

June 22, 1937.

H. C. LOCKWOOD

2,084,496

BELLOWS

Filed July 21, 1934

4 Sheets-Sheet 1

Fig. 1.

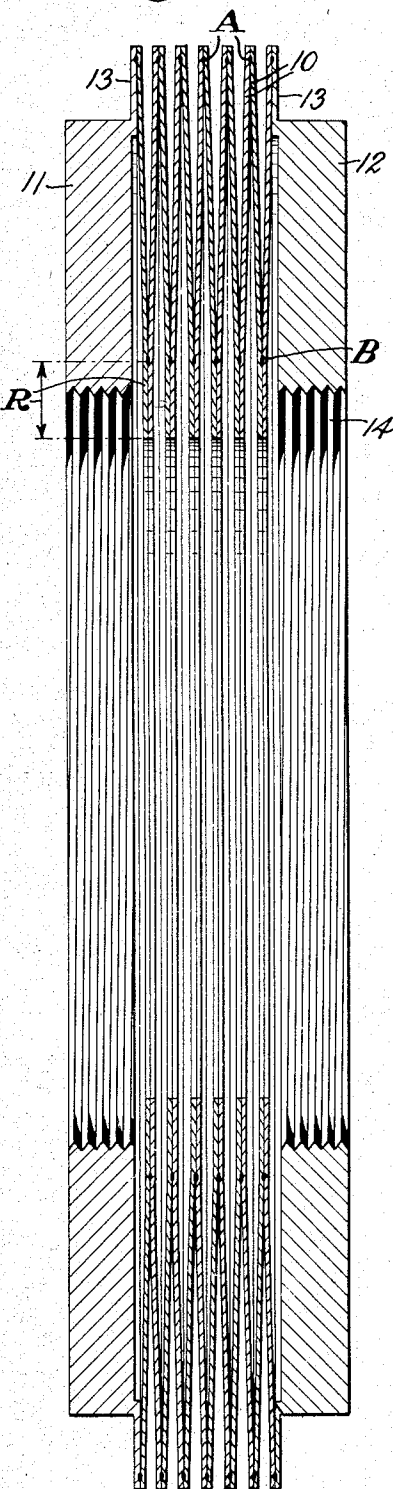


Fig. 2.

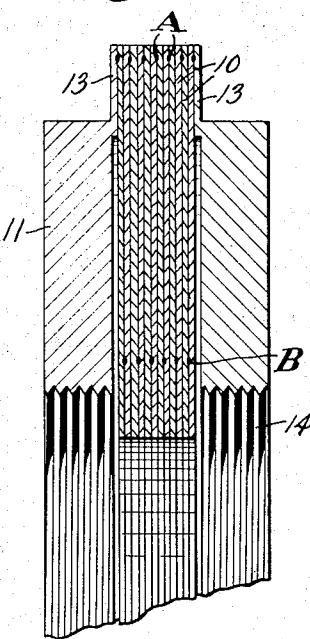


Fig. 4.

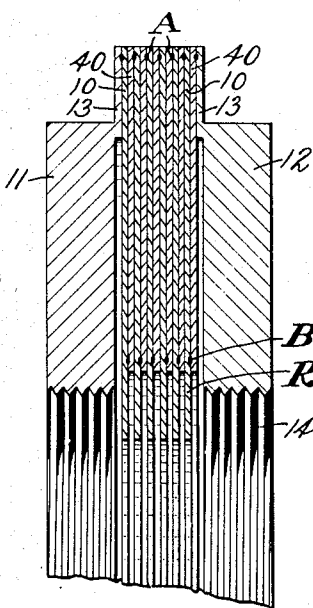
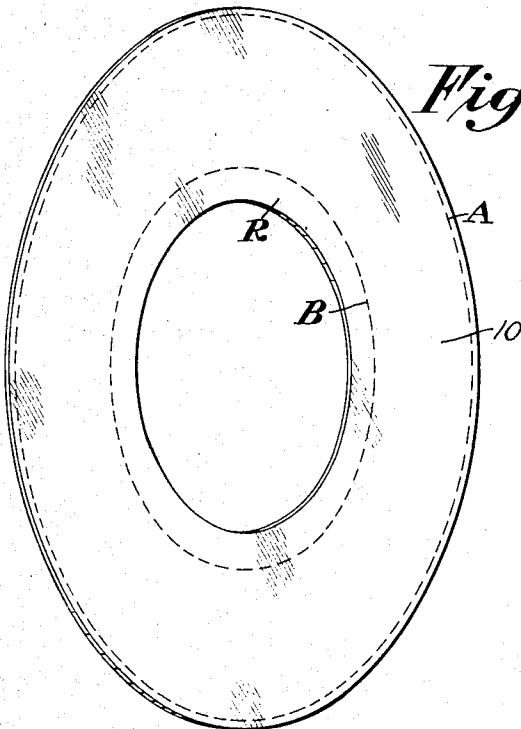


Fig. 3.



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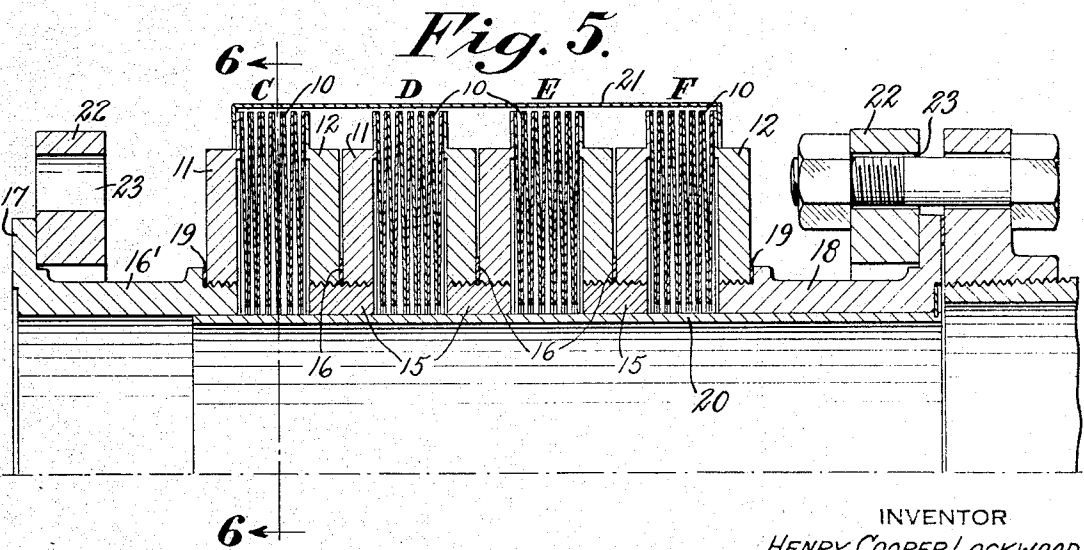
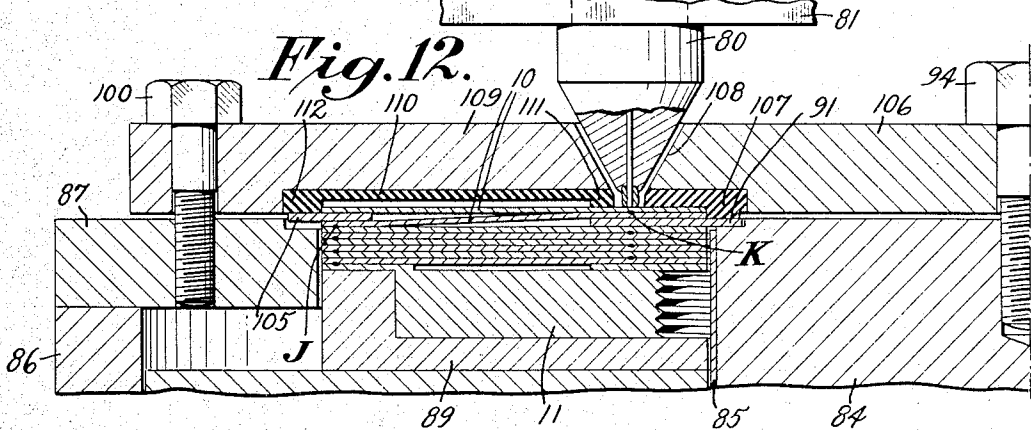
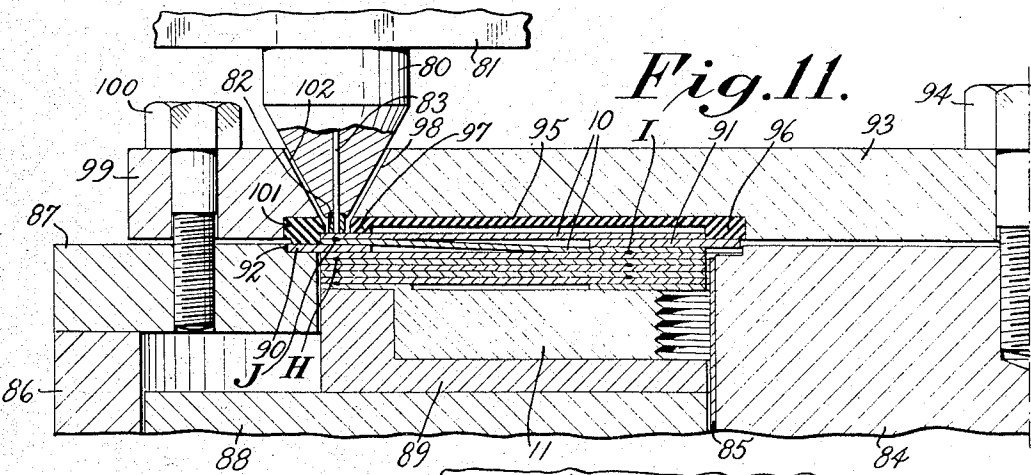
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4 Sheets-Sheet 2



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Fig. 6.

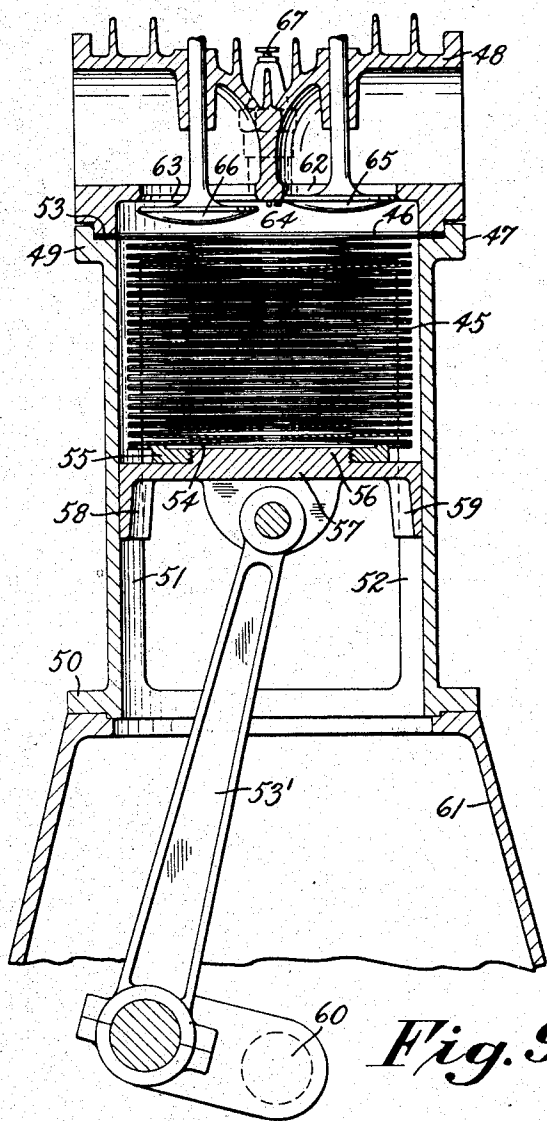
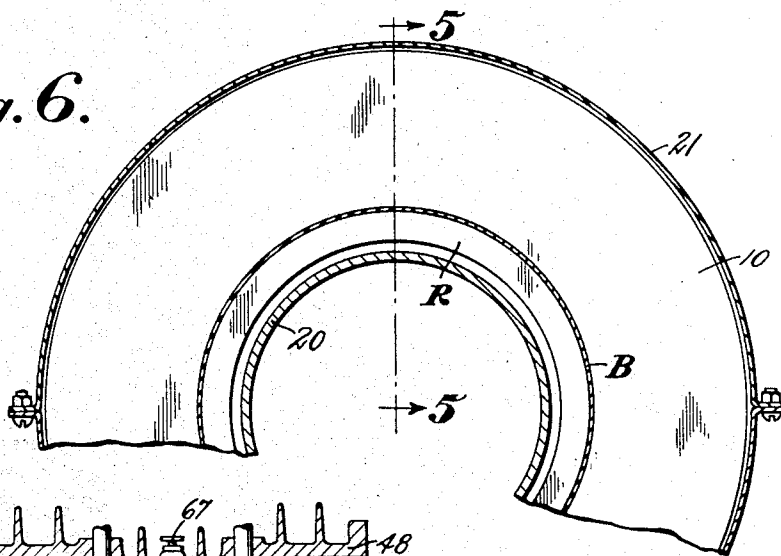


Fig. 9.

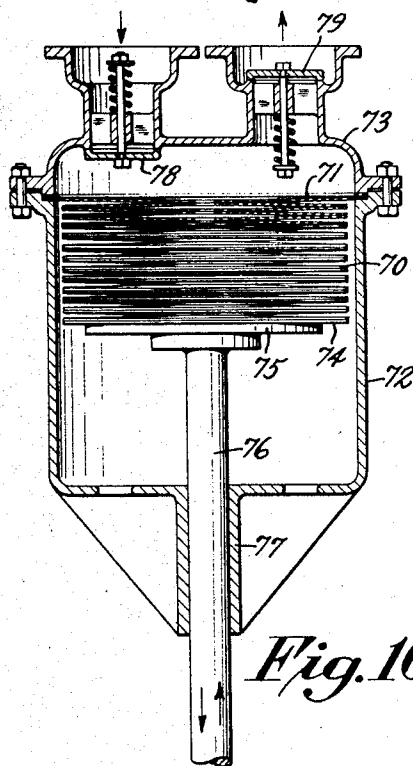


Fig. 10.

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4 Sheets-Sheet 4

Fig. 7.

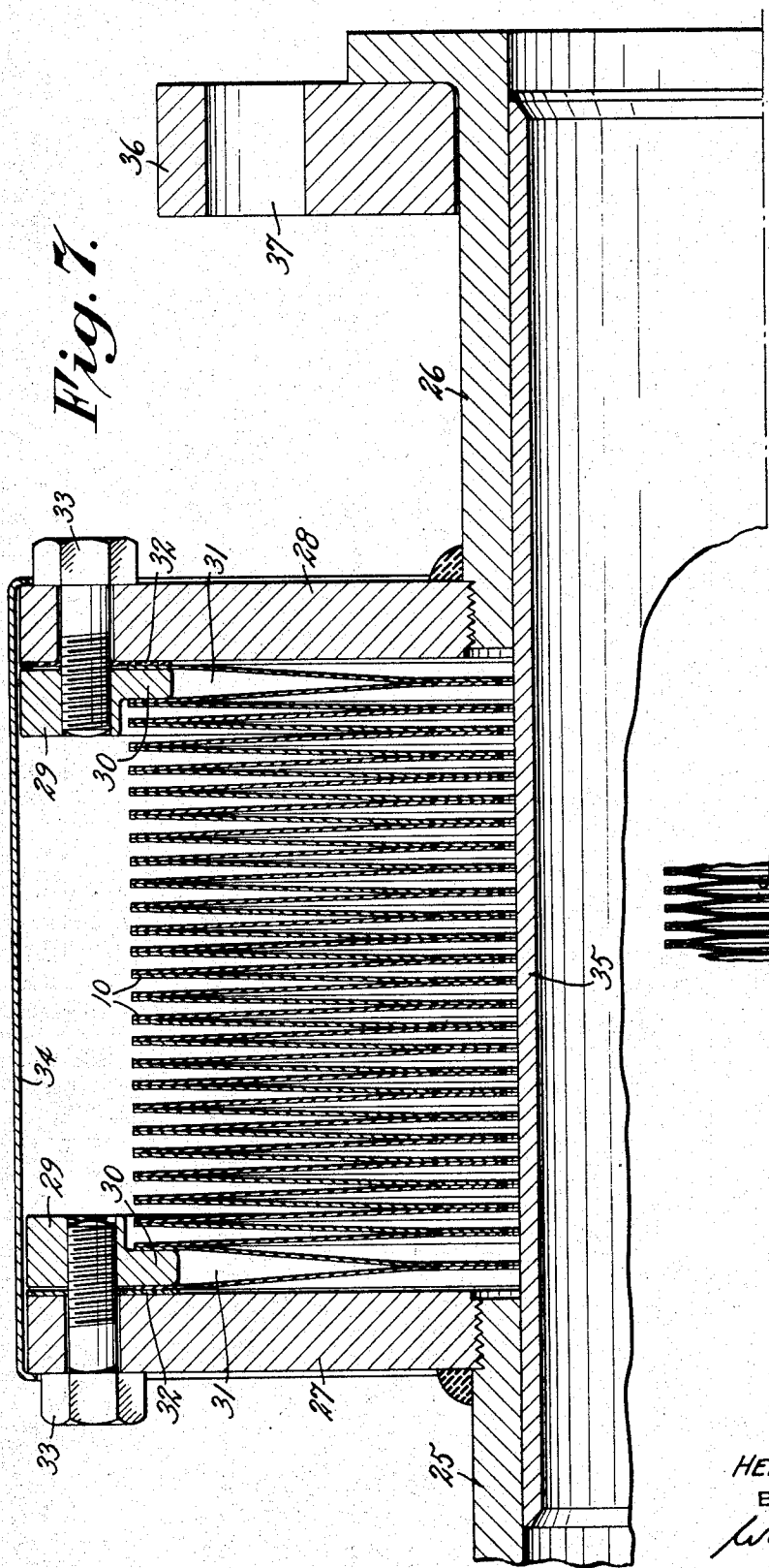
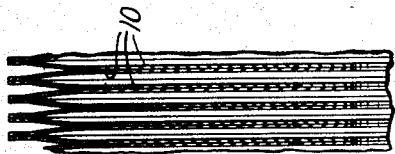


Fig. 8.



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UNITED STATES PATENT OFFICE

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BELLOWS

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Application July 21, 1934, Serial No. 736,396

7 Claims. (Cl. 137—156.5)

This invention is for a novel type of bellows which is capable of withstanding, without leakage or in any way impairing its normal operation, pressures greatly in excess of the pressures which prior types of bellows are capable of withstanding. The arrangement of the bellows is such that the flexing action of the flexible portions of the bellows in all particulars may be predetermined and limited as desired, in consequence of which definite control of the strength and fatigue susceptibility of the flexible bellows parts is obtained. Other advantages will appear hereinafter.

In the preferred embodiment of the invention, the bellows consists essentially of a plurality of relatively thin, flat plates of suitable metal, preferably stainless ferrous metal, having central openings and concentrically disposed and secured together adjacent their outer and inner peripheries as hereinafter described, by electric resistance welding. As so constituted, the plates of the bellows are in contact with adjacent plates throughout substantially the entire extent of their opposed faces when the bellows is fully contracted, so that at such times the bellows has the strength of a tube having a wall thickness equal to the radial depth of the bellows plates. When expanded, adjacent plates of the bellows which are welded together adjacent their inner peripheries, are moved into contact with each other throughout the greater extent of the area of their faces as a result of the internal pressure acting upon the bellows, in consequence of which the internal pressure is balanced, being equal and opposite on both sides of the contacting plates and the plates support each other. Relatively thin plates thus may be utilized for the bellows to resist relatively great pressures. Preferably also, the inner weld is made at a substantial distance from the inner peripheries of the plates to provide an inner reinforcement for the bellows against internal pressures.

The bellows of the present invention is capable of general application and may be used wherever bellows of prior types are employed. The invention is disclosed herein as applied to expansion joints, internal combustion engines and pumps but it is to be understood that the invention is not limited to such applications.

The nature of the invention will be understood from the following description considered in connection with the accompanying drawings forming a part thereof and in which:

Fig. 1 is a longitudinal sectional view of bellows embodying the invention, the bellows being shown in expanded condition;

Fig. 2 is a partial longitudinal sectional view, similar to Fig. 1, but showing the bellows fully contracted;

Fig. 3 is a perspective view of one form of a metal plate from which the bellows may be fabricated;

Fig. 4 is a view similar to Fig. 2, showing another form of bellows;

Fig. 5 is a longitudinal sectional view, showing the bellows utilized as an expansion joint, the expansion joint comprising a plurality of unit bellows sections connected together;

Fig. 6 is a transverse sectional view taken on line 6—6 of Fig. 5;

Fig. 7 is a longitudinal sectional view similar to Fig. 5, showing another form of expansion joint utilizing the invention;

Fig. 8 is a partial longitudinal sectional view of bellows embodying the invention and illustrating the manner in which adjacent plates support each other under pressure;

Fig. 9 is a longitudinal sectional view of an internal combustion engine in which the power chamber thereof is a bellows embodying the invention;

Fig. 10 is a longitudinal sectional view of a pump embodying the bellows invention;

Fig. 11 is a partial sectional view of apparatus for electric resistance seam welding the bellows plates adjacent their outer peripheries to produce the bellows; and

Fig. 12 is a similar view showing apparatus for effecting seam welding of the plates adjacent the inner peripheries thereof.

Like characters of reference refer to like or similar parts throughout the several views.

Referring to the form of the invention shown in Figs. 1 and 2, the bellows is fabricated from relatively thin, flat, annular sheet metal plates, stainless steel preferably, of the type shown in Fig. 3 and designated by reference character 10. The bellows may be fabricated from plates of other shapes, such as oval or square, having apertures of any configuration, and no intention is entertained to limit the invention to bellows produced from annular plates having circular apertures. The plates from which the bellows are fabricated are all disposed concentrically and are secured together alternately adjacent their inner and outer peripheries respectively by electric resistance welding as hereinafter disclosed.

As clearly shown in the drawings, each plate is welded to an adjacent plate which is disposed at one side of the first mentioned plate, on a

line closely adjacent the outer peripheries of these plates as indicated at A, and is welded to the other adjacent plate which is disposed at the other side of the first mentioned plate, on a line spaced a substantial distance from the inner peripheries of the plates, as indicated at B. One method by which resistance welding of this character is accomplished will be hereinafter disclosed. The outside plates of the bellows are resistance welded to terminal plates 11 and 12. As shown, each of these terminal plates comprises a relatively heavy annulus having a thin radial flange 13 projecting from its outer periphery to which an end plate of the bellows is welded, and having its inner periphery threaded as indicated at 14 to provide means for securing the bellows to the parts with which it is to be associated in use.

The bellows shown in Figs. 1 and 2 may be used with any desired number of sheet metal plates, in the form shown, or this organization may be utilized as a unit bellows section and employed as one of any number of bellows sections as illustrated in Figs. 5 and 6, wherein the bellows is utilized as an expansion joint. Four unit sections, designated respectively C, D, E, and F are employed, each of these sections being, as shown, identical with the bellows shown in Figs. 1 and 2. The unit sections CD, DE and EF, are connected together by being threaded on externally threaded nipples 15. An annular gasket 16 is inserted between the adjacent terminal plates 11 and 12 of adjacent unit sections and is disposed adjacent the nipples 15 to provide pressure tightness between the sections. Terminal plate 11 of section C is threaded on one end of a vanstone neck 16' having a vanstone lap 17 on the other end. Terminal plate 12 of section F is likewise threaded on one end of a vanstone neck 18. Gaskets 19 provide pressure tightness between the unit sections and the necks 16' and 18. An internal sleeve and alignment guide 20 is secured at one end to the outer end of the neck 18. An external sleeve and limit of expansion stop 21, split longitudinally as shown in Fig. 6 with the halves bolted together, prevents the entrance of foreign matter between the bellows plates and provides means for limiting the expansion of the bellows. Loose ring flanges 22 having bolt holes 23 provide means by which the expansion joint may be bolted to the parts with which it is to be associated.

Another expansion joint arrangement utilizing the bellows of the present invention is shown in Fig. 7, wherein the bellows part of the expansion joint is in one section as distinguished from a plurality of unit sections as shown in Fig. 5. The desired number of metal plates of the form shown in Fig. 3 are welded together adjacent their inner and outer peripheries as previously described, to form a bellows adequate to provide the movement of expansion and contraction desired and to withstand the required pressure. The vanstone necks 25 and 26 have radial flanges 27 and 28, respectively, threaded on the inner ends of the necks and secured in position by welding. The end plates 10 of the bellows are secured to the flanges 27 and 28, by means of split rings 29 having radially inwardly projecting flanges 30 which enter the space 31 between the end plates 10 and the thereto adjacent plates. A ring gasket 32 is placed between the flanges 27 and 28 and the end plates 10 for pressure tightness, and suitable means such as the bolts 33 secure the rings 29 to the flanges. An external sleeve and limit stop 34, split in half longitudinal-

ly and having means such as screws and nuts to hold the halves together, is placed over the bellows in engagement with the outer peripheries of the flanges 27 and 28. An internal sleeve and alignment guide 35 has one end secured, as by welding, to the vanstone neck 26. Loose ring flanges such as shown at 36 having bolt holes 37, provide means for bolting the joint to the pipe line or other parts with which it is to be used.

A further arrangement of bellows is shown in Fig. 4, which is the same as that shown in Figs. 1 and 2 with the exception that every other plate, indicated 40, has a greater inside diameter than the other plate 10, so that only the latter plates project a substantial distance radially inwardly of the lines of weld B to provide an integral inner reinforcement for the bellows, which will be referred to more fully hereinafter.

Fig. 9 illustrates one means for utilizing the bellows of the present invention as the combustion chamber of an internal combustion engine. The bellows designated 45, is similar in all respects to the bellows shown in Figs. 1, 2, and 7 except that the inside diameter of the individual metal plates is considerably smaller to reduce the internal residual volume of the bellows when closed to the proper value to provide the necessary ratio of compression for efficient operation. The uppermost plate 46 of the bellows is larger in diameter than the other plates to provide means for securing the upper end of the bellows in fixed position. Plate 46, in the form of motor shown, is clamped between the upper end of the guide 47 and the head 48. Guide 47 comprises upper and lower annuli 49 and 50, respectively, which are connected by opposed guides 51 and 52. A suitable gasket 53 may be interposed between the plate 46 and the head 48. The lowermost plate 54 is welded at its outer periphery to the outer periphery of a terminal plate 55 similar to the plates 11 and 12 of Figs. 1 and 2.

Plate 55 is threaded on a centrally disposed stud 56 projecting from the upper surface of a cross-head 57 having opposed bearing members 58 and 59 which move in the guides 51 and 52 respectively. A connecting rod 53' is connected for oscillatory movement at its upper end to the cross-head 57 and at its lower end is connected to a crank-shaft 60. A crank case 61 encloses the crank-shaft and associated mechanisms. Head 48 is provided with an inlet port 62 and an exhaust port 63 communicating with the combustion chamber 64, the ports being controlled by valves 65 and 66 respectively. A spark plug 67 is threaded into a depression in the head 48. With this arrangement, the motor is entirely air-cooled and no oil comes into contact with the heat of combustion. It will, of course, be understood that the form of internal combustion engine shown in Fig. 9 is merely illustrative of the application of the bellows invention to such engines and that the form and arrangement of the various parts may be varied as desired.

Fig. 10 illustrates the invention applied to pumps. The bellows 70 is substantially the same as the bellows 45 shown in Fig. 9, and is connected to the pump parts in the same manner that bellows 45 is connected to the motor parts. The uppermost plate 71 of the bellows is clamped between the bellows housing 72 and the pump head 73. The lowermost plate 74 of the bellows is welded to piston head 75, the upper part of which is like the plate 55 of the motor shown in Fig. 9.

Head 75 is carried on an end of piston rod 76 which moves in a guide 77 formed in the lower end of the housing 72. Head 73 is provided with suitable inlet and outlet valves 78 and 79 respectively. Fig. 10 is intended merely to illustrate one manner in which the bellows of this invention may be applied to pumps, so that it will be understood that the pump may be of any desired form or type.

Figs. 11 and 12 illustrate one method and means by which the bellows plates may be welded together alternately adjacent their inner and outer peripheries respectively to form the bellows of this invention. As indicated in these figures, the welding is effected by electric resistance line or seam welding. The electric current is supplied to the plates to be welded through an electrode which preferably confines the application of the welding current to the smallest possible practical area on the plates and which provides the requisite pressure on the plates, preferably through a non-conducting part of the electrode. Such an electrode may be of the form shown in Figs. 11 and 12 in which the electrode has a cylindrical body portion 80 of copper preferably, which is secured to a supporting member 81. The lower end of the electrode is in the form of an inverted cone and has a cylindrical tip 82 of non-conducting material. The electrode and tip have registering axial bores through which passes a copper wire 83 of small diameter. Means, not shown, disposed in the electrode, serves to exert sufficient pressure on the wire 83 to maintain the lower end thereof in contact with the work being welded and to release the pressure when the electrode is raised from contact with the work. Such means may operate pneumatically, hydraulically or otherwise.

As shown, the work supporting means, comprises a turntable, the upper portion only of which is shown in Figs. 11 and 12, which includes a centrally disposed cylindrical member 84 of copper preferably, having an insulating cylindrical sleeve 85 secured to its circumferential periphery. The table also includes an outer annulus 86 having a flange 87 projecting laterally inwardly from its upper end. An annular backing-up plate 88 is movable vertically in the space defined by the members 84 and 86. Suitable means are provided for moving the plate 88 vertically upwardly or downwardly and for rotating the turntable. A supporting plate 89, U-shaped in cross-section, supports the bellows terminal plate 11 on the turntable. The terminal plate 11 has been welded to the adjacent bellows plate 10 and a number of other plates 10 have been welded together. Accordingly, the welding method will be described in connection with the welding of plates 10 in an intermediate part of the bellows, but the same method may be used for the welding of all other plates as well as the welding of the plates to the terminal plates 11 and 12. The welding of adjacent plates adjacent their outer peripheries as illustrated in Fig. 11 will first be described.

Let it be assumed that an inner weld I has been made and that the electrode 80 has been moved upwardly and that the parts of the turntable which are normally disposed above the plates 10 have been removed. A continuous circular copper flat ring 91 which will hereinafter be referred to as a "welding gasket" is then placed above the inner peripheral portion of the plates 10 in preparation for the next inner weld to be made after the outer weld now being described is finished. Previous to making the last inner weld I, and

after the preceding outer weld H had been completed, a continuous circular copper welding gasket 90 was placed, as shown, over the outer peripheral portion of the uppermost plate 10 so as to cover the line of the weld and to project beyond the outer periphery of the plates 10 and to lie in the notch 92 in the flange 87. After welding gasket 90 had thus been placed in preparation for the outer weld now being described, a plate 10 was superposed and inner weld I made. The circular welding gasket 91 is placed in position as aforesaid, after which another plate 10 is placed in position on the table.

An inner circular clamping plate 93 is then placed in position and is secured to the member 84 by a bolt 94. Plate 93 has a circular recess in the outer peripheral portion of its under side and an insulating bearing-plate 95 of U-shaped cross-section is secured therein. Plate 95 is arranged so that the radially inner portion 96 acts as a centering device for plates 10 and the radially outer portion 97 bears on the uppermost plate 10 just inside the line of weld and above the inner portion of the copper welding gasket 90. The outer periphery of the plate 93 is beveled, as indicated at 98, to provide room for the lower end of the electrode 80 when the weld is being made. An outer annular clamping plate 99 is then secured to the flange 87 by a ring of bolts 100. Plate 99 has a circular recess in the inner peripheral portion of the lower face and an annular insulating bearing ring 101 is secured therein. Ring 101 bears upon the copper welding gasket 92 and presses it firmly against flange 87 to insure a good electrical contact between the welding gasket and flange. Ring 101 also bears upon the plates 10 being welded on its inner peripheral portion as clearly shown in Fig. 11. The inner periphery 102 of plate 99 is beveled as indicated, to provide sufficient room for the lower end of the electrode 80. When all is in readiness to make an outer weld, the several parts will be in the positions shown in Fig. 11. The backing-up plate 88 will have been moved upwardly to press the plates 10 firmly against the portion 97 of plate 95 and the overlapping portion of ring 101 and to provide a good electrical contact between the lower plate 10 being welded and the copper welding gasket 90. The turntable is then caused to rotate and electric current is supplied to the electrode 80 and will flow from the lower end of the electrode through the plates 10 to be welded, through copper gasket 90, flange 87, annulus 86 and through other parts of the turntable to complete the welding circuit. The turntable is rotated and the electrode is maintained in contact with the plates until the line of weld forms a complete circle, the weld being formed as the plates move relative to the electrode in sliding contact therewith. Water may be run on the electrode and permitted to flow into the trough provided by the beveled edges 98 and 102 to aid in dissipating the heat generated during the welding. After the completion of the weld J, the electrode is moved upwardly, bolts 94 and 100 are removed, plates 93 and 99 are removed and plate 88 is moved upwardly until copper welding gasket 90 is clear of flange 87. Welding gasket 90 is then moved to one side until a portion is free of the plates 10, after which it is cut radially or otherwise and is then removed from between the plates 10.

To make the next inner weld K, a copper welding gasket 105, like welding gasket 92, is first placed over the outer peripheral portion of the uppermost plate 10, and then another plate 10

to be welded to the inner portion of the said uppermost plate is placed in position. Backing-up plate 88 is then lowered until copper gasket 91 comes into contact with the notch in the upper outer part of member 84. A circular clamping plate 106 is then bolted to the member 84 by bolt 94. Plate 106 has an insulating bearing plate 107 secured in the outer peripheral portion of its lower face which serves to engage the uppermost plate 10 being welded, and to press the copper welding gasket 91 into firm contact with member 84. Plate 107 also acts as a centering device for plates 10. The outer periphery of plate 106 is beveled as indicated at 108. A clamping plate 109 is secured to the flange 87 by bolts 100 and is provided with an insulating bearing plate 110 in the outer portion of its lower face, having a portion 111 which bears against the uppermost plate 10 in the zone just outside the line of weld and in the zone of the outer portion of welding gasket 91. Plate 110 also has a portion 112 which bears against the upper inner portion of gasket 105. Before the weld is made the backing-up plate 88 is raised until the plates 10 are held flat and firm and the parts through which the welding current is to pass are in good electrical contact. The electrode is then lowered into contact with the work, the turntable is caused to rotate, the welding current is turned on and the weld is made while sufficient downward pressure is maintained on the electrode to produce a good line weld.

If desired, a thin hardened and ground tool steel ring may be placed below the lower surface of the welding gasket and the upper surface of the previously welded plate 10 and in firm contact with both to provide a rigid supporting means for the copper welding gasket which will prevent the latter from conforming to any irregularities in the surface of the plates 10 previously welded, and thus make it difficult to obtain a perfect weld.

The foregoing description is believed to be sufficient to disclose one method by which the plates 10 may be secured together to form a bellows of the present invention. This method, together with the means for carrying out the method, are more fully disclosed in my copending application, Serial No. 753,849, filed November 20, 1934, wherein the method and apparatus are claimed. The line welds made in accordance with the method herein disclosed are pressure tight and are capable of withstanding, without leakage or failure, pressures at least as great as the metal plates will withstand without welding. That is, line welds produced by this method will at least develop the full strength of the metal being welded. With the bellows plates seam-welded as described, the movements of expansion and contraction are entirely in the plates themselves, in the areas thereof between the outer and inner line welds, so that in operation no strain is placed on the welds themselves.

Means, other than welding, may be utilized for securing the individual plates together to form a bellows, if desired and if satisfactory for the purpose intended.

With the individual plates of the bellows welded together in accordance with the aforesaid method, no deposition of extraneous metal is required, in consequence of which the portions of the welded plates along the lines of weld are of no greater thickness than the portions not welded, and the plates are capable of the same close proximity to each other as if they were not welded. As a result, when the bellows is completely

contracted, as shown in Fig. 2, the bellows has the equivalent strength of a continuous tube of the same metal having a wall thickness equal to the radial depth of the plates from which the bellows is made. Also, as a result of the welded plates lying flat upon each other when the bellows is closed, there is no volume between plates in the closed position. This is of great value for internal combustion engines and pumps.

As the bellows expands from fully contracted condition, the strength of the bellows diminishes, somewhat in proportion to the extent of the expansion, or in proportion to the extent the plates are separated by the movement of expansion. However, the extent to which the individual plates must be separated for any given overall movement of expansion, may be readily controlled and limited by the simple expedient of fabricating the bellows with a sufficient number of plates to keep the extent of separation of the plates within the desired maximum. In this way, bellows consisting of relatively thin sheet metal plates welded together may be made to withstand relatively great pressures.

Another feature which renders the bellows of the present invention relatively very strong is the internal reinforcement provided by the metal of the plates between their inner peripheries and the inner lines of welds B. These integral reinforcing rings, designated R, maintain the inner vertices of the plates in fixed position upon expansion of the bellows and separation of the plates, and serve to resist any tendency of these vertices to move outwardly under pressure and thereby materially weaken the bellows. This internal reinforcement is provided in bellows fabricated from plates, all of which are of the same inside diameter as shown in Figs. 1 and 2 or will be provided in bellows wherein alternate plates are of greater inside diameter than the other plates, as shown in Fig. 4. With the latter arrangement, the number of reinforcing rings is smaller but the reinforcement provided will be ample for many purposes. If desired, adjacent plates which are welded together at a distance from the inner peripheries to provide the reinforcing rings R, Figs. 1 and 2, may also be welded together near their inner peripheries. Obviously, if the inner reinforcement is not required or desired, it may be omitted, in which event the plates will be welded close to their inner peripheries.

A further feature which contributes to the relatively great strength of the bellows is the fact that when the bellows is expanded, the plates thereof which are welded together adjacent their inner peripheries, are forced into contact with each other throughout the greater extent of their areas, as indicated in Fig. 8, as a result of the pressure to which the bellows plates are subjected, so that these plates support each other over their contacting areas. Equal and opposite pressures acting over equal areas balance each other and the contacting areas of the plates float and are subjected to no stress. The result of this is that the bellows may be made from relatively thin metal plates to withstand relatively great pressures. The thinner the plates, generally speaking, the greater will be the areas of adjacent plates which are in contact and the smaller will be the unsupported areas of the plates. Also, the greater the number of plates utilized to make up the bellows, the smaller will be the separation between plates and the greater will be the areas

of adjacent plates which are in contact and supporting each other.

The plates of the bellows automatically adjust their pressure balancing contact areas to suit any given pressure. The greater the pressure the further out the contact areas move, thus shortening the span of the zone of unbalanced pressure. It will be noted that this span decreases along with the magnitude of unbalanced pressure as the internal pressure increases. This action does not affect the flexibility of the bellows. The bellows also has great flexibility, even when designed for high operating pressures, since it is possible to use thin plates and deep sections. Any length of travel may also be obtained.

When the bellows is employed as the power chamber of an internal combustion engine, it is possible to secure the desired or required ratio of compression merely by varying the size of the central aperture of the plates making up the bellows. This is possible because of the fact that when the bellows is completely contracted, the individual plates are in contact throughout the extent of their face areas so that the volume existing between the plates when the bellows is compressed, is substantially zero. Prior types of bellows have their individual parts spaced from each other when compressed so that the desired ratio of compression is difficult if not impossible to obtain.

Moreover, the bellows herein disclosed will provide relatively large displacements at high speeds with comparatively low rate of movement of the individual plates of the bellows. For example, if a bellows embodying the present invention were employed as shown in Fig. 9, and the crankshaft were turning at 1800 R. P. M., and the amplitude of travel of the bellows were one-half inch, the axial speed of the moving head of the bellows would only be 150 feet per minute and if the bellows were composed of 50 pairs of discs, the individual discs would move at a speed of only 3 feet per minute, with respect to their own flexing movements.

As an indication of the strength of bellows embodying my invention, bellows fabricated from stainless steel plates of 0.018" thickness, having an outside diameter of 11½" and an inside diameter of 6" and seam welded together by electric resistance welding as shown in Figs. 1 and 2, were tested under hydraulic pressure and successfully withstood a pressure of 2,500 pounds per square inch without leakage and without any impairment of the normal functioning of the bellows.

Due to the fact that the bellows are fabricated from flat plates, these plates may be made of the groups of ferrous metals known as stainless steel and stainless iron. So far as I am aware, it has not been possible heretofore to make formed bellows from stainless steel, due to the comparative rigidity of the metal as compared with the softer metals, such as copper.

It will be perceived that the invention is independent of the size or shape of the plates from which the bellows are fabricated and that the thickness of plates used may vary over a comparatively wide range since definite control of the extent of separation of the plates is possible which provides control over the flexing of the individual plates.

Since variations are possible in the forms of the invention herein disclosed and the materials from which the bellows are made and since the

bellows may be applied to other uses than those disclosed without departing from the principles of the invention, it is understood that no intention is entertained to limit the invention except by the scope of the appended claims.

What I claim is:

1. Bellows comprising a plurality of flat, apertured, metallic discs concentrically disposed, alternate plates having a greater inside diameter than the other plates, each of said alternate plates being united to the adjacent plates disposed at one side, adjacent its outer periphery, and united to the adjacent plates disposed on the other side, adjacent its inner periphery, whereby the inner peripheral portions of said other plates are caused to act as reinforcements for the bellows.

2. Bellows having a movement absorbing portion comprising a plurality of thin, corrosion resistant, metallic elements of substantial mechanical strength having openings therein, joined together in fluid pressure tight relationship by fusion of the metal of adjacent elements only to unite in continuous lines oppositely disposed surfaces of adjacent elements within the confines of the peripheries of the elements.

3. Bellows having a movement absorbing portion comprising a plurality of thin, corrosion resistant, metallic elements of substantial mechanical strength having openings therein, joined together in fluid pressure tight relationship by fusion of the metal of adjacent elements only to unite in continuous lines oppositely disposed surfaces of adjacent elements within the confines of the peripheries of the elements, each element being secured adjacent its outer periphery to the adjacent element on one side and adjacent its inner periphery to the adjacent element on the other side.

4. Bellows having a movement absorbing portion comprising a plurality of thin, corrosion resistant, metallic elements of substantial mechanical strength having openings therein, joined together in fluid pressure tight relationship by fusion of the metal of adjacent elements only to unite in continuous lines oppositely disposed surfaces of adjacent elements within the confines of the peripheries of the elements, the arrangement being such that adjacent elements are in substantially full surface contact when the bellows is in fully contracted condition.

5. Bellows having a movement absorbing portion comprising a plurality of thin, corrosion resistant, metallic elements of substantial mechanical strength having openings therein, joined together in fluid pressure tight relationship by fusion of the metal of adjacent elements only to unite in continuous lines oppositely disposed surfaces of adjacent elements within the confines of the peripheries of the elements, and reinforcing means acting upon apices of the bellows.

6. Bellows having a movement absorbing portion comprising a plurality of thin, corrosion resistant, metallic elements of substantial mechanical strength having openings therein, joined together in fluid pressure tight relationship by fusion of the metal of adjacent elements only to unite in continuous lines oppositely disposed surfaces of adjacent elements within the confines of the peripheries of the elements, adjacent elements being secured together at a distance from the periphery of one or both of the elements sufficient to cause that portion of one or both of the elements disposed intermediate said periphery and

the line of juncture to provide bellows reinforcement.

- 5 7. Bellows having a movement absorbing portion comprising a plurality of thin, corrosion resistant, metallic elements of substantial mechanical strength having openings therein, joined to-

gether by fusion of the metal of adjacent elements only to unite in fluid pressure tight relationship oppositely disposed surfaces of adjacent elements within the confines of the peripheries of the elements.

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