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[54] **ENCASED GRADIENT HYDROPHONE ASSEMBLY**

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[52] **U.S. Cl.** ..... **340/8 R,** 181/.5 A

[51] **Int. Cl.** **H04b 13/00**

[58] **Field of Search** ..... 340/8, 9, 10, 11, 340/12, 13, 14; 181/.5 A

[56] **References Cited**

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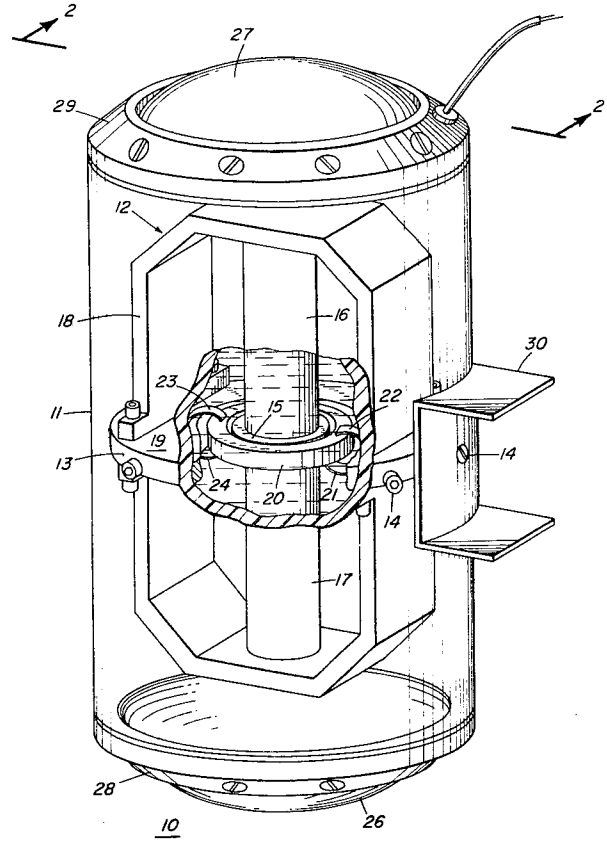
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Assistant Examiner—H. J. Tudor
Attorney—Martin M. Novack

[57] **ABSTRACT**

An encased gradient hydrophone assembly that is particularly suitable for operation when rigidly mounted underwater. A fluid-tight cylindrical casing having openings at its opposite ends is provided. A gradient-type hydrophone is positioned within the casing, the hydrophone including a magnetic field generating means and a movable coil. Means are provided for rigidly mounting the field generating means with respect to the casing, and for resiliently mounting the coil with respect to the casing. First and second flexible diaphragms form fluid-tight enclosures at opposite ends of the casing and a non-corrosive fluid fills the enclosed casing. In a preferred embodiment of the invention impedance plates with apertures of controlled size are rigidly mounted radially across opposite ends of the casing. The plates are a convenient means of providing controlled acoustic impedance and obtaining non-symmetrical hydrophone receiving patterns.

10 Claims, 3 Drawing Figures



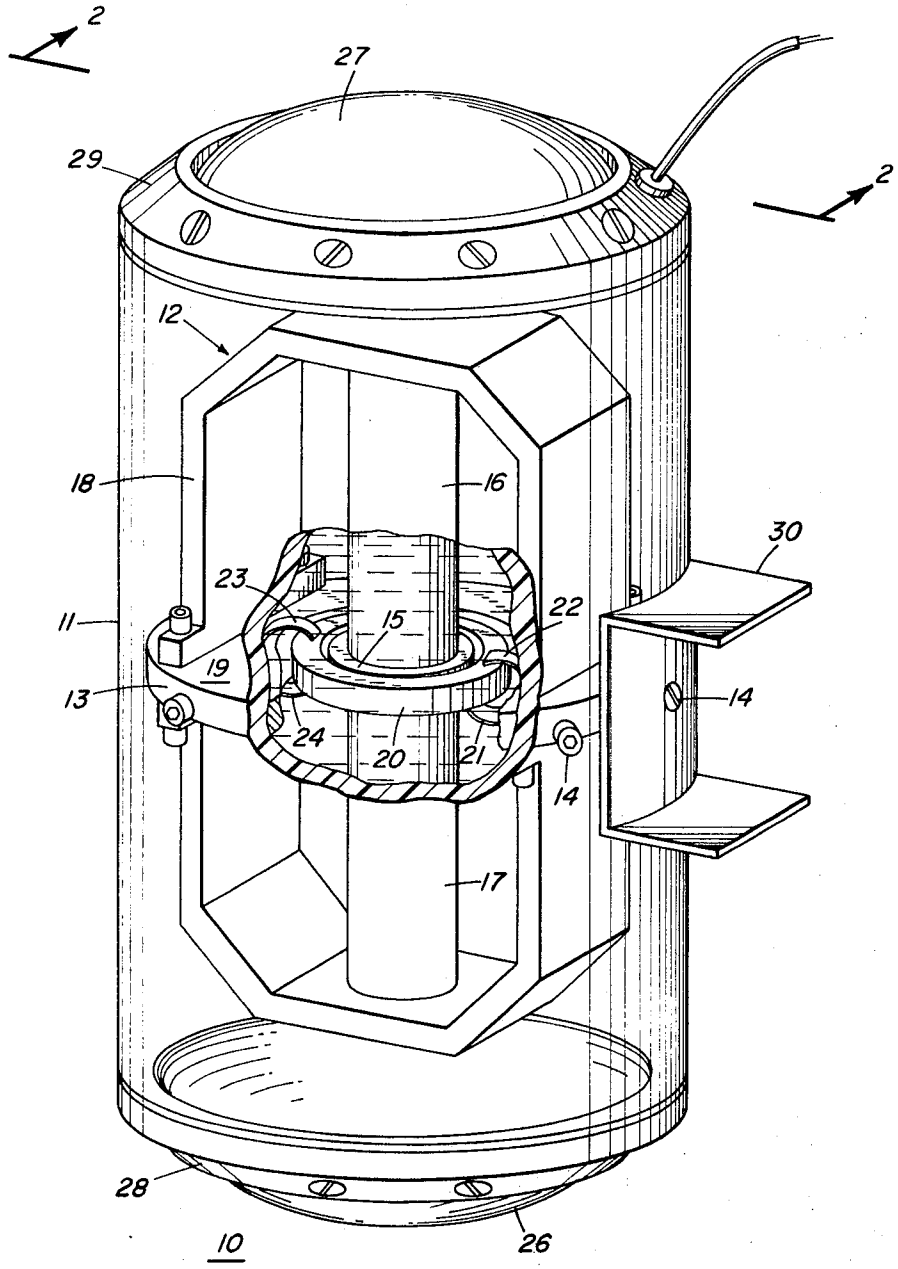


FIG. 1

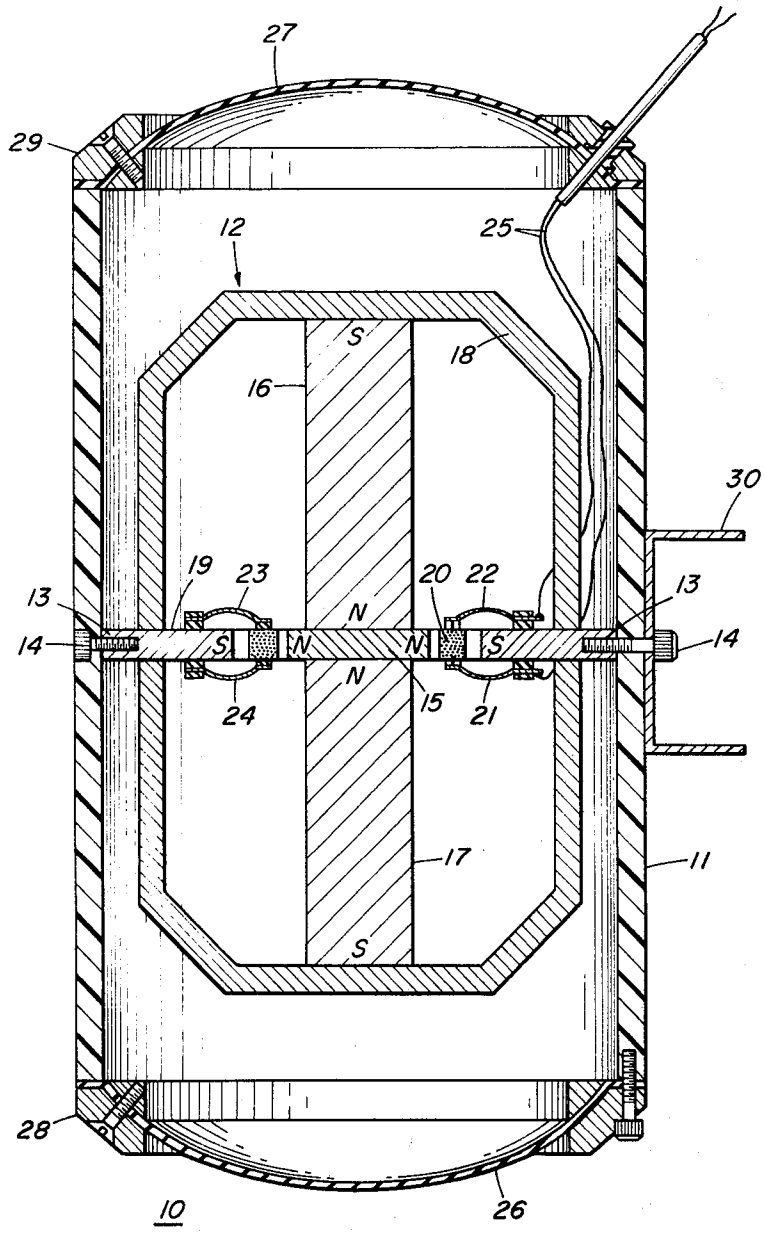

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FIG. 2

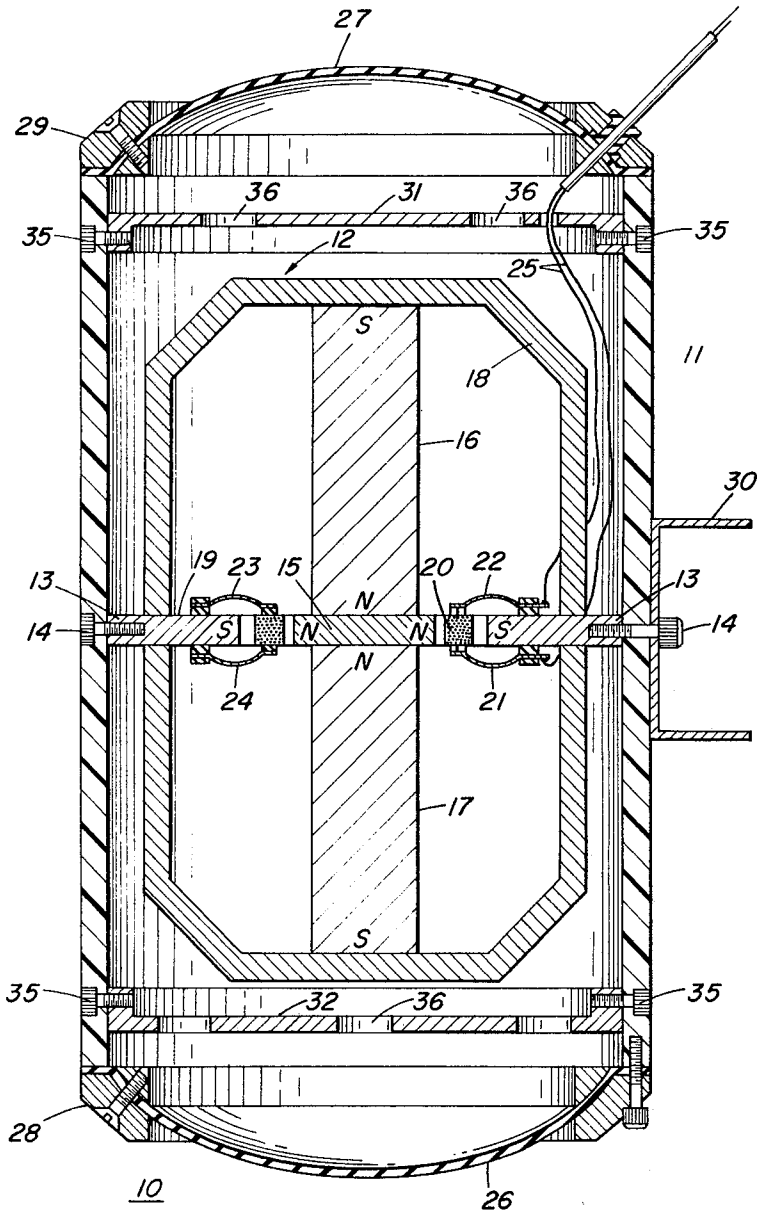

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FIG. 3

ENCASED GRADIENT HYDROPHONE ASSEMBLY

BACKGROUND OF THE INVENTION

The invention herein described was made in the course of or under a contract or subcontract thereunder with the Navy Department. This invention relates to hydrophones and, more particularly, to an encased hydrophone assembly suitable for operation when rigidly mounted underwater.

A gradient-type hydrophone operates by detecting pressure differences on opposite sides of a movable element. In a typical gradient-type hydrophone, the movable element is a coil which is resiliently mounted with respect to a pole structure that is used to set up a magnetic field. Motion of the coil is detected by observing changes in the currents induced in the coil as it crosses lines of magnetic flux.

Many of the operational problems of gradient-type hydrophones result from the enviroment in which they are used; i.e., water, and often sea water. If the hydrophone components were directly immersed, for example, in sea water, electrolytes in the water could cause a shorting of the hydrophone's electrical system. Also, metal parts of the hydrophone would be subject to corrosion and rust in a short time. The general solution to these problems has been to "boot" or encase the hydrophone in a water-tight container that is filled with a booting fluid such as oil.

The introduction of a casing presents the new problems of accurately transmitting the soundwave motion of the water through the encasing structure and to the moving coil element of the hydrophone. The approach generally used is as follows: The gradient hydrophone is supported within the casing by soft resilient mounts. The casing is filled with a booting fluid and, to allow for volume changes of the fluid caused by temperature and pressure Variations, the container is provided with a flexible diaphragm. In operation of the apparatus, the casing is submerged in the water in a manner which allows it to move freely in a sound field. When a soundwave encounters the casing, the variable pressures on different sides of the casing tend to establish a gradient field around the casing which, in turn, causes the casing to vibrate in an oscillatory fashion. The internal resilient mounting of the hydrophone within the casing is chosen to have a natural frequency such that, at the intended operating frequency of the apparatus, the internal hydrophone structure is essentially isolated from the outer case motion. The vibration of the casing sets the booting fluid in motion around the internal hydrophone structure and the fluid motion is transmitted to the moving coil element of the hydrophone (which is free to move, since it is resiliently mounted with respect to the rest of the hydrophone structure). The coil thus oscillates at a rate that is related to the characteristics of the exciting soundwave. As stated, the remaining portion of the hydrophone structure, i.e., all of the internal structure except the moving coil, is essentially isolated from exitations at the selected operating frequencies by virtue of the soft shock mounts.

In certain situations the described scheme works quite well, but the operational usefulness of this scheme is limited by various factors. One such limitation arises from the necessity of having the casing free to vibrate in the sound field. The need to allow freedom of movement of the casing is a significant disadvantage in applications where it would be desirable to have the

encased hydrophone assembly rigidly mounted to another structure. Problems also arise with the described scheme in applications where it is necessary to operate the hydrophone assembly in a vertical orientation. For conventional operation in a horizontal orientation, the casing can be, for example, suspended from a flexible vertical support. In such condition, the casing is free to move in the horizontal direction and thereby perform its intended function for soundwave components in this direction. The converse does not so easily apply, however, to a desired vertical orientation. When the casing is supported by horizontally extending mounts, the force of gravity exerts a natural bias on the mounts that can disturb the freedom of the casing to vibrate naturally in a vertically-oriented sound field. The same problem is, of course, present with respect to the moving coil which, in a vertical orientation of the hydrophone assembly, has a tendency to have a natural rest position that is affected by the downward force of gravity. In the case of the moving coil, however, the problem is readily solved by applying appropriate electrical bias that results in the coil having a rest position that does not put an initial stress on the springs or mounts that support it within the inner hydrophone structure. This type of solution does not apply, though, to overcoming the effect of gravity on the casing in a vertical orientation, and this problem continues to cause operational inconvenience.

In view of these problems, it is one of the objects of the present invention to provide an encased gradient-type hydrophone assembly that is suitable for operation when rigidly mounted underwater and which can be conveniently utilized in a vertical orientation.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a fluid-tight cylindrical casing having openings at its opposite ends. Within the casing is a gradient-type hydrophone which includes means for generating a magnetic field and a movable coil positioned to intercept the magnetic flux of the generated field. Means are provided for rigidly mounting the field generating means with respect to the casing and further means are provided for resiliently mounting the coil with respect to the casing. Additional means are provided for electrically sensing relative motion of the coil in the generated magnetic field. First and second diaphragms form fluid-tight enclosures at opposite ends of the casing, and a non-corrosive fluid fills the enclosed casing.

In one embodiment of the invention, first and second plates, each having at least one aperture are mounted radially across the casing on opposite sides of the coil. These plates act as controlled acoustic impedances that are operatively employed to yield non-symmetrical receiving patterns.

Further features and objects of the invention will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective, partially broken-away view of an encased hydrophone assembly in accordance with the invention;

FIG. 2 is a cross-sectional view of the hydrophone assembly of FIG. 1 as taken through arrows 2—2; and

FIG. 3 is a cross-sectional view of another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 5 1 and 2, there is shown an encased hydrophone assembly 10 in accordance with the invention. A fluid-tight cylindrical outer casing 11 is preferably formed of a rigid plastic such as Plexiglas. An inner hydrophone structure, generally designated by the reference numeral 12, is rigidly mounted within the casing 11 by a circular metal mounting ring 13 and mounting bolts 14. The hydrophone structure 12 includes a magnetized inner pole piece 15 that is supported between elongated permanent bar magnets 16 and 17. An iron housing frame 18 supports the bar magnets 16 and 17 and has an inwardly extending annular iron flange 19 that serves as an outer pole piece.

Located in the gap between the inner pole piece 15 and the outer pole piece 19 is a movable coil element 20 that is resiliently supported with respect to the outer casing by leaf springs 21–24. In the embodiment shown, the coil is resiliently mounted with respect to the casing via the outer pole piece 19, the frame 18, and the mounting ring 13. It will be appreciated, however, that there are other configurations by which the coil 20 could be resiliently mounted with respect to the casing. For example, the coil could be mounted by leaf springs extending from the bar magnets 16 and 17, or the leaf springs could be secured to and extend from the casing itself. The ends of the coil windings are electrically coupled through the leaf springs 21 and 22, and then, via insulated conductor pair 25, out of the encased hydrophone assembly through a sealed outlet port. When the inner hydrophone structure 12 has been completely assembled within the casing 11, the casing is filled with an inert booting fluid such as a silicone oil, and a pair of rubber diaphragms 26 and 27 are stretched over the respective ends of the casing and held in place by end retaining rings 28 and 29.

The permanent magnets 16 and 17 are oriented so as to have opposing like poles as indicated, for example, by the N's and S's in FIG. 2. This configuration yields an N polarization of the inner pole piece 15, an S polarization of the outer pole piece 19, and a resultant radially-extending magnetic field in the gap containing coil 20. The coil windings are perpendicular to the magnetic field lines so that they intercept a maximum amount of magnetic flux. The iron frame 18 provides a return path for the magnetic field. Motion of the coil results in the movement of the windings through the magnetic field and a resultant induced voltage as between the conductor pair 25.

In a typical operation of the encased hydrophone assembly 10, the casing 11 is rigidly mounted to an underwater body by means of a bracket 30 attached to the casing 11. For the vertical configuration shown in FIG.s 1 and 2, a vertically travelling soundwave (travelling down, for example) would first impinge upon the diaphragm 27 causing a pressure P_1 on this diaphragm. After a short delay, the same wave front, having travelled around the outside of the casing 11, impinges on the other diaphragm 26 causing a pressure P_2. Phase differences between P_1 and P_2 result in a net pressure ΔP acting between the two diaphragms, and this pressure tends to move the diaphragms, the internal fluid, and the coil 20 in a vibratory fashion. In this manner, motion related to the soundwave energy is transmitted into motion of the coil 20, and such motion is detected electrically over the line pair 25.

In the operational example just given, the encased hydrophone assembly is oriented for operation in the vertical direction, but operation in a horizontal orientation is equally effective. Also, while the encased hydrophone assembly of the present invention is particularly suitable for operation when rigidly mounted, the assembly can also function when mounted in conventional manner; i.e. with a freedom of motion of the entire outer casing.

Referring to FIG. 3, there is shown an embodiment of the invention wherein the encased hydrophone assembly of FIG.s 1 and 2 is conveniently modified to exhibit a non-symmetrical receiving pattern such as a cardioid pattern. This is achieved by placing controlled acoustic impedances on one or both sides of the inner hydrophone structure 12. In the embodiment of FIG. 3, these impedances take the form of metal disk plates 31 and 32 that are rigidly secured to the casing 11 by screws 35. Each of the plates contains one or more apertures 36, and the relative pressures on the fluid between the disks (caused by an impinging soundwave) are altered by an amount that is a function of the area and depth of the plate apertures. The principle of using controlled impedances to obtain non-symmetrical receiving patterns is described in detail with respect to the air microphone art in an article entitled "Uniphase, Unidirectional Microphones" by B. B. Bauer, Journal of the Acoustical Society of America, Vol. 13, 1941. In the typical prior art encased hydrophone assembly, where the entire inner hydrophone structure is resiliently mounted within the case, non-symmetrical receiving patterns are not implementable in the convenient and straightforward manner of FIG. 3.

I claim:

1. An encased hydrophone assembly suitable for operation when rigidly mounted underwater, comprising:
   a. a fluid-tight casing having openings at its opposite ends;
   b. a gradient-type hydrophone positioned within said casing, said hydrophone including means for generating a magnetic field and a movable coil positioned to intercept the magnetic flux of the generated field;
   c. means for rigidly mounted said field generating means with respect to said casing;
   d. means for resiliently mounting said coil with respect to said casing;
   e. means for electrically sensing relative motion of said coil in the generated magnetic field;
   f. first and second flexible diaphragms forming fluid-tight enclosures at opposite ends of said casing;
   g. fluid means filling said enclosed casing for transmitting wave motion of the water to said movable coil.

2. An encased hydrophone assembly as defined by claim 1 further comprising means for rigidly mounting said casing to a base member.

3. An encased hydrophone assembly as defined by claim 1 wherein said field generating means comprises a magnetized inner pole piece centrally positioned within said casing and an outer pole piece radially oriented within said casing and spaced from inner pole piece, a magnetic field being generated in the spacing between said inner and outer pole pieces.

4. An encased hydrophone assembly as defined by claim 3 wherein said inner and outer pole pieces are mounted in a metal frame member, said metal frame member being rigidly mounted to said casing.

5. An encased hydrophone assembly as defined by claim 4 wherein said coil is positioned in the spacing between said inner and outer pole pieces.

6. An encased hydrophone assembly as defined by claim 5 wherein said means for resiliently mounting said coil comprises a plurality of leaf springs coupled between said coil and outer pole piece.

7. An encased hydrophone assembly as defined by claim 1 further comprising an impedance plate having at least one aperture therein, said plate being rigidly mounted radially across said casing to one side of said coil.

8. An encased hydrophone assembly as defined by claim 7 further comprising a second impedance plate having at least one aperture therein, said second plate being rigidly mounted radially across said casing to the other side of said coil.

9. An encased hydrophone assembly as defined by claim 4 further comprising an impedance plate having at least one aperture therein, said plate being rigidly mounted radially across said casing to one side of said frame member.

10. An encased hydrophone assembly as defined by claim 9 further comprising a second impedance plate having at least one aperture, said second plate being rigidly mounted radially across said casing to the other side of said frame member.

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