April 7, 1931. R. GOLDSCHMIDT 1,799,162

DIAPHRAGM ESPECIALLY FOR THE REPRODUCTION OF SOUND

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Fig. 3.

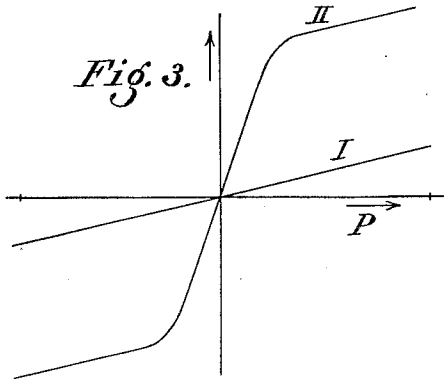


Fig. 5.

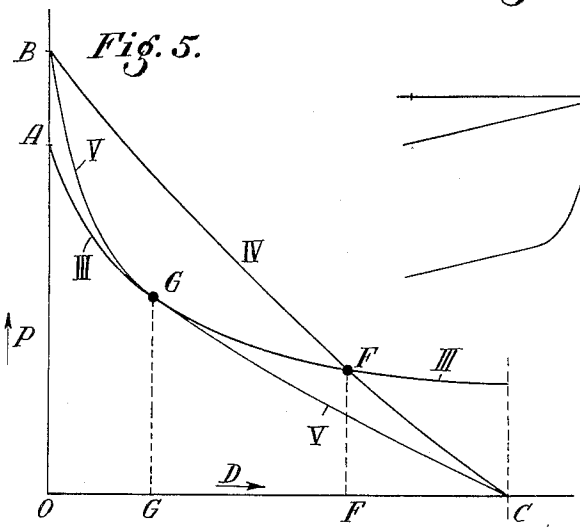


Fig. 1

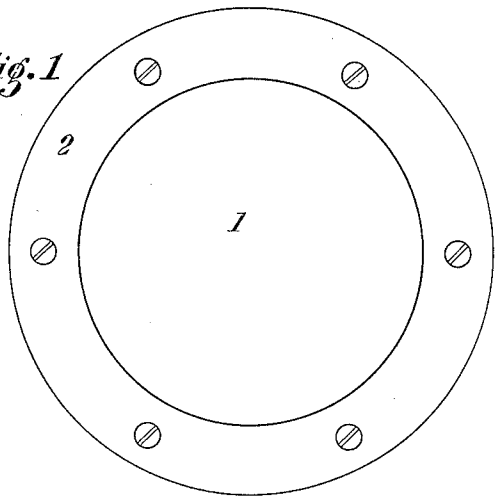
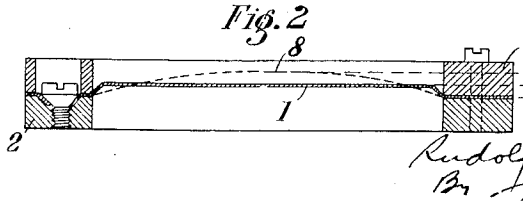


Fig. 2



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DIAPHRAGM ESPECIALLY FOR THE REPRODUCTION OF SOUND

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Fig. 4

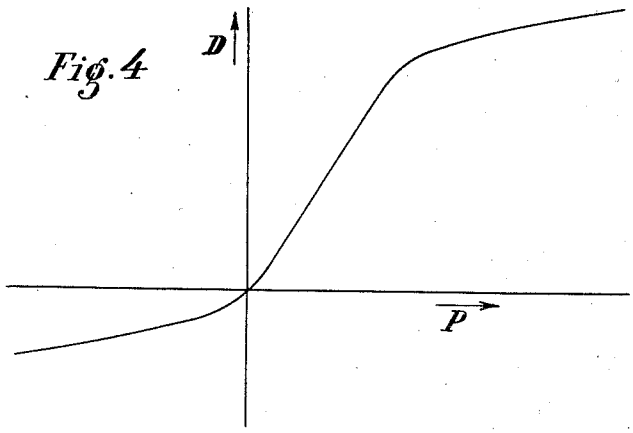


Fig. 6

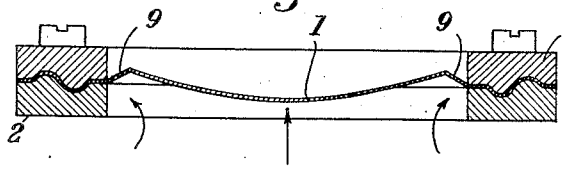


Fig. 7

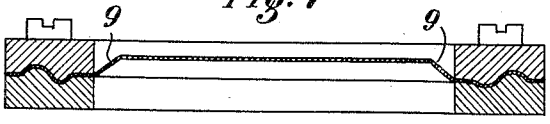


Fig. 8

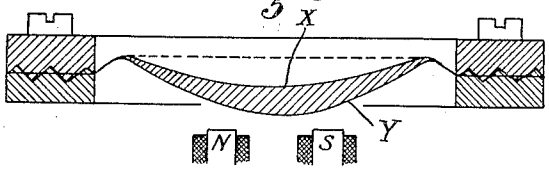
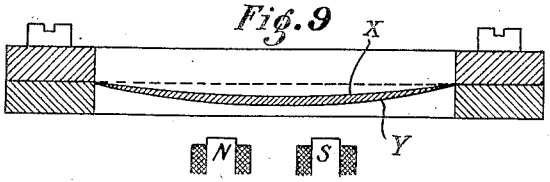


Fig. 9



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DIAPHRAGM ESPECIALLY FOR THE REPRODUCTION OF SOUND

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Fig. 10

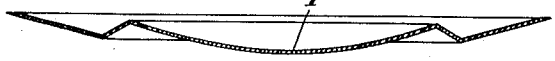


Fig. 11

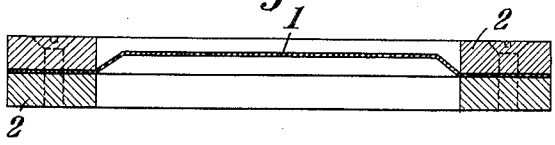


Fig. 12

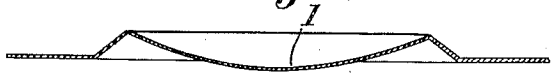


Fig. 13

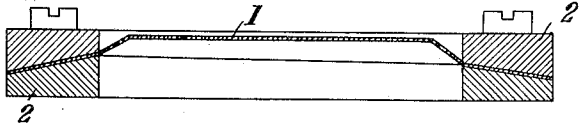


Fig. 14

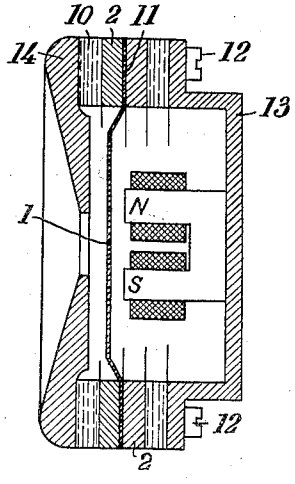
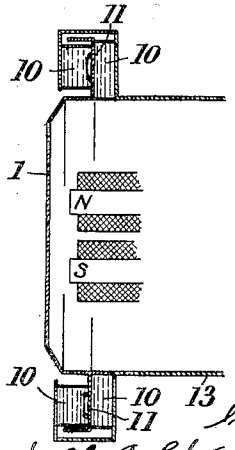


Fig. 15



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UNITED STATES PATENT OFFICE

RUDOLF GOLDSCHMIDT, OF BERLIN, GERMANY

DIAPHRAGM ESPECIALLY FOR THE REPRODUCTION OF SOUND

Application filed May 22, 1928, Serial No. 279,740, and in Germany September 1, 1927.

This invention relates to an improved diaphragm especially for the reproduction of sound. The following description is based chiefly on the example of an electro-magnetic telephone equipped with the improved diaphragm, but the latter may be equally advantageously applied to any other sound reproducing machine, for instance to an electro-static telephone, a loudspeaker and a phonograph as well as a regulating, measuring, and any other device, where power is transmitted through the medium of a diaphragm.

One object of this invention is to increase the elasticity of a given diaphragm.

Another equally important object is to give a bend and a considerable radius of curvature to the otherwise only slightly curved, practically straight, characteristic curve of elasticity which determines the deflection of the diaphragm under different loads or pulls.

These results are attained by means of certain stresses created artificially in the material of the diaphragm, so as to bring it more or less close to a state of balance (pseudo-astatic equilibrium).

In order that the invention may be more clearly understood reference is hereinafter made to the accompanying drawings wherein:—

Figure 1 is a plan view of my improved diaphragm; Fig. 2 shows a sectional view of the improved diaphragm shown in Fig. 1;

Figs. 3, 4 and 5, are diagrams graphically illustrating the effect of improvements in accordance with my invention;

Figs. 6 and 7 illustrate steps employed in the method of producing the useful stresses in the diaphragm of my invention;

Fig. 8 shows the form which the improved diaphragm of Fig. 10 assumes under the pull of an actuating magnet system;

Fig. 9 illustrates the section of a diaphragm under the pull of the magnet system, the dimensions being the same as that of Fig. 8, but without the improvements according to my invention;

Figs. 10, 11, 12 and 13 are modifications of the method for producing an improved diaphragm; and

Figs. 14 and 15 illustrate methods of protecting the diaphragm against distortion.

In the several drawings the deflection, bulging and vaulting of the diaphragm, in order to make them at all discernible in the drawings, have been considerably exaggerated.

With reference to Figs. 1 and 2, as a first example, the diaphragm is first given the vaulted form 8. After this vaulting process, the first operation, the bowl or vaulted shape, 8 in Fig. 7, is annihilated entirely, or to a large extent, by bending it into the form 1, Fig. 2, the depth of the bowl being reduced from f to f^1. This counter-operation, which, for the sake of reference, may be called "the stretching" is to be more or less of a nature such that the diaphragm, after having been stretched into an almost entirely flat form 1 or beyond this and held back in the new position, retains some tendency to return towards its former shape 8 through latent elastic stresses.

The stresses are spread over the whole diaphragm, practically every square millimeter taking part in the vaulting and stretching. The effect of this preparation is that the diaphragm is made to resist a strong magnetic pull and to adapt its characteristic to that of the magnet, the meaning of which will be explained with reference to Figs. 3, 4 and 5.

In diagram Fig. 3, P is the pull upon a diaphragm vertical to its plane, and D is the corresponding deflection. Character I refers to an ordinary diaphragm. If the latter is prepared as described above the characteristic changes to curve II in Fig. 3 or assumes the unsymmetrical shape Fig. 4. The characteristic can be shaped at will and depends entirely upon the vaulting and stretching process.

For the adaption of the characteristic of the diaphragm to a given purpose, the electro-magnetic telephone is a good example. The pull exercised by the permanent magnet upon the diaphragm depends on their relative distance, a relation indicated by the characteristic of the magnet, curve III in Fig. 5. If the distance is zero the pull is OA. If there was no magnetic pull at all, the position

of the diaphragm would be at C. The distance OC must be such that, if the diaphragm is deflected until it touches the magnet, its elastic force OB exceeds the attractive force OA of the magnet by an amount of safety AB, so that the diaphragm cannot stick to the magnet. An ordinary diaphragm with a straight characteristic (IV in Fig. 5) would deflect into position F (distance OF), a point where the magnetic and elastic forces are equal. The position which an improved characteristic (curve V) would assume in the magnetic field, would correspond to the point of intersection G (distance OG) of the curves III and V. The angle of intersection ought to be very near zero or at least extremely acute. The characteristic of elasticity V may be so closely adapted or assimilated to the characteristic III of the magnetic force that through the differential action of both forces in the area near G the resultant elasticity of the diaphragm becomes almost infinite. The diaphragm practically "floats" in the magnetic field, this result being achieved under the essential condition that—due to the very pronounced curvature of its characteristic—there is no danger of the diaphragm sticking to the magnet. Extreme elasticity is combined with stability. Naturally the diaphragm connot be quite astatic over a wide range, but is very close to a state which in steam engineering and physics is called "pseudo-astatic", a term which might be used to designate such a condition of sensitiveness.

The pseudo-astatic state may be verified by holding the telephone to the ear and exercising a small pressure upon the case of the telephone, thereby compressing slightly the air enclosed between the tympanum and the diaphragm and noting the clicking noise due to the extreme sensitiveness of the diaphragm upon the slightest change of pressure.

The method of vaulting and stretching may be varied considerably. I prefer the mode as illustrated by Figs. 6 and 7. The diaphragm 1 is pressed (vaulted) into the form Fig. 6 and afterwards by pressure from below as indicated by the arrows, transformed (stretched) into that of Fig. 7. The bevelling (9) of the diaphragm along its circumference (like a mirror) is important. It gives way and adapts itself automatically and permanently to the shape of the diaphragm, when the latter undergoes its transformation. This helps to secure the bending momentums and is essential in producing diaphragms with practically equal properties. It forms a buffer between the frame or rim and the diaphragm proper, thus protecting the latter against natural as well as accidental changes.

The unsymmetrical shape Fig. 4, which is very useful in electromagnetic telephones, is obtained by stretching the diaphragm so that it bulges out somewhat beyond the flat form into a curvature opposite to the original vaulting.

To show still more clearly the influence of the artificial interior stresses upon the elastic properties of a diaphragm, reference is made to Figs. 8 and 9 which are the results of actual measurements. Fig. 8 refers to a diaphragm in accordance with this invention, assuming the shape X under the influence of the magnet. This shape changes to Y, if a small direct current is passed through the telephone coils upon the magnet. For an ordinary diaphragm with the identical general dimensions but without the artificial stresses the corresponding forms are those of Fig. 9. Figs. 8 and 9 are directly comparable, the cross-hatched areas illustrating the larger volume of air displaced under influence of the same current by the diaphragm Fig. 8 in accordance with this invention.

Figs. 10–13 illustrate a mode of stretching carried out at the same time as the diaphragm (1) is insered into its frame (2), the vaulting having been done beforehand.

The permanent maintenance of the stresses in the diaphragm is of fundamental importance. Before providing proper means to secure them, I have had the experience that a number of originally excellent diaphragms had become perfectly useless within 24 hours, others within a week. One of the protecting means is the bevelling (Fig. 7). Others are indicated in Figs. 1, 2, 6 and 8, where the diaphragm is secured in a strong frame by corrugating the rim during the process of fixing it in the frame.

In order to guard against extension and contraction through the influence of temperature changes, the material of the frame ought to be chosen so that it has practically the same coefficient of extension as that of the diaphragm itself. An iron diaphragm ought to have an iron frame, if possible. If, however, the latter is firmly screwed against a different material, a bi-metallic action may again make the diaphragm alive to the temperature of its surroundings, destroying its qualities through warping. This influence has been borne out by my early experiments with a telephone equipped with the new diaphragm, the latter becoming useful only after warming it up by holding the telephone to the ear for several minutes.

To make the diaphragm independent of its neighbourhood flexible insertions (10), Figs. 14–15, for instance paper or rubber rings are provided which insulate the diaphragm mechanically.

If such insertions are made very flexible and the shape of the diaphragm and its rim such that it becomes in itself resistant against alteration of the interior stresses, the frame (2) may be reduced to plain rings which are

pressed against the rim (11) of the diaphragm (1) by the screws (12) that hold the case (13) and the ear-piece (14) together.

Fig. 15 is an example of a diaphragm with its rim (11) pressed into a shape which is stiff enough in itself to preserve, without insertion into a frame, the original stresses, provided that the metal is not too thin.

With a very thin diaphragm of large diameter, however, it is necessary, not only to insert it securely, into a strong frame, but to do so before the vaulting or anyway before the stretching operation is carried out, as otherwise there is a chance that the diaphragm has become an absolutely different one, after having been placed into the apparatus of which it forms a part.

Claims:

1. The method of creating artificial stresses in a diaphragm which consists in forming the diaphragm into a vaulted shape and subsequently applying permanently bending forces to the diaphragm in the direction from the convex to the concave side of the original vaulting for shifting said diaphragm in a direction opposite to the vaulted position thereof.

2. The method of creating artificial stresses in a diaphragm upon which a permanent pull is exercised which comprises forcing the material of the diaphragm into a vaulted shape and thereafter deforming said diaphragm to a position wherein the combined action of the external and internal forces are such that the diaphragm operates near a point of flexure of its characteristic curve.

3. A sound reproducing diaphragm comprising a sheet of material which is subjected to artificial stresses, a clamping device, the rim of said diaphragm being rigidly secured in said clamping device, said diaphragm having an annular beveled portion pressed therein intermediate the clamped portion and the central portion thereof, said central portion having the material thereof compressed for establishing permanent internal forces in said diaphragm.

4. A diaphragm comprising a sheet of magnetic material, a clamping device for securing a rim portion of said diaphragm at its periphery, said diaphragm having a central portion and an annular bevelled portion pressed therein intermediate the clamped portion and said central portion, said central portion being stamped with dies having the shapes of continuous curves first in one direction and then in the opposite direction, and said central portion having the material thereof compressed for establishing permanent internal forces in said diaphragm.

5. A sound reproducing diaphragm comprising a sheet of material having an annular rim portion and a central portion, said annular rim portion being fixed in a retaining frame, said diaphragm being pressed in a direction normal to the frame and subsequently pressed in the opposite direction for restoring said diaphragm to a position approximating the original position of the diaphragm with internal forces established therein and maintained by said retaining frame.

6. The method of forming a sound reproducing diaphragm which consists in applying forces to the diaphragm to press the diaphragm into an arched shape and subsequently applying forces to the diaphragm in the opposite direction to flatten the arched shape diaphragm into a substantially plane surface for establishing permanent internal forces within the material of the diaphragm.

7. A sound reproducing diaphragm comprising a sheet of material having an annular rim portion and a central sound reproducing surface, means for gripping said sheet of material at its rim portion, said diaphragm being vaulted in the central portion thereof in one direction and flattened substantially throughout the vaulted portion by forces applied in the opposite direction for establishing permanent internal forces within the material of the diaphragm.

8. A sound reproducing diaphragm comprising a sheet of material having a rim portion, means for gripping said rim portion, the central portion of said diaphragm being vaulted in shape in one direction and thereafter deformed from the vaulted shape in the opposite direction to a position in which the internal structure of said diaphragm is maintained under a state of permanent internal stress.

9. In a sound reproducing diaphragm, a sheet of material having a rim portion and a central portion, a frame for gripping said rim portion, said frame having substantially the same coefficient of expansion under conditions of rising temperature as the material of the diaphragm, the central portion of said diaphragm being vaulted first in one direction and subsequently deformed in the opposite direction for maintaining said diaphragm in a condition of permanent internal stress.

10. A sound reproducing diaphragm comprising a sheet of material having a rim portion and a central portion, a frame structure surrounding said rim portion, thermal insulation means disposed between said frame structure and said rim portion, said central portion being vaulted first in one direction and subsequently deformed in the opposite direction to maintain the internal structure of said diaphragm in a condition of internal stress.

11. The method of forming an accoustic diaphragm to be actuated by the force of an external field which varies at different points in a gap, which consists in vaulting said dia-

phragm in one direction by stamping with a curvilinear die, and counter-vaulting by stamping in the opposite direction in such manner that the restoring force of said diaphragm is approximately equal to said external field force over a substantial part of the working portion of said gap.

12. The method of forming an acoustic diaphragm to be actuated by the force of an external field which varies at different points in a gap which consists in imparting to said diaphragm stresses such that the restoring force of said diaphragm is approximately equal to the said external field force over a substantial part of the working portion of said gap.

13. The method of forming an acoustic diaphragm to be actuated by the force of an external field which varies at different points in a gap, which consists in clamping said diaphragm tightly in a mounting frame, vaulting said diaphragm in one direction by stamping with a curvilinear die, and counter-vaulting by stamping in the opposite direction, in such manner that the restoring force of said diaphragm is approximately equal to said external field force over a substantial part of the working portion of said gap.

14. The method of forming an acoustic diaphragm to be actuated by the force of an external field which varies at different points in a gap which consists in clamping said diaphragm in a mounting ring, stamping said diaphragm with die and counter-die to form a central arched portion, and an annular rim portion bent from the flat position in a direction opposite to the direction of such vaulting, and then applying pressure from the convex side of said vaulted portion to cause said vaulted portion to assume a substantially flattened form, whereby the restoring force of said diaphragm is approximately equal to the said external field force over a substantial part of the working portion of said gap.

15. The method of lowering the resonance frequency of an acoustic diaphragm which consists in vaulting said diaphragm by stamping with a curvilinear die, and counter-vaulting said diaphragm by stamping in the opposite direction.

16. In an acoustic device, an acoustic diaphragm adapted to be actuated by the force of an external field which varies at different points in a gap, a mounting frame of a material having the same temperature coefficient as said diaphragm in which said diaphragm is clamped, said diaphragm being vaulted and counter-vaulted by stamping operations in opposite directions whereby said diaphragm possesses a restoring force approximately equal to said external field force over a substantial part of the working portion of said gap.

17. In a acoustic device, an acoustic diaphragm adapted to be actuated by the force of an external field which varies at different points in a gap, a mounting frame in which said diaphragm is clamped, heat insulating pieces insulating said diaphragm from said frame, said diaphragm being vaulted and counter-vaulted by stamping operations in opposite directions whereby said diaphragm possesses a restoring force approximately equal to said external field force over a substantial part of the working portion of said gap.

18. The method of forming an acoustic diaphragm to be actuated by the force of an external field which varies at different points in a gap, which consists in clamping said diaphragm tightly in a mounting frame, and applying permanent compressive forces in said diaphragm by vaulting said diaphragm in one direction by stamping with a curvilinear die, and counter-vaulting by stamping in the opposite direction.

19. The method of forming an acoustic diaphragm to be actuated by the force of an external field which varies at different points in a gap which consists in clamping said diaphragm in a mounting ring, stamping said diaphragm with die and counter-die to form a central arched portion and a frusto-conical annular zone, and then applying pressure from the convex side of said vaulted portion to cause said vaulted portion to assume a substantially flattened form, whereby the restoring force of said diaphragm is approximately equal to the said external field force over a substantial part of the working portion of said gap.

In testimony whereof I affix my signature.

RUDOLF GOLDSCHMIDT.