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Yocum

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[54] **MOLDED LOUDSPEAKER DIAPHRAGM**

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[52] **U.S. Cl.** ..... **181/32 R**

[51] **Int. Cl.** **G10k 13/00**, H04r 7/00

[58] **Field of Search** ..... 181/32 R

[56] **References Cited**

UNITED STATES PATENTS

1,984,019	12/1934	Hawley	181/32 R
2,006,830	7/1935	Hawley	181/32 R
2,017,496	10/1935	Hawley	181/32 R
2,605,855	8/1952	Lenz	181/32 R
2,619,012	11/1952	Brennan	181/32 R
3,253,970	5/1966	Williams	156/228

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[57] **ABSTRACT**

A loudspeaker diaphragm is formed by dipping a suitably-shaped mold into a fibrous slurry. After drying, there is provided a diaphragm having a frusto-conical body and a flange arranged to be fixedly mounted. The diaphragm is then laterally compressed. When a driver mechanism is coupled to the smaller end of the body and is energized, the flange is repetitively flexed. The flange is capable of withstanding substantial and prolonged flexing by virtue of having been compressed during the construction thereof.

1 Claim, 9 Drawing Figures

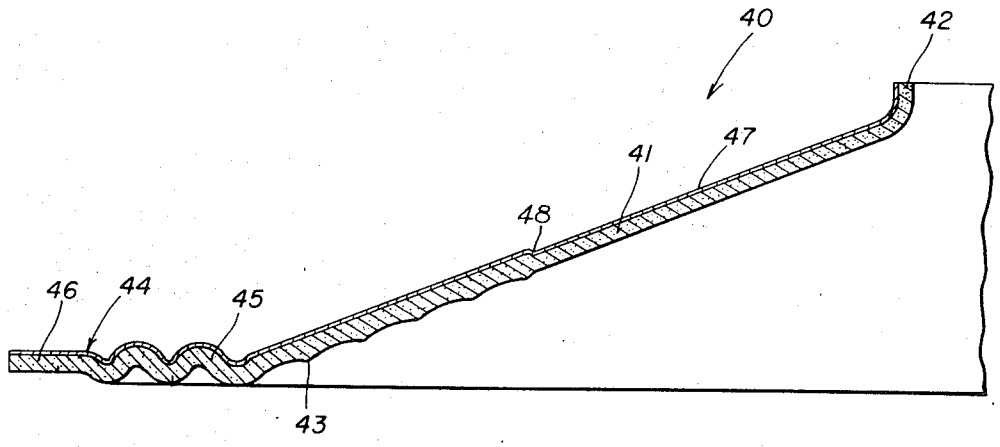


FIG. 1

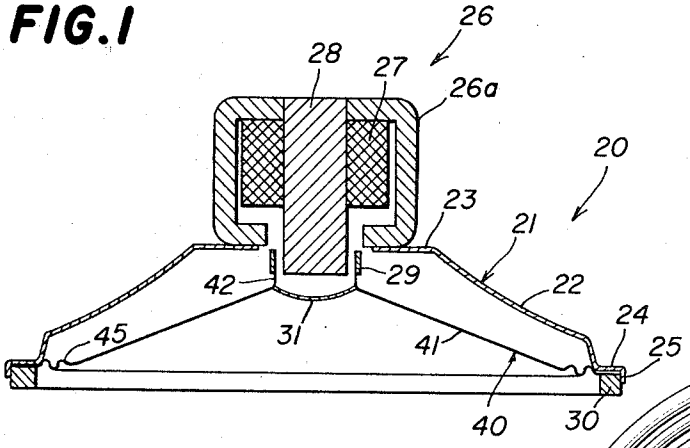


FIG. 2

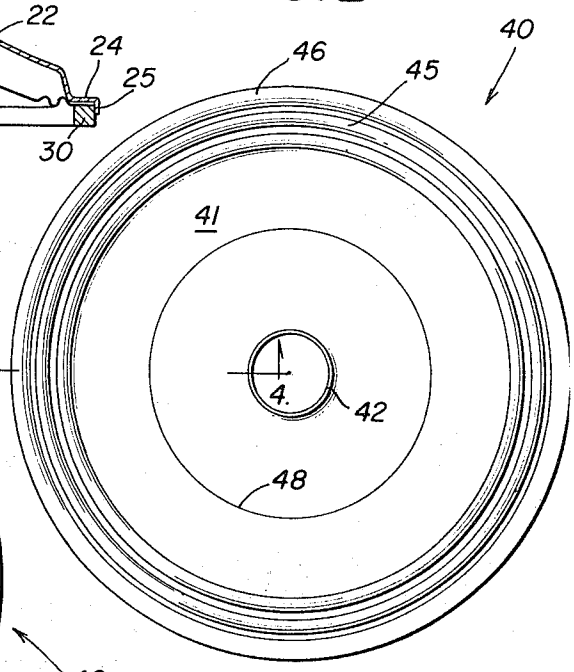


FIG. 3

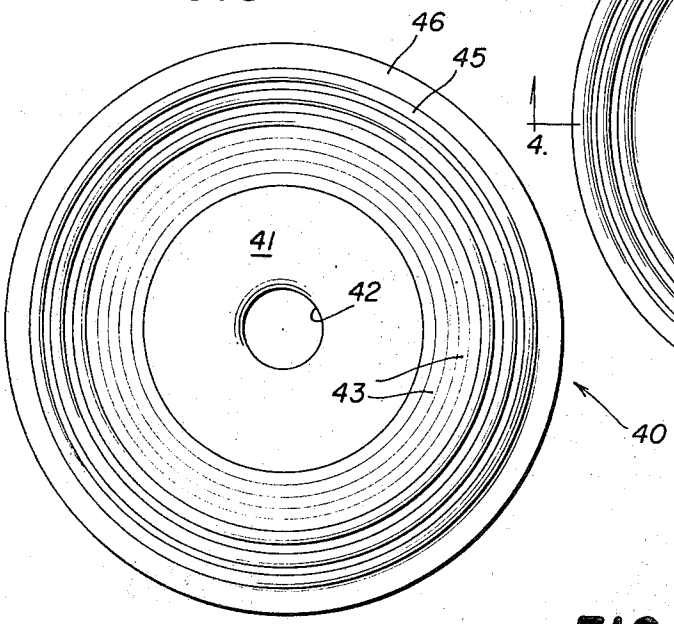


FIG. 4

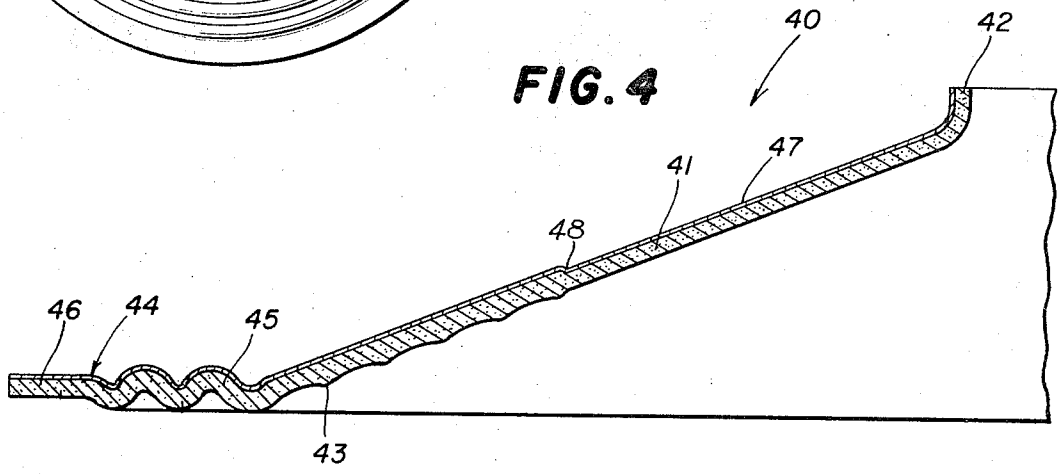


FIG. 6

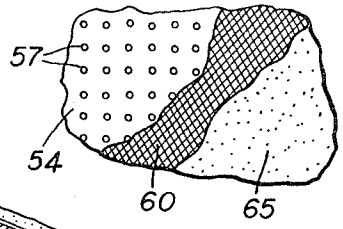


FIG. 5

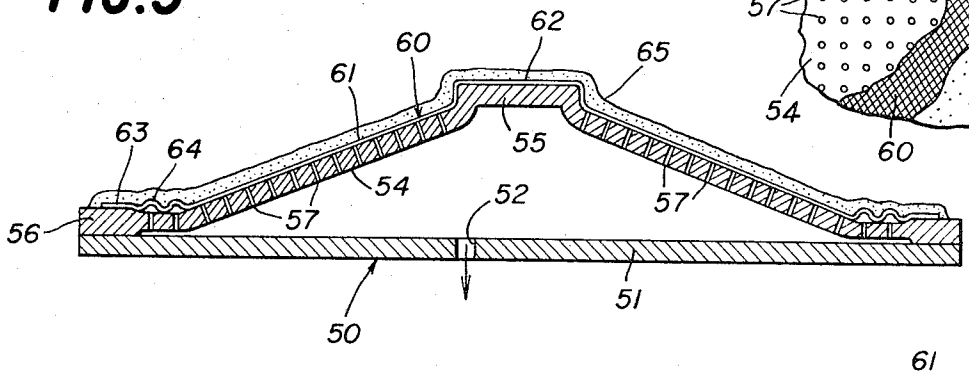


FIG. 7

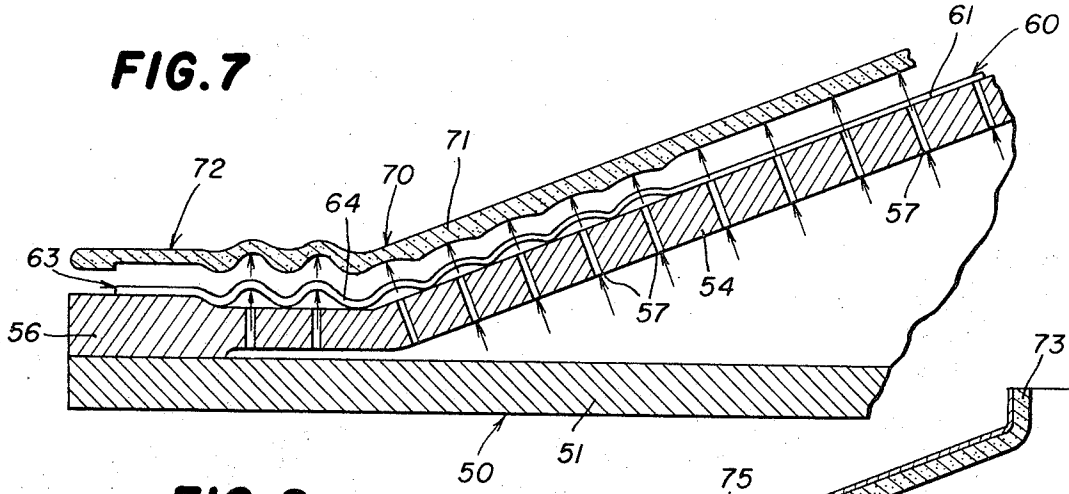


FIG. 8

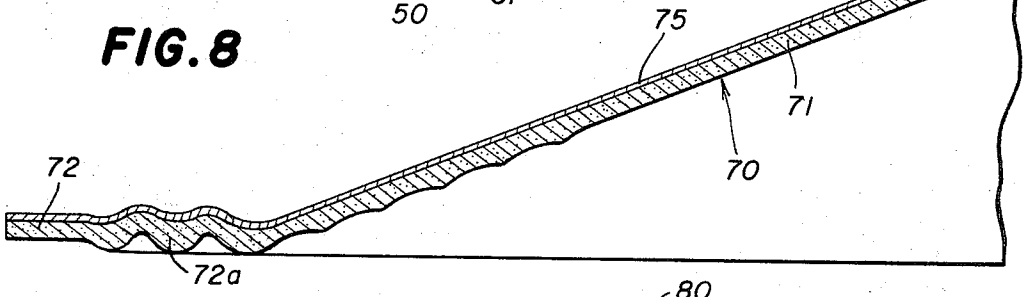
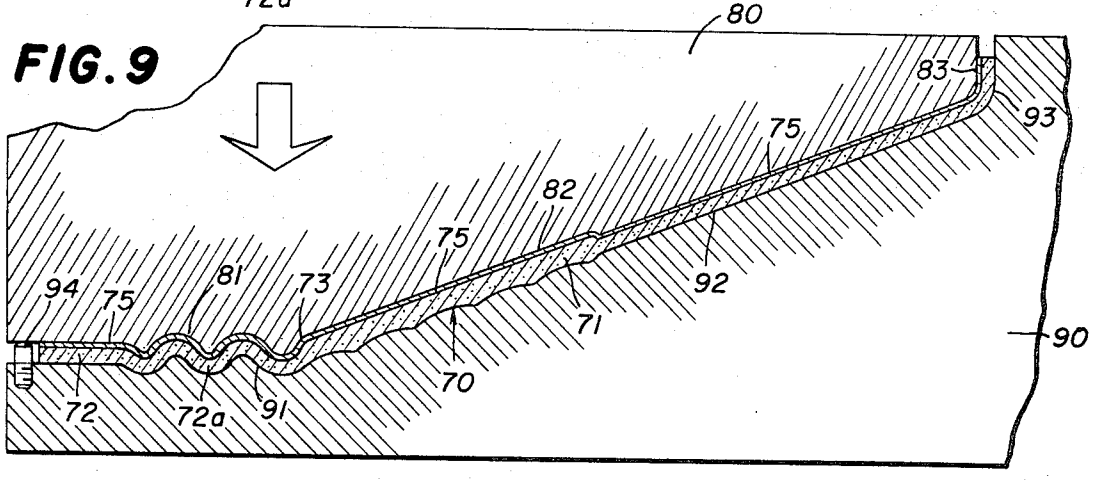


FIG. 9



MOLDED LOUDSPEAKER DIAPHRAGM

BACKGROUND OF THE INVENTION

In a direct radiator type of moving-conductor loudspeaker, there is provided a diaphragm including a body having a frusto-conical shape, with a flange on the larger end of the body. The flange is secured to a housing, which housing also carries a driver mechanism mechanically coupled to the smaller end of the diaphragm body. When the driver is energized, the diaphragm vibrates at the frequency of the energization signal. The resonant frequency of the diaphragm is the frequency at which the diaphragm vibrations are the greatest. In order to achieve good reproduction of low frequency tones, it is desirable to so construct the diaphragm that the resonant frequency is as low as possible.

In the past, in order to reduce the resonant frequency, it has been common to shave material from the flange portion of the diaphragm. Since the flange, which usually has "rolls" therein, functions much like a hinge between the frusto-conical body of the flange and the mounting means therefor, the thinner diaphragm facilitates the bending action of that flange. The entire diaphram is not made thinner initially, since that would cause the body to have insufficient rigidity to be self-supporting.

Although the shaving of the flange had the desired effect of reducing the resonant frequency, it also undesirably lessened the useful life of the diaphragm. In installations where the diaphram would be subjected to extensive use, or in an environment in which it was subjected to extensive jostling or the like, the shaved flange would tear, crack, or otherwise become damaged.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to prolong the life of a molded loudspeaker diaphragm that is extensively used and/or used in an environment in which it is subjected to substantial jostling.

It is another object to provide an improved, molded loudspeaker diaphragm formed first by dipping a suitably-shaped mold into a slurry, followed by a drying process, and then subjecting the thus formed member to a substantial pressure.

Another object is to apply a lacquer or other hardening agent to a molded loudspeaker diaphragm which has been compressed, thereby retaining the diaphram in its compressed state.

In summary, there is provided a loudspeaker diaphram of a compressible material and comprising a body having a frusto-conical shape with a larger end and a smaller end coupled in use to a driver, a flange on the larger end and adapted to be fixedly mounted in use, the flange having been laterally compressed under a pressure of at least about 10 lbs. per square inch, whereby said flange is capable of withstanding extensive and prolonged flexing thereof when the body is vibrated by the driver.

In another form of the invention there is provided an improved method of making a loudspeaker diaphragm, which method comprises the steps of providing a slurry including fibers in a liquid carrier, depositing the slurry on a diaphragm mold, drying the slurry to provide a member generally conforming to the shape of the mold, removing the member from the mold, and compressing the member under a pressure of at least about 10 lbs. per square inch.

With the foregoing and other objects in view which will appear as the description proceeds, the invention consists of certain novel steps and certain features of construction, and a combination of parts hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the steps and in the form, proportion, size, and minor details of the structure may be made without departing from the spirit or sacrificing any of the advantages of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawings a preferred embodiment thereof, from an inspection of which, when considered in connection with the following description, the invention, its mode of construction, assembly and operation, and many of its advantages should be readily understood and appreciated.

FIG. **1** is a cross-sectional view of a loudspeaker incorporating therein a loudspeaker diaphragm constructed in accordance with the features of the present invention;

FIG. **2** is a top plan view of the diaphragm;

FIG. **3** is a bottom plan view of the diaphragm;

FIG. **4** is a view in vertical section on an enlarged scale taken along the line **4—4** of FIG. **2**;

FIG. **5** is a view in vertical section of a mold used in making the diaphragm shown in FIGS. **1–4** and a slurry deposited on such mold;

FIG. **6** is a fragmentary view on an enlarged scale of the mold and slurry shown in FIG. **5**, with portions broken away to expose the various layers;

FIG. **7** is an enlarged view in vertical section showing the diaphragm member being blown from the mold;

FIG. **8** is a view of the diaphragm with a lacquer coating applied thereto; and

FIG. **9** is a view of a press consisting of two die members to compress the diaphragm.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to the drawings, and more particularly to FIG. **1** thereof, there is shown a loudspeaker **20** including a housing **21** which is round in outline, the housing **21** having a central portion **22** which is generally frusto-conically shaped, and a rear wall **23** disposed in a plane generally perpendicular to the axis of the central portion **22**. Toward the front of the central portion **22** is a front wall **24** also located in a plane normal to the axis of the central portion **22**. The outer end of the front wall **24** carries a forwardly-directed lip **25**. Mounted on the rear wall **23** is a driver mechanism **26** including a field coil case **26***a*, which carries therein a field coil **27** wrapped about a pole piece **28**. Associated with the pole piece **28** is the usual voice coil **29**. The driver mechanism **26** is well-known in the art, whereby further details will not be given herein.

Also carried in the housing **21** is a diaphragm **40**, the details of which will be described presently. The smaller end of the diaphragm **40** is attached to the voice coil **29**, and the flange on the larger end of the diaphragm **40** abuts against the front wall **24**. A ring-

shaped baffle gasket **30** fits inside the lip **25** and holds the outermost portion of the flange of the diaphragm **40** against the front wall **24** of the housing **21.** There is also provided a dust cap **31** adjacent the smaller end of the diaphragm **40** to preclude dust from entering the driver mechanism **26.**

Turning now to FIGS. **2–4,** the details of construction of the diaphragm **40** will be described. The diaphragm **40** is constructed of a molded fibrous material, which fibers may be sulfites, sulfates, cotton, wool, kapok, combinations thereof, or other fibrous materials capable of being compressed. The diaphragm **40** includes a body **41** in the shape of the frustum of a cone. In the particular form shown, the cone is one of revolution. However, it is to be understood that other conical shapes are contemplated, such as one in which the directrix is an ellipse. The smaller end of the body **41** terminates in a circular neck or apex **42** which has its axis common with the axis of the body **41.** On approximately the lowermost half of the inside surface of the body **41** is a plurality of laterally spaced apart, circular ridges or ribs **43** (FIG. 3) which serve to rigidify the body **41.** At the larger end of the body **41** is a flange **44** which is ring-like in form and is defined by a plane that is normal to the axis of the body **41.** On the innermost portion of the flange **44** is a plurality of annular undulations or rolls **45,** the innermost one of which is a continuation of the body **41.** The outermost portion **46** of the flange **44** is flat and is arranged to be disposed between the front wall **24** of the housing **21** and the gasket **30.** Also, the voice coil **29** is mechanically coupled to the apex **42** of the diaphragm **40.**

When the driver mechanism **26** is energized by virtue of an AC signal applied to the input conductors (now shown) of the field coil **27,** the voice coil **29** will reciprocate at a frequency dependent upon the frequency of the signal. The diaphragm **40,** being connected to the voice coil **29,** will be moved thereby in a piston-like motion, with the rolls **45** serving as a hinge or pivot to enable the body **41** to reciprocate with respect to the outermost portion **46** of the flange **44.**

In order that the diaphragm **40** be capable of reproducing low frequency sounds, it is desirable that the resonant frequency of the diaphragm be low. By lessening the thickness of the material which makes up the rolls **45,** the resonant frequency of the diaphragm **40** can be reduced. In the past, such reduction in thickness was accomplished by shaving material from the flange, or in the case of a molded diaphragm depositing less material in the flange region. However, the flexing of the rolls formed in such a flange would, after a certain period of time, crack, tear or otherwise become damaged.

In the instant invention, on the other hand, the material making up the rolls **45** is compressed, as will be explained, so as greatly to lengthen the life of the diaphragm.

The diaphragm **40** has a coating of lacquer **47** or other hardening agent applied thereto. If desired, the hardening agent may be mixed in with the slurry. The lacquer **47** serves to retain the diaphragm **40** in its compressed state, to repel water and to affect the over-all frequency response characteristic of the diaphragm **40.** In the specific form shown, a lacquer of one concentration was applied over the body **41** and a lacquer of another concentration was applied to the flange **44.** Pressure was applied to the flange **44** and to the portion of the body **41** between the circle **48** and the apex **42.** By suitably choosing the laquer concentrations and the portion of the body **41** subjected to pressure, the over-all frequency response of the diaphragm **40** can be adjusted.

Turning now to FIGS. **5-9,** the method of making the diaphragm **40** will be described. There is provided a mold **50** which is round in outline and has a base **51** with an inlet opening **52.** The mold also includes a body **54** in the shape of a frustrum of a cone. At the smaller end of the body **54** is a head **55,** and at the larger end of the body **54** is a ring-like flange **56** which is arranged to be substantially normal to the axis of the body **54.** There are provided a number of air holes **57** in the body **54** and in the flange **56.** There is also provided a screen **60** of very fine mesh and entirely self-supporting. The screen **60** has the overall shape of the mold **50,** that is, it has a body **61** which is in the shape of the frustrum of a cone, a head **62** at the smaller end of the body **61,** and a flange **63** on the larger end of the body **61,** the flange **63** having centric undulations or rolls **64** therein.

The mold **50** is dipped into a tank containing a slurry made up of a water carrier and fibrous materials, such as sulfites, sulfates, cotton, wool, kapok, or the like. Any wood or vegetable fibers may be used, the requisite characteristic being that the fibers be capable of compression. The slurry solution is prepared by stirring and agitating a pulp and water solution to separate the fibers, one from the other. A dye is added to provide the solution with the proper color. The basic characteristics of the fibers will have an effect on the frequency response of the diaphragm. Softer fibers, such as wool, would result in a lower resonant frequency than would harder fibers, such as wood.

A vacuum pump (not shown) is connected to the opening **52,** which vacuum pump is operated to create a partial vacuum within the mold **50,** drawing onto the mold a uniform thickness of the slurry. The mold **50** and the slurry thereon are then withdrawn from the tank, with the vacuum pump continuing to operate to dry the slurry. Hot air in the immediate vicinity of the mold **50** is sucked through the opening **52** to complete the drying of the slurry and thereby provide a partially-formed member **70.** A blast of air delivered through the opening **52** and one of the openings **57** blows the member **70** off the mold **50** (see FIG. **7**). The mold **50** is then used to mold the next member **70.** It is to be understood that a number of techniques may be utilized in mass-producing the member **70** on such a mold or molds.

The lower surface (as viewed in FIG. **5**) of the member **70** conforms precisely to the screen **60.** Specifically, the flange **63** in the screen **60** causes a similarly-shaped flange **72** to be formed in the member **70.** The portion of the flange **63** having the rolls **64** therein forms similarly-shaped rolls **72***a* in the flange **72;** and the flat portion of the flange **63** causes the flange **72** also to have a flat portion. The conically-shaped body **61** of the screen **60** causes the body **71** of the member **70** to have a similar shape, and the head **62** forms a head **73** in the member **70.** Although the surface of the member **70** in contact with the screen **60** has the precisely desired final shape, the upper surface is not so well defined, as most clearly seen in FIG. **7.** Particularly, it should be noted that the valleys of the rolls on the member **70** are thicker than the peaks.

The next step in making the diaphragm is to apply laquer **75** or other hardening agent to the member **70**, preferably to both sides of the member **70**. Good results have been attained by dipping the member **70** into the lacquer so as to impregnate the lacquer in the member. Alternatively, the lacquer may be applied in a variety of other ways, such as brushing or spraying. The lacquer **75** will cause the member **70** to retain the compressive forces which are applied in the following step.

In one form of the invention, lacquer of one concentration was applied to the body **71** of the member **70** and lacquer of a different concentration was applied to the flange **72** of the member **70**. In this manner, the frequency response of the completed diaphragm may be selected. For example, using a low concentration lacquer on the flange **72** will not significantly increase the resonant frequency. In other words, the compression applied to the flange **72**, as described hereinafter, serves to reduce the resonant frequency, and any lacquer applied to the flange **72** would serve to increase the resonant frequency. The amount of increase may be minimized by selecting a lower concentration lacquer, yet achieving water repellancy and the ability to retain the compressive forces. By utilizing a higher concentration lacquer on the body **71**, the frequency response in the higher range of frequencies may be controlled. It is to be understood that the invention contemplates a single lacquer or hardening agent, on the one hand, or any number of different hardening agents, on the other, depending upon the exact type of frequency response sought.

Finally, referring to FIG. **9**, the member **70** is subjected to pressure by two dies **80** and **90**, which dies have mating surfaces that conform precisely to the shape of the final product. Specifically, the dies **80** and **90** respectively have mating undulations **81** and **91** therein conforming precisely to the undulations or rolls that are to be present in the finished product. The lower die **90**, in addition to the undulations **91**, has a frusto-conical surface **92** and a vertical surface **93**, the upper die **80** also having a vertical surface **83**. Of course, the portion of the member between the surfaces **83** and **93** will become the apex of the member **70**. The undulations **81** and **91** compress the rolls **72a** in the flange **72** of the member **70**, to give better definition to the valleys and also to decrease the over-all thickness of the rolls, in accordance with the objectives previously explained. The die **80** also includes a relief portion **82**, that is, a portion which does not contact, and hence does not compress the member **70**. Thus, referring to FIGS. **2–4**, the portion between the flange **44** and the circle **48** is not compressed, whereas the flange **44** and the portion of the body **41** between the circle **48** and the apex **42** are compressed. By controlling the extent to which the body **71** of the member **70** is compressed, the frequency response in the higher range of frequencies can be controlled.

The lower die **90** is also provided with a plurality of stops **94** and **95** which serve to limit the extent to which the upper die **80** can compress the member **70**. In one form of the invention, the force applied to the upper die **80** was about 2,400 lbs., whereby on a member **70** having 10 square inches of area, the pressure exerted on the member would be about 240 lbs. per square inch. On the other hand, if the area of the member **70** where, say, 100 square inches, the pressure would be 24 lbs. per square inch. By properly adjusting the height of the stops, the final thickness of the product of the member **70** can be selected and the over-all pressure can be adjusted. To achieve the desired definition in the rolls in the flange **72** of the member **70**, the pressure should be at least 10 lbs. per square inch and preferably within a range of about 40 lbs. per square inch to 150 lbs. per square inch. It should be clear that the compression of the flange **72** of the member **70** reduces the resonant frequency of the finished diaphragm without lessening the life of the diaphragm or rendering it non-self-supporting.

Preferably, the member **70** is moistened prior to being compressed, and the dies **80** and **90** are heated so as to steam-press the member **70**. The finished member is then trimmed, both at the flange and at the neck **73** to provide the diaphragm **40** shown in FIGS. **1–4**.

In a diaphragm **40** produced by this method and having an over-all diameter slightly less than 5 ½ inches and having two complete rolls **45**, the resonant frequency was about 100 Hz. The application of lacquer or other hardening agent to the flange had the effect of slightly increasing the resonant frequency to about 110 Hz.

It is believed that the invention, its mode of construction and assembly, and many of its advantages should be readily understood from the foregoing without further description, and it should also be manifest that, while the preferred embodiment of the invention has been shown and described for illustrative purposes, the structural details are, nevertheless, capable of wide variation within the purview of the invention, as defined in the appended claims.

What is claimed is:

1. A molded loudspeaker diaphragm comprising a body having a frusto-conical shape with a larger end and a smaller end coupled in use to a driver means, and a flange on said larger end, said flange having a flat portion and a roll portion, said flat portion adapted to be fixedly mounted in use, said flange portion further comprising a lacquer of a first concentration, said body comprising said lacquer of a second concentration, said flange and at least a portion of said body having been laterally compressed under a pressure of at least about 10 pounds per square inch, whereby said roller portion is capable of withstanding extensive flexing thereof as the result of said body being vibrated by the driver means and whereby the response of said diaphragm is improved.

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