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ELECTROMAGNETIC PUMPING DEVICE FOR PUMPING FLUIDS

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Fig. 1.

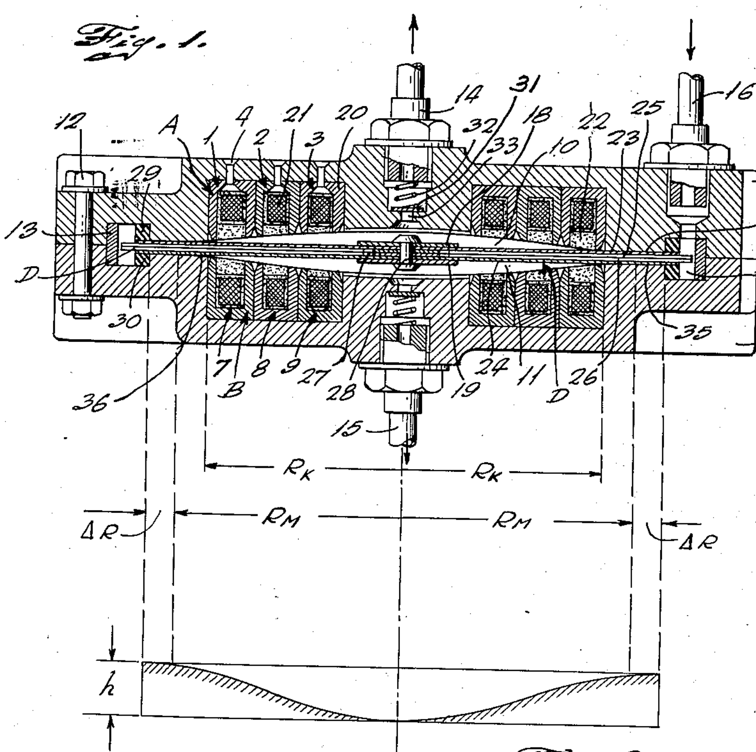

Fig. 2.

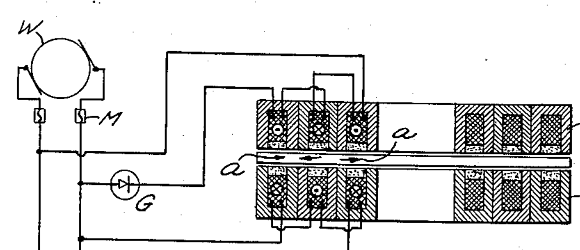

Fig. 3.

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ELECTROMAGNETIC PUMPING DEVICE FOR PUMPING FLUIDS

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9 Claims. (Cl. 103—53)

This invention relates to electromagnetic pumping devices for pumping a gaseous or liquid fluid either with or without increase in pressure.

In particular, the present invention relates to an electromagnetic pumping device or compressor of the type in which electromagnetic means including a plurality of magnetizable concentric portions forming one or two substantially continuous surfaces are disposed within a housing. Each of the said surfaces may be inwardly curved to form a shallow bowl. The concentric magnetizable portions coact with armature means in form of a flexible diaphragm which is supported along its periphery in the housing in a position facing the continuous surface or surfaces and forms together with each adjacent continuous surface a pumping chamber. Electric means are provided for energizing the said concentric portions intermittently so as to cause the diaphragm to oscillate thereby intermittently varying the capacity of the pumping chamber or chambers. Each pumping chamber communicates with fluid admission means and fluid discharge means. The fluid admission means admit fluid into the respective chamber upon oscillation of the diaphragm in one direction and the fluid discharge means discharge fluid from the respective chamber upon oscillatory movement of the diaphragm in opposite direction. An electromagnetic pumping device of this type is more fully described in my co-pending application Ser. No. 46,377, filed on August 27, 1948.

With electromagnetic pumping devices of the general type, above referred to, the efficiency of the pumping action is substantially affected by the extent to which the diaphragm, when oscillating, can nest itself in the bowl formed by the aforesaid continuous surface or surfaces. As will be apparent, appreciable airgaps remaining between a fully flexed diaphragm and the respective continuous curved surface will adversely influence the magnetic force available for the attraction of the diaphragm and, hence, the power of the pumping action.

One of the objects of the present invention is to provide a novel and improved mounting arrangement for the diaphragm and also a novel and improved configuration of the continuously curved surface which latter surface together with the adjacent surface of the diaphragm forms a pumping chamber. More specifically, the diaphragm is so arranged that, when deflected, it forms a twice flexed surface the meridian cross-section of which is somewhat similar to the elastic line of a loaded girder held at both

ends, and the curvature of the continuously curved surface is so selected that the deflected diaphragm can hug the same closely thereby preventing the retention of appreciable local air gaps between the diaphragm and the said continuous surface.

Another object of the invention is to provide means by which the amount of pumping work rendered by the outer portions of the electromagnetic means is increased.

Other and further objects, features and advantages of the invention will be pointed out hereinafter and set forth in the appended claims forming part of the application.

In the accompanying drawing a now preferred embodiment of the invention is shown by way of illustration and not by way of limitation.

In the drawing:

Fig. 1 is a cross-sectional view of an electromagnetic pumping device according to the invention.

Fig. 2 is a graph of the bending line of the diaphragm, and

Fig. 3 is a diagrammatic circuit system for the electromagnetic means of a pumping device according to the invention.

Referring now in detail to the embodiment shown on Fig. 1, the electromagnetic pumping device according to this figure is shown as a double acting pump for pumping liquid or gas. The pump comprises two casing or housing halves **5** and **6** housing the electromagnetic means of the device. These electromagnetic means are shown as comprising two sets A and B of concentrically arranged magnet members. Three members, generally designated by **1**, **2**, **3** and **7**, **8**, **9** are shown for each set. Each of said members comprises an annular ferro-magnetic core **20** of substantially U-shaped cross-section. The annular cores may be ring-shaped, polygonal or otherwise shaped. They may be secured to the respective casing half by any suitable means such as rivets **4**. The exciting coils **21** of the magnet members are inserted in the open grooves of the cores and are embedded therein in a mass of an insulation material **22** of a type becoming very hard when dry. This insulation mass together with the pole faces of the cores forms a substantially continuous smooth surface in form of a curved shallow bowl as can be clearly seen on Fig. 1. This figure also shows that the shanks of the cores are tapered toward the pole faces to provide for the greatest possible flux density of the magnetic fields at or near the pole faces.

The two halves **5** and **6** of the casing or housing may be joined by any suitable means such as bolts and nuts **12**.

The armature means, generally designated by D, are inserted between the two halves of the casing and positioned to face the two sets A and B of the electromagnetic means. The armature means are shown in form of a flexible diaphragm which may comprise a single disc or be composed of several thin discs or laminae. There are shown two outer full or cover discs **23** and **24** made of ferro-magnetic or other magnetizable material and two inner or filling discs **25** and **26** which may or may not be made of magnetizable material. The inner discs **25** and **26** are provided with a plurality of radially spaced slots (not shown) each in registry with one of holes **27** in the cover discs **23** and **24**. Slotted plates **18** and **19** respectively are fastened by means of a rivet **28** to the outside of each cover plate. The slots of plates **18** and **19** form a plurality of fingers each covering one of the holes **27**. As will be more fully explained later on, plates **18** and **19** together with holes **27** form valves. Rivet **28** is preferably unround to prevent rotation of plates **18** and **19** relative to holes **27**.

The diaphragm disc is held between the halves of the casing and is centered in the casing by means of a centering ring **13**. Two sealing rings **29** and **30** serve to prevent seepage of fluid between the casing halves and the outside of cover plates **23** and **24**.

As can best be seen on Fig. 1, the peripheral edge of the inner discs of the diaphragm is extended into an annular channel **17** thereby permitting fluid to flow from channel **17** into the slots of discs **25** and **26**. Channel **17** communicates with an inlet flange **16** which should be visualized as being connected to a supply of fluid to be pumped.

The diaphragm forms together with each adjacent continuous surface a pumping chamber **10** and **11** respectively. Chamber **10** communicates with a discharge valve **14** and chamber **11** with a discharge valve **15**. Each discharge valve comprises a valve plate **31** pressed by a spring **32** against a valve seat. The valve plates, when seated, close a bore **33** leading into the respective pumping chamber.

According to the invention, the peripheral rim portion of diaphragm D is held between parallel wall portions **35** and **37** formed by the facing surfaces of housing halves **5** and **6**. As can best be seen on Fig. 2, these parallel wall portions have a radial width ΔR. The parallel wall portions are continued by slightly slanted wall portions **36** which form continuations of the aforesaid continuously curved surfaces and hence also of the pumping chambers **10** and **11**. A diaphragm thus held between the halves of the housing experiences the intended double deflection as is clearly shown on Fig. 2. The slants of the aforementioned wall portions **36** which in effect form part of one of the walls of the pumping chambers must of course be so selected that they match the configuration of the deflected diaphragm. In other words, a peripheral recess is formed between the two housing halves defined by inner parallel wall portions **35** and **37** and slanted outer wall portions **36**.

It will further be noted that the total width of the concentric magnet members which is indicated by the radii R_k, that is, of the magnetically active portion of the device, is less than the total width of the pumping chambers indicated by radii R_m. The portion of the continuous surfaces represented by the zone $R_m - R_k$ is preferably made of a non-magnetic material. The radial width of this peripheral rim portion is indicated by ΔR.

The electric connections for energizing the magnet members of the sets A and B respectively can be so made that all the members of the two sets are alternately and intermittently energized or that the individual coils of each set are successively energized. The connections of the individual coils in each set of magnet members may also be so made that the direction of current is reversed in the coils of adjacent annular cores and that the direction of the current flow in the corresponding exciting coils of the upper set and in the lower set of magnet members is opposite. As a result, the magnetization of the diaphragm during the alternate excitation of the upper and lower set is not reversed and the iron losses of the diaphragm are thus reduced.

Suitable connections are shown in Fig. 3. The arrows a indicate the direction of the magnetic flux for each annular core element, and the marks in the coils (circle with point and circle with cross) indicate the direction of current in the respective coil.

In the circuit diagram, A is the upper and B is the lower set of magnet members; a single phase alternating current generator is designated by W; G and G_1 indicate the rectifiers in the one phase net; R and S are the main lines from the generator; and M are cut-out fuses.

The operation of the double acting pumping device or compressor, as hereinbefore described is as follows:

When the compressor is connected to a circuit system according to Fig. 3, the rectifiers (each group of coils must be connected to a rectifier) G and G_1 let each pass one half wave of the alternating current. Accordingly, during each period of the current the lower and upper set of magnet members are alternately excited so that the magnetic attraction forces thus created pull the diaphragm alternately into opposite direction. Consequently, the diaphragm is flexed toward the curved surface of the excited set of magnet members. At the same time a partial vacuum is formed in the pumping chamber bounded by the opposite face of the diaphragm so that gas or liquid is sucked through the annular channel **17**, the radial slots of the filling discs **25** and **26** and the temporarily uncovered openings **27**. The other valve plate, of course, remains pressed against the diaphragm. As a result, fluid is sucked into the respective pumping chamber. If now the other pumping chamber has been filled previously with fluid, this fluid will press the respective valve plate **31** away from its seat against the action of spring **32** so that the fluid is discharged through the respective discharge valve **14** or **15**. The same cycle is repeated when the other set of magnet members is subsequently energized.

Let it be assumed that the upper set of magnet members is excited. Then, the outer marginal zone of the diaphragm is first attracted since the airgap is smallest in this zone. As a result, the compression of fluid in the respective pumping chamber begins and the airgap is gradually reduced from the exterior toward the center as the deflection of the diaphragm progresses. As the diaphragm is deflected, it experiences a double bending or curvature. Fig. 2 shows a meridian section of a deflected diaphragm. The depth h of the deflection is shown exaggerated relative to the diameter of the diaphragm for purpose of clarity. As will be apparent, the double bending line of the diaphragm is caused by the provision and configuration of the walls 35 and 37. It is characteristic for the bending line according to Fig. 2 that the airgap increases slowly up to the first bending zone and then more rapidly. The arrangement that the radius R_k of the outermost magnet member 1 is smaller than the radius R_m of the pumping chambers 10 and 11 has the advantage that the outermost magnet member, now facing a comparatively wide portion of the airgrap, produces a high portion of the total pumping work.

The invention has been illustrated in connection with a double acting pump but it is equally applicable to single acting pumps of the type here in question as are described in the aforementioned pending application and other applications and patents of the applicant.

While the invention has been described in detail with respect to a certain now preferred example and embodiment of the invention it will be understood by those skilled in the art after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention and it is intended, therefore, to cover all such changes and modifications in the appended claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In an electromagnetic pumping device for pumping a fluid, in combination a housing, electromagnetic means within the housing including a plurality of ring-shaped magnetizable portions in concentric arrangement, adjacent face sides on one side of said ring portions being disposed in a special relationship so as to form a substantially continuous inwardly curved circular surface, armature means in form of a flexible circular diaphragm disposed within the housing so as to form a pumping chamber between the diaphragm and the continuous surface, said housing having in its inner wall a peripheral recess defining opposite outer wall portions disposed adjacent to said continuous surface and slanted so as to form substantially a continuation thereof, said recess further defining opposite inner wall portions disposed parallel to each other, the peripheral rim of the diaphragm being extended into and held between the parallel wall-portions of the inner recess portion, the curvature of the continuous surface corresponding to the configuration of the diaphragm in flexed position, electric means for intermittently energizing said concentric magnetizable portions so as to cause the diaphragm to oscillate thereby varying the capacity of the pumping chamber, the said concentric portions, when magnetized, attracting adjacent corresponding zones of the diaphragm, fluid admission means arranged to communicate with the pumping chamber and to admit fluid into the chamber upon oscillatory movement of the diaphragm in one direction, and fluid discharge means arranged to communicate with the pumping chamber to discharge fluid from a chamber upon oscillatory movement of the diaphragm in opposite direction.

2. An electromagnetic pumping device as defined in claim 1, wherein the slant of said outer wall portions of the recess walls is less than the slant of the adjacent portion of the continuous curved surface, thereby causing the diaphragm to experience a bending adjacent to the rim of

said outer recess portion and a second opposite bending at its center when flexed.

3. An electromagnetic pumping device as defined in claim 1, wherein said housing is formed by two halves, said recess being formed between adjacent surfaces of said halves.

4. An electromagnetic pumping device as defined in claim 1, wherein the total width of said concentric magnetizable ring portions corresponds substantially to the diameter of said continuous curved surface less the continuation thereof.

5. An electromagnetic pumping device as defined in claim 1, wherein the wall portions forming said slanted outer recess portion are made of non-magnetic material.

6. In an electromagnetic pumping device for pumping a fluid, in combination a housing, electromagnetic means comprising two electromagnets, each including a plurality of magnetizable ring-shaped portions in concentric arrangement, adjacent face sides on one side of said ring portions being disposed in a spacial relationship so as to form one substantially continuous inwardly curved surface, said electromagnets being disposed within the housing opposite to each other spaced apart, armature means in form of a flexible circular diaphragm disposed within the housing so as to form a pumping chamber between the diaphragm and each adjacent continuous surface, said housing having in its inner wall a peripheral recess defining outer wall portions disposed adjacent to said continuous surface and each slanted so as to form an extension of the adjacent portion of the respective curved continuous surface and inner wall portions disposed parallel to each other, the peripheral rim of the diaphragm being extended into and held between the parallel wall portions of the inner recess portion, the curvature of each continuous surface corresponding to the configuration of the diaphragm in flexed position, electric means for intermittently energizing said concentric magnetizable portions so as to cause the diaphragm to oscillate thereby varying the capacity of each pumping chamber, the said concentric portions, when magnetized, attracting adjacent corresponding zones of the diaphragm, fluid admission means arranged to communicate with each pumping chamber and to admit fluid into a chamber upon oscillatory movement of the diaphragm in one direction, and fluid discharge means arranged to communicate with each pumping chamber to discharge fluid from a chamber upon oscillatory movement of the diaphragm in opposite direction.

7. An electromagnetic pumping device as defined in claim 1, wherein said housing comprises two substantially symmetrical sections joined together and each being formed with a wall facing the corresponding wall of the other section, each of said facing walls including a portion forming together with the adjacent wall portion of the other section said parallel wall portions of the recess and a portion forming together with the adjacent wall portion of the other section said slanted wall portions of the recess.

8. An electromagnetic pumping device as defined in claim 7, wherein said slanted wall portions forming a continuation of said curved surface are also ring shaped for forming together with the diaphragm said pumping chamber, and wherein said diaphragm faces the continuously curved surface formed by the magnetizable portions and also the said extension of said surface,

the maximum outer diameter of said ring shaped magnetizable portions being smaller than the outer diameter of the diaphragm.

9. An electromagnetic pumping device as defined in claim 8, wherein said slanted ring shaped housing wall portions between the maximum outer diameter of the magnetizable portions and the maximum outer diameter of said extension of the curved surface are made of non-magnetic material.

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