Dec. 19, 1967 E. A. FROWEIN 3,359,390

COMPRESSED GAS CIRCUIT BREAKER WITH CIRCULATING SYSTEM FOR COMPRESSED GAS

Filed June 2, 1965 2 Sheets-Sheet 1

Fig. 1.

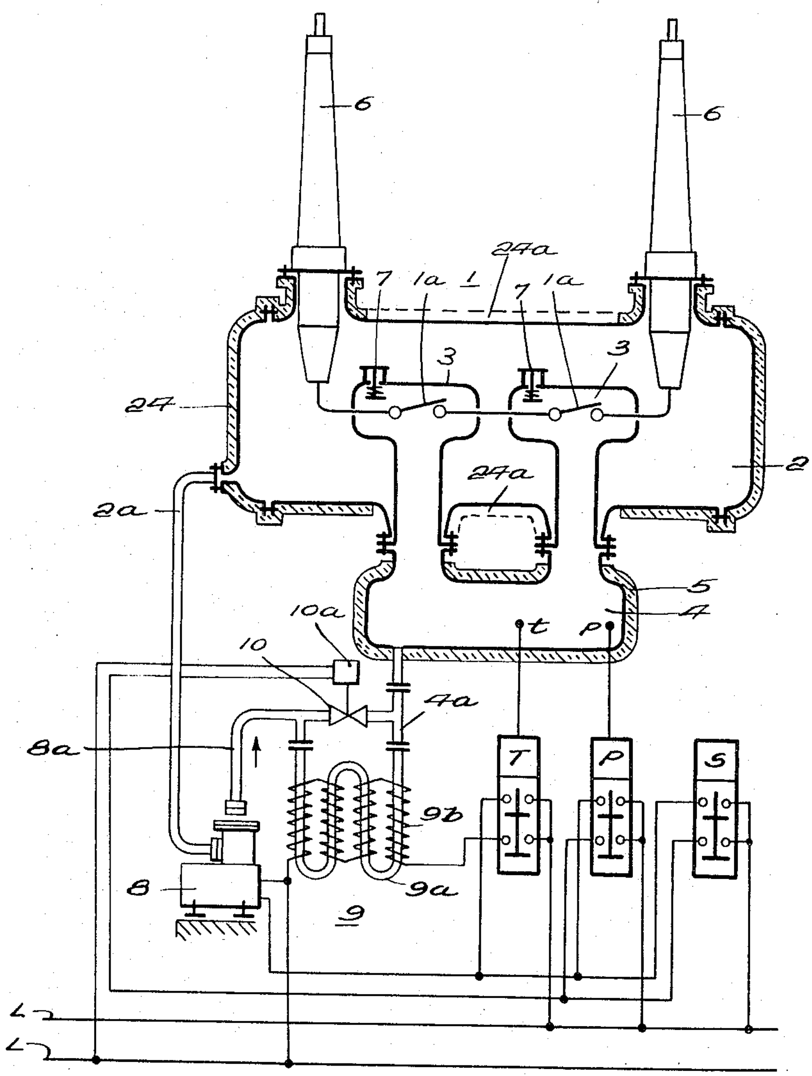

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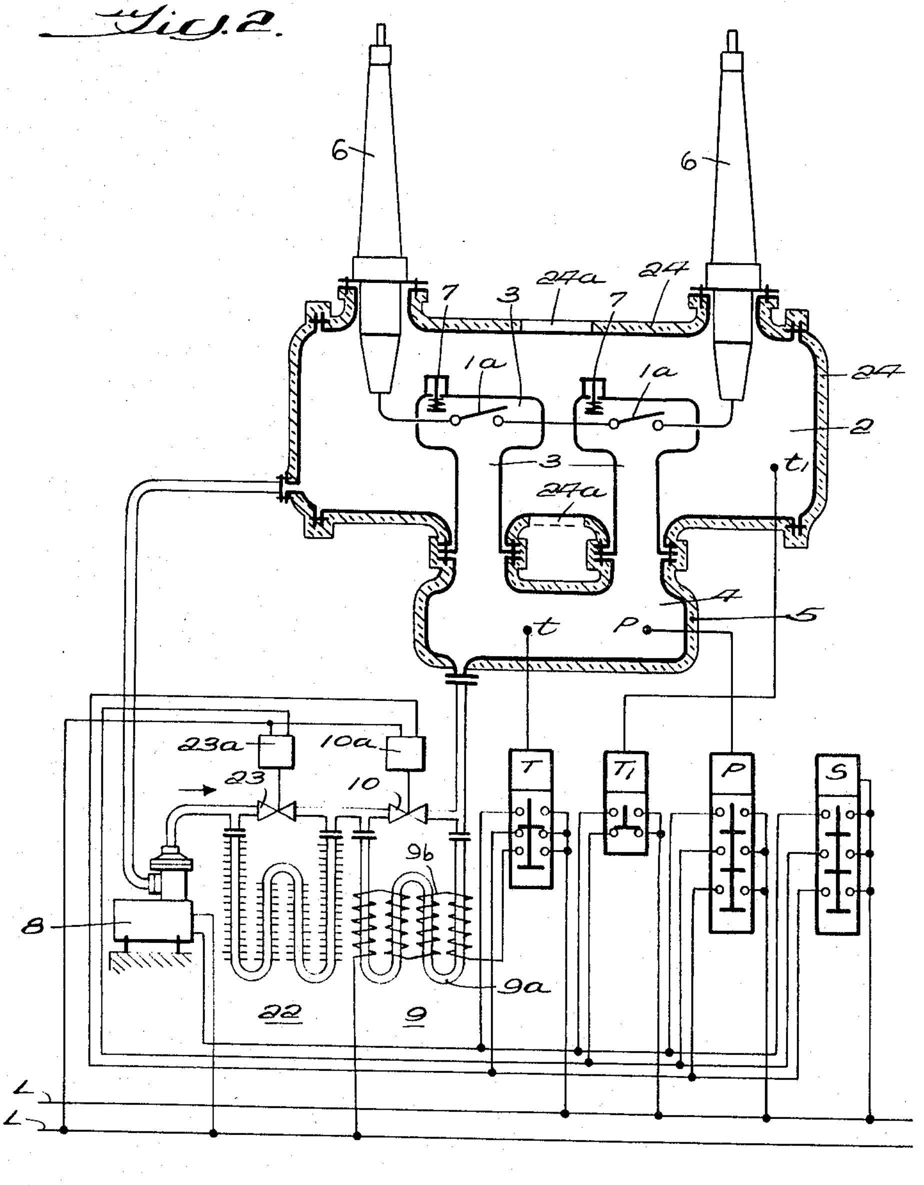
Fig. 2.



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United States Patent Office 3,359,390
Patented Dec. 19, 1967

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COMPRESSED GAS CIRCUIT BREAKER WITH CIRCULATING SYSTEM FOR COMPRESSED GAS

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Filed June 2, 1965, Ser. No. 460,690
Claims priority, application Switzerland, June 10, 1964, 7,582/64
10 Claims. (Cl. 200—148)

The present invention relates to circuit breakers of the compressed gas type and wherein the gas, for example SF6, is heated and flows in a closed circuit which comprises a high-pressure tank in communication with the contacts of the circuit breaker, a low-pressure tank and a compressor. Circuit breakers of this general type are known and operate in such manner that the high-pressure tank receives the pressure gas from the compressor whenever the temperature of the pressure gas in the high-pressure tank drops below a certain value, or whenever the gas pressure in the high-pressure tank has dropped too far. When the temperature of the high-pressure gas has dropped below a certain value, a bi-metal valve is actuated, so that the difference in gas pressure as between the high-pressure and low-pressure tanks decreases. A pressure relay trips and starts the compressor which feeds the gas, heated by the compression, to the high-pressure tank. This process results in an undesired delay until the correct operating temperature is restored. Because of this long delay, it is necessary to maintain a relatively great temperature interval of the pressure working point from the liquefaction line in the pressure-temperature diagram. Moreover, it takes a long time until the differential pressure relay starts the compressor. These disadvantages are avoided by the invention, which makes it possible to work with a small pressure tolerance and a short delay.

The foregoing object of the present invention is obtained by an improved arrangement which is characterized in that the high-pressure tank is completely insulated as much as possible to prevent heat transfer through the walls thereof whereas the low-pressure tank is only partially heat-insulated, that over-pressure valves are provided between the high-pressure and low-pressure tanks to permit gas flow under certain over-pressure conditions from the high-pressure tank to the low-pressure tank; that a heating unit is arranged in series with the compressor unit in the gas flow circuit to and from the high and low pressure tanks; that relays are provided for bringing the compressor and heating units into operation, of which one relay operates in dependence upon the gas pressure in the high-pressure tank, another on the gas temperature in the high-pressure tank, and still another in response to a disconnecting signal at the circuit breaker.

The object of the invention will become more clearly understood from the following detailed description of two embodiments thereof and from the accompanying drawings wherein:

FIG. 1 is a somewhat diagrammatic view of one suitable arrangement for a circuit breaker of the closed cycle, compressed gas, type incorporating the invention; and

FIG. 2 is a view similar to FIG. 1 but showing a modification wherein means are provided for cooling certain live parts of the circuit breaker in order to reduce the power expended in heating of the compressed gas.

With reference now to FIG. 1, it will be seen that the circuit breaker 1 to which the invention has been applied is essentially a single-pole type but which includes two physically separate but series connected switching points 1*a*. A separate switching chamber 3 is provided for each switching point and the interior of each chamber 3 is in

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open, i.e. continuous communication with the interior of the high-pressure tank 4 containing the compressed SF6 gas. Thus, when the switch contacts are closed, the interiors of switch chambers 3 are each filled with the high pressure gas.

Switch chambers 3 are housed within a low-pressure tank 2 the interior of which is connected via pipe line 2*a* with the low-pressure, intake side of compressor 8. The high-pressure side of the compressor is connected through the pipe line 8*a* with the high-pressure tank. In this closed circulation system, the compressor takes in expanded pressure gas from the low-pressure tank and feeds with it over-pressure to the high-pressure tank. The high-pressure tank is completely heat-insulated by a heat insulation 5. The low-pressure tank is partly heat-insulated by an open heat-insulating layer 24. Each of the switch chambers 3 is provided with an over-pressure valve 7 opening in the direction of the low-pressure tank 2 which permits the pressure gas to flow off from chamber 3 to the low-pressure tank 2 when the gas pressure difference in the high and low-pressure tanks has exceeded a predetermined value.

Connected in series with the compressor 8 through the pipe lines 8*a* and 4*a* is in an electrical heating unit 9. The latter consists of a pipe coil 9*a* on which is wound a filament type heating winding 9*b*. The heating unit 9 serves to increase the temperature of the pressure gas in a certain predetermined manner after it leaves the compressor. Gas-pressure sensing element *p* and temperature sensing element *t* functionally associated with the high-pressure tank 4 control relays P and T and serve to keep the pressure and the temperature of the pressure gas a certain operating value. With the filament winding 9*b* connected to its electrical source represented by lines L through the contacts of relay T, the pressure gas is heated before it enters the high-pressure tank.

It may be of advantage to arrange a bypass parallel to the pipe coil 9*a* of the heating unit, which is provided with a shut-off valve 10. With the shut-off valve open, the major part of the pressure gas flows from the compressor within a short time directly into the high-pressure tank bypassing the heating unit. When the shut-off valve is closed, the entire pressure gas flows from the compressor through the heating unit. The shut-off valve 10 is actuated by means of a switching solenoid 10*a* over one set of contacts of the relay P when the gas pressure in the high-pressure tank drops below a predetermined value and it is also actuated over one set of contacts on the relay S, which trips when a disconnecting signal is sent to the circuit breaker. Relays T, P and S are also used for the control of the compressor and of the heating current for the heating unit. Relay T with its temperature sensing element *t* works in dependence on the temperature of the gas in the high-pressure tank 4, relay P with its pressure sensing element *p* in dependence on the pressure of the gas in the high-pressure tank, and relay S when a disconnecting signal is sent to the circuit breaker.

The connection of the contacts of relays T, P and S with the compressor 8 and with the filament winding 9*b* of the heating unit 9 is effected in such a way that it results in the following interaction: When the temperature of the gas in the high-pressure tank is too low, the two sets of contacts on the T-relay connect the electric driving motor of compressor 8 and the heating element 9*b* to the electrical supply line L—L. The shut-off valve 10 remains closed.

Heated gas is thus pumped into the high-pressure tank 4 so that the pressure and the temperature rise there. When a predetermined pressure in the high-pressure tank is exceeded, the over-pressure valves open 7 and the following gas circuit: high-pressure tank 4—over-pressure valves 7—low-pressure tank 2—compressor 8—heating unit 9—high-pressure tank 4 is established. This closed circuit is maintained until the necessary temperature is restored in the high-pressure tank. Due to this control, which reacts directly to the temperature in the high-pressure tank, the normal temperature in the high-pressure tank is restored in a very short time.

If the gas pressure in the high-pressure tank drops, due to internal leakage, the P-relay trips, so that the compressor is started and the bypass valve **10** opened, after which the compressor brings the high-pressure tank within a short time to the pressure desired to be maintained, bypassing the heating unit **9**. If a disconnecting signal is to be sent to the switching points, so that pressure gas flows from the high-pressure tank through the switching points in the low-pressure tank in order to extinguish the electric arc drawn between the contacts **1***a* as they separate, one does not wait with the recharging of the high-pressure tank until the pressure in this tank has dropped so far that the P-relay trips, but rather the S-relay is actuated directly by the disconnecting signal, which starts the compressor and also opens the bypass valve **10**.

When the switching order is completed, the pressure in the high-pressure tank has dropped in the meantime so far that the P-relay has tripped. This relay then takes over the control of the compressor **8** and of the shut-off valve **10** until the normal pressure in the high-pressure tank is restored again.

In the system according to FIG. 1, one endeavors to keep the total heating power derived from the compressor and heating unit as low as possible. A favorable compromise is achieved by the following measure. The low-pressure tank **2** is partly insulated with a heat-insulation **24** to such an extent that the heat due to energy losses of the live parts of the circuit breaker is just transferred to the surrounding at the maximum ambient temperature. By this expedient the predetermined maximum temperature for these parts are not exceeded. The electrical power consumed by the compressor and heater unit is reduced by this measure to a tolerable minimum.

According to a further development of the invention, it is possible to reduce the required power in heater unit **9** further by providing additional cooling of the live i.e. current-carrying parts of the circuit breaker. To this end, a cooler **22** with a shut-off valve **23** controlled by solenoid **23***a* in a bypass parallel to the cooler is arranged according to FIG. 2 in the gas flow line in the direction of flow of the gas from compressor **8**.

In addition to the pressure relay P and the switching relay S, the solenoid **23***a* of the shut-off valve as is also actuated by a relay T1, which depends on the temperature of the gas in the low-pressure tank **2** which is monitored by a sensing element t_1. The low-pressure tank is also provided with partial heat insulation **24**. By means of this arrangement, it is possible either to heat the gas in the high-pressure tank **4** or to cool the live parts of the circuit breaker as required.

The method of operation of the arrangement according to FIG. 2 is as follows:

1. Temperature of gas in high-pressure tank too low

The temperature relay T trips, the compressor **8** is started, the bypass valve **10** is closed, and the heating unit **9** is connected in. The bypass valve **23** is opened. The compressor takes in gas from the low-pressure tank **2** and pumps it through the heating unit **9** into the high-pressure tank **4**, bypassing the cooler **22**. The heated gas heats this tank and the switch chambers **3** and escapes then through the over-pressure valves **7** into the low-pressure tank, which is heated at the same time. From there the gas returns to the compressor **8**. A new cycle starts until the desired temperature in the high-pressure tank has been attained and the relay T drops out and opens its contacts.

2. Temperature in low-pressure tank too high

The temperature relay T_1 trips to a contact-closed position, the compressor **8** is started and the bypass valve **23** is closed. The cooler **22** is started, the bypass valve **10** is open and the heating unit **9** is bypassed.

The compressor takes in too-hot gas from the low-pressure tank and pumps it through the cooler **22** into the high-pressure tank **4** and the switch chambers **3**. After the gas has left the cooler, it has cooled off substantially to ambient temperature and cools at the same time the live parts of the circuit breaker. It flows through the over-pressure valves **7** into the low-pressure tank, where it has a cooling effect on the parts arranged there and then flows back to the compressor.

This cycle of gas circulation is maintained until the temperature in the low-pressure tank has again attained the desired value and whereupon relay T_1 drops out and opens its contacts.

The effect of the system in the case of internal pressure losses in the high-pressure chamber and the tanks respectively, and the tripping of the relays P and S, are the same as already described in the system in FIG. 1.

It is clear that the additional cooling of the live parts of the circuit breaker with the above described cycle can only take place so long as the gas fed to the high-pressure tank, and thus to the switch chambers, has a temperature which is higher than the above mentioned lowest admissible temperature of the gas in the high-pressure tank in order to avoid condensation.

Below this temperature, the cooling system cannot be used, and the heat generated by the live parts of the circuit breaker is transferred at the uninsulated part **24***a* of the low pressure tank to the surrounding air.

In the arrangement according to FIG. 2, the low-pressure tank can therefore be heat-insulated to such an extent that the live parts can just transfer their heat due to energy losses over the uninsulated part of the low-pressure tank to the surrounding at an ambient temperature slightly higher but approximately equal to the predetermined minimum temperature of the pressure gas in the high-pressure tank, without exceeding the maximum temperatures predetermined for these parts. But because the predetermined minimum temperature of the high-pressure gas is far below the maximum ambient temperature, a substantially greater part of the low-pressure tank can be heat-insulated in this case than it is possible in the arrangement according to FIG. 1. Accordingly, the heating power to be expended in the system according to FIG. 2 is much lower.

In the range of the ambient temperature in which the circuit breaker must be heated, the heat generated in the live parts is eliminated automatically, and above this range additional cooling of these parts may therefore be necessary, depending on the current load.

Altogether the partial insulation of the low-pressure tank has the result that the heating power and the running time of the compressor are greatly reduced at low ambient temperatures, while at high ambient temperatures the compressor must run a certain time to obtain an additional cooling of the live parts.

Depending on the climatic conditions, a minimum of total annual output can be achieved by a suitable selection of the ratio of the heat insulated surface to the uninsulated surface of the low-pressure tank.

I claim:

1. In a circuit breaker of the compressed gas type operating on a closed gas circulation system, the combination comprising a switch chamber containing contact means for the circuit breaker actuatable between closed and open positions, a high-pressure tank in communication with and supplying gas at high pressure into said switch chamber, a low-pressure tank within which said switch chamber is located, valve means between said switch chamber and low-pressure tank actuatable to open position at a predetermined over-pressure to effect gas flow from said high-pressure tank to said low-pressure tank, said high-pressure tank being fully heat insulated and said low-pressure tank being only partly heat insulated, a gas flow circuit connecting an outlet from said low-pressure tank with an inlet to said high-pressure tank, said gas flow circuit including a gas compressor and a gas heater unit connected in series, first relay means responsive to the gas temperature within said high-pressure tank for controlling said heater unit, second relay means responsive to the gas pressure within said high-pressure tank for controlling said compressor, and third relay means responsive upon receipt of a disconnect signal for said contact means of said circuit breaker for controlling said compressor.

2. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 1 wherein said heater unit includes a by-pass, and means also responsive to operation of said second relay means for opening said by-pass.

3. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 1 wherein said heater unit includes a by-pass, and means also responsive to operation of said third relay means for opening said by-pass.

4. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 1 wherein said first relay means also serves to control operation of said compressor.

5. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 1 wherein said heater unit includes a by-pass, means responsive to operation of either said second or said third relay means for opening said by-pass, and wherein said first relay means also serves to control the operation of said compressor.

6. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 1 wherein said gas flow circuit includes a series connected cooler unit located at the discharge side of said compressor, a by-pass for said cooler unit, and fourth relay means responsive to the gas temperature within said low-pressure tank for controlling said by-pass to said cooler unit, said by-pass to said cooler unit being closed when the temperature in said low-pressure tank exceeds a predetermined value.

7. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 6 wherein said fourth relay means also serves to control the operation of said compressor, said compressor being turned on when said by-pass to said cooler unit is closed.

8. A compressed gas circuit breaker operating on a closed gas circulation system as defined in claim 1 wherein said gas flow circuit includes a series connected cooler unit located at the discharge side of said compressor, a by-pass for said cooler unit, fourth relay means responsive to the gas temperature within said low pressure tank for controlling said by-pass to said cooler unit and for controlling the operation of said compressor, said by-pass to said cooler unit being closed when the temperature in said low-pressure tank exceeds a predetermined value and said compressor being turned on.

9. In a circuit breaker of the compressed gas type operating on a closed gas circulation system, the combination comprising a switch contact casing containing contact means for the circuit breaker actuatable between closed and open positions, a high-pressure tank in communication with and supplying gas at high pressure into said switch contact casing, a low-pressure tank within which said switch contact casing is located, valve means between said switch contact casing and low-pressure tank actuatable to open position at a predetermined over-pressure to effect gas flow from said high-pressure tank to said low-pressure tank, said high-pressure tank being fully heat insulated and said low-pressure tank being only partly heat insulated, a gas flow circuit connecting an outlet from said low-pressure tank with an inlet to said high-pressure tank, said gas flow circuit including a gas compressor and a gas heater unit connected in series, a by-pass for said heater unit, first relay means responsive to the gas temperature within said high-pressure tank for controlling said heater unit as well as said compressor, said heater unit and compressor being turned on when the temperature in said high-pressure tank drops below a predetermined minimum value, second relay means responsive to the gas pressure within said high-pressure tank for controlling said compressor as well as said by-pass for said heater unit, said compressor being turned on and said by-pass being opened when the pressure in said high-pressure tank drops below a predetermined minimum value, and third relay means responsive to a signal for disconnecting said contact means of said circuit breaker for controlling said compressor as well as said by-pass for said heater unit, said compressor being turned on and said by-pass being opened upon receipt of a disconnect signal.

10. In a circuit breaker of this compressed gas type operating on a closed gas circulation system, the combination comprising a switch contact casing containing contact means for the circuit breaker actuatable between closed and open positions, a high-pressure tank in communication with and supplying gas at high pressure into said switch contact casing, a low-pressure tank within which said switch contact casing is located, valve means between said switch contact casing and low-pressure tank actuatable to open position at a predetermined over-pressure to effect gas flow from said high-pressure tank to said low-pressure tank, said high-pressure tank being fully heat insulated and said low-pressure tank being only partly heat insulated, a gas flow circuit connecting an outlet from said low-pressure tank with an inlet to said high-pressure tank, said gas flow circuit including a gas compressor, a gas cooler unit and a gas heater unit connected in series, said cooler unit being located at the discharge side of said compressor, a by-pass for said cooler unit, a by-pass for said heater unit, first relay means responsive to the gas temperature within said high-pressure tank for controlling said heater unit and its by-pass as well as said compressor, said heater unit and compressor being turned on and said heater unit by-pass being closed when the temperature in said high-pressure tank drops below a predetermined minimum value, second relay means responsive to the gas pressure within said high-pressure tank for controlling said compressor as well as said by-passes for said heater and cooler units, said compressor being turned on and said by-passes being opened when the pressure in said high-pressure tank drops below a predetermined minimum value, third relay means responsive to a signal for disconnecting said contact means of said circuit breaker for controlling said compressor as well as said by-passes for said heater and cooler units, said compressor being turned on and said by-passes being opened upon receipt of a disconnect signal, and fourth relay means responsive to the gas temperature within said low-pressure tank for controlling said compressor and said by-pass to said cooler unit, said compressor being turned on and said by-pass to said cooler unit being closed when the gas temperature within said low-pressure tank exceeds a predetermined value.

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