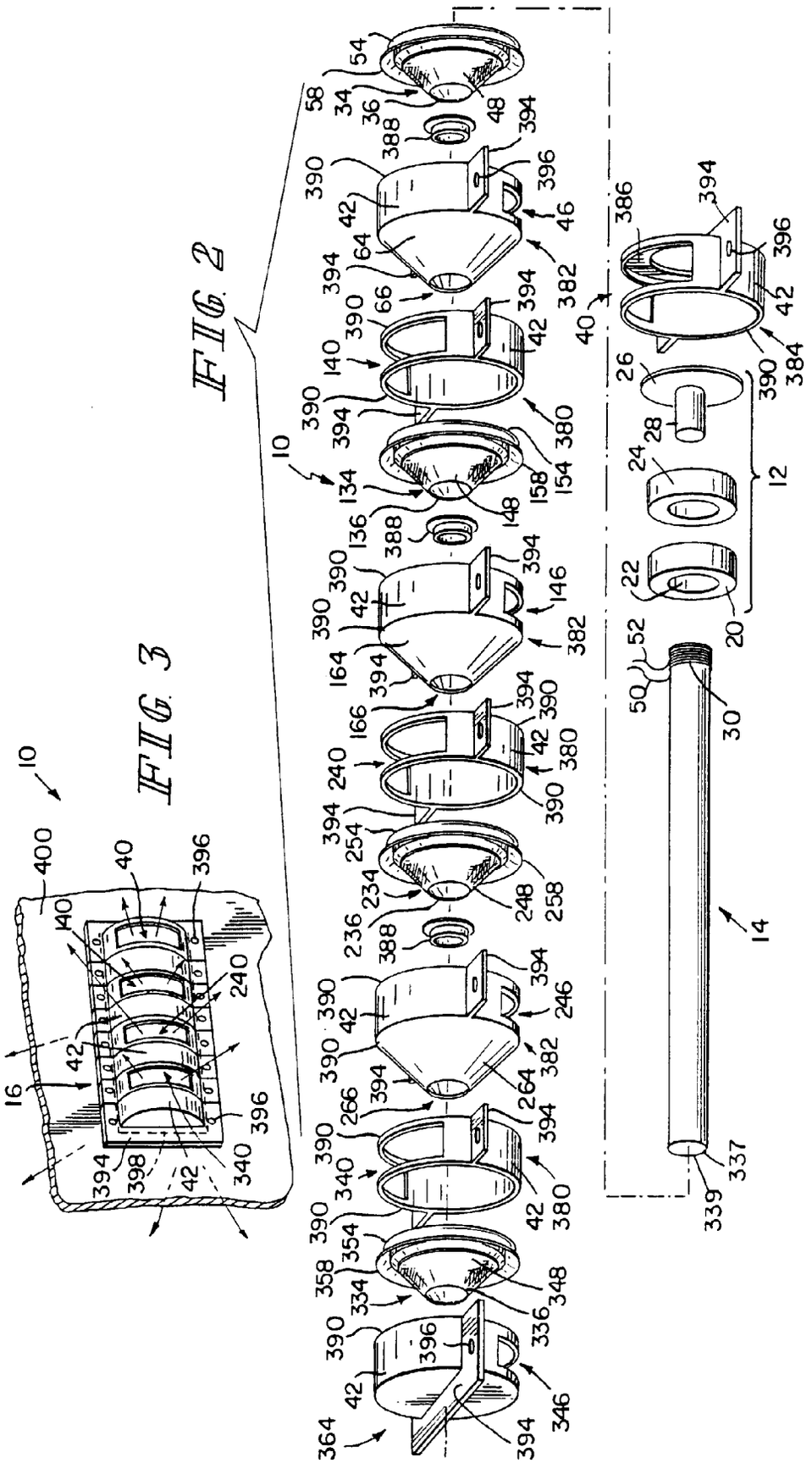

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 7675

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.6)
X	US-A-4 039 044 (HEIL OSKAR) 2 August 1977 * column 3, line 9 - column 4, line 63 * * column 7, line 41 - column 10, line 53; figures 1-3,13-19 *	1,3,4,6, 7,9-11, 13	H04R9/06 H04R1/40
Y	---	2,5,8,12	
X	US-A-4 107 479 (HEIL OSKAR) 15 August 1978 * column 7, line 47 - column 10, line 44; figures 3-6 *	1,3,4	
Y	---	2,5,8,12	
Y	US-A-4 552 242 (KASHIWABARA AKIHIKO) 12 November 1985 * column 2, line 17 - line 66; figure 1 *	2,5,8	
Y	---	2,5,8	
	US-A-4 206 832 (YOCUM THOMAS A) 10 June 1980 * column 1, line 6 - line 34 * * column 2, line 34 - column 3, line 23; figures 1,2 *		TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04R
A	--- US-A-3 636 278 (HEIL OAKAR) 18 January 1972 * column 6, line 69 - column 9, line 27; figures 14-18 *	1-13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	27 January 1997	Nieuwenhuis, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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