United States Patent

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[33] Netherlands
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[54] SF_6 SYSTEM WITH CONSTANT DENSITY AND CONSTANT PRESSURE DIFFERENTIAL MAINTAINING MEANS FOR A HIGH-VOLTAGE SWITCHGEAR

7 Claims, 5 Drawing Figs.

[52] U.S. Cl. .... 200/148 E, 200/148 B
[51] Int. Cl. H01h 33/56
[50] Field of Search .... 200/148 R, 148 E, 148 B, 84; 174/14

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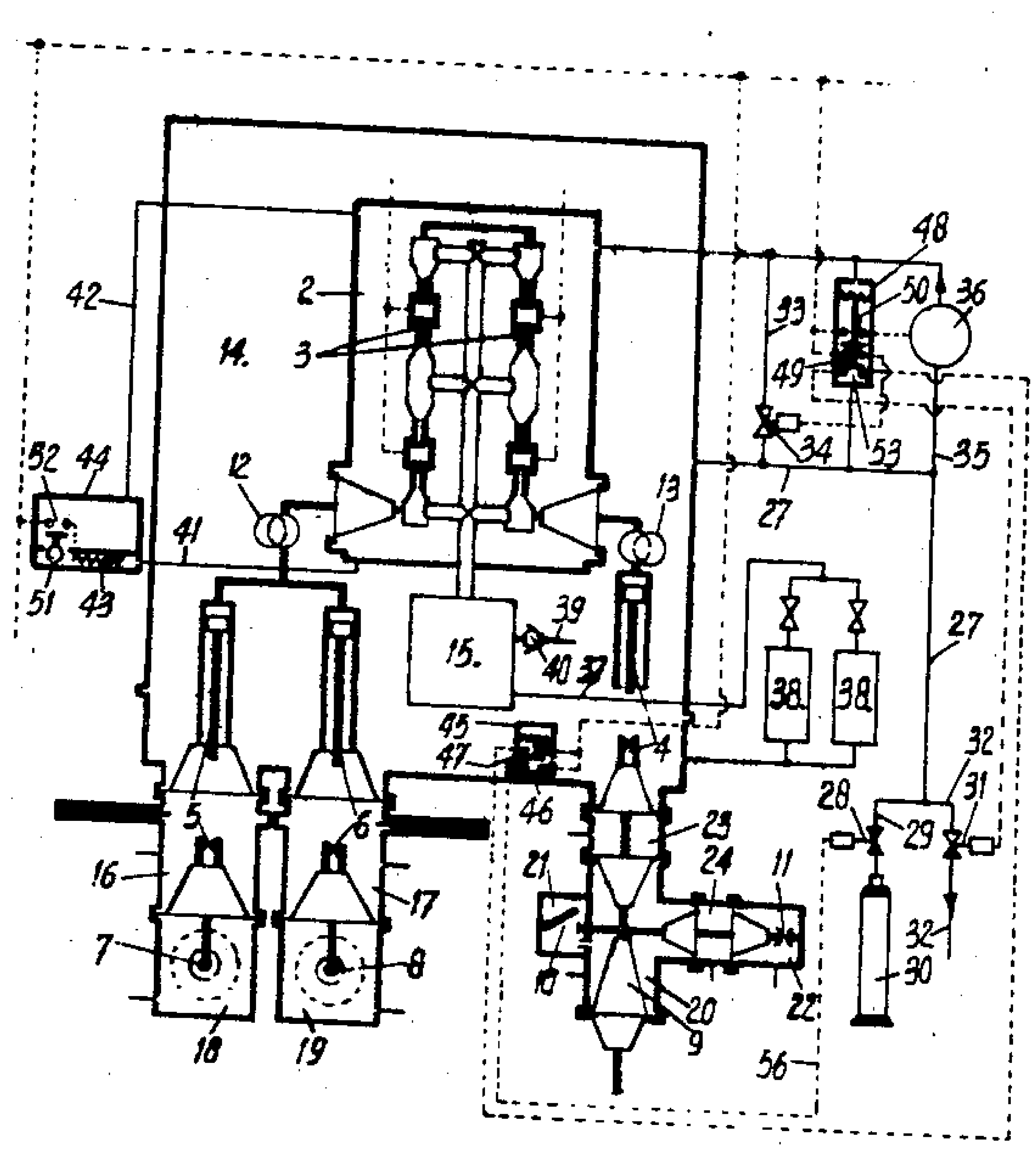
ABSTRACT: Metal clad switch gear for high voltages comprising switches and accessories, low-overpressure and high-overpressure compartments filled with SF_6-gas and a gas-controlsystem controlling the flow of gas to and from said compartments and keeping both the pressure difference between said compartments and the density of the SF_6-gas in the low-overpressure compartment(s) substantially constant.



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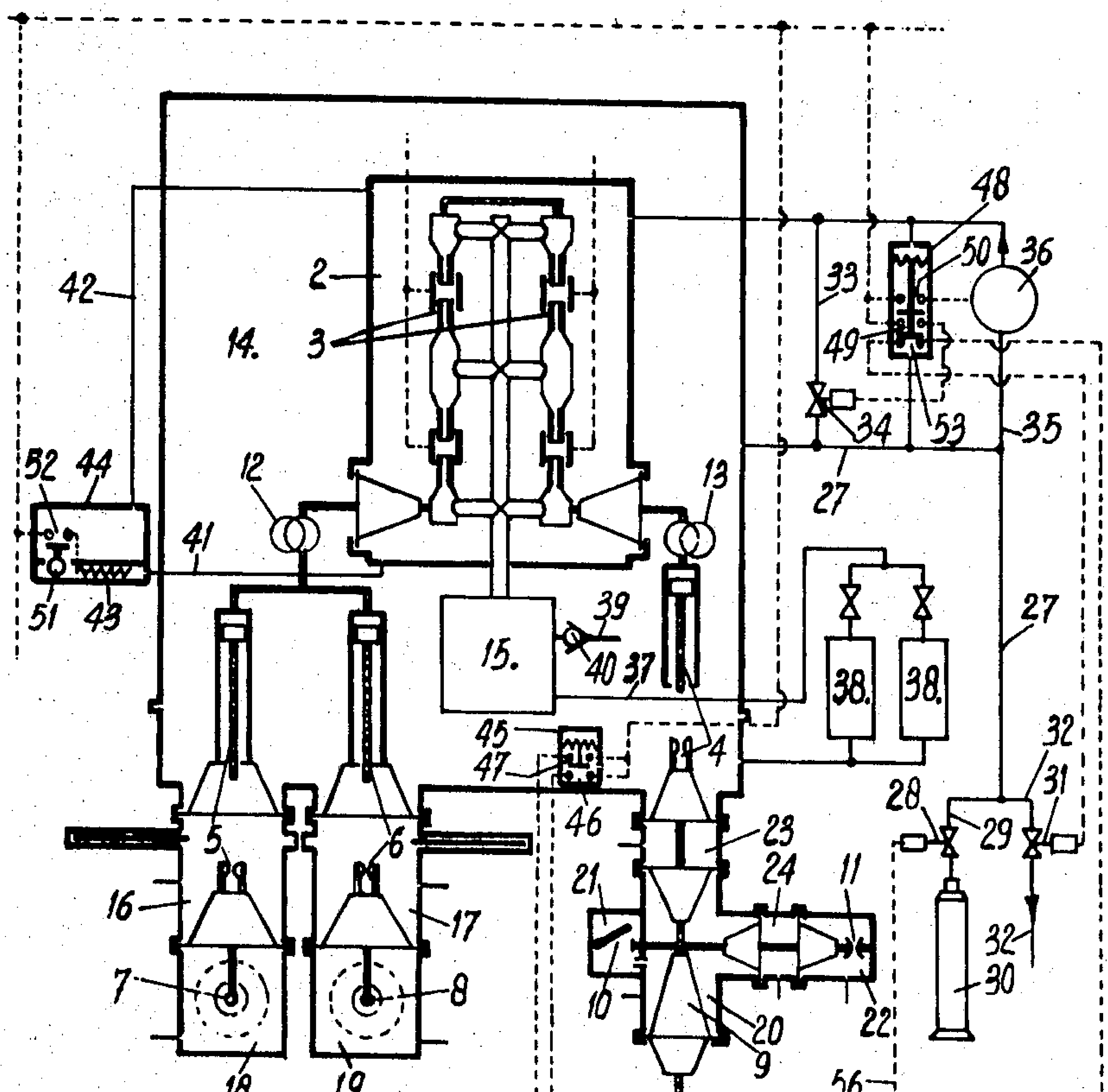

FIG.2

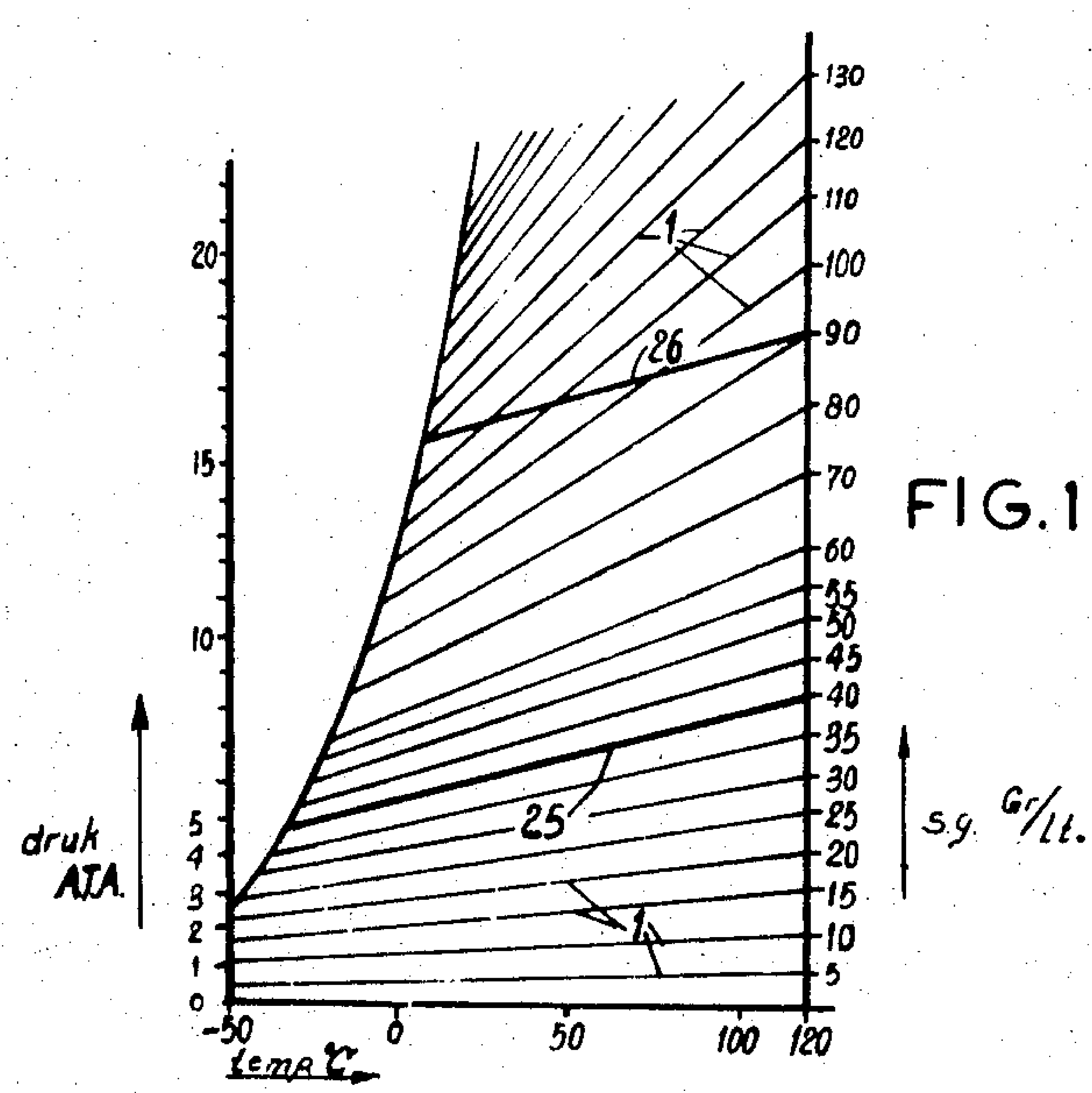

FIG.1

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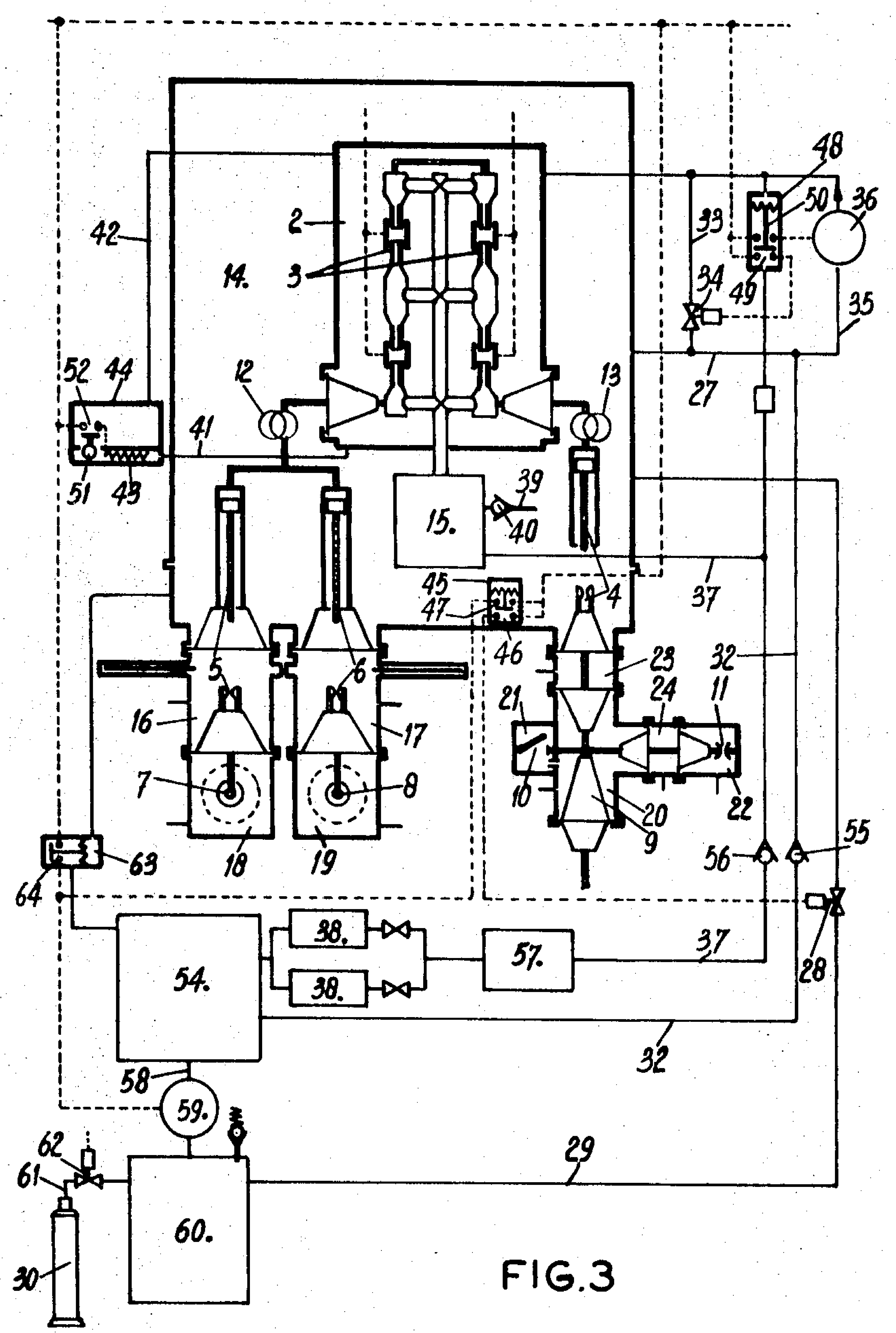

FIG.3

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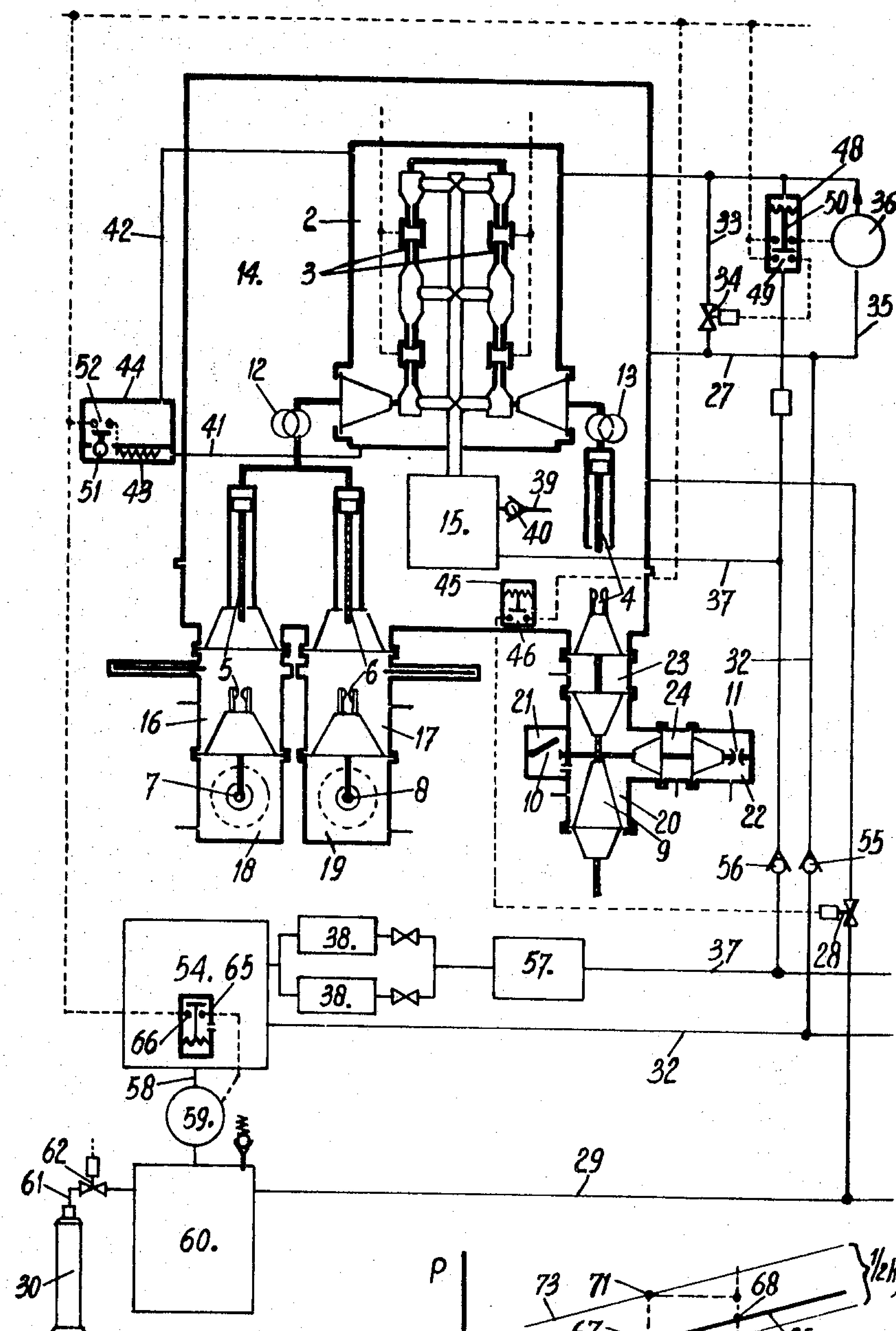

FIG. 4

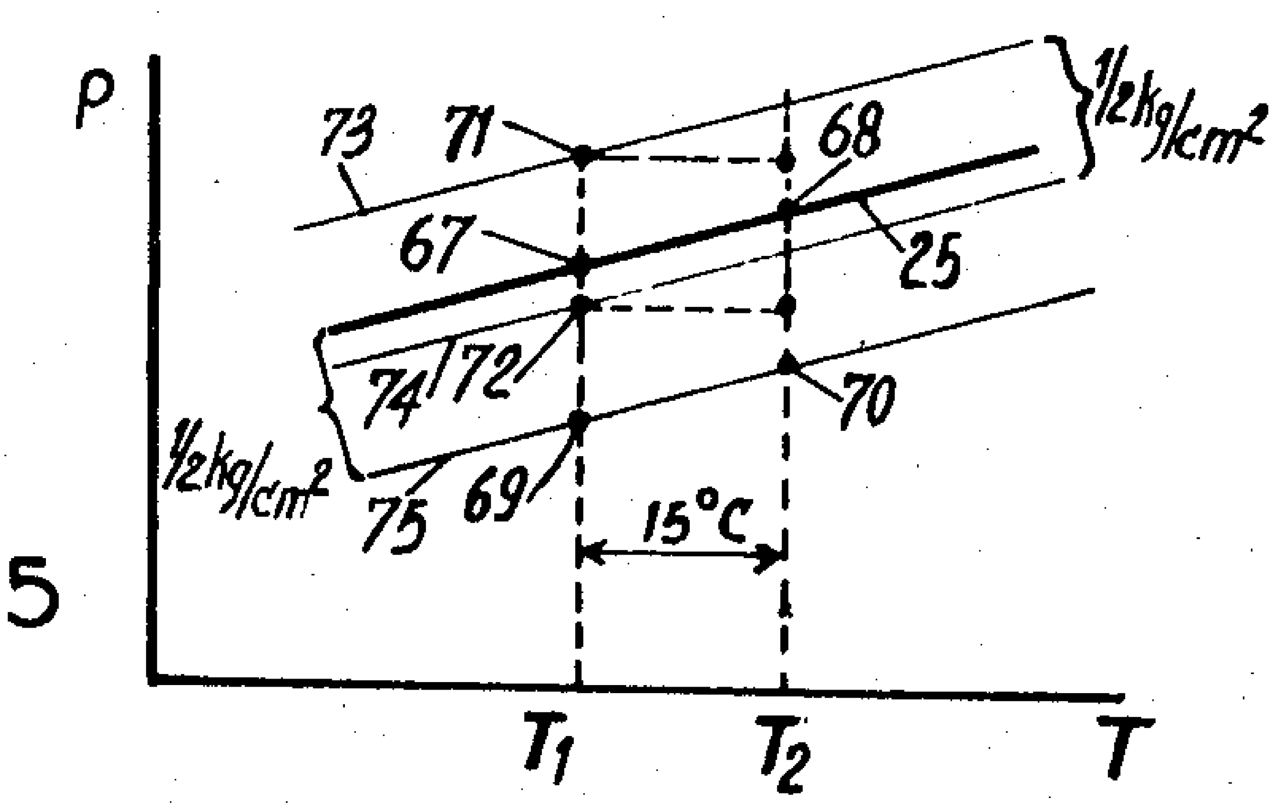

FIG. 5

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SF SYSTEM WITH CONSTANT DENSITY AND CONSTANT PRESSURE DIFFERENTIAL MAINTAINING MEANS FOR A HIGH-VOLTAGE SWITCHGEAR

The invention relates to metal clad switch gear for high voltages comprising a metal envelope adapted to be connected to earth and containing at least a gas blast circuit breaker, a low-pressure compartment filled with SF_6-gas of lower overpressure for the insulation of the live parts of the switch gear from earth and a high-pressure compartment filled with SF_6-gas of higher overpressure for the extinction of the switching arc and a composite gas-control system to control the flow of gas to and from said compartments, said gas-control system being arranged to keep the pressure difference between both compartments substantially constant by controlling the density of the SF_6-gas in each one of the two compartments.

In switch gear filled with SF_6-gas changes of the state of the gas economy occur repeatedly as a result of the properties of said gas and the operation of the switch gear. In switch gear local temperature variations can occur which are produced by the current flowing through the conductors and the continuously varying temperature of the outer air. These temperature variations can have, during operation, a range of −25° C. to +85° C. For the extinction of the switching arc and, if necessary, for driving the switches gas from the high-pressure compartment is used and either directly or by a roundabout way returned to the low-pressure compartment, Moreover, the change of pressure of a SF_6-gas mass of a given volume due to a change of temperature is greater as the density of said mass is higher, which means that the isochores in the pressure-versus-temperature diagram are steeper at higher density than at lower density. Within the range of operation of the switch gear the pressure and the temperature of the SF_6-gas can have values, at which said gas condenses. The gas-control system must reckon with these properties and also ensure that the density of the SF_6-gas in no one of the compartments containing live parts falls down below a given value, since otherwise the insulation from earth is endangered, and that the pressure difference between the high-pressure compartment and the low-pressure compartment remains above the minimum value required for a sufficient extinguishing action and, if necessary, for a satisfactory driving of the switches.

Switch gear of the described kind, in which the various above mentioned facts are reckoned with, has been disclosed in U.S. Pat. 3,390,241. In said switch gear the gas-control system tries to keep both the total quantity of SF_6-gas contained in the switch gear and the pressure difference between the high-pressure gas mass and the low-pressure gas mass constant as much as possible. This means, that not only during the switching process, but also at a rise in temperature in the stationary state of the switch gear SF_6-gas must be transported from the high-pressure compartment towards the low-pressure compartment, so that the pressure in the low-pressure compartment then will increase more than would have been the case, when in the low-pressure compartment only a rise in temperature occurs. This additional increase of pressure in the low-pressure compartment has the disadvantage that the envelope of said compartment, which is considerably larger than that of the high-pressure compartment, must be made stronger and that also the sealing and the packing between the separable parts of the envelope of the low-pressure compartment must be made proof against higher pressures. This sealing may give difficulties in view of the large dimensions of the joints to be sealed between said parts of the envelope. The stronger envelope and the heavier sealing make the switch gear more expensive. The attention is drawn to the fact that an increase of the density of the SF_6-gas in the low-pressure compartment has no real advantage regarding to the safe state of insulation in the switch gear, since the minimum density of the gas in the low-pressure compartment, said density obtaining in the known switchgear at the lowest temperature to be expected, say a temperature of −25° C., guarantees already a sufficiently safe state of insulation.

The invention has for its object to provide switchgear of the kind referred to which is simpler, has a cheaper construction, can be easily made gastight and for which a relatively simple gas-control system is required. It consists in that the gas-control system is so arranged and so operates as to keep also, under all circumstances, the density of the SF_6-gas in the low-pressure compartment substantially constant. This measure has the advantage that at a rise in temperature the pressures in the low-pressure compartment and in the high-pressure compartment will increase relatively slightly, so that lighter structures can be used and a satisfactory seal can easily be realized. Moreover, a relatively simple gas-control system can be used, since the control has only to do with two quantities, viz the density in the low-pressure compartment and the said pressure difference.

It is observed that switchgear filled and operating with SF_6-gas and comprising high- and low-pressure compartments, in which the density of the SF_6-gas in the low-pressure compartment is kept constant, has been disclosed by the U.S. Pat. specification 3,129,309. Also in this switchgear the density of the SF_6-gas in the high-pressure compartment is kept constant. This results in that the pressure difference between both compartments and in consequence thereof the switching process strongly depend on the temperature and in that at great rises in temperature high pressures will obtain in the high-pressure system.

Advantageously, the switchgear can be so constructed that the low-pressure compartment is connected to a discharge conduit and a supply conduit, said conduits cooperating with means acting on the density of the gas in said compartment, said means ensuring that gas flows from and to the low-pressure compartment, when the density of the gas in said compartment becomes higher and lower than the required density, respectively, whereas a conduit provided with a valve and a conduit with a compressor are connected between the low-pressure compartment and the high-pressure compartment, both compartments being connected to a differential-pressure relay which opens said valve or starts said compressor when the pressure difference between both compartments becomes higher or lower than the required pressure difference, respectively. In this switchgear only a relay acting on the density of the SF_6-gas contained in the low-pressure compartment and a differential-pressure relay are necessary. The high-pressure compartment can only receive gas from or supply gas to the low-pressure compartment, so that the gas supply of the switchgear takes place only through the low pressure compartment.

As SF_6-gas is too expensive to be discarded, switchgear is recommended in which gas discharged from the switchgear is collected in a storage tank. The switchgear and its gas-control system may then be constructed in such a manner that the discharge conduit is connected through a check valve closing towards the low-pressure compartment with a low-pressure storage tank and the supply conduit is connected through a valve to a high-pressure storage tank, whereas the two storage tanks are interconnected by a conduit provided with a second compressor and a relay acting on the density of the gas in the low-pressure compartment is used said relay opening and closing said valve, when the density of the gas in the low-pressure compartment becomes a given value lower than or becomes equal to the required density, respectively. In addition, means are provided which start the second compressor, when the low-pressure storage tank contains too much gas for temperature in said tank. Owing to the use of storage tanks in the gas-control system no SF_6-gas will be lost except by leakage. By using a high-pressure storage tank in the gas circuit a relatively large stock of SF_6-gas can be stored in a relatively small volume and it becomes possible to supply the insulating compartments of the switchgear very quickly with gas, when therein the density of the gas, for whatever reason, falls down below a value which is dangerous to the state of insulation.

If each switching unit of the switchgear has a gas-control system provided with its own gas storage tanks, this system may advantageously be made in such a manner, that the relay acting on the density of the gas in the low-pressure compartment starts and stops the second compressor, when the density of the gas in said compartment becomes higher or a given value lower than the required density, respectively the low-pressure compartment and the low-pressure storage tank being connected to a differential-pressure relay which starts the second compressor, when the pressure in the low-pressure storage tank becomes higher than the pressure in the low-pressure compartment. The differential-pressure relay provided between the low-pressure compartment and the low-pressure storage tank ensures that the pressures in said compartment and said tank remain substantially equal, notwithstanding the fact that the temperature of the gas in the storage tank, said gas having the temperature of the outer air, can differ considerably from that of the gas in the low-pressure compartment, through which the main current heating the gas passes. At a change of this temperature difference, said change resulting in a change of the pressure difference between the low-pressure compartment and the low-pressure storage tank, the gas from the low-pressure compartment could circulate continuously through the two storage tanks. The differential-pressure relay prevents the unnecessary circulation of the gas in the low-pressure system.

The switchgear can be made considerably simpler, when the gas-control systems of a plurality of switching units cooperate with a common low-pressure storage tank, a common high-pressure storage tank and a conduit connected between these storage tanks which is provided with a second compressor. In that case the differential-pressure relay can be omitted. However, also a relay acting on the density of the gas in the low-pressure storage tank is then provided, said latter relay starting and stopping the second compressor at density values which are so much higher than the density values, at which the relay acting on the density of the gas in the low-pressure compartment closes and opens the valve, as to guarantee that at the maximum temperature difference to be expected between the gas in the low-pressure compartment and the gas in the low-pressure storage tank the second compressor is started at a higher gas pressure than that, at which the valve is closed, and is stopped at a higher gas pressure than that, at which the valve is opened. If the density relays in the low-pressure compartments of the switching units are adjusted in this manner in respect of the density relay provided in the common low-pressure storage tank, the gas systems of said switching units cannot influence one another.

If the gas blast circuit breaker is provided with an expansion tank to collect the used extinguishing gas, it is advantageous to connect the expansion tank through a conduit having a check valve closing towards said tank and a filter to the low-pressure storage tank and through a conduit having a check valve closing towards the low-pressure compartment to said compartment. During the switching process the extinguishing gas, which is deionized in the expansion tank and cleansed by the filter, will then reach the low-pressure compartment not directly but by a roundabout way, so that in the low-pressure compartment a sudden rise of the density will not be produced, since said rise of density is neutralized relatively slowly by the control system. Moreover, the used highly heated extinguishing gas will get sufficient time to cool down, before it is returned into the switchgear. Preferably, a buffer tank is inserted in the conduit extending between the expansion tank and the low-pressure storage tank, said buffer tank being provided between the check valve and the filter. This buffer tank damps the velocity of the extinguishing gas which escapes from the expansion tank during the switching-off process, so that it flows slowly through the filter and can be well cleansed. The conduit having the check valve and extending between the low-pressure compartment and the expansion tank ensures that in the stationary state of the switchgear the pressure in the expansion tank is about equal to that in the low-pressure compartment.

If at a predetermined temperature and pressure of the SF_6-gas condensation should occur in the high-pressure compartment, the pressure in said compartment would remain constant, notwithstanding the supply of gas from or the discharge thereof to the low-pressure compartment, as long as condensate is to be found in the high-pressure compartment. In that case it is not possible to keep the pressure difference between the high-pressure compartment and the low-pressure compartment constant, when the circumstances change. In order to avoid this difficulty the high-pressure compartment can be connected by a condensate conduit and a vapor conduit to an evaporator adapted to be heated by a heating element and provided with a relay acting on the liquid level in the evaporator, said relay putting the heating element into operation, when said level exceeds a predetermined value. By this measure the SF_6-gas contained in the high-pressure compartment is heated above its dew point.

The invention will be further elucidated with the aid of the accompanying drawing. Therein is:

FIG. 1 a temperature-versus-pressure diagram of SF_6-gas at constant volume for the range which is interesting to switch gear constructed according to the invention, said FIG. 1 showing lines of constant density (isochores),

FIG. 2 a schematic view of the part of the switchgear which is necessary to understand the invention, said switchgear being provided with a gas-control system carried out in accordance with the invention,

FIG. 3 a similar schematic view of an other embodiment of the gas-control system of said switchgear,

FIG. 4 a schematic view of a variant of the gas-control system shown in FIG. 3 and

FIG. 5 a pressure-versus-temperature diagram to determine the adjustment of density relays used in the gas-control system shown in FIG. 4.

From the diagram shown in FIG. 1, in which the pressure of the SF_6-gas has been plotted vertically and the temperature thereof horizontally, it appears that at constant volume the pressure of the gas rises less at lower density than at higher density. The lines 1 of constant density (isochores) thus show a greater steepness as the density of the SF_6-gas is higher.

The metal clad switchgear illustrated in FIGS. 2 and 3 comprise a gas blast circuit breaker 3 accommodated in a high-pressure compartment 2 filled with SF_6-gas, said circuit breaker having four places of interruption to interrupt the main current circuit, an isolator switch 4 connected in series with said circuit breaker and adapted to keep the main current circuit interrupted and to close said circuit, two bus bar isolators 5, 6 connected in series with the gas blast circuit breaker 3, two rails 7, 8 forming part of different bus bar systems, a cabel terminal box 9, an earthing switch 10, an overvoltage protective device 11 and current transformers 12, 13 for measuring and protection.

The container enclosing the high-pressure compartment 2 and accommodating the gas blast circuit breaker 3 is positioned in a low-pressure compartment 14 also filled with SF_6-gas and surrounded by a metal envelope adapted to be connected to earth. Mounted in said compartment 14 are also the isolator switch 4, the movable contacts of the bus bar isolator switches 5, 6, the current transformers 12, 13 and an expansion tank 15, in which the extinguishing gas from the high-pressure compartment 2 and used to extinguish the switching arcs during the switching-off process is collected and deionized. The fixed contacts of the bus bar isolators 5, 6, the rails 7, 8, the cabel terminal box 9, the earthing switch 10, the overvoltage protective device 11 and the connecting conductors extending between the isolator switch 4 and the cabel terminal box 9 and between said box and the overvoltage protective device 11 are accommodated in individual low-pressure compartments 16, 17, 18, 19, 20, 21, 22, 23, 24 filled with SF_6-gas, said latter compartments communicating in a not shown manner with the low-pressure compartment 14, so that therein the same pressure obtains and all these compartments may be considered as one single low-pressure compartment.

The SF_6-gas contained in the low-pressure compartment serves mainly to insulate the live parts from earth. The SF_6-gas contained in the high-pressure compartment 2 is in the first place used to extinguish the switching arcs but it may also be used for the pneumatical driving of the gas blast circuit breaker and the isolator switches **4, 5, 6**.

According to the invention the density of the SF_6-gas in the low-pressure compartment **14** and, consequently, also in the other low-pressure compartments is kept constant as much as possible, e.g. at a value of 40 gram per liter. This value has been indicated in the diagram shown in FIG. **1** by the thick isochore **25**. In addition, the density in the high-pressure compartment **2** is so controlled, as to keep also the pressure difference between the high-pressure compartment **2** and the low-pressure compartment **14** substantially constant, e.g. at a value of 10 kg./cm.^{2} In order to maintain this pressure difference under all circumstances the density of the gas contained in the high-pressure compartment must be changed in accordance with the thick line **26** shown in the diagram given in FIG. **1** at a change of temperature.

For the desired gas economy in the switchgear a gas-control system has been provided which in the embodiment shown in FIG. **2** is carried out and operates as follows:

The low-pressure compartment **14** is connected both to a supply conduit **29** provided with an electromagnetically controlled valve **28** and connected with a gas bottle **30** and to a discharge conduit **32** provided with an electromagnetically controlled valve **31**. Connected between the low-pressure compartment **14** and the high-pressure compartment **2** are a conduit **33** provided with an electromagnetically controlled valve **34** and a conduit **35** provided with a compressor **36**. The expansion tank **15** is connected to the low-pressure compartment **14** both by means of a conduit **37** provided with two filters **38**, which can be cleaned alternately, and by means of a conduit **39** provided with a check valve **40** closing towards the low-pressure compartment **14**. The high-pressure compartment **2** is connected by means of a condensate conduit **41** and a vapor conduit **42** with an evaporator **44** adapted to be heated by an electric heating element **43**.

For controlling the gas-control system a relay **45** acting on the density of the SF_6-gas, contained in the low-pressure compartment **14**, and having contacts **46, 47** for the electric control of the valves **28, 31** is provided in the low-pressure compartment **14** and a differential-pressure relay **48** having contacts **49, 50** for the electric control of the valve **34** and the compressor **36** is connected to the low-pressure compartment **14** and the high-pressure compartment **2**. Moreover, mounted in the evaporator **44** is a relay **51** acting on the level of the condensate, collected therein, and having a contact **52** for the control of the heating element. The control is effected as follows:

In the stationary state of the switchgear the gas in the low-pressure compartment **14** has the required density and the gas in the high-pressure compartment **2** has such a density as to guarantee that the pressure difference between the compartments **2** and **14** has the required value. The pressure in the expansion tank **15** is equal to that in the low-pressure compartment **14**.

During operation of the switchgear different changes of the conditions may occur. If the temperaturs in the switchgear rises, the pressure in the high-pressure compartment **2** will increase more than that in the low-pressure compartment **14** (see the diagram shown in FIG. **1**). In that case the pressure difference between both compartments will become greater than desired. This has the effect that the differential-pressure relay **48** comes into action and closes the contact **49**, so that the valve **34** is opened. Gas from the high-pressure compartment **2** then flows through the conduit **33** to the low-pressure compartment **14** till the required pressure difference has been restored. The gas fed to the low-pressure compartment **14** increases the density of the gas in said compartment, which has the result that the density relay **45** comes into action and closes the contact **47**. Due thereto the valve **31** is opened, so that the excess gas can flow away from the low-pressure compartment **14** through the conduits **27** and **32**. Should the temperature in the switchgear fall down, the pressure in the high-pressure compartment **2** will fall further down than that in the low-pressure compartment **14**. Also in that case the relay **48** comes into action, so that the contact **50** is closed, the compressor **36** is put into operation and gas is pumped from the low-pressure compartment **14** to the high-pressure compartment **2**. Owing thereto the density in the low-pressure compartment **14** decreases, the relay **45** comes into action, the contact **46** is closed and the valve **28** is opened, so that gas from the gas bottle **30** is supplied to the low-pressure compartment **14** to supply the gas deficiency in said compartment.

Not only a change of temperature but also the switching-off process upsets the stationary state. During the switching-off process gas flows from the high-pressure compartment **2** through the switching contacts of the gas blast circuit breaker **3** to the expansion tank **15** and thereafter from this tank through the conduit **37** and a filter **38** to the low-pressure compartment **14**. This results in that the pressure difference between the compartments **2** and **14** decreases and the density in the low-pressure compartment **14** increases. The differential-pressure relay **48** then closes the contact **50**, whereby the compressor **36** is started. Also the density relay **45** comes into action and closes the contact **47**. However, the closing of this contact **47** does not result in opening the valve **31** of the discharge conduit **32**, since this contact is connected in series with an auxiliary contact **53** of the differential-pressure relay **48**, said auxiliary contact **53** being closed in the state of equilibrium of the relay **48** and in the position thereof, in which the contact **49** is closed, but being opened in the position of the relay **48**, in which the contact **50** is closed and the compressor **36** operates. In that case no gas is lost through the discharge conduit **32** notwithstanding the density in the compartment **14** is too high.

At a predetermined pressure and a predetermined temperature within the pressure-temperature range, in which the switchgear operates, the SF_6-gas can condense. This danger only occurs in the high-pressure compartment **2**. As the condensation of the gas and the evaporation of the condensate have a disturbing effect on maintaining the pressure difference between the high- and low-pressure compartment the heating element **43** is set into operation as soon as condensate flows into the evaporator **44**. Due thereto the SF_6-gas in the high-pressure compartment **2** is heated to get a temperature above the dew point.

As SF_6-gas is too expensive to be discharged to the open air the gas-control system shown in FIG. **3** is provided with a low-pressure storage tank **54**, the discharge conduit **32** being connected to said storage tank **54** through a check valve **55** closing towards the low-pressure compartments **14** of the switchgear. The expansion tank **15** is connected to the low-pressure storage tank **54** through the conduit **37**, a check valve **56** closing towards the low-pressure compartment **14**, a buffer tank **57** and the filters **38**. The low-pressure storage tank **54** is connected to a high-pressure storage tank **60** by a conduit **58** provided with a second compressor **59**, said high-pressure storage tank **60** being connected to the supply conduit **29** provided with the electromagnetically operating valve **28**. The gas bottle **30** is connected with the high-pressure storage tank **60** by a conduit **61** provided with a valve **62** and it has the task to cover losses of SF_6-gas by leakage. In this case the differential-pressure relay **48** is connected to the low-pressure compartment **14** through the expansion tank **15** and the conduit **39** provided with the check valve **40**. This has the advantage that the differential-pressure relay **48** becomes earlier active and also starts the compressor **36**, during the switching-off process, earlier than it does in the system shown in FIG. **2**, since, during a switching-off operation, the pressure in the expansion tank **15** rises much quicker than the pressure in the low-pressure compartment **14**.

The relay **45** acting on the density of the gas in the low-pressure compartment **14** controls by its contact **46** the valve

28 provided in the supply conduit 29 and by its contact 47 the second compressor 59. Finally a second differential-pressure relay 63 is provided between the low-pressure compartment 14 and the low-pressure storage tank 54, the contact 64 of said relay controlling the compressor 59. This gas-control system operates as follows:

If, due to a rise in temperature in the switchgear, the pressure in the high-pressure compartment 2 becomes too high in respect of that in the low-pressure compartment 14 the valve 34 is opened by the relay 48. This has the effect that gas flows from the compartment 2 to the compartment 14 and from the latter through the conduit 32 and the check valve 55 to the low-pressure storage tank 54. In that case the density in the low-pressure compartment 14 increases, so that the relay 45 closes its contact 47 and starts the compressor 59. This compressor sucks the gas excess from the low-pressure compartment 14 and the low-pressure storage tank 54 and pumps it into the high-pressure storage tank 60.

If, due to a drop of temperature in the switchgear, the pressure in the high-pressure compartment 2 becomes too low in respect of that in the low-pressure compartment 14 the relay 48 starts the compressor 36. Owing thereto the compartment 2 receives gas from the compartment 14 and the density of the gas in the low-pressure compartment 14 decreases and becomes too low, so that the relay 45 closes its contact 46 resulting in that the valve 28 is opened and gas flows from the high-pressure storage tank 60 to the low-pressure compartment 14 to supply the gas deficiency. Since no gas can flow from the low-pressure storage tank 54 to the low-pressure compartment 14 the pressure in the tank 54 will temporarily become higher than that in the compartment 14, so that, depending on the sensibility of the relay 63, the contact 64 is closed and thereby the compressor 59 is started. The latter continues to operate till the moment, at which the pressures in the compartment 14 and the tank 54 will be equal again. From that moment on the low-pressure compartment 14 and, through this compartment, the conduit 27, 32, the check valve 55 and the low-pressure storage tank 54 are fed with gas from the high-pressure storage tank 60 till the gas in the low-pressure compartment 14 has reached the right density.

In the stationary state of the switchgear the same pressure obtains in the expansion tank 15 as in the low-pressure compartment 14 owing to the connection through the conduit 39 provided with the check valve 40. During the switching-off process the pressure in the expansion tank rises considerably and the pressure in the high-pressure compartment 2 falls down. The result thereof is that the relay 48 comes immediately into action and it starts the compressor 36 over the contact 50. The density of the gas in the low-pressure compartment 14 then decreases, so that also the relay 45 is put in action and it opens the valve 28 by means of its contact 46. Due thereto gas flows from the high-pressure storage tank 60 to the low-pressure compartment 14. Owing to the fact that at first the density and the pressure in the low-pressure compartment 14 decrease, as well as due to the fact that the extinguishing gas flows from the expansion tank 15 through the conduit 37, the check valve 56, the buffer tank 57 and a filter 38 to the low-pressure storage tank 54, so that the pressure in the tank 54 rises, the differential-pressure relay 63 comes into action and the contact 64 is closed, whereby the compressor 59 is started and the gas excess is pumped away from the low-pressure storage tank 54 to the high-pressure storage tank. As soon as the right pressure difference between the high-pressure compartment 2 and the low-pressure compartment 14 has been restored and the density in this compartment 14 has again reached the right value, the relays 45, 48 and 63 return to their rest positions, the compressors 36 and 59 are stopped and the valve 28 is closed.

The storage tanks 54 and 60 are situated outside the switchgear and no electric current flows through them, so that great temperature differences can be set up between the gas in these tanks and the gas in the switchgear. Said temperature differences could disturb the stationary gas economy in the system. If the switchgear has been dead for a long time the temperature in the switchgear and that in the low-pressure storage tank 54 will be equal, so that the gas densities in the compartment 14 and the tank 54 will also be equal, since the pressures are equal too. However, if current flows through the switchgear the temperature in the low-pressure compartment 14 will become higher than that in the low-pressure storage tank 54. This results in that, if the pressure does not change, the density in the storage tank 54 will become higher and the density in the low-pressure compartment 14 will become lower. Consequently, there will be no gas transport from the compartment 14 to the storage tank 54. If the density in the compartment 14 becomes too low the relay 45 will come into action, the contact 46 will be closed and the valve 28 will be opened, so that the gas deficiency in the low-pressure compartment 14 will be supplied from the high-pressure storage tank 60. It is also possible that in the considered case, due to the decrease of the density in the compartment 14, the pressure difference between the high-pressure compartment 2 and the low-pressure compartment 14 makes the relay 48 operative, so that the valve 34 is opened, which will last till the moment, at which the required pressure difference has been restored. From that moment on the pressure in the low-pressure compartment 14 continues to rise due to the supply of gas from the storage tank 60, so that the relay 48 comes into action and starts the compressor 36 again till, at the right density in the low-pressure compartment 14, the right pressure difference between the compartments 2 and 14 has again been reached. If after the termination of this control action the temperature difference between the gas in the switchgear and the gas in the storage tank 54 decreases again, either owing to an unintended heating of the tank 54 or, which is more probable, owing to the fact that the switchgear becomes currentless, the density in the low-pressure compartment 14 will not change but there will be set up a pressure difference between the storage tank 54 and said compartment 14, said pressure difference putting the relay 63 into operation so that the compressor 59 is started and the pressure in the tank 54 is made equal again to that in the low-pressure compartment 14. The same control occurs when the temperature in the storage tank 54 would, for whatever reason, become higher than that in the low-pressure compartment 14.

By the right adjustment of the sensibility of the relays 45, 48 and 63 it is avoided that the control becomes instable. The sensibility of these relays defines, within which range the density in the low-pressure compartment 14 and the pressure difference between the compartments 2 and 14 can be kept constant. It will be obvious, that it is not possible to keep these quantities exactly constant.

The buffer tank 57 has the object to level the sudden pressure rise in the expansion tank 15 due to the switching-off of the gas blast circuit breaker 3, so that the extinguishing gas which is contaminated by the switching process flows with low speed through the filter 38 to the low-pressure storage tank 54. The effect of the filter is thereby considerably increased.

In the switchgear shown in FIG. 3 each switching unit is provided with its own set of storage tanks 54, 60 and accessories. In many cases it is more advantageous to use one single low-pressure storage tank and one single high-pressure storage tank for a plurality of switching units. The gas-control system then must be so arranged, that change of the conditions in a given switching unit does not affect the conditions in other switching units of the switchgear. An example of switchgear consisting of a plurality of switching units which are connected in parallel to a set of storage tanks 54, 60 is illustrated in FIG. 4.

The gas-control system in FIG. 4 differs from that shown in FIG. 3 in that the differential-pressure relay 63 has been omitted, the density relay 45 in the low-pressure compartment 14 has the contact 46 only and in the low-pressure storage tank 54 also a relay 65 acting on the density of the gas in said tank has been provided. The density relay 65 opens and closes the contact 66 inserted in the circuit of the second compressor 59. This system operates as follows:

From FIG. 5 it appears that the density relay **65** tries to keep the density of the gas in the low-pressure compartment **14** at a value lying on the isochore **25**, that means in the present case at a value of 40 g./liter, by opening and closing the valve **28**. Has this value been reached the relay **45** opens the contact **46** and the valve **28** admitting gas from the high-pressure storage tank **60** into the compartment **14** is closed. At the temperature T_1 this closing occurs at the pressure indicated by point **67** and at the higher temperature T_2 this closing takes place at the higher pressure indicated by point **68**. The density relay **45** closes the contact **46**, when the pressure in the low-pressure compartment **14** becomes a value equal to one-half kg./cm.^{2} lower than that defined by the isochore **25**. Consequently, at the temperature T_1 the valve **28** is opened, when the gas pressure in the compartment **14** has reached the value indicated by point **69** but at the temperature T_2 the valve **28** will open at the pressure indicated by the point **70**. The density relay **65** in the low-pressure storage tank **54** has been adjusted at higher density values. At the temperature T_1 the contact **66** of the relay **65** is closed and the second compressor **59** is started, when the density in said storage tank has reached a value, at which the pressure in said tank has the value indicated by the point **71**. The contact **66** is opened and the compressor **59** is stopped again, when the pressure in the storage tank **54** is returned to the pressure indicated by the point **72**, said pressure being, in the present case, one-half kg./cm.^{2} lower than the pressure at the point **71** which starts the compressor. Now, the adjustment of the density relay **65** is so chosen as to render the density values indicated by the parallel lines **73** and **74**, at which the second compressor **59** is started and stopped, respectively, so much higher than the density values given by the isochore **25** and the line **75** parallel thereto, at which the valve **28** is closed and opened, respectively, that even at the maximum difference to be expected of say 15° C. between the lower temperature of the gas in the low-pressure storage tank **54** and the higher temperature of the gas in the low-pressure compartment **14** the relay **65** puts the compressor **59** in operation at a pressure which is higher than the pressure, at which the relay **45** closes the valve **28**, and stops the compressor **59** at a pressure, which is higher than the pressure at which the relay **45** opens the valve **28**. This means, that in the given example, in which the temperatures T_1 and T_2 differ the expected maximum value of 15° C. under normal operational circumstances, the point **71** comes to lie higher than the point **68** and the point **72** comes to lie higher than the point **70**. Only, when the relays **45** and **65** are thus adjusted, the control of the gas-control system of each switching unit is stable, which will appear from the following:

If one starts from the state, in which a switching unit is dead, the gas in the low-pressure compartment **14** of said unit has the right density defined by the isochore **25** (FIG. **5**) and the temperature of the gas in the low-pressure compartment **14** is equal to the temperature of the gas in the low-pressure storage tank **54**, that means is equal to T_1, the gas densities and the gas pressures in said compartment **14** and said storage tank **54** will be equal too. The gas pressure then is given by the point **67**. If thereafter the switching unit is switched in, so that current flows through it, the temperature in the low-pressure compartment **14** could, in the most unfavorable situation, rise 15° C. with respect to the value T_2, so that the pressure in said compartment **14** will rise to the point **68** and gas will flow from the compartment **14** through the conduit **32** and the check valve **55** to the storage tank **54** till the pressure in the tank **54** has become equal to that in the compartment **14** again. The pressure in the compartment **14** then is somewhat lower than that indicated by the point **68** and the pressure in the tank **54** then is somewhat higher than that indicated by the point **67**. Should, for whatever reason, a further loss of gas occur from the compartment **14**, so that the pressure indicated by the point **70** is reached, the valve **28** will be opened by the relay **45** till the pressures in the compartment **14** and the storage tank **54** have again reached the value indicated by the point **68**. Since the point **71**, at which the compressor **59** is put in action, lies higher than the point **68** said compressor will remain inoperative.

If, owing to the switching-off of the gas blast circuit breaker **3**, gas flows from the high-pressure compartment **2** to the low-pressure storage tank **54** the pressure therein can exceed the value indicated by the point **71**, so that then the compressor **59** is started and gas is pumped from the low-pressure storage tank **54** to the high-pressure storage tank **60** till the pressure in the low-pressure storage tank **54** (that means also the pressure in the low-pressure compartment **14**) has reached the value indicated by the point **72**. As this value lies above the value indicated by the point **70**, at which the valve **28** is opened by the relay **45**, said valve remains closed. It follows therefrom, that the compressor **59** will not be put into operation when the valve **28** is in its open position and also that the valve **28** will not be opened, when the compressor **59** is in operation, so that the instable situation, in which the valve **28** is open and the compressor **59** is in operation, whereby gas would be continuously pumped from the low-pressure storage tank **54** to the high-pressure storage tank **60** and hence to the low-pressure compartment **14** and through the conduit **32** back to the low-pressure storage tank **54**, can not occur.

If one has to reckon with a higher maximum temperature difference than say 15° C. the adjustment of the density relay **65** and that of the density relay **45** must differ more, that means the lines **73** and **74** will have to lie higher in respect of the lines **25** and **75** than has been illustrated in FIG. **5**.

What we claim is:

1. A switchgear system for high voltage electrical circuits, comprising in combination;

an electrically conductive envelope housing at least a gas blast circuit breaker and related portions of a high voltage electrical circuit, said envelope being adapted for connection to earth and defining low-pressure and high-pressure compartments of fixed volumes, said low pressure compartment being filled with an amount of gaseous sulfur hexafluoride sufficient to establish a relatively low pressure in such compartment which will insulate live parts of the switchgear from earth, and said high-pressure compartment being filled with an amount of gaseous sulfur hexafluoride sufficient to establish a relatively high pressure in such compartment which is capable of extinguishing a switching arc caused by operation of said circuit breaker;

means for maintaining a substantially constant density of gas in said low-pressure compartment whereby the low-pressure compartment is subjected to limited gas pressure variation in response to temperature variations; and

means for varying the density of the gas in said high-pressure compartment to maintain a substantially constant gas pressure differential between said high-pressure and low-pressure compartments.

2. Metal clad switchgear as claimed in claim **1** wherein said means for maintaining a substantially constant density of gas in said low-pressure compartment comprises a discharge conduit (**32**) and a supply conduit (**29**), said conduits (**32, 29**) being connected to the low-pressure compartment (**14**) and cooperating with flow regulating means (**45, 31, 28**) acting on the density of the gas in said compartment (**14**), said flow regulating means ensuring that gas flows from and to the low-pressure compartment (**14**) when the density of the gas in said compartment (**14**) becomes higher and lower than the required density, respectively, said means for varying the density of the gas in said high-pressure compartment comprising a conduit (**33**) provided with a valve (**34**) and a conduit (**35**) provided with a compressor (**36**), said conduits being connected between the low-pressure compartment (**14**) and the high-pressure compartment (**2**), and a differential-pressure relay (**48, 49, 50**) connected to both compartments (**2, 14**) and either opening said valve (**34**) or starting said compressor (**36**), when the pressure difference between both compartments (**2, 14**) becomes higher or lower than the required pressure difference, respectively (FIGS. **2, 3, 4**).

3. Metal clad switchgear as claimed in claim **2**, comprising a check valve (**55**) closing towards the low-pressure compartment (**14**) and being provided in the discharge conduit (**32**) which is connected to a low-pressure storage tank (54), the supply conduit (29) being connected through a valve (28) to a high-pressure storage tank (60), a conduit (58) provided with a second compressor (59) being connected between both storage tanks (54, 60), a relay (45) acting on the density of the gas in the low-pressure compartment (14) and adapted to open and to close said valve (28) when the density of the gas in the low-pressure compartment 14 becomes a given value lower than or becomes equal to the required density, respectively, and means (63, 65) for starting the second compressor (59), when the low-pressure storage tank (54) contains too much gas at the temperature obtaining in said tank (FIG. 3, 4).

4. Metal clad switchgear as claimed in claim 3, in which the relay (45) acting on the density of the gas in the low-pressure compartment (14) starts and stops the second compressor (59) when the density of the gas in said compartment (14) becomes higher or a given value lower than the required density, respectively, a differential-pressure relay (63) being provided which is connected both to the low-pressure compartment (14) and the low-pressure storage tank (54) and is adapted to start the second compressor (59), when the pressure in the low-pressure compartment (14) (FIG. 3).

5. Metal clad switchgear as claimed in claim 3, comprising also a relay (65) acting on the density of the gas in the low-pressure storage tank (54), said relay starting and stopping the second compressor (59) at density values which are so much higher than the density values, at which the relay (45) acting on the density of the gas in the lower-pressure compartment (14) closes and opens the valve (28), that at the maximum temperature difference to be expected between the gas in the lower-pressure compartment (14) and the gas in the lower-pressure storage tank (54) the second compressor (59) is started at a higher gas pressure than that, at which the valve (28) is closed, and is stopped at a higher gas pressure than that, at which the valve (28) is opened (FIG. 4).

6. Metal clad switchgear as claimed in claim 3, comprising a gas blast circuit breaker provided with an expansion tank (15) to collect the used extinguishing gas, said expansion tank (15) communicating with the low-pressure storage tank (54) through a conduit (37) provided with a check valve (56) closing towards said tank and a filter (38), said expansion tank (15) also communicating with the low-pressure compartment (14) through a conduit (39) provided with a check valve (40) closing towards said compartment (14).

7. Metal clad switchgear as claimed in claim 6, comprising a buffer tank (57) provided between the check valve (56) and the filter (38) in the conduit (37) extending between the expansion-tank (15) and the low-pressure storage tank (54).