(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 016 881**
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **79300509.1**

(22) Date of filing: **29.03.79**

(51) Int. Cl.³: **F 17 C 5/04**, F 17 C 7/02, H 01 H 33/56

(43) Date of publication of application: **15.10.80**
Bulletin 80/21

(84) Designated Contracting States: **BE DE FR GB IT NL**

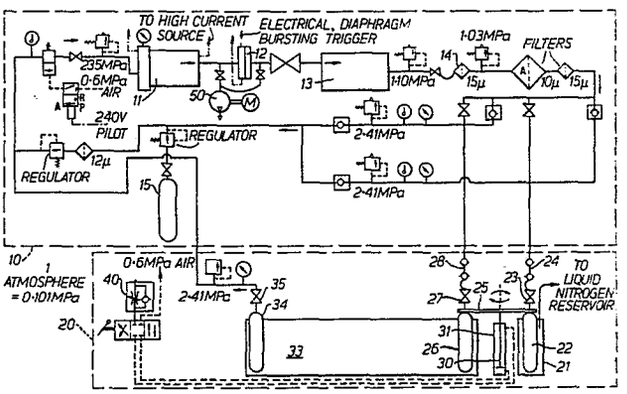
(71) Applicant: **UNIVERSITY OF SYDNEY, Parramatta Road, Sydney New South Wales 2006 (AU)**

(72) Inventor: **Stokes, Anthony David Dr., 116, Lucinda Avenue, Wahroonga, 2076 New South Wales (AU)**

(74) Representative: **Kirk, Geoffrey Thomas et al, BATCHELLOR, KIRK & EYLES 2, Pear Tree Court Farringdon Road, London EC1R 0DS (GB)**

(54) A method and apparatus for the recovery of gases from enclosures.

(57) A gas recovery method and apparatus for the recovery and storage of a gas from a gas enclosure or circuit, particularly suitable for the recovery of sulphur hexafluoride (SF_6) from the arc chamber of a high voltage/current circuit breaker. A gas holding vessel (22) is connected, suitably via quick connect coupling (24) and a non-return valve (23), to the gas circuit or enclosure. Means (21) are provided to hold the vessel at a temperature below that at which the gas is transformed from vapour to liquid or solid phase. Suitably a Dewar flask and liquid nitrogen are used. The liquefied or solidified gas can be stored in the vessel until required for recharging the circuit or enclosure.



EP 0 016 881 A1

TITLE MODIFIED
see front page

"GAS RECOVERY"

This invention relates to gas recovery and is more specifically concerned with the recovery of gases from enclosures containing equipment which has to operate in a gaseous environment other than air.

There are many areas of technology in which fairly large equipment is required to operate in an atmosphere of a particular gas. One such area is the electrical supply industry where, for example, electric circuit breakers are often required to operate in an atmosphere of sulphur hexafluoride (SF_6) gas.

Sulphur hexafluoride gas is relatively expensive and it is normally recovered and stored if equipment which normally works in the gas is to be serviced or repaired. As the equipment may be sited in remote areas, a portable assembly is used to recover the gas and to recharge the equipment with the gas after the equipment has been serviced or repaired. Such assembly comprises a large pump and a storage vessel normally mounted on a vehicle. The amount of gas to be recovered may be 200kg or more, and, as it is normally at pressures between 4 and perhaps 20 atmospheres in the enclosure, the pump used must have a high capacity and the assembly is therefore a cumbersome and expensive piece of equipment, which is used only intermittently.

The present invention seeks to amend the need for

high capacity pumps by providing a gas recovery apparatus comprising at least one vessel connectable to an enclosure or circuit from which a gas is to be recovered and means for holding the vessel at a temperature below that at which the gas is transformed from its vapour phase to a liquid or solid phase.

The apparatus of the invention has the advantage that the use of a high pressure pump is avoided altogether and the gas storage vessels are reduced in size, perhaps fourfold. The conversion of the recovered gas to its liquid phase produces a drop in pressure which induces its own pumping action so that the gas can be rapidly withdrawn from the enclosure or circuit by way of a coupling and, when cold, stored at a pressure at or beneath atmospheric pressure.

The cooling arrangement conveniently comprises a bath of liquid nitrogen. The vessel may take the form of a stainless steel or aluminium cylinder mounted in the bath. Liquid nitrogen has the advantage that air is not liquified when contained in vessels at temperatures just above the boiling point of the liquid nitrogen. The recovered gas may therefore be separated from air which may have contaminated it through leakage, by applying a vacuum pump to the vessel after the gas has been solidified in the vessel.

The invention is particularly well-suited to recovering sulphur hexafluoride from electrical circuit breakers and other such equipment. Sulphur hexafluoride is solid at the temperature of liquid nitrogen (-196°C) and liquid nitrogen is readily available as a cheap safe, refrigerant. The apparatus can be stored at a maintenance depot for servicing a number of circuit breakers and temporarily transported to any breaker which requires servicing.

According to the invention there is provided a gas recovery apparatus comprising at least one vessel connectable to an enclosure or circuit from which a gas is to be recovered such that the gas is enabled to flow from the enclosure or circuit into the vessel and means for holding the vessel at a temperature below that at which the gas is transformed from its vapour phase to its liquid phase or to its solid phase thereby storing the gas in the vessel.

According to the invention there is further provided a method of recovering gas from an enclosure or circuit, the method comprising connecting to the enclosure or circuit a gas receiving vessel which is held at a temperature below that at which the gas is transformed from its vapour phase to its liquid phase or to its solid phase and storing the gas in the receiving vessel.

The invention will now be described in more detail in a preferred embodiment, by way of example, with reference to the accompanying drawings, in which:-

FIGURE 1 is a graph showing the vapour pressure of sulphur hexafluoride as a function of its temperature.

FIGURE 2 is a schematic circuit diagram of apparatus for recovering sulphur hexafluoride from a circuit breaker, the diagram showing also the sulphur hexafluoride gas circuit for the breaker, and

FIGURE 3 is a code chart which identifies the legends employed in Figure 2.

As is shown in the curve of Figure 1, between a critical point 5 and a point 6, sulphur hexafluoride is either at a liquid phase or a gaseous phase dependent on its temperature and pressure. Between the points 6 and 7 sulphur hexafluoride exists either in its gaseous phase or its solid phase in accordance with the temperature and pressure. Point 8 on the curve of Figure 1 shows that at

temperatures beneath -60°C the sulphur hexafluoride exists in its solid state at atmospheric pressure.

It will be seen from the curve that at a temperature of -196°C, which is the temperature of liquid nitrogen, sulphur hexafluoride exists in a solid phase unless its pressure is reduced below about $10^{-2.5}$ Torr. Bearing in mind that one Torr is equal to 1/760th of an atmosphere, this is almost a pure vacuum condition. As with most gases the conversion of sulphur hexafluoride from its gaseous to its solid phase is accompanied by a very great reduction in volume, exceeding 100:1 at one atmosphere pressure.

Referring now to the apparatus as shown schematically in Figure 2 and having the elements identified by the legends encoded in Figure 3;

Figure 2 shows, within the broken line 10 equipment associated with a gas-filled circuit breaker using sulphur hexafluoride gas. This equipment comprises an arc chamber 11 from which sulphur hexafluoride gas travels through a fast opening valve 12 to a dump tank 13. Typically, the gas is at a pressure of four atmospheres and the arc chamber and its surrounding enclosure together contain about 8 litres of gas, although this varies with design. Gas from the dump tank is cleaned by passage through filters 14 before being recycled back to the arc chamber with additional gas provided for topping-up purposes from a gas bottle 15.

The equipment also includes manual valves, one-way valves, meters, regulators and additional filters, as identified by the legend encoding of Figure 3. These elements form a normal part of most fluid circuits and are not therefore detailed herein.

The apparatus for recovering sulphur hexafluoride from the circuit shown in Figure 2 is contained within the broken outline 20. It comprises a dewar flask 21 contain-

ing a stainless steel vessel 22 connected by a valve 23 and a quick-connector coupling 24 to the gas circuit of the equipment and apparatus 10. The vessel 22 is carried at one end of a yoke 25 which carries at its other end a second similar vessel 26 also connected by a valve 27 and a quick-release coupling 28 to the gas circuit of the breaker. The yoke 25 can be raised and lowered by a double-acting piston 30 operating in a cylinder 31 in which the piston can rotate when raised.

The vessel 26 is partially immersed in a heated water tank 33 which contains a further vessel 34 containing sulphur hexafluoride and connected through a valve 35 which can be opened to provide a rapid pressure build up of sulphur hexafluoride gas to the circuit breaker enclosure as it by-passes the regulators which control the gas flow into the circuit from the vessel 26.

A pressure switch 40 and associated 4-part, 3-position hand operated valve controlling a compressed air supply is used to provide compressed air as the working fluid to the cylinder 31.

A large dewar flask of liquid nitrogen (not illustrated) may also be provided as a liquid nitrogen reservoir.

When the sulphur hexafluoride gas is to be recovered from the circuit breaker enclosure the vessel 22 is connected to the gas circuit by means of the quick connector couplings and operation of the non-return valve. The sulphur hexafluoride gas from the gas circuit of the breaker flows quickly into the stainless steel vessel 22 where it liquifies and quickly solidifies. A pumping rate of approximately 400 grms per square meter of cooled cylinder area is maintained provided the connecting pipework can deliver this quantity of gas. The gas in the

circuit is rapidly converted into liquid and then solid sulphur hexafluoride in the cooled vessel 22. It is important that the neck of the vessel is not held at temperatures at which it could be choked by SF_6 snow formation as it enters the vessel 22. Also the SF_6 should preferably pass from a gaseous phase to a liquid phase in the vessel 22, before solidifying, so that it collects in the base of the vessel 22 and leaves the vessel walls free of any insulation caused by solid SF_6 build up. The pressure within the vessel falls to very low values and the consumption of nitrogen is approximately one litre per kg of sulphur hexafluoride gas recovered. Air which may have seeped into the gas circuit is not liquified at the temperature of liquid nitrogen, and can be evacuated by a vacuum pump normally provided but not shown.

When the sulphur hexafluoride has been recovered, valve 23 is closed and the circuit breaker enclosure can then be opened up for maintenance or other work to be carried out.

When necessary work has been completed, the enclosure is evacuated by means of the vacuum pump 50 provided and the system is recharged with sulphur hexafluoride gas. This gas may be obtained by raising, turning and then lowering the yoke 25 so that the vessel 22 is located in the heated bath 33 in the position previously occupied by vessel 26. Vessel 22 thus becomes vessel 26, as shown in Figure 2, and as such it is heated to cause the previously recovered sulphur hexafluoride to be discharged into the gas circuit enclosed by the dotted line 10. Vessel 34 also may be used to recharge the gas circuit quickly, if required, as its connections by-pass the regulators.

The vessel 22 and 26 can be positionally inter-

changed after raising the piston, by rotating the yoke, as above described. Alternatively cylinder 22 can be used alone if heated by electric heaters when it is required to recharge the equipment with the previous recovered gas.

In such case the apparatus would comprise a single liquid nitrogen flask 21 containing an electrical heater and the vessel 22. Connections would allow the liquid nitrogen to be fed between the flask and a reservoir of liquid nitrogen. Control circuitry would enable the vessel 22 to be cooled when sulphur hexafluoride was to be recovered and heated when it was to be fed back into a breaker connected temporarily to the apparatus. The apparatus could be portably mounted.

From the above description it will be appreciated that the gas recovery apparatus of the invention is cheap to make, has low running costs, is very much more compact than currently available gas recovery apparatus, and is perhaps one quarter of the size. Because there are few moving parts, there is also a lesser risk of damage. Although care has to be taken when handling liquid nitrogen, it is a cheap commodity and requires no special precautions to be taken other than those associated with low temperature liquids and which are fairly well known at this time.

Although the invention has been above described in the context of removing hexafluoride gas from an electric circuit breaker, it is to be understood that this is only one application of the invention and that it has broader significance. Thus, the invention may be applied to the recovery of any gas from any device, using the concept of holding the vessel which is used in recovery of the gas at a temperature beneath that at which the recovered gas is transformed from its vapour phase to a liquid or solid phase.

It has been found that the apparatus for carrying out the invention may be even more economically provided by using aluminium vessels instead of stainless steel vessels. Aluminium vessels are commercially available and are cheaper than stainless steel vessels. Additionally, if the invention is being applied to the recovery of sulphur hexafluoride gas from a high voltage circuit breaker and the servicing time on the breaker is likely to be extensive the liquid or solid phase gas stored in the vessel may be allowed to slowly return to room or ambient temperature without the aid of the aforementioned heating bath. Under such circumstances the natural heat transfer from the ambient to the liquified or solidified gas may be sufficient over the service time to bring the stored gas back to the ambient temperature and hence at appropriate pressure for that temperature.

Claims:

1. A gas recovery apparatus comprising at least one vessel adapted to be connected to an enclosure or circuit from which a gas is to be recovered such that the gas is enabled to flow from the enclosure or circuit into the vessel and means for maintaining the vessel at a temperature below that at which the gas is transformed from its vapour phase to its liquid or solid phase thereby storing the liquefied or solidified gas in the vessel.

2. Apparatus as claimed in claim 1, wherein the means for maintaining the vessel at the said temperature comprises a housing for the vessel, the housing being connected to a source of a liquefied gas having a vapour-phase to liquid-phase transition temperature lower than that of the gas to be recovered.

3. Apparatus as claimed in claim 1 or 2 further including means to effect recharging of the enclosure or circuit from which the gas has been recovered, said means to effect recharging comprising means for applying heat to the vessel sufficient to cause vaporisation of the liquefied or solidified stored gas in the vessel such that the vaporised gas is enabled to flow from the vessel into the enclosure or circuit.

4. Apparatus as claimed in claim 3, comprising two

said vessels, a first one of which is located at a cooling station provided with the means for maintaining the vessel at the said temperature, and a second one of which is located at a heating station provided with the said means for applying heat to the vessel, the two vessels being connectible via respective couplings and valves to the enclosure or circuit and the two vessels being interchangeable as to their stations.

5. Apparatus as claimed in claim 4, wherein the cooling station comprises a Dewar flask arranged to receive the said first vessel and to receive a supply of liquefied gas, the liquefied gas having a vapour-phase to liquid-phase transition temperature lower than that of the gas to be recovered, and wherein the heating station comprises a heated water bath arranged to receive said second vessel.

6. Apparatus as claimed in claim 5, including a yoke supporting the two vessels and a ram mechanism supporting the yoke, the ram mechanism being actuable to lift the yoke and hence raise the vessels from their respective stations, the yoke being arranged for rotation sufficient to interchange the vessels from one station to the other.

7. Apparatus as claimed in claims 2 and 3 or claims 4, 5 or 6, where dependent thereon, wherein the housing includes a heating element and control means are provided to effect connection of the housing to the source of

liqiefied gas or to effect energisation of the heating element, whichever is required.

8. Apparatus as claimed in any one of the preceding claims, wherein the or each vessel is connectible to the enclosure or circuit via at least one regulator valve.

9. Apparatus as claimed in claim 8, wherein a further vessel containing gas to be delivered to the enclosure or circuit is provided, said further vessel being connectible to the enclosure or circuit in such a way as to by-pass the regulator valve(s).

10. A sulphur hexafluoride gas recovery apparatus as claimed in any one of the preceding claims adapted to be connected to an electric circuit breaker, the sulphur hexafluoride apparatus comprising at least one vessel connectible to a gas circuit of the circuit breaker, and means for holding the vessel at a temperature below that at which sulphur hexafluoride gas is transformed from its vapour phase to a liquid or solid phase.

11. Apparatus as claimed in claim 1, wherein the liquefied gas comprises liquid nitrogen.

12. Apparatus as claimed in any one of the preceding claims, wherein the vessel or vessels are constructed substantially of aluminium.

13. In combination, an electric circuit breaker containing sulphur hexafluoride and gas recovery apparatus according to any one of the preceding claims.

14. A method of recovering gas from an enclosure or circuit comprising connecting to the closure or circuit a gas receiving vessel which is held at a temperature below that at which the gas to be recovered is transformed from its vapour phase to its liquid or solid phase and storing the liquefied or solidified gas in the receiving vessel.

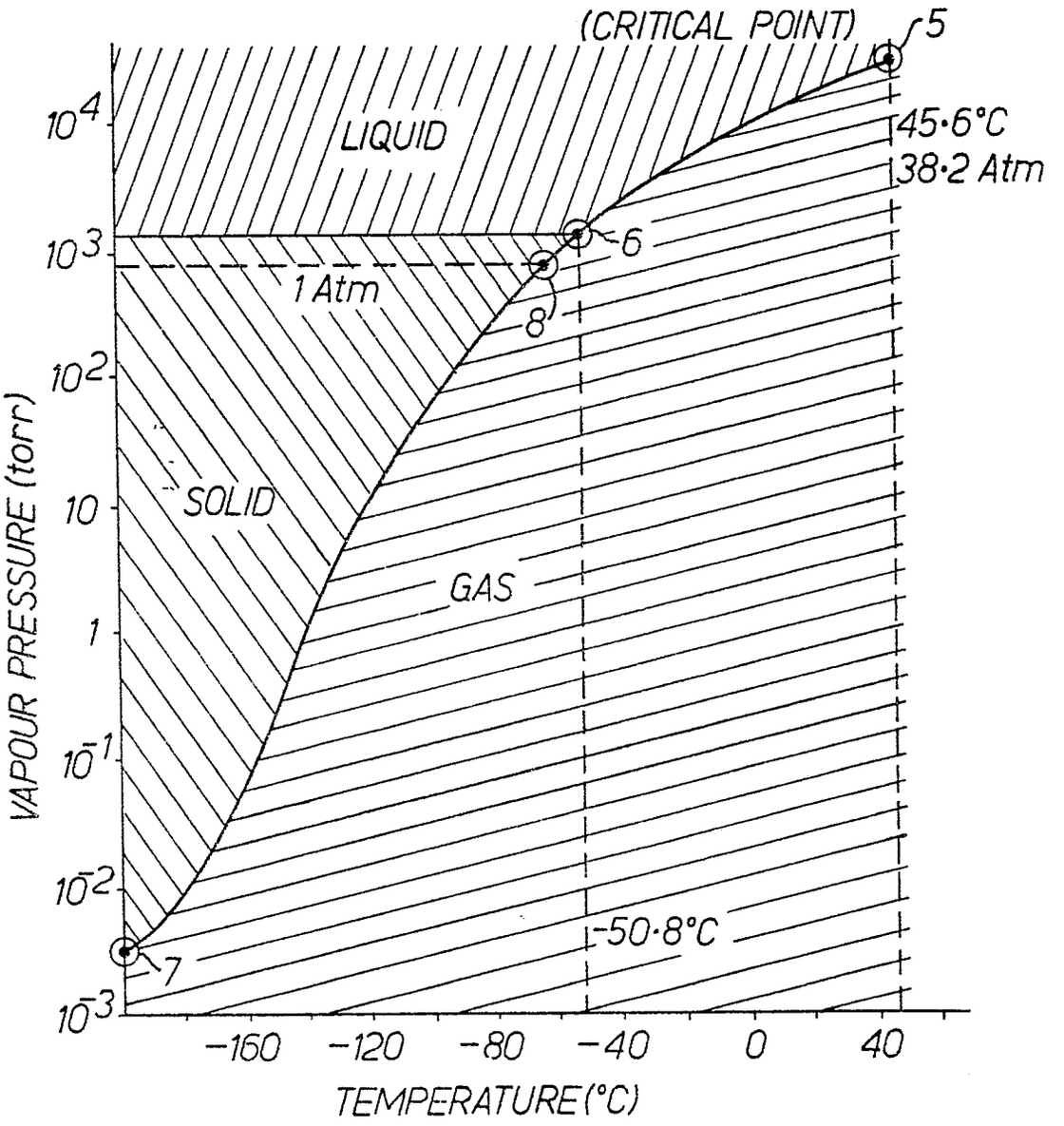

(CRITICAL POINT)
5
LIQUID
45·6°C
38·2 Atm
6
1 Atm
8
SOLID
GAS
-50·8°C
7
VAPOUR PRESSURE (torr)
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
-160
-120
-80
-40
0
40
TEMPERATURE (°C)

FIG. 1.

0016881

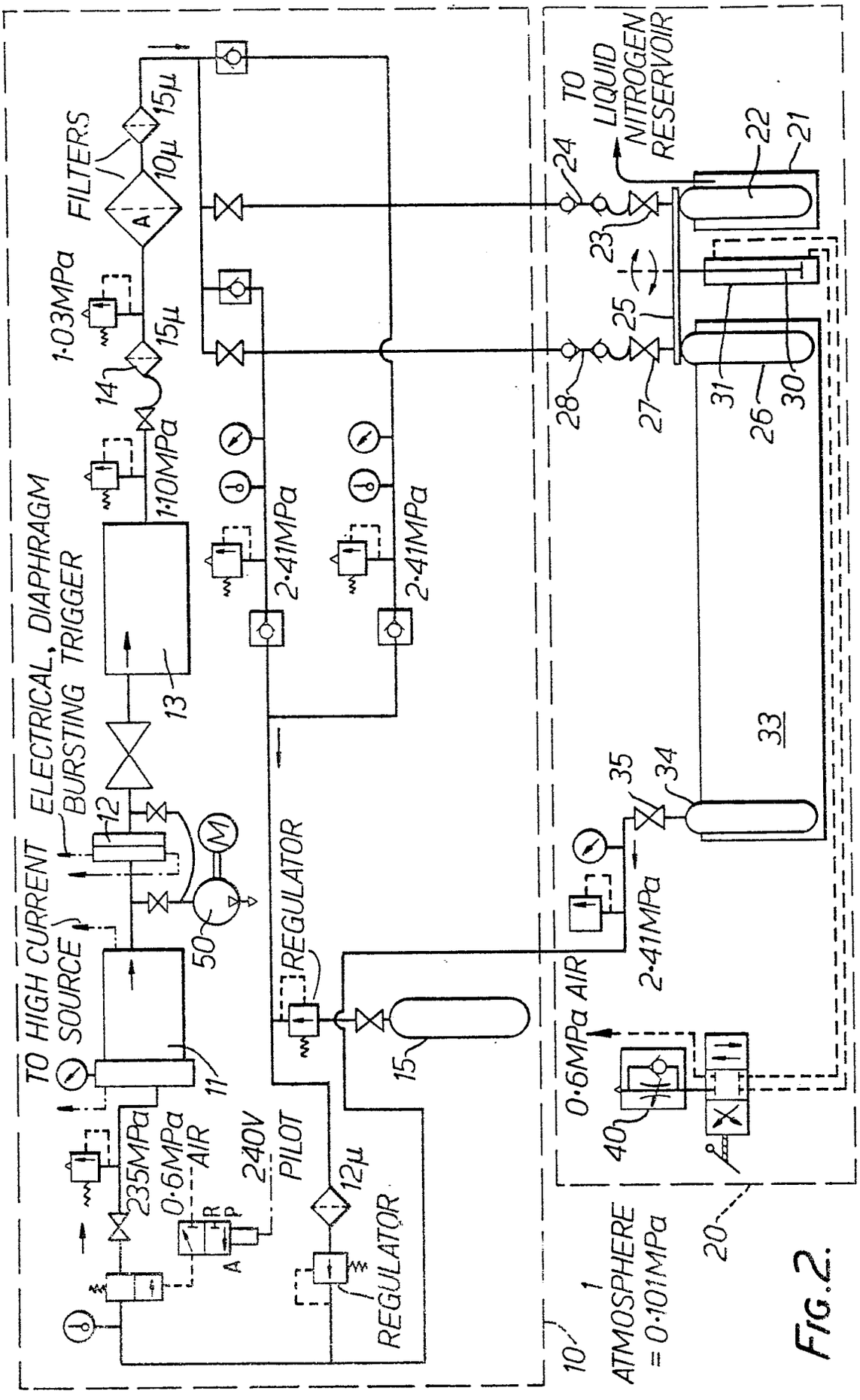
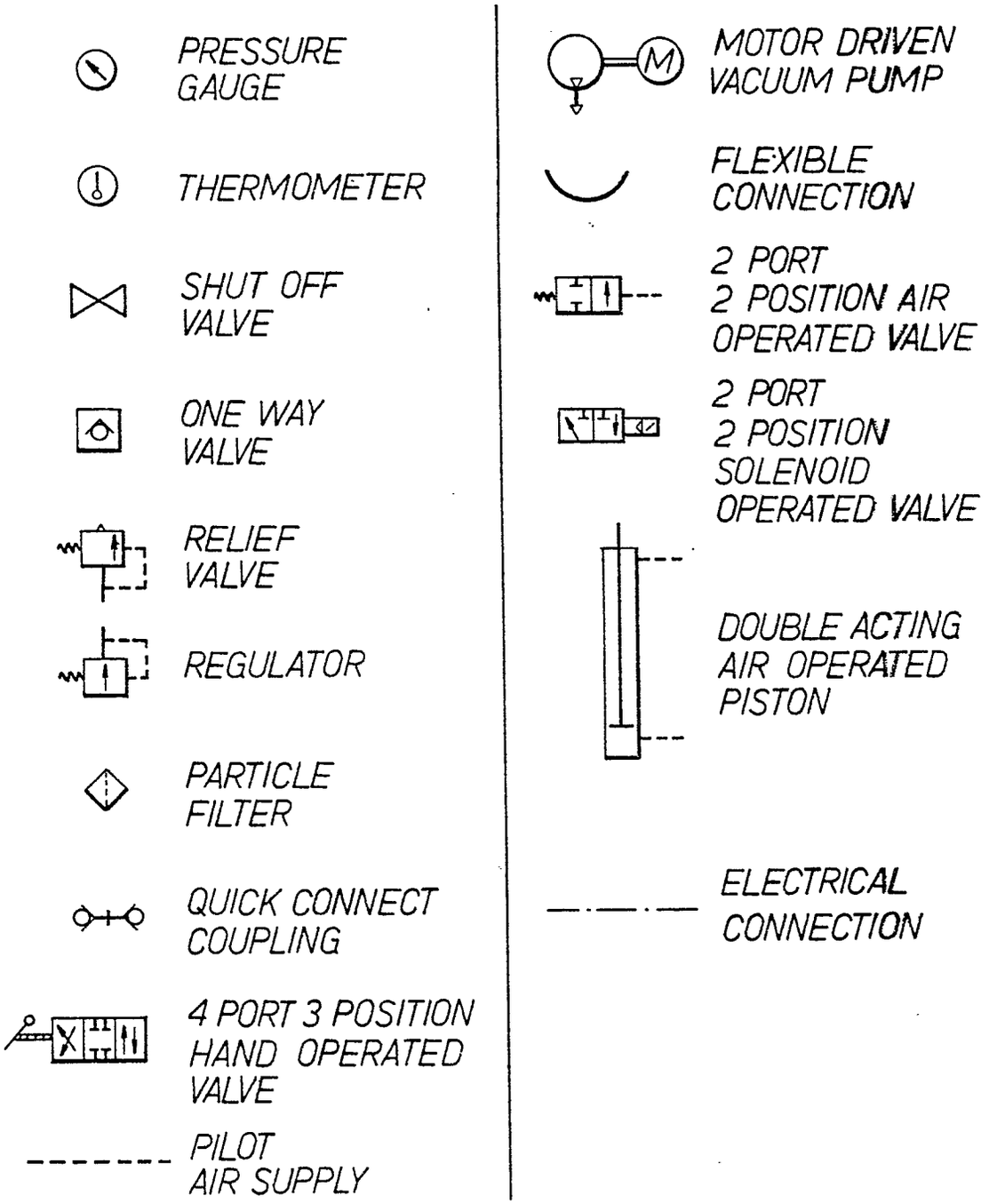


FIG. 2.


PRESSURE GAUGE
THERMOMETER
SHUT OFF VALVE
ONE WAY VALVE
RELIEF VALVE
REGULATOR
PARTICLE FILTER
QUICK CONNECT COUPLING
4 PORT 3 POSITION HAND OPERATED VALVE
PILOT AIR SUPPLY
M
MOTOR DRIVEN VACUUM PUMP
FLEXIBLE CONNECTION
2 PORT 2 POSITION AIR OPERATED VALVE
2 PORT 2 POSITION SOLENOID OPERATED VALVE
DOUBLE ACTING AIR OPERATED PISTON
ELECTRICAL CONNECTION

(LEGEND)

FIG. 3.

European Patent Office

EUROPEAN SEARCH REPORT

0016881
Application number
EP 79 30 0509

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	US - A - 3 210 952 (A.P. STROM) * Column 1, lines 14-18; column 2, line 71 - column 3, line 8; column 4, line 9 - column 6, line 35; column 6, table, line 55; figure 2 *	1,2,7, 10,11, 13,14	F 17 C 5/04 7/02 H 01 H 33/56
A	US - A - 1 906 035 (R.G. WULFF)		
A	DE - C - 718 178 (HESSENWERK RUDOLF MAJERT)		TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
			H 01 H 33/56 33/57 F 17 C 5/00 5/04 7/02 F 25 J 1/02

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	23-11-1979	SIEM

EPO Form 1503.1 08.78