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PRESSURE RESPONSIVE PROTECTIVE MEANS FOR VACUUM TYPE CIRCUIT INTERRUPTERS

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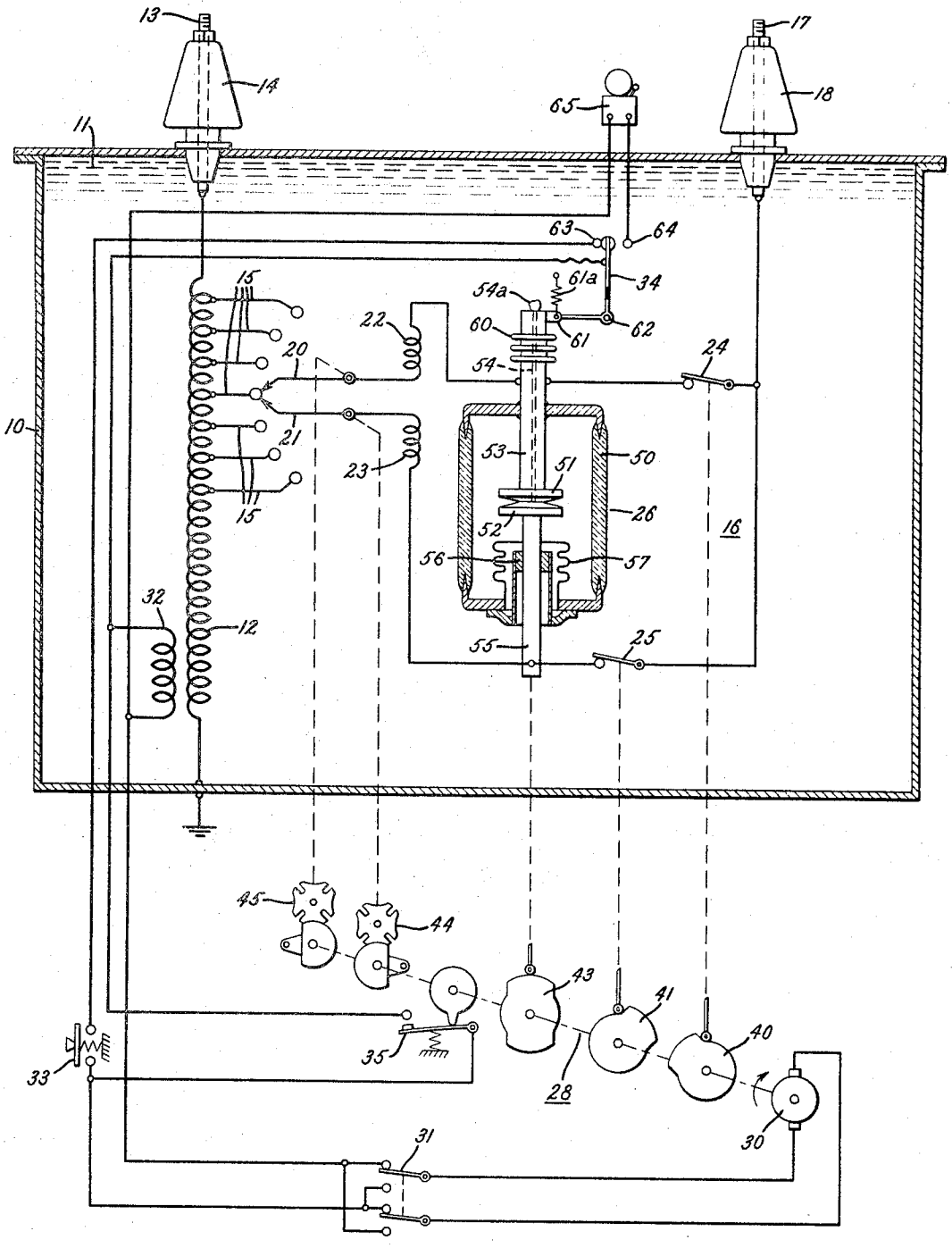

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PRESSURE RESPONSIVE PROTECTIVE MEANS FOR VACUUM TYPE CIRCUIT INTERRUPTERS

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My invenntion relates to protective apparatus for vacuum type circuit interrupters, annd particularly to means for preventing damage to such interrupters in the event of significant loss of vacuum while immersed in a body of liquid.

Vacuum type current interrupting devices of high interrupting capacity are useful in electric switches and circuit breakers of all types, and are presently available in voltage and current ratings capable of interrupting power flow at voltage commonly used in commercial and industrial distribution and transmission systems. In most applications the vacuum interrupting device is likely to be located in an ambient atmosphere of air, so that even a large leak in the evacuated envelope can do no more than fill the envelope with air or gas at ambient pressure. Under such conditions the device may fail to interrupt current, but the contained air or gas is not likely to build up sufficient presure to fracture the envelope. In certain special applications it is desirable to immerse a vacuum interrupting device in a surrounding ambient liquid. In such locations it is possible that a leak of appreciable size and time duration will admit to the switch envelope a pool of liquid sufficient, if heated excessively by an arc, to develop a bursting pressure.

One special application where it is desirable to immerse a vacuum interrupter in a surrounding ambient liquid is in load tap changing apparatus for power transformers. Such transformers are usually filled with a dielectric liquid such as oil or askarel, and the tap changing equipment is also liquid immersed. However, the tap changer ordinarily includes an arc current interrupting switch which has been located in a separate liquid-filled compartment to avoid contamination of the main body of transformer oil as a result of arcing at the switch. To accommodate the mechanical interconnection of the arcing switch with the transfer contacts and other switches in a tap changing apparatus, it has been customary to locate the entire tap changing apparatus in the separate liquid-filled compartment. This requires that all the tap leads from the transformer winding be brought out from the main body of the transformer to the tap changing compartment. In high voltage apparatus this is an expensive procedure in both labor and material costs.

It would be desirable, if possible, to locate all the tap changing apparatus for high voltage power transformers directly within the main transformer tank and immersed in the main body of transformer oil or other dielectric liquid. This economical arrangement does become possible when the arcing interrupting switch is of the vacuum type. With the entire tap changing apparatus so located, the tap leads need not be brought out of the tank, and no separate tap changing compartment need be provided. Even if a separate compartment is otherwise desirable, a vacuum interrupting device is advantageous in a load tap changer in order to avoid contamination of the oil in that compartment and the consequent frequent maintenance. On the other hand a vacuum interrupting device so located in the dielectric liquid of an associated electrical apparatus should not be permitted to develop any leak sufficiently large to admit liquid to the switch envelope. Even in the absence of further damage, a fractured interrupter would so contaminate the dielectric liquid that expensive and time-consuming maintenance work would be required.

Accordingly, it is a general object of my invention to

provide improved leak responsive protective means for vacuum type circuit interrupting apparatus.

It is another object of my invention to provide means for preventing the development of excessive pressures as a result of leaks in liquid-immersed vacuum type circuit interrupters.

Another object of my invention is the provision of liquid-immersed vacuum type arc interrupter apparatus for transformer tap changing equipment having means to prevent fracture of the interrupter in the event of liquid leakage.

It is a particular object of my invention to provide, in a vacuum type circuit interrupting device, an integral leak detecting means which does not require additional apertures or seals associated with the glass or ceramic envelope of such a device.

In carrying out my invention in one preferred embodiment, I utilize a normally closed vaccum type circuit interrupting device having an evacuated envelope immersed in a dielectric liquid and including relatively movable contacts separable within the envelope. One such contact is stationary and includes a rod or stem passing through a wall of the envelope and provided with a bore or passageway through which the envelope may be evacuated. Fixed to the stationary contact rod outside the envelope and in communication with the passageway through the rod, I provide an expansible bellows or other deformable closure sealed to the rod and thus in vacuum-sealing relation with the envelope. Upon a significant loss of vacuum this bellows fixed to the stationary contact rod expands to actuate suitable alarm or control means. For vacuum device immersed in liquid, a loss of vacuum, or presure increase, certainly is significant if it is large enough to indicate the probable presence of liquid within the device, but lesser increases may be regarded as also significant. Preferably a control means actuated by the deformable bellows or the like is coupled to the operating means for the movable contact in such a way that the operating means is disabled in closed circuit position. In a cyclically operated normally closed interrupter, such as used in a tap changing apparatus, the disabling means is connected to be ineffective if actuated during a switching cycle but effective to prevent initiation of another cycle thereafter.

My invention will be more fully understood and its several objects and advantages further appreciated by referring now to the accompanying detailed specification taken in conjunction with the attached drawing, the single figure of which is a schematic illustration of a transformer load tap changing equipment including a vacuum type are interrupting apparatus embodying my invention.

Referring to the drawing, I have illustrated a high voltage auto-transformer of the liquid-immersed type, including a tank or enclosure **10** substantially filled with insulating oil or other dielectric fluid **11**, and having positioned therein a winding **12**. The transformer winding **12** is grounded at its low voltage end, as by connection to the tank **10**, and at its other end it is connected to a high voltage line conductor **13** which passes out of the tank through an insulating bushing **14**. The high voltage end of the auto-transformer winding **12** is provided with a plurality of selectable voltage taps **15**, any selected one of which is connected through a load tap changing apparatus **16** to a secondary line conductor **17** disposed in an insulating bushing **18**. The load tap changing apparatus designated generally by the reference numeral **16** includes a pair of movable tap selecting contacts **20**, **21**, associated current limiting reactors **22**, **23**, a pair of selector switches **24**, **25**, a vacuum type circuit interrupting switch **26** and a motor-driven cycle timer (designated generally as **28**) for controlling the operation of the foregoing switches.

The tap selector circuit **16** itself is a well-known type. This circuit provides two parallel current paths between any selected tap contact **15** and the secondary line conductor **17**, each parallel path including one of the tap selector contacts **20**, **21** in series with one of the reactors **22**, **23** and one of the selector switches **24**, **25**. The arcing contact vacuum interrupting device **26** is connected between the parallel circuits with the selector switches **24**, **25** in series circuit relation directly across the arcing contacts.

The cycle timer **28** is selectively operable in either direction to effect sequential stepping movement of the tap selector contacts **20**, **21** progressively in either direction along the group of transformer tap contacts **15**. The cycle timer is driven selectably in either direction by a motor **30** through a reversing switch **31** from a suitable source of control voltage shown as a tertiary winding **32** on the transformer **12**. When energized the timer starts from a normal rest position and operates for a single complete cycle to effect a single stepping movement of both contacts **20**, **21**. The motor energizing circuit includes a normally open starting switch **33** which, for the purpose of illustration, may be considered to be manually operable, connected in series circuit relation with a normally closed protective switch **34** which will be described more fully hereinafter. The cycle timer includes a motor holding and limit switch **35** connected in parallel circuit relation across the switches **33** and **34** and arranged to deenergize the motor at the end of a single cycle of operation in either direction.

The cycle timer **28** comprises a pair of cams **40** and **41** arranged to open the selector switches **24** and **25** respectively in sequential relation in either direction of operation, and a cam **43** arranged to open the arcing contact switch **26** at two spaced-apart intervals during a cycle. A pair of Geneva gears **44** and **45** driven by the cycle timer is connected to actuate the tap selector contacts **21** and **20** respectively in sequential relation at appropriate times during a cycle of operation in either direction.

A typical single cycle of operation of the tap changing apparatus described above is as follows. If the starting switch **33** is closed momentarily to energize the motor **30**, the cycle timer begins to rotate in a selected direction (assume clockwise) as determined by the reversing switch **31**. Immediately upon initiation of operation, the holding and limit switch **35** closes to maintain motor energization for a full cycle. During this cycle of operation the cam **40** first opens the selector switch **24**, thereby to substitute the contacts of the arcing contact switch **26** for the switch **24** in the circuit through the tap selector contact **20** and reactor **22**. Following opening of the selector switch **24**, the contacts of the arcing switch **26** are opened by the cam **43**, thereby to interrupt current through the tap selector contact **20**. Thereafter the Geneva gear **45** moves the tap selector contact **20** to the next adjacent tap **15** in the selected direction, and the selector switch **24** is reclosed by cam **40**. Following this operation the cam **43** again closes the contacts of the arcing switch **26**, and thereafter the cam **41** opens the selector switch **25**. After opening of the switch **25** the cam **43** again opens the arcing switch **26** thereby to interrupt current through the tap selector contact **21** and the reactor **23**. While the contact **21** is deenergized, the Geneva gear **44** moves the tap selector contact **21** to the next adjacent tap **15** to which the selector contact **20** was previously moved. Thereafter the arcing contact switch **26** is again closed by the cam **43**, and the selector switch **25** is reclosed by the cam **41**. This completes a single cycle of operation, and the limit switch **35** thereupon deenergizes the motor **30**. It will be evident to those skilled in the art that operation in the reverse direction is entirely similar.

Reference will now be had more particularly to the arcing contact vacuum interrupter **26** connected between the parallel tap selector circuits. This circuit interrupter comprises an evacuated envelope **50** within which are disposed a pair of relatively movable contacts **51**, **52**. As shown, the contact **51** is stationary and includes a conducting rod or stem **53** having an axial bore or passageway **54** through which the envelope **50** is adapted to be evacuated. The contact rod **53** passes through a wall of the envelope **50** in fixed relation, and a vacuum-tight seal is provided therebetween. A seal **54***a* is shown at the outer end of the fixed contact rod **53** to close the evacuation passage **54**. The moving contact **52** of the vacuum interrupter is carried upon a rod **55** reciprocably mounted in a bearing **56**. To provide a vacuum-tight seal between the moving contact and the envelope **50** a flexible metallic bellows **57** is connected at one end of the envelope and at the other end to the moving contact rod **55**.

Outside the envelope **50** the fixed contact rod **53** is divided into two axially spaced-apart sections and between these sections there is interposed a deformable metallic bellows **60** which is evacuated through the passageway **54** along with the interior of the envelope **50**. At the remote end of the fixed contact rod **53** there is provided a lug **61** or other suitable connection to which the protective switch contact **34** is connected for actuation. This connection is shown by way of example as being a bell crank lever pivoted at a point **62**. It will be understood that when evacuated the bellows **60** in the fixed contact rod is collapsed by external atmospheric pressure, and that the bellows will expand and thus effectively lengthen the fixed contact rod in the event that vacuum within the envelope **50** and the bellows **60** is lost. To ensure expansion of the bellows **60**, a spring **61***a* may be provided. The moving contact arm **34** is shown normally in engagement with a switch contact **63** and is arranged, when actuated by expansion of the bellows **60**, to disengage the contact **63** and engage a normally open contact **64**. The normally open contact **64**, when engaged, connects a suitable alarm device, such as a bell **65**, for energization from the control power source **32**.

It will now be understood by those skilled in the art that in the normal operation of the vacuum interrupter tap changing apparatus which I have illustrated, the vacuum type arcing contact device **26** is normally in closed circuit position, and the cycle timer **28** is normally stationary in the rest position illustrated until such time as a tap change is desired. If in this condition of the apparatus vacuum is lost in the switch envelope **50** to a sufficient extent to permit expansion of the bellows **60**, the starting circuit of the motor **30** is interrupted at the contact **63** so that the motor cannot be energized by closure of the starting switch **33**. If the protective switch contact **63** is disengaged while the cycle timer **28** is in operation, the cycle will be completed through the holding and limit switch **35** whether the vacuum switching device **26** is in open or in closed circuit position. However, as soon as the cycle timer reaches its rest position with limit switch **35** open and the vacuum interrupter contacts **51**, **52** in closed position, the open contact **63** prevents restarting of motor **30**. The actuating cam **43** for the vacuum interrupter **26** is therefore disabled in its contact closing position so that the interrupter contacts **51**, **52** cannot be separated to draw an arc.

It will be noted from the foregoing that the pressure responsive leak detector comprising the bellows **60** and switch contact **63** is ineffective to disable the vacuum interrupter actuating mechanism if the interrupter contacts are open, i.e., as during a cycle of tap changing operation. The disabling means becomes effective only at the end of any existing cycle after the interrupter contacts have assumed their normal closed position. If, of course, the protective contact is opened with the cycle timer at rest, the disabling action is immediately effective to prevent the start of a cycle and the opening of the vacuum interrupter contacts. This arrangement assures that the tap changing apparatus will not be brought to rest in a position where the interrupter contacts **51**, **52** are open with an arc between them.

In the tap changing apparatus illustrated, or in other

applications where an immersed vacuum interrupting device is normally closed and opened for only short intervals, it is preferable to defer the disabling action until the interrupter contacts are closed. While this may permit arcing for a short period, it precludes arcing for extended periods, as by immobilizing the cycle time while an arc exists.

The leak detection apparatus of my invention need not be sensitive to such relatively small pressure increase in the switch envelope **50** as will preclude arc interruption. In a switch of the type described, a high vacuum of the order of about 10^{-4} millimeters of mercury is usually necessary to assure interruption. While a very small leak may raise internal pressure above this value by several orders of magnitude, it is unlikely that fluid will be admitted unless the leak and thus the pressure increase is considerably greater. In my apparatus I intend to detect primarily pressure increases of a magnitude sufficient to signify that fluid may be present in the envelope.

It will be evident to those skilled in the art that in my tap changing apparatus a current which is not interrupted by the vacuum device **26** will be interrupted at the tap selector contacts **20, 21.** This is not objectionable for a few short operations, and such defiective operation may be otherwise detected, as described, for example, in Patent 3,206,569, McCarty. If, however, the failure to interrupt is due to conditions where liquid may be present in the interrupter **26,** repeated operation must be precluded promptly to avoid vaporization of the liquid to such a point that the envelope **50** may be fractured. It will be evident that while small changes in gaseous pressure may not actuate the bellows **60,** even a small amount of liquid in the envelope **50** will cause an abrupt pressure increase when any arcing occurs. This avalanche effect will assure prompt operation of the bellows and disabling of the vacuum interrupter contacts in closed position at the end of any cycle wherein such pressure increase occurs.

Thus it will be evident that in protecting a liquid-immersed vacuum switching device itself against loss of vacuum sufficiently great to signify the admission of liquid to the device, it is not necessary to detect small gaseous pressure increases sufficient to preclude arc interruption, but only to preclude arcing with liquid present. Even such arcing can be tolerated for short intervals insufficient to cause execssive heating of the liquid. By permitting such arcing for short intervals and using a pressure responsive proctective device, I assure positive operation of the device if any liquid is in fact present or if a sufficient amount of gas is present to respond to arc heating.

While I have illustrated a preferred embodiment of my invention by way of example, various modifications will occur to those skilled in the art. I therefore wish to have it understood that I intend in the appended claims to cover all such modifications as may fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A vacuum circuit interrupting apparatus comprising, a vacuum interrupting device having an evacuated envelope and including fixed and movable cooperating contact members extending through wall portions of said envelope in sealed relation therewith, said fixed contact member including a stem portion fixedly sealed to said envelope and provided with an internal passageway opening into the interior of said evacuated envelope, an expansible chamber fixed to said stem outside said envelope and in communication with said passageway, an ambient body of liquid in which said envelope is at least partially immersed, actuating means for said movable contact member operable between contact closing and opening positions, and means operable in response to expansion of said chamber upon significant increase of pressure within said envelope to disable said actuating means in said contact closing position.

2. A vacuum circuit interrupting apparatus comprising a vacuum interrupting device having an evacuated envelope and including a pair of relatively movable cooperating contact members adapted when separated to draw an arc within said envelope, actuating means for moving said contact members between open and closed circuit positions, pressure responsive means having a deformable wall portion and connected to said envelope in vacuum sealing relation, a body of liquid at least partially immersing said envelope, and means operable in response to deformation of said wall portion upon significant increase of pressure within said envelope to disable said actuating means only in closed circuit position of said contact members.

3. A circuit interrupting apparatus according to claim **2** wherein said actuating means normally retains said contact members in closed circuit position and is operable when energized to open and reclose said contact members in cyclic intervals of short duration.

4. In combination with a circuit interrupting apparatus according to claim **2,** a transformer tap changing apparatus including said vacuum interrupter device and having a single step cycle timer including said actuating means, said cycle timer having a normal rest position in which said actuating means retains said contact members in closed circuit position, said disabling means being operable in said rest position to prevent reenergization of said cycle timer.

5. In a vacuum type circuit interrupter, an evacuated envelope in sealed relation therewith and into cooperaextending through spaced-apart wall portions of said envelope in sealed relation therewith and into cooperative juxtaposition within said envelope, said fixed contact member including a stem portion having an internal passageway communicating between the interior and exterior of said evacuated envelope, and an expansible chamber fixed to said stem outside said envelope and in communication with said passageway.

6. In a vacuum type circuit interrupter, an evacuated envelope, fixed and movable conductive contact members extending through spaced-apart wall portions of said envelope in sealed relation therewith and into cooperative juxtaposition within said envelope, said fixed contact member including a stem portion fixedly sealed to a wall of said envelope and provided with an internal passageway through which said envelope is adapted to be evacuated, an expansible tubular member interposed between spaced-apart portions of said fixed contact stem on the outer side of said evacuated envelope, and means sealing said passageway on that side of said tubular member remote from said evacuated envelope.

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