Oct. 28, 1941. A. C. HOOF 2,260,667

DIAPHRAGM FORMING DEVICE

Original Filed Jan. 19, 1938 4 Sheets-Sheet 1

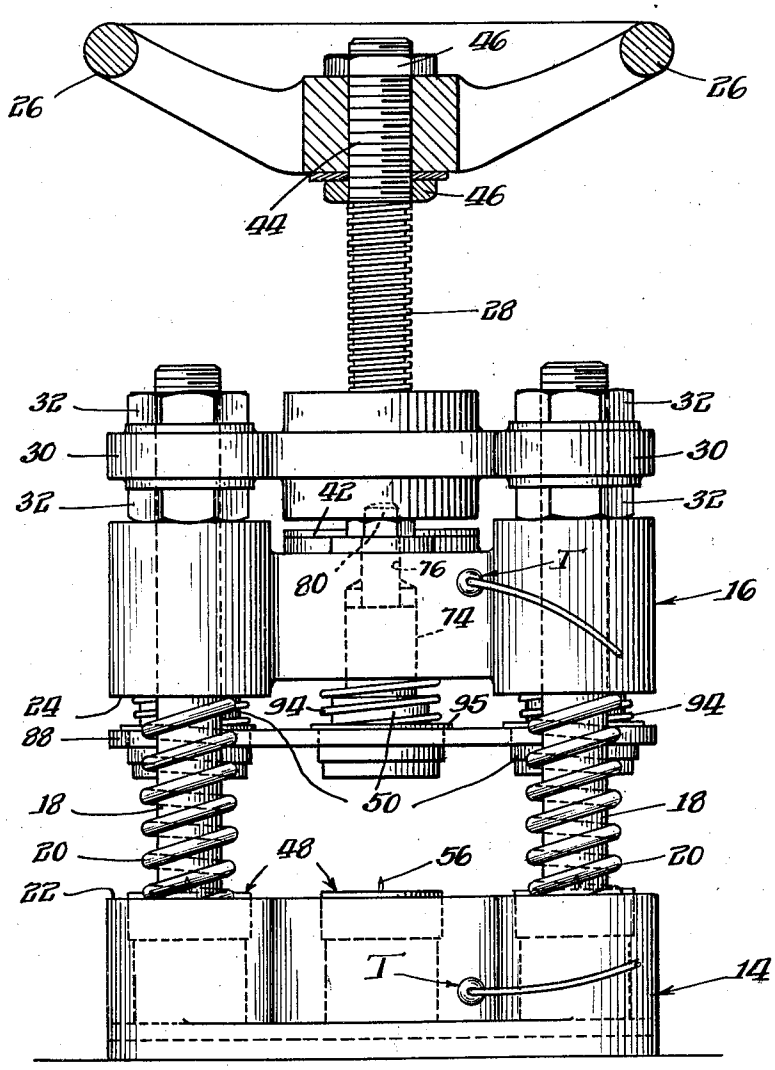


FIG. 1.

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DIAPHRAGM FORMING DEVICE

Original Filed Jan. 19, 1938 4 Sheets-Sheet 2

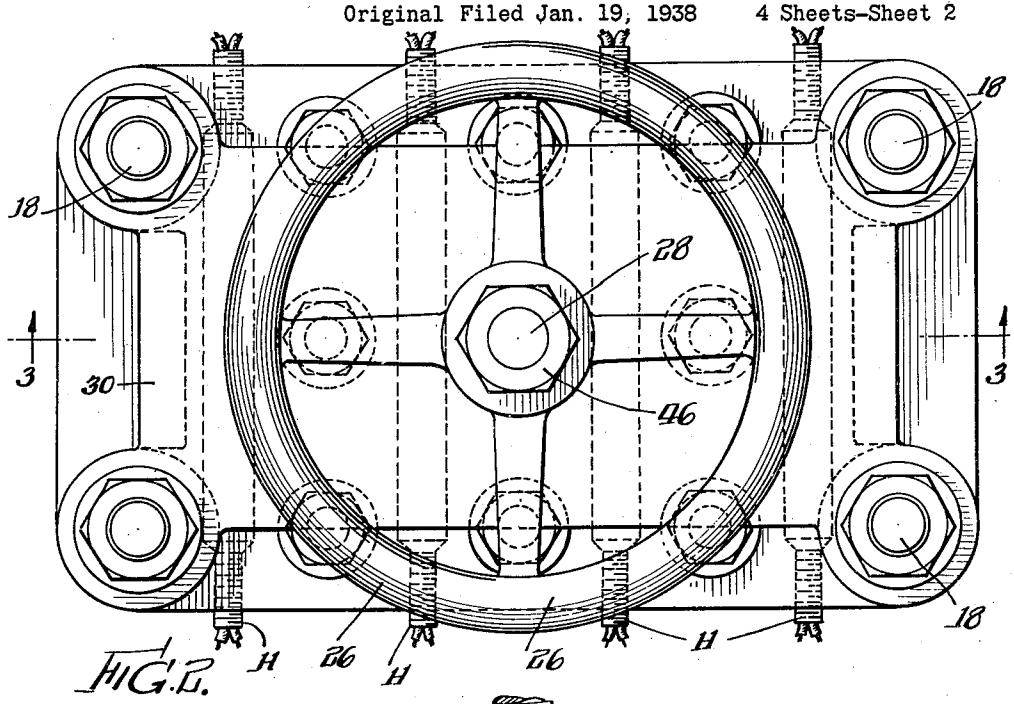


FIG. 2.

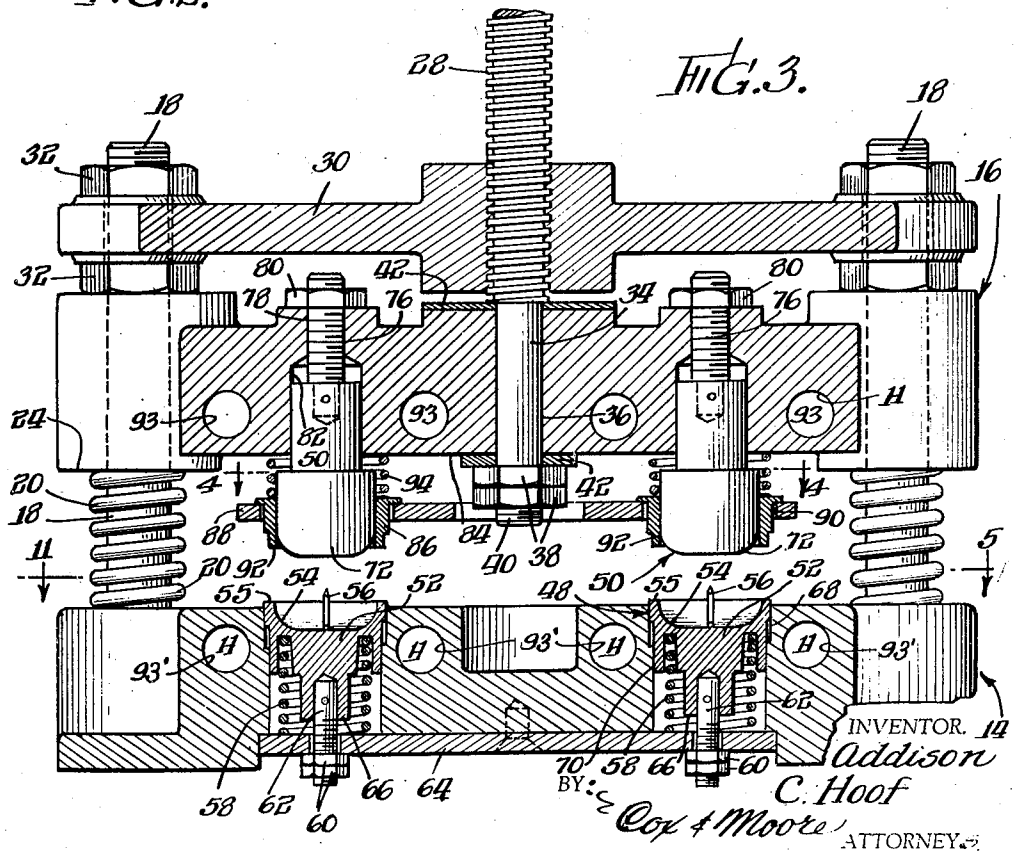


FIG. 3.

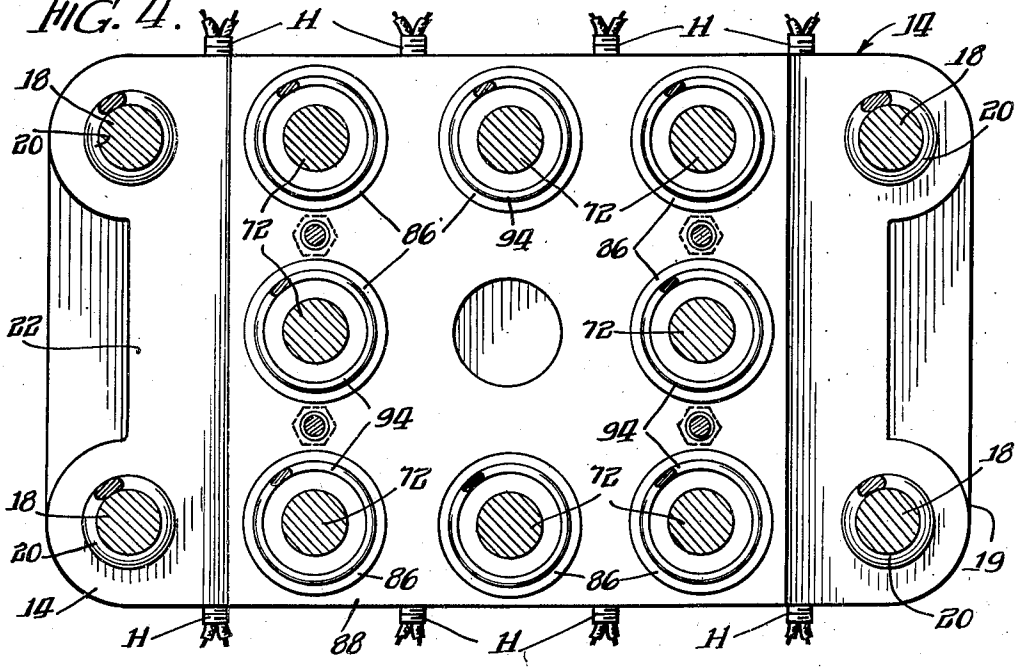
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DIAPHRAGM FORMING DEVICE

Original Filed Jan. 19, 1938 4 Sheets-Sheet 3

FIG. 4.



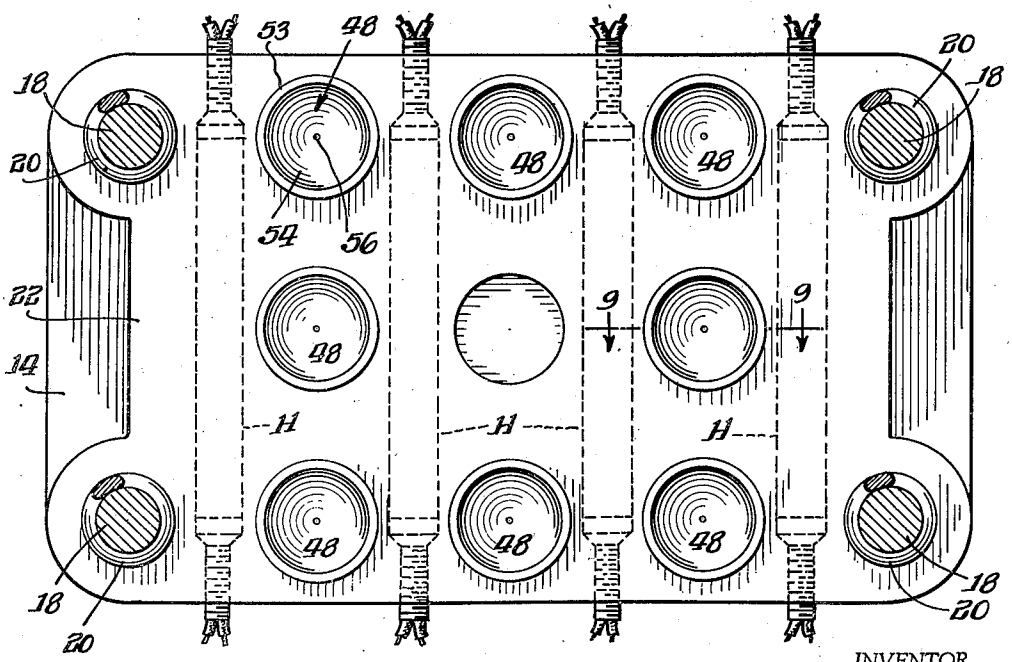


FIG. 5.

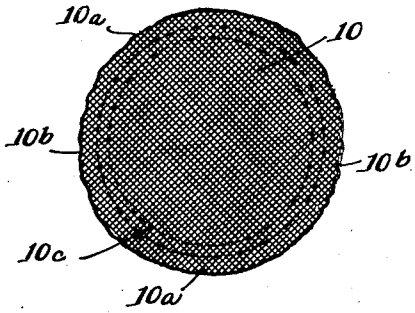
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DIAPHRAGM FORMING DEVICE

Original Filed Jan. 19, 1938 4 Sheets-Sheet 4

FIG. 6.



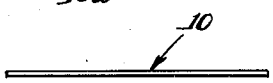


FIG. 7.

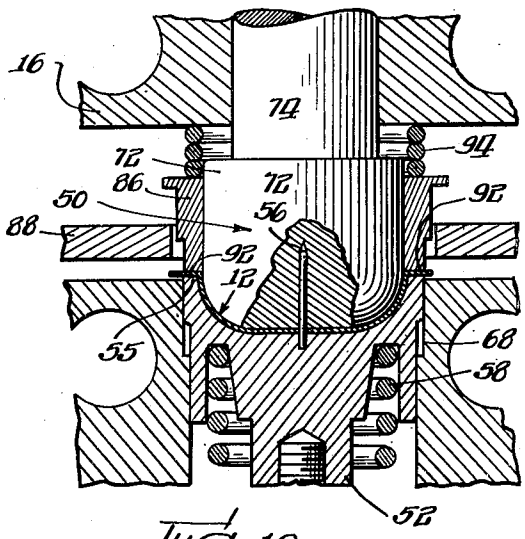


FIG. 10.

FIG. 8.

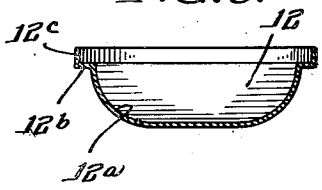
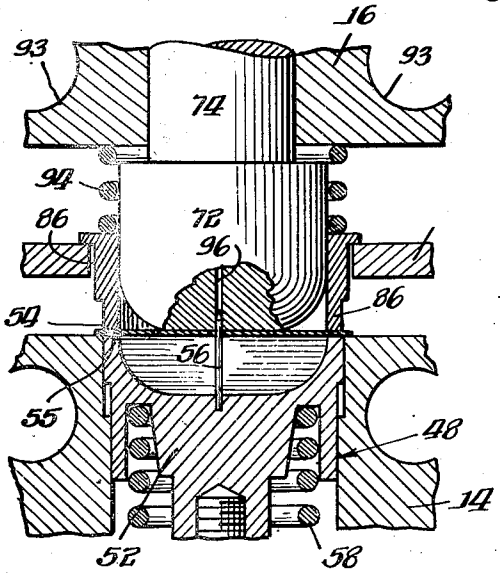


FIG. 9.



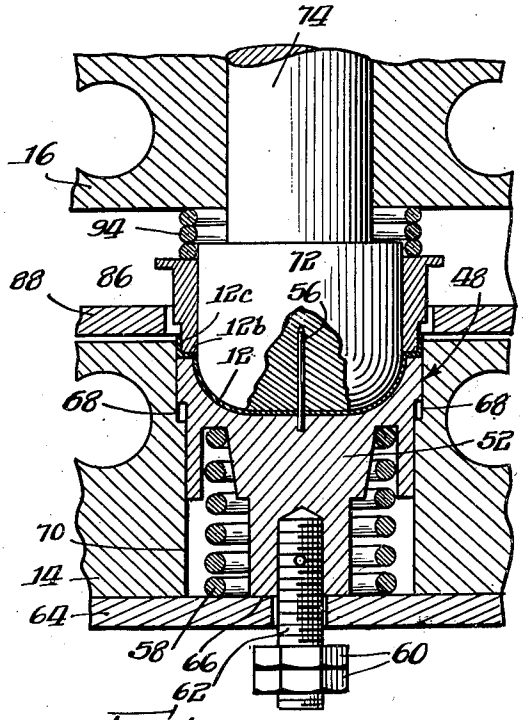


FIG. 11.

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Patented Oct. 28, 1941

2,260,667

UNITED STATES PATENT OFFICE

2,260,667

DIAPHRAGM FORMING DEVICE

Addison C. Hoof, Hinsdale, Ill.

Original application January 19, 1938, Serial No. 185,748. Divided and this application April 25, 1940, Serial No. 331,623

7 Claims. (Cl. 18—19)

The present invention relates to the manufacture of diaphragms and more particularly to a means for forming or molding diaphragms for use as machine or control elements.

The present application more particularly is a division of Addison C. Hoof application, Serial No. 185,748, filed January 19, 1938, now Patent No. 2,208,583, the claims of which are directed more specifically to the process of diaphragm formation.

The present invention claims specifically the mechanism and device in which the diaphragm formation occurs.

The present invention contemplates the manufacture of flexible diaphragm machine elements from an impervious, yieldable and flexible sheet or web. More specifically, the present invention is concerned with the molding of such a sheet to a predetermined, suitable form having a central portion laterally displaced out of the plane of the sheet and thus adapted to flex or yield laterally in response to a variation in fluid pressure on the opposite lateral faces of the diaphragm.

It is an object of the present invention to provide means for permanently molding and forming a diaphragm, as above, which coincidentally forms and shapes the peripheral margin thereof for engagement by suitable supporting and retaining means. Diaphragm elements of the present character must normally be supported under hermetic conditions so as to be repsonsive to the foregoing pressure differentials and to provide a permanent support. The present invention, therefore, contemplates the formation of a diaphragm preferably with a circular, flat margin terminating in an axial or lateral flange arranged in a cylindrical plane.

It is accordingly an object of the present invention to provide a molding machine which permanently molds the foregoing peripheral configuration coincidentally with the molding of the central portion of the diaphragm.

It is a yet more specific object of the present invention to provide a mechanism as above wherein one of the molding dies is yieldably, slidably supported for movement away from the complementary die so that at molding pressures the yieldable die member moves axially into the slide-away to shape and mold the peripheral margin of the blank in said axial direction.

The present invention further contemplates diaphragm manufacture, as above, from a suitable web or sheet formed of a suitable, conventional, yieldable plastic reinforced with or impregnated upon a reinforcing weave or fabric. Considerable difficulty has been hitherto experienced in permanently reforming and shaping such material. Thus it will be apparent that an extensive lateral de-formation of the sheet entails at some points distension or extending the material of the sheet in a plane thereof, and at other points a compacting or compression, necessitating in effect a re-arrangement of the fibers. It has been discovered that re-arrangement is not practically permissible in the production of a diaphragm for either a precision or a serviceable mechanism where the fibers are unduly stressed, strained or irregularly re-arranged..

It is accordingly an object of the present invention to provide a mechanism as above wherein the web is held during molding by means limiting the stress within the web to a predetermined moderate value whereby the threads of the web are only moderately longitudinally stressed while being permitted to re-arrange themselves in bias directions under the said tension to facilitate uniform molding.

Among other objects of the present invention are to provide a mold, as above, adapted to complete curing of the molded articles, and to provide a mechanism which reserves the initial shaping of the marginal flange configuration until the molding of the central diaphragm portion is completed.

Yet other and further objects and advantages of the present invention will be apparent from the following detailed description when considered in connection with the accompanying drawings, wherein

Fig. 1 is an elevational view of a machine embodying the principles of the present invention, portions of the handle being broken away and shown in section.

Fig. 2 is a planned view of the device shown in Fig. 1.

Fig. 3 is a sectional view taken centrally through the device of Fig. 2 on the line **3—3** thereof.

Fig. 4 is a sectional view taken horizontally on the line **4—4** of Fig. 3.

Fig. 5 is a sectional view taken horizontally through the machine of Fig. 3 on the line **5—5** thereof.

Fig. 6 is a plan view of a sheet or blank of moldable material prior to molding.

Fig. 7 is a side elevational view thereof.

Fig. 8 is a sectional view taken centrally through the diaphragm formed from the blank of Figs. 6 and 7 subsequent to molding thereof.

Figs. 9, 10 and 11 are detailed sectional views taken centrally through one of the molding sections or units on the line 9—9 of Fig. 5 and showing respectively the relative positioning of the parts during the process of molding.

There is shown in Figs. 1 to 5 a device constructed in accordance with the present invention and disclosed in detail herein for illustrative purposes.

The device more particularly comprises a rectangular base 14 and a rectangular upper platen 16 movable vertically with respect to the base upon a plurality of guide members or tension rods 18. The upper platen 18 has corner embossments 19 slidably receiving the guide bars 18. Compression springs 20 embracing the guide bars 18 are disposed between the lower surface of the platen 16 and the upper surface of the base 14 and operative normally to urge the platen 16 upwardly.

A hand wheel 26 and screw 28 combination, threadedly engaged with a plate or frame member 30, are adapted for forcibly urging the platen 16 toward the base 14. To this end it will be noted that the member 30 comprises a fixed portion of the frame of the machine permanently mounted at the upper extremities of the guide bars or uprights 18 through the agency of lock nuts 32. The threaded or pressure bar 28 rotationally engages the platen 16 through a reduced lower extremity 34 journaled in a central bore 36 within the platen and retained by lock nuts 38 engaging the shank as at 40. An anti-friction washer 42 completes the journal assembly. The hand wheel 26 threadedly mounted upon the pressure bar 28, as shown, is retained by lock nuts 46 and preferably keyed to the threaded bar 28.

It will be obvious from the foregoing that rotation of the hand wheel 26 and accordingly the threaded bar 28 results in the foregoing assembly and also the upper platen 16 being carried upwardly or downwardly with respect to the lower platen.

In accordance with the present invention, molding is carried out through the agency of oppositely disposed complementary female and male die assemblies 48 and 50 respectively. The opposed dies are disposed regularly about the surface of the opposed platen members, as indicated in Figs. 3, 4 and 5 and the construction and arrangement of the individual die members is illustrated in detail in Figs. 3 and 9 to 11. Referring to these last-named figures, it will be seen that each female die assembly comprises a cylindrical member 52 having a depressed or recessed upper surface 54 bounded by a flat, marginal surface 55 annularly disposed, a centering pin 56 projecting vertically from the central portion of the recess 54.

Attention is particularly directed to the fact that the lower die member 52 is vertically, slidably mounted in a complementary, cylindrical recess in the base platen 14, being normally urged upwardly to the position shown in Fig. 3 by a comparatively strong compression spring 58 operating oppositely against each of the lower die members 52 and against a lower plate 64 rigidly secured on the lower surface of the base 14 by means not shown. The die member is positively and adjustably limited in its uppermost position by means of a pair of lock nuts 60 exteriorly of the bottom plate 64 and adjustably engaged upon the lower end of a stud 62 permanentiy mounted in the lower die member 52 and passing through an aperture in the said plate 64. In the embodiment shown, the lowermost position of the vertically yieldable die member 52 is determined by contact with the lower end 66 of this member with the plate 64.

It should be noted that the die 52 has a generally cylindrical side surface slightly enlarged at its upper portion. Accordingly the complementary guide-way in which the member 52 is located for vertical reciprocation comprises an upper, relatively enlarged bore or counter-bore 68 and a lower bored or drilled portion 70.

The upper die assembly 50 includes a projecting member 72 having a lower extremity substantially complementary to the lower die and a reduced shank portion 74. Each of the upper die blocks is rigidly though adjustably mounted on the movable platen 16 through the agency of screw threaded studs 76 (see Fig. 3) engageable with complementary recesses 78 within the platen 16 and locked by jamb nuts 80. To assure rigidity each cylindrical shank 74 is received within a complementary, cylindrical bore or guide-way 82.

In cooperative association with each of the die members 50 is arranged a yieldable collar 86 received by a rectangular plate 88 mounted in spaced relationship below the under-surface of the upper movable plate 16 by means not shown. The plate 88 may be either rigidly or yieldably disposed in the position shown, although it is preferred that the plate mounting means provide a rigid, adjustable support, for reasons which will hereinafter appear more in detail.

For embracing and supporting a plurality of collar members the plate 88 is provided with a plurality of openings in which the several collars 86 are axially shiftable. It will be seen from the drawings that each collar is formed with a lower, annular pressure surface 92 oppositely aligned with the upper surface 55 of the plunger 52 arranged in a path of slightly lesser diameter for a purpose which will hereinafter be fully apparent. In other words, the lower, cylindrical portions of each collar 86 has an outer surface which fits within the cylindrical bore or recess 68 with some predetermined clearance, as compared with the association therewith of the lower die which resides within the same recess for positively retained, slidable reciprocation.

Compression springs 94 normally urge each collar downwardly to a lower position limited by abutment with the radially projecting, annular flange 95 at the upper extremity of each collar. The upper die is recessed as at 96 for accommodating the centering pin 66.

The present invention contemplates the curing of the molded elements and, to this end, a plurality of elongated heating elements H are disposed within the opposed platens of the die members. Thus, horizontal bores 93 and 93' in the platen 16 and base 14 respectively are provided to receive the heating elements. Suitable thermostatic controls T are disposed adjacent the platen members for regulating the temperature of the dies to any desired value.

In the preferred method of the present invention the so-called fabric comprises a thermo setting resinous plastic sheet reinforced by an impregnated fabric comprising warp and weft threads. While the object of the disclosed, illustrated process is to manufacture a substantially circular diaphragm, it should be noted that the blank 10 is cut so that the transverse dimension at the points where the warp and

weft threads run substantially radially of the piece, is relatively greater. In other words, at points where the threads approximate a radial direction additional material is provided as compared with intermediate peripheral portions wherein the threads are located at an angle to the radial direction.

It is important to point out that this configuration results from the discovery, in accordance with the present invention, that the present sheet material cannot and should not be stretched in a direction where the threads or fibers run radially, whereas at intermediate portions where the threads of the warp and weft make an appreciable angle with the radii, stretching and compressing or compacting of the fibers in the plane of the web is readily accomplished. This is of extreme importance in connection with the present invention wherein the diaphragms are to be employed for control purposes in connection with delicate pressure responsive devices where the threads must accordingly be free from appreciable longitudinal stressing.

At the same time it is of great importance to note that when material is molded in a circular female die without stressing of the threads, that peripheral material must obviously and necessarily be drawn into the die. In other words, the flat material normally superposed above the die is clearly insufficient to conform to the additional length of the curved surface of the die recess. Peripheral influx of material, however, while supplying the necessary radial demand, necessarily adds an excess material in an annular direction and thus would result in crumpling or other defects completely fatal in the manufacture of a control diaphragm of the present kind. In accordance with the present invention, however, as will appear hereinafter more in detail, the material is fed radially from the periphery at points where the threads run substantially radially while being relatively positively held at annular peripheral points where the threads make a substantial angle to the radii. As a result, stretching and compressing take place at intermediate portions where the threads make an angle with the radii in order to compensate for the material supplied at other peripheral points.

It is thought that it will be understood by anyone skilled in the art, after considering the foregoing, that the spring **94** is adapted to exert a resilient tension of predetermined value substantially less than the spring **58**. That is to say, the spring **94** applies to the periphery of the blank a predetermined, carefully controlled tension such as to result in stressing or rearrangement of the fabric threads in a biased direction while permitting ingress or peripheral supply of material at points where the threads extend radially. In other words, excess longitudinal stressing of the individual threads is effectively prevented.

It is thought that it will be understood from the foregoing that the operation of the present device is as follows: A piece **10** of moldable sheet is placed in the position shown over the lower die assembly **48**, with the pin member **76** piercing the same and extending through the complementary opening **96**. The platen **16** and the male die assembly is lowered so that the first contact between the dies will be between the lower surface **92** of the collar **86** and the upper surface **53** of the plunger **52**. This will cause a gripping of the piece **10** around a peripheral area **10c** indicated by dotted lines in Fig. 6. As the platen is advanced and the male die portion **72** stretches the material to the shape shown in Fig. 10, the piece **10** will still be held in the area **10c** due to the pressure of the compression spring **94**, except adjacent extremities of the warp and filler threads wherein there is no appreciable stretching and the excess material must be necessarily supplied externally. Thus only the body of material within this circular area will be stretched to the cup shape of the dies. Further downward movement of the platen **16** will cause the plunger **52** to be depressed against the action of the spring **58** to the position shown in Fig. 11, where the upright ledge **12c** of the diaphragm is formed. In this position, with the dies heated to a temperature of between 275 and 300 degrees Fahrenheit, the diaphragms are maintained for a period of from five to eight minutes, so that a revulcanization of the plastic may take place. After the elapse of the above specified time, the hand wheel **26** may be rotated to withdraw the platen **16** and the male die members, after which the formed diaphragms may be withdrawn.

Any suitable moldable plastic material may be employed whether thermoplastic or thermosetting, but there may be employed material such as rubber or its equivalents. Natural or synthetic commercial yieldable plastics such as the so-called "DuPrene" and "NeoPrene" have been found desirable for the present purpose.

From the above description it will be apparent that a comparatively simple and inexpensive diaphragm forming machine has been provided. It will be obvious that the exact shape or construction of the die assemblies may be varied or changed, and that, depending upon the type of material employed, the length of time of the amount of heat required in the dies may be changed.

From the foregoing it will be apparent that the present process results in a diaphragm which is uniform, regular in character and free from undesired stressing or straining of the threads longitudinally of the length. Thus it will be apparent that the foregoing process, as a result of the approach of the male and female portions of the die, results in the flat sheet being drawn into a curved shape. During this drawing action any substantial stressing of the threads is prevented by virtue of the fact that the stresses longitudinally of the thread only occur in an appreciable degree where the threads run radially to the circular blank. At intermediate peripheral portions, however, peripheral supply of material in any appreciable degree is unnecessary for the reason that the threads are not longitudinally stressed and a normal angular arrangement of the fabric threads, with respect to the radial application of the forming stresses, permits the fabric to re-arrange itself to absorb these stresses. This would be of only minor significance were it not for the fact that the influx of certain peripheral portions necessarily carries with it a quantity of material of increased annular extent which is accommodated within the die without crumpling or even corresponding microscopic irregularity. The present invention solves this problem by accommodating this excess material at the intermediate portions wherein stretching would ordinarily otherwise occur. In other words, it might be said that the present invention reconciles the necessity for a peripheral supply of material with a coincidental supply of an ex-

cess of material in an annular direction in such a manner that an un-stressed, uniform product results. It has been found in accordance with the present invention that the final molded diaphragms have a dense, uniform, non-stressed structure wherein the threads, particularly in the outer portion of the concave part, are actually held in closer association than that in which they exist in the original fabric.

I do not wish to limit myself to the exact details shown, nor to the specific steps of the method explained; rather what I desire to secure and protect by Letters Patent of the United States is:

The invention is hereby claimed as follows:

1. A diaphragm forming machine comprising a female die assembly including a member having a longitudinally extending guideway, a movable female die, yieldable means for urging said female die in one direction longitudinally thereof, said female die including a central recess and a rim portion, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having a portion spaced inwardly from the walls of said guideway when said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die, said last named yieldable means acting in a direction opposite to that of said first mentioned yieldable means and being of substantially less strength than the first mentioned yieldable means associated with said female die.

2. A diaphragm forming machine comprising a female die assembly including a member having a longitudinally extending guideway, a movable female die, yieldable means for urging said female die in one direction longitudinally thereof, said female die including a central recess and a rim portion, said rim portion being normally disposed outwardly beyond one longitudinal extremity of said guideway, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having a portion spaced inwardly from the walls of said guideway when said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die, said last named yieldable means acting in a direction opposite to that of said first mentioned yieldable means and being of substantially less strength than the first mentioned yieldable means associated with said female die.

3. A diaphragm forming machine comprising a female die assembly including a member having a longitudinally extending, generally cylindrical guideway, a generally cylindrical, movable female die complementarily received in the guideway, yieldable means for urging said female die in one direction longitudinally thereof, said female die including a central recess and a rim portion, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having a portion spaced radially inwardly from the walls of said guideway when said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die, said last named yieldable means acting in a direction opposite to that of said first mentioned yieldable means and being of substantially less strength than the first mentioned yieldable means associated with said female die.

4. A diaphragm forming machine comprising a female die assembly including a member having a longitudinally extending, generally cylindrical guideway, a generally cylindrical, movable female die complementarily received in the guideway, yieldable means for urging said female die in one direction longitudinally thereof, said female die including a central recess and a rim portion, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having an annular wall portion spaced radially inwardly from the walls of said guideway when said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die, said last named yieldable means acting in a direction opposite to that of said first mentioned yieldable means and being of substantially less strength than the first mentioned yieldable means associated with said female die.

5. A diaphragm forming machine comprising a female die assembly including a member having a longitudinally extending, generally cylindrical guideway, a generally cylindrical, movable female die complementarily received in the guideway, yieldable means for urging said female die in one direction longitudinally thereof, said female die including a central recess and a rim portion, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having a portion spaced radially inwardly from the walls of said guideway when said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die.

6. A diaphragm forming machine comprising a female die assembly including a member having a longitudinally extending, generally cylindrical guideway, a generally cylindrical, movable female die complementarily received in the guideway, yieldable means for urging said female die in one direction longitudinally thereof, said female die including a central recess and a rim portion, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having a portion spaced radially inwardly from the walls of said guideway when

said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die, said last named yieldable means acting in a direction opposite to that of said first mentioned yieldable means.

7. A diaphragm forming machine including a die member having an outer working surface adapted to receive a blank and a longitudinally extending guideway formed in said member and extending normally to said surface, a movable female die, yieldable means for urging said female die in a direction longitudinally of the guideway toward said surface, said female die including a central recess and a rim portion, means limiting the movement of said female die in said direction when the rim portion resides in the vicinity of said workng surface, a male die assembly movable to and from said female die assembly and including a male die disposed in alignment with the recess, collar means embracing the male die and disposed in alignment with said rim, the outer face of said collar having a portion spaced inwardly from the walls of said guideway when said male die assembly is in operative position whereby to provide a molding space between the collar and the walls of the guideway when the collar is received therein, and yieldable means urging the collar toward the rim of said female die, said last named yieldable means acting in a direction opposite to that of said first mentioned yieldable means and being of substantially less strength than the first mentioned yieldable means associated with said female die.

ADDISON C. HOOF.