United States Patent [19]

Koblents et al.

[11] **3,711,749**

[45] **Jan. 16, 1973**

[54] REED SWITCH

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[22] Filed: **Oct. 7, 1971**

[21] Appl. No.: **187,312**

[52] **U.S. Cl.** **317/155,** 200/144, 317/11, 335/151, 335/154

[51] **Int. Cl.**.....**H01h 47/04,** H01h 51/28

[58] **Field of Search** ...335/151, 154, 153; 200/144 B; 317/155, 11

[56] **References Cited**

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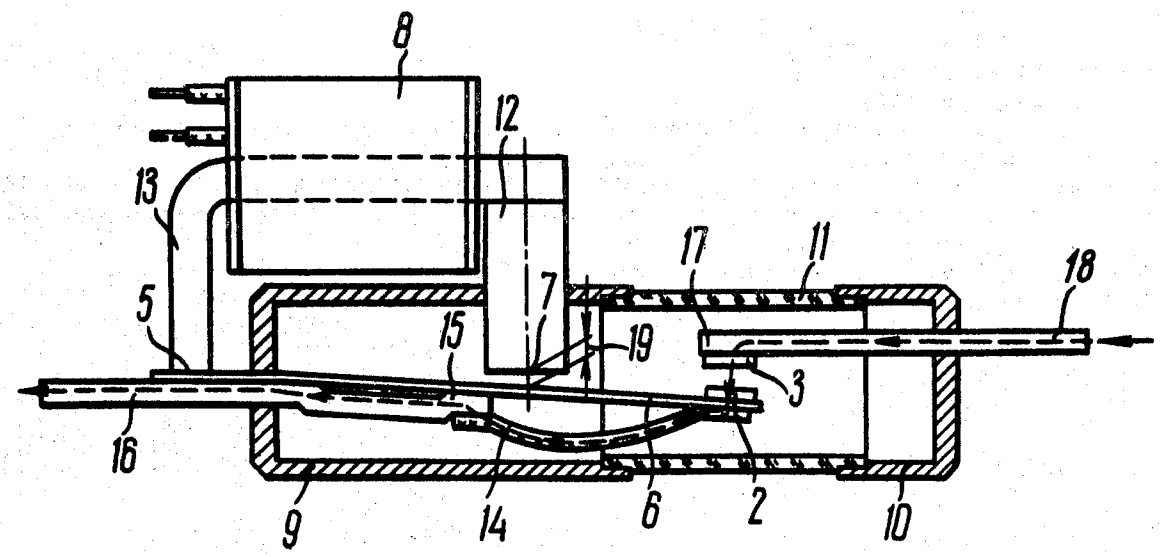
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Primary Examiner—Roy N. Envall, Jr.
Attorney—Holman & Stern

[57] **ABSTRACT**

A reed type electromagnetic circuit switch designed mainly for operation in power circuits of switchgear installations, as well as in automatic control and electric drive systems where the power handled may amount to tens of thousands of voltamperes and rated currents may reach tens and hundreds of amperes; the current circuit of the reed switch is made up of solid current leads, a flexible shunt, and contact tips, manufactured from materials possessing high electrical conductivity. The arrangement includes an armature consisting of a ferromagnetic reed member and thinner ferromagnetic strips and provides for high electromagnetic pull and contact pressure, while a shield and a loop increase the reliability of the reed-to-reed insulation in the off-position and make it possible to develop most reliable and wear resistant contactors. An electromagnet is arranged to attract the armature, and has poles which are introduced into a sealed casing, while the coil of the electromagnet is disposed outside the casing.

8 Claims, 16 Drawing Figures



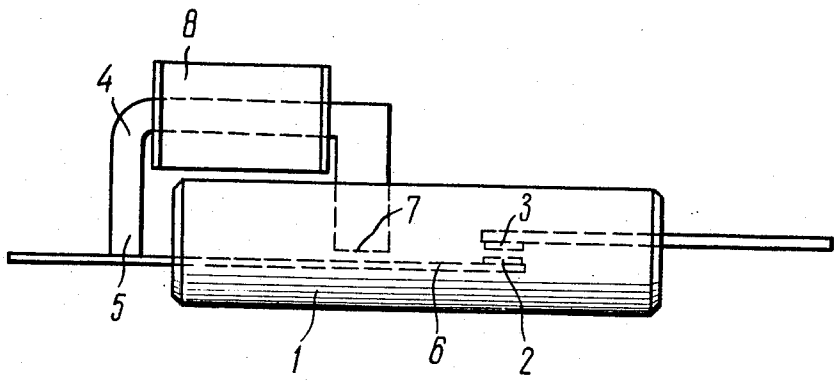


FIG. 1

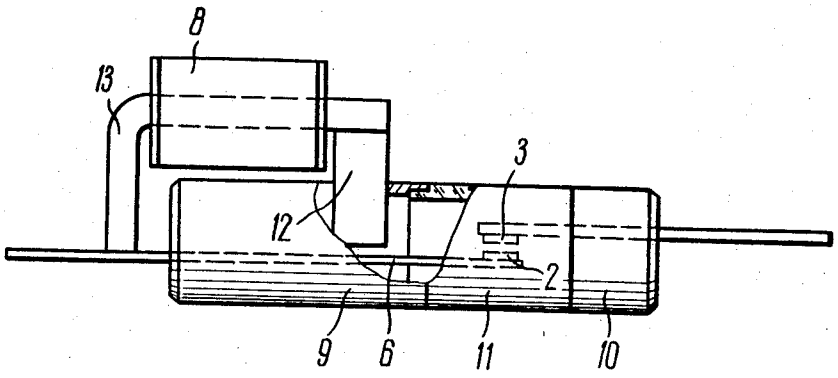


FIG. 2

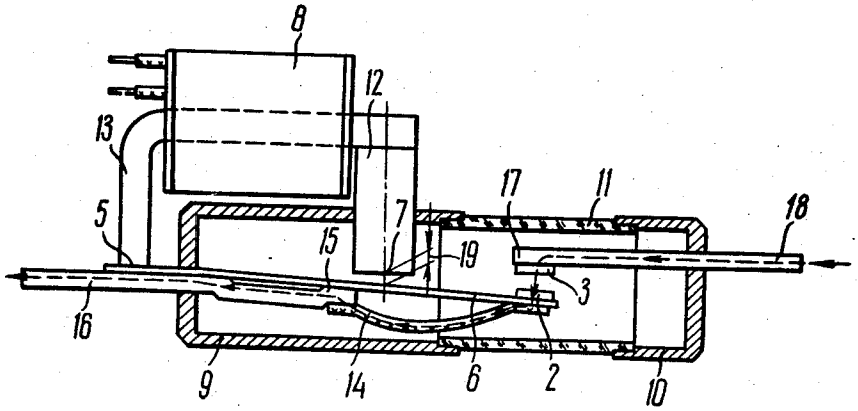

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FIG. 3

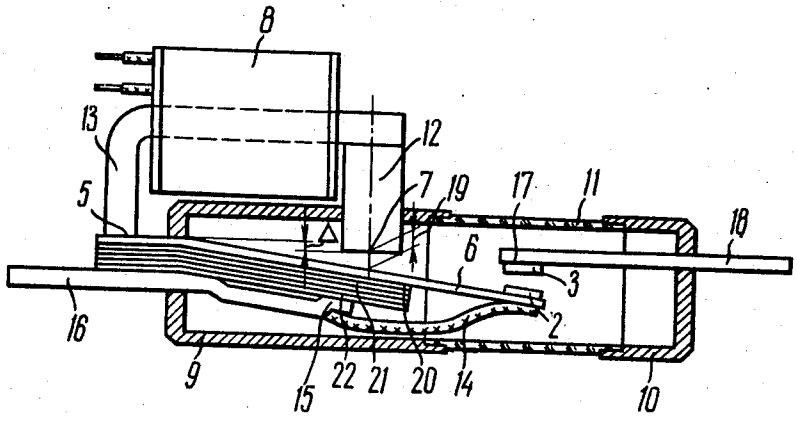

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FIG. 4

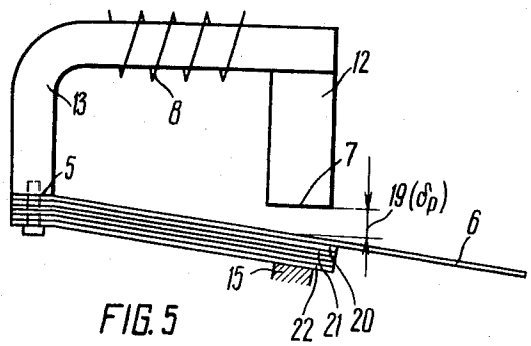


FIG. 5

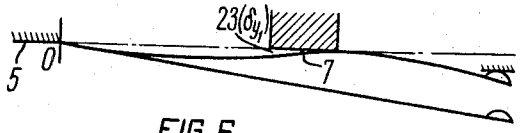


FIG. 6

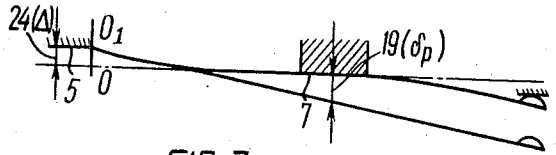


FIG. 7

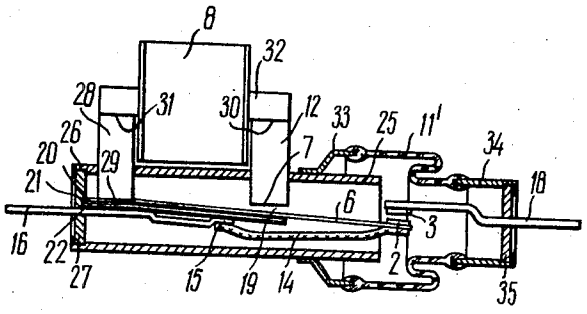


FIG. 11

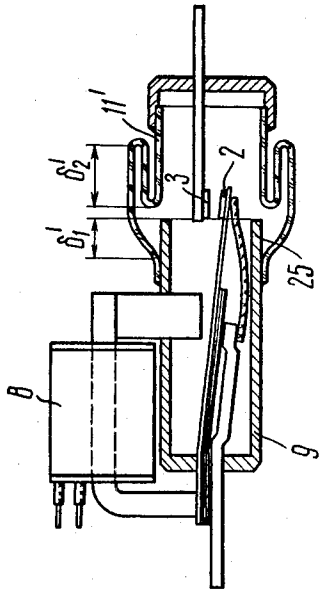


FIG.10

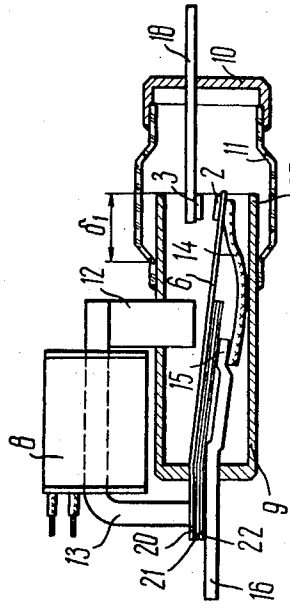


FIG.8

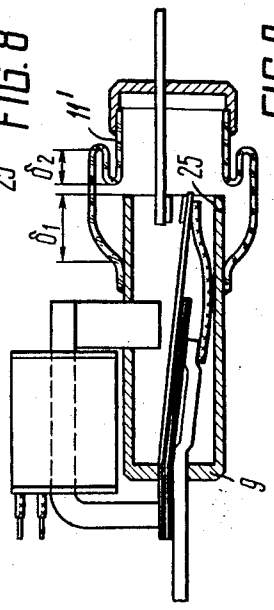


FIG.9

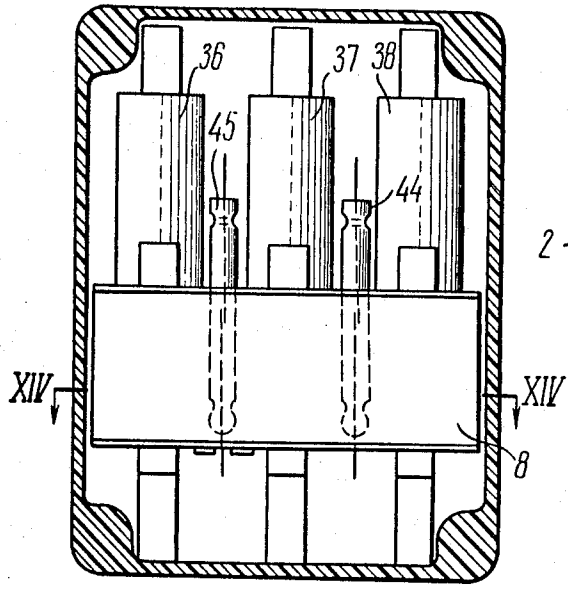


FIG. 12

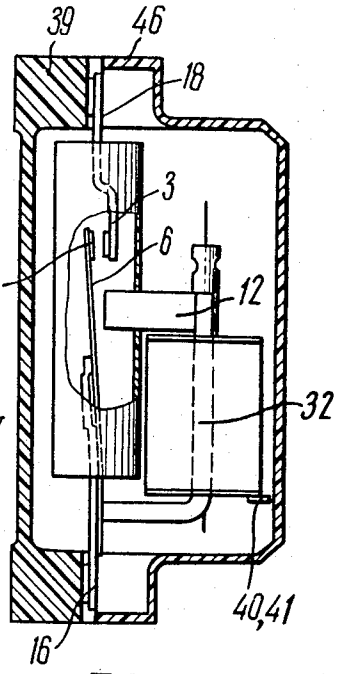


FIG. 13

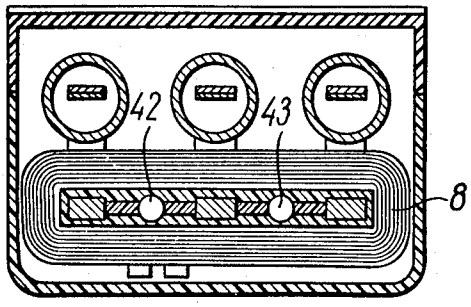


FIG. 14

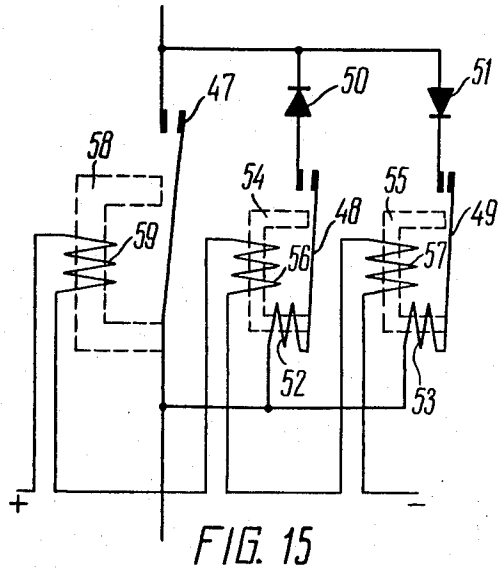

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FIG. 15

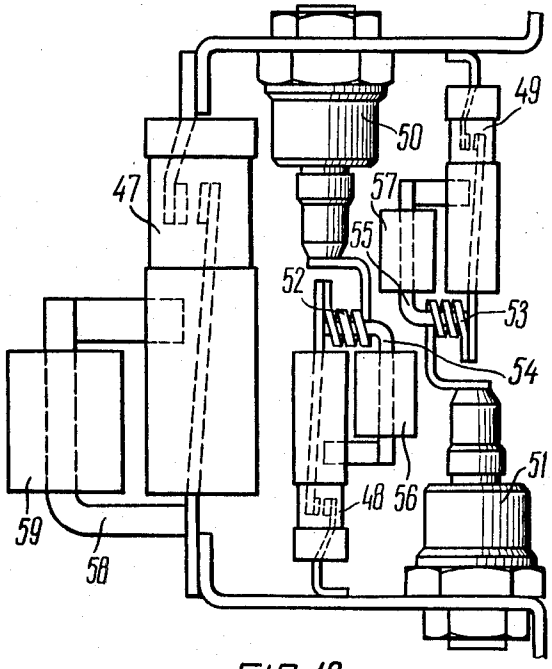

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FIG. 16

REED SWITCH

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to electric circuit switching devices and, more particularly, to reed switches with ferromagnetic reeds, designed mainly for operation in power circuits of switchgear installations, as well as in automatic control and electric drive systems where the power handled may amount to tens of thousands of voltamperes and rated currents may reach tens and hundreds of amperes.

2. Description of Prior Art

Most known reed switches, also termed reed relays, usually comprise a sealed casing or container and two light ferromagnetic reed members mounted in the casing and disposed to be under the effect of a magnetic field whereby said reed members move their free ends functioning as contact members over a short distance equivalent of parts per ten and hundred of a millimeter creating a contact pressure of about 20 – 30 g.

Such reed switches have lately found a wide application in a number of branches of light-current engineering and have been acknowledged as reliable contact devices noted for high mechanical wear resistance, fast response, high insulation resistance, reliability and many other advantages which warrant using them to better advantage in conjunction with up-to-date semiconductor devices and even as substitutes of the latter.

A disadvantage of the known reed switches is their low rated current, low power handled and low maximum switching capacity which does not exceed 100 VA for large-scale produced designs and 500 VA for special designs.

Further, in spite of the afore-mentioned advantages of the known reed switches, and also the possibility of providing a sealed construction, because of their low rated current and limited maximum switching capacity they cannot be used as final elements of logic systems or as power and auxiliary contacts of contactors and starters in electric drive automatic control systems and as contacts of relays where power to be handled may amount to tens of thousands of voltamperes and rated currents may reach tens and hundreds of amperes.

Such low rated currents and switching capacity of known reed switches is caused by extremely small distances over which the contacting surfaces move, determining contact separation and follow through, as well as by low contact pressure.

It is not feasible to increase contact pressure, separation and follow through in the reed switches built according to conventional principles of design. If we increase the sectional area of the reeds in order to obtain a higher contact pressure and if we provide a larger air gap between the free ends of the reeds so as to place solid contact tips and, hence, to provide high switching capacity, then it will be impossible to increase the electromagnetic pull to overcome the opposing force due to the following factors:

a. the magnetic flux closes through the air gap before reaching the ferromagnetic reeds, which involves high leakage fluxes and requires very large megnetomotive forces to overcome them;

b. the sectional area of the reeds is limited as their saturation restricts the flux traversing the operative air gap and, hence, the electromagnetic pull between the contact members.

Taking into account that the opposing force is proportional to the third power of sectional area of the ferromagnetic reed, and the electromagnetic pull is proportional to the first power of sectional area, it becomes evident that the reed switches with larger sectional areas of reeds will fail to operate.

Besides, materials and sectional areas of current-carrying parts in the existing reed switches are not suitable to pass heavy currents.

Known in the art is a reed switch disclosed in U.S. Pat. (cl.335–153) No.3,253,097 comprising a sealed casing accommodating two light ferromagnetic reeds, as well as a coil and a guide member mounted outside the vessel. An additional external guide member provides for a reduction in the flux leakage and makes it possible to obtain the required magnetic flux applying a reduced magnetomotive force.

This construction may not always provide desirable results since even with the external guide member the flux passes on its way through very large stray non-operative air gaps.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a reed switch which is simple in design and is distinguished by high contact pressure and contact travel so as to make it possible to operate at large rated currents and to handle high power.

It is another object of this invention to provide contactors built around new reed switches characterized in high wear resistance.

This invention aims at providing a switching device built around reed switches ensuring long service life due to its new constructional solution.

This is achieved in that in a reed switch comprising at least two contact members, of which at least one includes a resilient ferromagnetic member, accommodated within a closed casing with at least one guide member fixed on the latter; one end of the guide member carries a coil, and is fixed, according to the invention, with the end of the resilient contact member and with a first long solid current lead made from high-conductivity material, while the other end, forming an operative air gap together with the resilient ferromagnetic contact member, is accommodated within the vessel at a distance from the contact tips, while the resilient contact member is shorted out with a flexible cable, one end of the latter being connected to the current lead and the other current lead being made from solid high-conductivity material.

It is another feature of this invention that the casing consists of at least two complementary parts one of them being made from metal and connected to that end of the guide member which is accommodated within the vessel, while the other part is made from insulating material, and the resilient contact member presenting a single ferromagnetic strip carrying a contact member tip is fitted with at least two resilient ferromagnetic strips of smaller thickness and length to form a stack, each strip being fixed at one end to the butt end of the guide member and the entire stack being supported by the extension of the long current lead, the surface of said butt end of the guide member being displaced relative to the surface of the other butt end of said guide member towards the coil.

It is still another feature of this invention that the part of the casing made from insulating material and having in its section the shape of, say, a loop, is secured to the metal part of the vessel so that the end of the latter partially shields the insulating casing from the tips of the contact members; further the butt end of the guide member fixed with the ends of the resilient ferromagnetic contact member, with those of the resilient ferromagnetic strips and with the long solid current lead is accommodated within the compound metal part of the casing and is joined with the latter; also the reed switch employs a rectifier and an auxiliary current coil wound on the guide member, all being connected into the contact member circuit.

It is therefore reasonable to build around said reed switches a contactor each current pole of which is assembled of one large-power reed switch and two parallel-connected reed switches of lower power, all forming a single structure.

The reed switches of lower power have a lower drop-out time of the contact tips, hence one of them is closed all the time while its rectifier is conductive during the half-cycle following the off-operation of the contactor, ensuring thereby an arcless disconnection of the load.

The reed switches of this invention have an electric circuit completed by high-conductivity members and a guide member arranged so that non-operative (stray) air gaps are practically eliminated. Magnetic flux passes to the operative flux of the guide member through ferromagnetic contact members only, and the sectional area of the ferromagnetic reeds does not limit the flux contributed to the operative air gap.

All these features have made it possible to obtain a contact pressure as high as 1.5 kg, a contact separation exceeding 2.5 mm and a follow through over 1.5 mm for experimental models of reed switches rated 63 to 100 A, and a contact pressure over 70 g, contact separation exceeding 1.5 mm, follow through more than 0.7 mm for models rated 6.3 to 10 A. Experiments carried out with models rated 6.3 to 10 A have shown that even these small reed switches are capable of handling maximum power exceeding 10,000 VA. They have high mechanical wear resistance and fast response. The models have remained serviceable after more than 150.10^6 operating cycles; their response time at on-operation was within the range of 7 to 10 sec and at off-operation it was about 1 msec.

BRIEF DESCRIPTION OF THE DRAWING

This invention will be further understood from the foregoing detailed description with reference to the appended drawings wherein only specific terms have been selected for detailed disclosure; it should be borne in mind, however, that the invention is not to be restricted by adopted specific terms and that each term embraces all equivalent elements serving the same purpose in the scope of this invention.

It should be also borne in mind that other objects and advantages of this invention besides those mentioned above will be further understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows an illustration of the mutual arrangement of reed switch basic components;

FIG. 2 shows the reed switch of FIG. 1 with a sectionalized casing;

FIG. 3 is the reed switch of FIG. 2 with solid current leads and flexible cable;

FIG. 4 is the reed switch of FIG. 3 with auxiliary thin ferromagnetic strips;

FIG. 5 is a diagrammatic representation electromagnet of the arrangement shown in FIG 4;

FIG. 6 is a diagram showing the position of the ferromagnetic reed when the butt ends of the guide member are in one plane;

FIG. 7 is a diagram showing the position of the ferromagnetic reed when the butt ends of the guide member are displaced;

FIG. 8 shows the reed switch according to FIG. 4 with additional protection off a part of the insulating casing against contact metal splashes;

FIG. 9 shows a further embodiment of the reed switch similar to the one shown in FIG. 8;

FIG. 10 is a modification of the reed switch shown in FIG. 9;

FIG. 11 is a constructional form of the reed switch;

FIG. 12 shows an illustration of a contactor built around the reed switches of the invention;

FIG. 13 is the side view of the contactor of FIG. 12;

FIG. 14 is the plan view of the contactor of FIG. 12;

FIG. 15 is an electric circuit diagram of one pole of an arcless switching contactor built around reed switches of the invention;

FIG. 16 is an illustration of one pole of an arcless switching contactor built around reed switches of the invention.

Certain other objects and advantages of this invention besides those mentioned earlier will become apparent from the further detailed description with reference to the appended drawings.

The ferromagnetic guide member of the reed switch, according to this invention, in distinct from that made in accordance with U.S. Pat. No. 3,253,097, and is arranged so that its one end is tightly fitted to the external end of the ferromagnetic reed carrying the movable contact, while the other end is introduced into a sealed casing wherein it is placed in close proximity to said reed forming thereby an operative magnetic gap, and the contacting point of the contact members is displaced with respect to the operative magnetic gap in the direction opposite to the point of attachment of said ferromagnetic reed, which serves at the same time as an armature, the operating coil being wound on the guide member.

The mentioned guide member, according to this invention, can be made up of a core one end of which is introduced into the sealed casing and a yoke arranged outside of the casing, and the casing can be composed of two non-ferromagnetic shells and an insulating (say, glass) tube.

The reed switch arrangement described thereof makes it possible to considerably increase contact separation at a relative decrease of the required magnetomotive force of the operating coil and to employ contact tips made from high wear-resistant material, all this leading to a considerable increase in the switching capacity and electric wear resistance.

Referring to FIG. 1, there is shown a reed switch comprising a sealed casing 1 accommodating contact tips 2 and 3 and a ferromagnetic guide member 4. The guide member 4 is arranged so that its one end 5 is tightly fitted to the external end of the light ferromag-

netic reed 6 carrying movable contact 2, and its other end 7 is introduced into the sealed casing 1 and placed in close proximity to the reed 6 between the point of attachment of movable contact 2 and the point of fastening of said reed within the vessel 1. An operating coil 8 providing for the required magnetomotive force is wound on the guide member 4.

With this arrangement of components, as distinct from the known designs of reed switches, flux passes to the operative air gap of the guide member (between the ferromagnetic reed 6 and the end of the guide member 7 attached within the casing 1) through ferromagnetic components over its entire path (since non-operative stray air gaps are practically eliminated) which minimizes leakage fluxes and substantially reduces the amount of magnetomotive force required for moving the contacts and creating the required contact pressure.

Due to the relative displacement of the guide member air gap and the air gap between the contacts it has become possible to minimize the operative air gap of the guide member and to considerably increase the air gap between the contacts which ensures a high switching capacity of the device.

It is easily understood from FIG. 2 that in order to provide for the adjustment of the guide member operative air gap determining the contact separation and follow through as well as to improve their heat dissipation, the casing 1 (FIG. 1) can be made of two non-ferromagnetic shells 9 and 10 joined by means of an insulating (say, glass) tube 11.

To improve the mechanical design of the device, the guide member 4 can be composed of a core portion 12 (FIG. 2) inserted with its one end into the shell of the sealed casing 9, and a yoke portion 13 placed outside of the casing.

The reed switch operates as follows. When power is supplied to the operating coil 8 a magnetic flux is set up in the magnetic circuit of guide member 12, 13 under the effect of the magnetomotive force. This magnetic flux passes through the guide member and the ferromagnetic reed or armature 6 bearing a contact tip 2 and is concentrated in the operative air gap of the guide member. As a result, an electromagnetic pull is created within this air gap which causes the reed 6 to strain and to shift the movable contact member 2 secured on its end until it is closed with the fixed contact member 3.

As soon as the operating coil 8 is deenergized, the reed 6 returns resiliently to the initial position under the effect of opposing forces and opens the contact members.

It is a well-known fact that the rated current of existing reed switches is limited because of heavy power loss and extremely high heating of the switching device caused by high resistance of current-carrying parts (which have low electrical conductance) because these parts serve as guide members for magnetic flux and are electric contacts at the same time.

These drawbacks have been eliminated in the reed switch of this invention by shorting out the ferromagnetic reed accommodated within a sealed casing and carrying a movable contact by means of a flexible copper shunt 14 (FIG. 3).

One end of the shunt is connected (soldered) directly to the contact tip 2 and the other end to the output current lead of the movable contact 16 whose end is brought inside the vessel and is used also as the retainer of the reed (or armature) travel. Placing the armature retainer within the casing has given an additional possibility of reliably adjusting the armature angle of turn determining the contact separation and follow through in the course of assembling the switching device before putting on the glass tube.

The part carrying the fixed contact, as well as the current lead of the movable contact are made from high-conductivity material, such as copper.

Hence, along with above-mentioned advantages, all the current circuit components of the device of this invention are made from high-conductivity materials which makes it possible to reduce Joule loss and to increase the rated current of the switching device.

Mentioned advantages have been achieved by rendering solid contacts, a single movable component being comprised in the guide member, dispensing with a solid ferromagnetic block, which has improved the response of the device.

The solid movable contact (tip) 2 placed within a sealed casing 9, 10, 11 (FIG. 3) is fixed on a flat ferromagnetic reed 6 which serves as an armature of the guide members 12, 13 which are part of a magnetic circuit. The ferromagnetic reed 6 is shorted out by means of a flexible shunt 14 made from a copper bunched conductor whose one end, as has been mentioned, is soldered or welded to contact 2 and the other end with the armature travel retainer 15 which also serves as the external lead 16 of the movable contact made from a material possessing high conductivity and mechanical strength. The part 17 carrying the solid fixed contact (tip) 3 is also made from a material having high conductivity and mechanical strength and serves at the same time as an external lead 18 of the fixed contact.

The armature travel retainer 15 provides for a more reliable adjustment of the operative air gap 19 in the guide member while assembling the switching device.

When the coil 8 is energized, the armature 6 is pulled in and the contacts 2, 3 close passing the current in the power circuit through components possessing high electrical conductivity (the current path is indicated by arrows). The current branched off to the ferromagnetic reed 6 is negligible as the resistance of the latter is much higher than the resistance of the flexible shunt 14.

A considerable decrease in the resistance of the current circuit as compared to the known arrangements, has made it possible to develop reed switches for high current ratings.

In order to make the contact suitable for carrying heavy currents, however, it is necessary to ensure, accordingly, a high contact pressure.

As has been stated above, a mere increase in the thickness of the ferromagnetic reed carrying the contact member will not give necessary results, as the opposing torque will increase with contact pressure and the electromagnetic torque will rise negligibly due to the fact that the sectional area of the electromagnet armature (flat reed) varies to a small degree. Therefore, the sectional area of the reed cannot be selected arbitrarily as it should be determined by the selected contact pressure.

In selecting the size of the reed, taking into account the mentioned conditions, the sectional area of the reed is usually much less than that of the fixed part of the guide member which makes the armature heavily saturated and confines flux, and consequently, electromagnetic torque, in the operative air gap.

As is known, the sag of the flat reed

$$y=(Px^2/6Ey)\,(3l-x),$$

where l is the distance from the point of attachment of the reed to the point of force application;

x is the distance from the point of attachment of the reed to the sectional area concerned;

E is the material modulus of elasticity;

y is the inertia moment of the reed sectional area.

$$y=bh^3/12,$$

where b is the reed width;

h is the reed height.

Upon consideration of the above equations it becomes evident that the force created by the reed on arm **1**

$$P=\frac{6Eyb}{x^2(36-x)12}\,h^3=\lambda h^3$$

Sectional area of the reed $S=bh$.

Hence, the force created by the reed varies as the cube of its height whereas its sectional area is proportional to the first power of the height.

It follows from the above considerations that a small increase in the thickness of the reed causes a considerable increase of the opposing torque developed by the reed at a substantially smaller increase of its sectional area. The opposing torque, therefore, will rise more rapidly than the electromagnetic torque and the electromagnet will fail to operate if the thickness of the ferromagnetic reed is increased. To reduce the armature saturation and at the same time retain all the advantages of devices comprising ferromagnetic reeds, it is preferred to employ one reed ensuring the required opposing torque and to place thinner ferromagnetic reeds in parallel to the former. Such an arrangement will ensure a considerable increase in the electromagnetic torque since the armature saturation will decrease and the flux in the operative air gap will increase with the increase of the armature sectional area, the opposing torque being practically the same.

As an example we may take an arrangement in which five ferromagnetic reeds are set in parallel to the main reed, each of the former being 5 times thinner than the latter. Then the armature sectional area will be twice as large and the opposing torque (force) will rise **1.04** times only since

$$\frac{P_{I+5}}{P_I}=\frac{Kh^3+K\sum_{n=1}^{n=5}\left(\frac{h}{5}\right)^3}{Kh^3}=I+5\left(\frac{I}{5}\right)^3=I.04$$

Hence, the opposing torque is practically the same. This fact gives the precondition for building an armature of high-power reed switches rated at tens and hundreds of amperes out of additional flat ferromagnetic reeds.

Replacing a solid armature by one built up of separate ferromagnetic strips arranged in parallel to the butt ends further of the guide member fixed part and rigidly secured at one end increases the shock and vibration resistance of the device.

Besides, eddy currents arising in the armature at the moment the electromagnet coil is switched on or off are decreased thus reducing the opening and closing time of the device.

Referring to FIG. **4** and FIG. **5** there is shown an arrangement in which one of the ends of flat ferromagnetic reeds **6**, **20**, **21**, **22** (the number of reeds may be much greater than indicated) is rigidly secured at the butt end **5** of the fixed part of the guide member **13** carrying the coil **8** so that in the open position an operating air gap **19** is set up between the butt end **7** and the extreme reed **6**, the magnitude of said air gap being fixed by the retainer **15** which provides for the preliminary tension ensuring that in the off position all the reeds within the operative air gap are pressed tight to each other. Therefore, a smaller amount of magnetomotive force is required for conducting the flux through the air gap.

When the pull-in coil is energized, the flux passed to the air gap is sharply increased due to additional strips increasing the sectional area of the armature.

The contact tip **2** is secured to the main (thick) ferromagnetic reed **6** and the thin ferromagnetic reeds **20**, **21**, **22** are fixed on one end and are free to move on the other end.

If the butt ends **5** and **7** of the guide member are placed in one plane, as shown in FIG. **6**, the reed will come in contact with the core on one side only (on the right) while on the other side an air gap **23** will be set up between the reed and the core. If the electromagnetic pull is much greater than the force of the reed, then the latter may get fully attracted to the core, but in this case inadmissible internal strain will be produced in the reed causing residual deformation, a change in its settings and a reduction of its operational reliability.

Besides, too large an air gap in the pulled-in position of the armature (reed) will increase the total air gap in the off-position and decrease the conductance of the operative air gap and the electromagnetic torque. Then higher ampere-turns will be required to obtain the necessary contact separation, follow through, and pressure.

It is, therefore, preferable to fix the reed at a point located in respect to the core as illustrated by FIG. **7** so that in the pulled-in position there is no apparent air gap between the reed and the core. This can be achieved by shifting the reed axis from point **0** to point 0_1 over a distance Δ, ref.**24** (FIG.**7**); in such a case air gap δy_1, ref.**23** (FIG.**6**) will be eliminated.

From calculations and investigations it was found that the reed fixing axis should be optimally shifted relative to the plane crossing the operating surface of the core over a distance Δ equal to a half of the air gap δp between the operating surface of the core and the reed,

$$\Delta=\delta p/2.$$

Due to such an arrangement non-operative non-magnetic air gaps are practically eliminated as the reed carrying a contact tip has a tight fit with the butt end at which it is fixed.

In the course of prolonged use of reed switches and after a great number of on-off operations, splashes of molten contact material may get deposited the insulating (glass) tube causing a gradual bonding of the inner surface of the glass tube, which may result in a decrease of electric strength and insulation resistance between the contact members in the open position.

In order to decrease the effect of this factor, the contacts are made from hard materials having high melting points. In such a case the contact material will not splash but the contact resistance may increase. To use softer materials for contacts providing a much lower contact resistance, provision should be made for shielding, at least partially, the contact members so as to prevent splashes of molten contact material from getting on the glass insulating one contact from another.

The reed switch of this invention has a shield protecting the insulating glass from metal splashes made from the structural components of the device proper so as to dispense with additional parts and complication of mechanical design.

The metal housing **9** (FIG.8) carrying the flat ferromagnetic reed **6** and the core **12** serves as a shield protecting the glass enclosure **11** from splashes of molten contact material. Part of the housing **25** located on the side of the core **12** is set at a distance and braces with its end the contacts **2** and **3**. The glass enclosure **11** is secured on the outside of the housing **9** at a distance of δ_1 from the edge. The enclosure is essentially a glass tube widened in the middle so that a space is provided between the outer surface of the vessel and the inner surface of the widened portion of the glass tube on length δ_1. This space is hard for molten metal splashes to get at. In this way the insulation reliability upon wear of contacts is improved without complicating the mechanical design of the switching device.

In order to obtain a still greater reliability of insulation upon wear of contacts, the glass vessel **11** (FIG.9) is made in the form of a tube widened in the middle and looped on length δ_2. In this case a much greater area of the inner surface of the vessel is protected against molten metal splashes, the length of this area being equal to $\delta_1 + \delta_2$.

To facilitate observation of the contacts while the switching device is assembled, the metal housing is made longer by a value of $\delta_1' < \delta_1$ as shown in FIG. **10** so that it does not close the contacts.

At the same time, the loop δ_2' is made longer to provide better protection of the vessel against molten metal splashes. Due to this measure the vessel surface to be protected remains unchanged:

$$\delta_1 + \delta_2 = \delta_1' + \delta_2',$$

while the contacts are now easily observed in the course of assembly and adjustment of the switching device.

The device operates as follows. When the coil **8** is energized, the flat ferromagnetic reed or armature is pulled in to the core **12**, and the contacts **2, 3** close. As soon as the coil is deenergized, the armature drops out and the contact members start separating. An electric arc formed between the separating contact melts the material of the contacts which splashes in all directions and may get on the metal and glass portions of the housing. But since the metal vessel and the glass loop are elongated, the major portion of the inner surface of the glass tube **11** is protected against these splashes.

To improve sealing of the switching device and to simplify its manufacturing technique, the ferromagnetic strips should be arranged within the casing and all the components of the device should be joined together by metal-to-metal welding or soldering. This can be achieved in the reed contact by introducing the other butt end of the guide member into the vessel, by sectionalizing the metal casing and by terminating the insulating tube with suitable metal (or an alloy such as Kovar) soldered to the end faces of the glass tube.

As distinguished from the arrangement considered earlier, this device has a sectionalized metal casing made from a non-ferrous sleeve **26** (FIG.11) and a disc **27** at the bottom of the sleeve. Coupled with the sleeve **26** are two ferromagnetic core members **12** and **28** which have similar ends **7, 29** placed within the sleeve and the other end **30, 31** outside of the sleeve. The end **7** of one of the cores is arranged, like in reed switches referred to before, in close proximity to the ferromagnetic reed **6** forming thereby an operative air gap, while the other end **29** of the core inserted into the sleeve **26** is tightly fitted to the end of the ferromagnetic reed **6** carrying the contact tip **2**. This same core end **29** bears thin ferromagnetic strips **20, 21, 22** and a long solid current lead of the movable contact **2**, one end **16** of this lead being passed through the pole in the disc **27** outside of the vessel while the other end **15**, with a flexible stranded conductor **14** attached to it, serves as a bearing surface for the strips **22, 21, 20**, these strips functioning as the electromagnet armature.

Attached to the core ends **30** and **31** passed outside of the vessel is a yoke **32** which carries a wound coil **8**.

The insulating portion of the vessel (**11'**) made from, say, glass is welded at the ends to metal (Kovar) rings **33** and **34**.

The ring **34** is joined with the disc **35** to form another shell of the casing. Another solid current lead **18** carrying the contact tip **3** is passed through the hole in the disc **35**. The other end of the ring **33** built integral with the insulating portion of the casing **11** is rigidly fixed with the sleeve **26**, after the contact separation, follow through and pressure have been adjusted, so that the glass portion arranged behind the end of the sleeve **25** is out of reach of metal fragments which may appear when heavy currents are handled by the contacts.

The development of reed switches with an independent operating electromagnet for each contact pair suitable for operation in electric power circuits has made it possible to construct unique designs of contactors which, in the first place, can operate in different atmospheres containing dust, gases, and other aggressive or corrossive agents which otherwise (in non-sealed designs) might impair switching; in the second place, the reed switches of the invention have a mechanical wear resistance at least one order higher than all known designs of contactors; and in the third place, these reed switches introduce new aspects in the construction of automatic control electric drive systems due to the absence of any mechanical tie between the movable contact members of separate contacts fulfilling common functions.

Referring to FIGS. 12, 13, 14, there is shown the mechanical design of a three-pole contactor rated 10 A and built around reed switches of the invention. This contactor can be used for starting and stopping light-power induction motors.

Since the electromagnet core 12 is placed partially within the casing and partially outside of it, the winding 8 can be arranged outside so as to be common for all the poles. Three reed switches 36, 37, 38 are secured on an insulating base 39. Each contactor consists of a casing accommodating a fixed contact assembly 3, a movable contact assembly 2 (functioning at the same time as an armature), and a portion of the core 12. Another portion of the core is arranged outside of the vessel which makes it possible to mount the coil 8 outside of the vessel and to provide a common winding for all the poles, to which end the yoke 32 is placed in appropriate slots in the coil former.

The power circuit lead is connected directly to the leads 16 and 18 of the reed switches while to the coil leads it is connected through the leads 10 provided on the coil former. The coil former is fitted with holes 42 and 43 intended to receive light-power reed switches 44, 45 which are used as auxiliary contacts. The entire device is housed in a common casing closed with a cover 46 which is put on the base 39.

The contactor operates as follows. When the operating coil 8 is energized, magnetic flux is set up at all the poles simultaneously. This flux traverses the cores 12 and the ferromagnetic reeds 6 which function as armatures and contact holders, causing an electromagnetic pull in the operative air gap. As a result, the contacts close. Simultaneously operate the reed switches placed inside the coil former and excited by the magnetomotive force of the operating winding.

When the operating coil is deenergized, the movable contacts or armatures of all the poles as well as the reed switches functioning as auxiliary contacts are reset to the initial position.

As the coil is common for all the poles, its ampere-turns will remain unchanged irrespective of the number of poles, the sectional area of the magnet wire and the space factor, as well as the cooling surface of the coil can be increased causing a decrease in the coil heating, simultaneous operation is ensured and the device reliability is improved.

In manufacturing contactors built around power reed switches and designed to control high-power circuits (including those of high-power A.C.motors), it is good practice to make provision for arcless off-operation to ensure high electrical wear resistance of contacts. Power reed switches introduce new aspects in the development of arcless switching devices.

The most reliable in operation of all known arcless switching contactors are those wherein their power contacts shorted out by two power thyristors connected in parallel opposition and start passing current at the instant the power contacts separate and are deenergized at the moment the current passes zero. In such contactors firing of thyristors can be effected by applying a transformed and rectified power circuit current to the control electrode; such an arrangement involves a rather complicated control system employing a great number of auxiliary elements.

A simpler circuit arrangement can be obtained by firing the thyristors from the auxiliary contacts of the contactor proper. In such a case, however, the contactor mechanical design should be of utmost reliability as to the operating sequence of power and auxiliary contacts; as the contactor wears down, its contacts tend to get maladjusted and the system fails. It is just for this reason that such an arrangement has not found a practical application.

In addition to the mentioned disadvantages of arcless switching circuits in which the power contacts are shorted out by thyristors (or any other rectifiers), their essential drawback consists in the absence of electrical decoupling of circuits in the off-position of the contactor (the rectifiers will pass leakage currents). This calls for the connection of disconnecting switches or other similar devices in series with the power contacts.

Electrical decoupling of circuits in arrangements where the power contact are shorted out by rectifiers connected in parallel opposition can be achieved by inserting the auxiliary contacts of the contactors in series with the rectifiers. In such an arrangement an appropriate sequence of separation of the power and auxiliary contacts of a particular pole is essential to ensure an arcless opening of electric circuits.

All the known contactors employing diodes for arcless switching have a common electromagnetic operating mechanism which operates both power and auxiliary contacts of the particular pole. Therefore, the required sequence in contact separation is achieved by mechanical means: appropriate adjustment of contact follow through, setting of miscellaneous latches, special electromagnetic locks, etc. With a common operating mechanism, these mechanical ties between contacts (and the latter are subject to wear and maladjustment) cause a considerable reduction of mechanical wear resistance and reliability of mechanical design; hence, such arrangements have not found practical application.

The known arcless switching contactors have a single operating mechanism irrespective of the number of poles which actuates a shaft or a crosspiece coupled with the movable members of the power contacts. To this end, a special form of design of the shaft, crosspiece and other parts should be available for each contactor design according to the number of poles (one, two, three, four, five).

Besides, a single electromagnet common for all designs is usually rated for the maximum number of poles; therefore single-pole and two-pole contactors are made conservative which leads to extra expenditure of materials and power.

In known contactor designs arcless switching is aforded by the above-mentioned method with the aid of special attachments to standard contactors. This makes the contact assembly of a standard contactor too complicated.

The power reed switches used in contactors will make it possible to develop a contactor in which arcless switching is achieved without any mechanical tie between the contacts of different poles and between separate contacts of one pole as each pole contact (both power and auxiliary) is fitted with a separate electromagnetic operating mechanism, the operating sequence of contacts being afforded by electrical, and not mechanical, coupling.

FIG.15 illustrates an electric circuit of one pole of a heavy-current power contactor.

Each pole of this contactor is a self-contained unit comprising one high-power reed switch 47 rated continuously to carry the power circuit rated current and two auxiliary reed switches 48, 49 having a much higher resistance of the current circuit and a little longer inherent opening time than the reed switch 47, and consequently, a smaller size and current rating which makes up 10 to 20 per cent of the power circuit rated current. Diodes 50 and 51 as well as hold-in current coils 52 and 53 are connected in series opposition to each auxiliary contact 48 and 49.

The current circuits of the auxiliary contacts are connected across the power contact 47. The turns of the hold-in current windings 52 and 53 mounted on the guide members 54 and 55 are wound in such a way that at the instant the power contact 47 opens (the auxiliary contact 48 or 49 starts passing the respective half of the power circuit current) the flux produced by the hold-in coil 52 and 53 is in added relation with the flux created by the respective D.C. pull-in coil 56 or 57 mounted on the guide member 54 or 55, respectively. It is preferable to connect the pull-in coil 59 of the high-power reed switch 47 mounted on the guide member 50 in series with the pull-in coils of the auxiliary contacts 48 and 49 to exclude non-synchronous off-operation upon the occurrence of an open circuit in one of the coils.

All the poles of multipole contactors have a similar design.

The device operates as follows.

When the control circuit is connected to a D.C. supply, the armatures of all the three electromagnets 58, 54, 55 are pulled in, the contact tips of the contacts 47, 48, 49 close and switch on the load. The load current will flow mainly through the power reed switch 47 which has a much higher contact pressure and a much lower contact resistance, than the tips of the auxiliary reed switches 48, 49.

Disconnection of the control circuit deenergizes the coils 59, 56, and 57; the armature of the electromagnet 58 holding the contact tips of the power reed switch 47 as well as the armature of one of the electromagnets holding the contact tips of the auxiliary reed switch whose diode is cut off at the particular half-cycle (say, the electromagnet 54 holding the contact tips of the reed switch 48) drop out. Then the armature of the electromagnet 55 will be held by the flux set up by the hold-in coil 53 as the diode 51 will pass current at the particular half-cycle. The contact tips of the reed switch 49 will remain closed and will pass all the power circuit current as the contact tips of the reed switches 47 and 48 are open.

As soon as the instantaneous value of current in the half-wave passed by the diode 51 decreases, the flux created by the hold-in coil 53 reduces and when the current approaches zero, the armature of the electromagnet 55 drops out; as a result, the contact tips of the reed switch 49 open. During the next half-cycle the diode 51 is cut off; thus the danger of its repeated firing and armature attraction is excluded.

A similar process will take place in the circuit of the reed switch 48 in case the reed switch 47 opens at the instant the diode 51 is cut off and the circuit of the reed switch 49 does not pass current.

Hence, the device of this invention is suitable for disconnecting the load at the instant the instantaneous value of current approaches, or is equal to, zero providing thereby an arcless switching.

A single pole of an arcless switching contactor rated at 100 A is illustrated on FIG.6 This pole is a self-contained unit with all its parts interconnected by busbars which are intended for external connections. This unit comprises a single reed switch 47 rated at 100 A, two reed switches 49, 50 carrying 10-A hold-in coils 52, 53, and two silicon diodes 50, 51 rated at 100 A. Such units can be used to make up a contactor for any desired number of poles dispensing with additional special parts.

Such an arcless switching contactor will be characterized in high degree of reliability, low power requirement, short operating time, and low cost.

What is claimed is:

1. A high-power reed switch for switching an electric circuit, comprising: a casing and at least two contact members arranged therein in apposition, the first of said two contact members being fixed and having a high conductivity lead, the second of said two contact members being movable; a magnetic member provided with means to induce magnetic flux therein and having an open frame-like configuration with two substantially parallel butt end faces formed at the ends of two spaced limbs of the magnetic member; a resilient ferromagnetic elongated member secured at one end thereof to said second contact member and secured and cantilevered at the other end thereof with the first of said two butt end faces, said resilient elongated member being so disposed as to form an air-gap at a switch "OFF" position between said elongated member and the second of the said butt end faces, said air-gap being at a distance from said two contact members; and a second high conductivity lead passing through said casing and having a flexible conductive lead attached to the second high conductivity lead at one end thereof and to said second movable contact member at the other end, whereby said resilient ferromagnetic elongated member forms part of an uninterrupted magnetic circuit provided by said magnetic member so as to minimize leakage flux, and increase the switch current rating in view of said flexible lead.

2. A high-power reed switch for switching electric circuits, according to claim 1, in which:

said casing is made up of at least two end parts and a middle part, the first of said two end parts being metallic and being coupled with part of said magnetic member whose said first butt end face is accommodated within the casing, the middle part of the casing being made from insulating material.

3. A high-power reed switch for switching electric circuits, according to claim 2, in which:

said resilient ferromagnetic member is made in the form of a single ferromagnetic strip carrying said second contact tip, and is fitted with at least two further resilient ferromagnetic strips of lower thickness and length to form a stack, each strip being fixed with its one end to said first butt end surface, while the entire stack rests upon the projection of an elongated current lead, said first butt end surface being displaced relative to the second butt end surface in a direction away from said contact-members.

4. A high-power reed switch for switching electric circuits, according to claim 3, in which:

said part of the casing made from insulating material is shaped in its sectional region to form a loop, and wherein the insulating part is fastened to the metal casing so that its end partially shields the insulating part of the casing from the contact tips.

5. A high-power reed switch for switching electric circuits, according to claim 4, in which:

said first butt end surface fixed with the ends of the single resilient ferromagnetic strip and said at least two further resilient ferromagnetic strips, as well as said elongated current lead are introduced into and coupled with said metallic first end part of the casing.

6. A reed switch according to claim 4,

wherein said means to induce magnetic flux in said magnetic member comprises a d.c. coil, the reed switch further including a rectifier, an an additional current winding wound on said magnetic member, said rectifier and said additional current winding being connected in series with said first and second contacts, so that said additional current winding aids the magnetic flux in the magnetic member, and upon connection of the reed switch to an a.c. line, the flux due to the additional current winding dies out at the first current zero of the a.c. line and said first and second contacts can stay separated without chattering.

7. A reed switch as in claim 1 wherein said means for inducing magnetic flux in said magnetic member comprises d.c. coil capable of producing magnetic flux simultaneously in a plurality of reed switches, and said resilient ferromagnetic elongated member forms part of an uninterrupted magnetic circuit in an "ON" position of the reed switch.

8. A contactor assembly for an a.c. circuit, including a high-power reed switch as in claim 7, and further second and third reed switches connected in parallel therewith, said second and third reed switches each having an additional magnetizing current coil disposed on the corresponding magnetic member, and a diode connected in series with corresponding set of first and second contact members, the corresponding contact members of the second and third reed switches having an inherent drop-out time longer than that of said first switch, so that, after an "OFF" operation of the contactor assembly, one of said second and third reed switches remains closed during a half cycle of the a.c. circuit power when its diode is conductive, providing thereby an arcless interruption of the a.c. circuit load.

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