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THE N₂ - SYSTEM OF THE PROPANE BUBBLE CHAMBER

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1. INTRODUCTION.

The bubble chamber has been designed to work within a pressure range from 15 - 35 atm for the compression and 5 - 18 atm for the expansion depending on the liquid which is used, and a cycling rate of 1 expansion every 2 or 3 sec. A membrane separates the liquid from the gas. For moving the membrane nitrogen is used if the chamber is filled with propane and air if it is filled with freon. The gas consumption per cycle is about 1.6 Nm³. To supply the bubble chamber with the necessary amount of gas at the desired pressures, a system, herein called N₂ - system, has been designed which allows high flexibility in pressure range and gas flow.

The N₂ - system consists of five major components : the main compressor, the auxiliary compressor, the N₂ - rack, the regulation rack and the bubble chamber itself. This description will deal with the four first mentioned components. The expansion system of the bubble chamber itself will be described in another note which will particularly deal with the design and operation of the latter.

A diagram of the complete N₂ - system is shown in Fig. 1.

The main and auxiliary compressor are located in the South Generator Building ; the N₂ and regulation rack near the bubble chamber.

2. MAIN COMPRESSOR.

2.1. Characteristics

Capacity	:	2800 Nm ³ /h
Inlet pressure	:	4 atm
Inlet temp.	:	35° C
Outlet pressure	:	44 atm
Outlet temp.	:	140° C
Motor rating	:	400 HP
Revolutions	:	485 min ⁻¹
Diameter cylinder 1st stage	:	300 mm
Diameter cylinder 2nd stage	:	175 mm
Stroke	:	200 mm

2.2. The compressor is of 2 stage double acting type with direct coupled driving motor. The compressor and the pneumatic system of the bubble chamber form a closed circuit in which the inlet pressure of the compressor is kept constant at about 4 atm. Its outlet pressure depends on the total amount of gas present in the system and is set according to the liquid which is used in the bubble chamber. The intermittent gas consumption of the bubble chamber gives rise to pressure oscillations which are smoothed out by pressure vessels on the in- and outlet line and a regulated bypass. This bypass is designed for the full compressor capacity. This means that the compressor can work at full load without bubble chamber.

The gas flows on the low pressure side through a cooler, pressure vessel and filter. In between the stages there is an intermediate cooler. On the high pressure side are a cooler, oil filter, pressure vessel and filter. The gas flow is measured by means of an orifice in the high pressure line. An orifice is also used for measuring the gas flow in the bypass. The pressure and temperature are measured at different points.

For filling the system a connection is foreseen on the high and low pressure side and it can be filled with compressed air from the common supply line or with N_2 from the N_2 - bottles. In normal operation the filling is done automatically. When the pressure in R6 decreases below a given value, the pressure switch PS 4 will open the magnetic valve E 4 through which air from the 8 atm compressed air system through T 39 and T 33 or nitrogen through T 26 and V 9 will flow into the low pressure side of the compressor circuit. When the pressure in R 6 has reached the desired value E 4 is closed. Different devices protect the compressor system against overload, overpressure or overheating, and in case of fault the compressor is switched off.

The electrical and pneumatic regulation and monitoring devices are built in into a common switchboard. This switchboard and the regulation rack are connected with a cable for transmitting signals.

A separate detailed instruction manual for the main compressor is available. (MPS/Int. POW 61 - 7 , 5th May, 1961, by B. de Raad).

3. AUXILIARY COMPRESSOR.

3.1. Characteristics

Capacity	:	32 Nm ³ /h
Outlet pressure	:	150 atm
Motor rating	:	24 HP
Revolutions	:	950 min ⁻¹
Diameter cylinders	:	
1st stage	:	80 mm
2nd stage	:	40 mm
3rd stage	:	22 mm
Stroke	:	80 mm

3.2. The compressor is a 3-stage simple acting type with direct coupled driving motor. A filter is placed in front of the inlet when the compressor operates in open circuit. After each stage there is an air-cooler, a manometer and a safety valve. The manometer after the 3rd stage has a maximum contact. Further protection devices are a pressure switch which controls the oil level for the piston lubrication and a pressure switch which protects the compressor against suction of vacuum.

The purpose of this compressor is filling the N₂ - stock which consists of 78 bottles divided up into 3 batteries with air or with N₂ up to 150 kg/cm². The bottles supply the N₂ - rack for certain purposes with compressed air or N₂ during stanby and operation. They are also used to fill or empty the main compressor system in case N₂ is used.

Separate operating instructions for the auxiliary compressor exist. (NPA/HLBC, Instructions - 1, Meyrin, 8th May, 1961, revised, 17th July, 1963).

4. N₂ - RACK.

4.1. All pressure regulators and valves, which are necessary for the operation of the pneumatic system of the bubble chamber, filters and the electrical gas heater are built into a rack. All the stems of the valves extend through the front panel which shows the flow diagram in different colours.

Between the N₂ - rack and the main recompression reservoir is a heater which is controlled by a thermometer in the gas circuit and a flip-flop, which switches on and off its circuit breaker during variable times. Its purpose is to heat up the gas for the compression-expansion system in order to prevent a cooling down of the bubble chamber during operation.

A filter is placed in each supply line from the N₂ - rack to the bubble chamber.

4.2. All pressures for the bubble chamber are stabilised by pressure regulating valves. The working ranges are :

Barksdale pilots	:	15 - 35 atm
Barksdale compression	:	20 - 40 atm
Main compression	:	20 - 40 atm
Main expansion	:	5 - 18 atm
Barksdale expansion	:	5 - 18 atm

4.3. Manometers are used for measuring the pressure in all important parts of the system. The main compression and expansion pressures are recorded.

4.4. For easier control of the pressures and preventing the pressure regulators from oscillating there are small bypasses which connect the main compression with the main expansion, the Barksdale compression and the Barksdale pilots with the Barksdale expansion. The flow can be controlled by hand operated valves, T 75 to T 77. These are in series with magnetic valves which shut the bypass in case of emergency.

5. REGULATION RACK.

5.1. The regulation rack contains all the pneumatic devices which are necessary for controlling the 5 regulation valves, all the electrical interlocks and also a signal panel which shows the operation of the main compressor. Further there are manometers for the pressure of Barksdale pilots, inner and outer Barksdale compression, main compression, main expansion, Barksdale expansion and expansion volume. By means of differential pressure transformers the differential pressure is measured between Barksdale pilot and Barksdale compression, Barksdale compression and main compression and main expansion and Barksdale expansion.

5.2. Each regulating valve is controlled by a "Messwertwandler" which transforms the high pressure into a proportional lower pressure max. 1.3 kg/cm^2 , a "Sollwertgeber" by which the desired pressure can be set and a "P I Regler" which compares the pressure given by the "Messwertwandler" and "Sollwertgeber". If there is a difference it gives a signal to the "Stellrelais" which opens or closes the compressed air supply line to the regulation valve. According to it the regulation valve opens or closes. The value of the "Sollwertgeber" can be adjusted by hand. Small manometers indicate the pressure after the "Messwertwandler", "Sollwertgeber" and "P I Regler". The "P I Regler" is a pneumatic differential amplifier of which the proportional and integral response can be adjusted separately in order to optimise the performance of the regulating loop.

6. OPERATION OF THE N_2 - SYSTEM.

6.1. General.

Since the maintenance and operation of the main and auxiliary compressor will be done by the powerhouse operators this note will only deal with the operation of the N_2 - rack and regulation rack. For operation of the main and auxiliary compressor reference is made to their special instructions. However, one should always keep close contact with the operators in the powerhouse. When the main compressor is started the valves T 3 and T 4 must be closed and before opening them check that everything is in order on the N_2 - rack. In particular the valves T 50, T 57 and T 58 must be closed.

Before operating a valve, check the condition in which the system is and into which it will come. Check if all other valves are in the correct position. Operate the valve slowly and watch all relevant manometers, to see if the pressure change is the expected one.

6.2. Standby.

During the period when the bubble chamber is heated up, is hot but not in operation or it is cooled down the N_2 - system is put into a stand by condition. During this period there is still need for compressed gas, namely for the pressure equalising system and to keep the main valves G 1 and G 2 on the bubble chamber closed.

The pressure equalising system keeps the pressure in the safety tank always approximately equal to that in the chamber in order to keep the stress on the glass window low. The valves G 1 and G 2 must always be closed, to avoid the loss of liquid in case of breaking of the membrane.

The compressed air is supplied by the N_2 - reservoir, 78 bottles which are divided up into three batteries and placed outside of the South Power House. Two batteries are sufficient as a pressure reservoir, the third should be kept for safety. The pressure in the former two batteries should always be higher than 70 kg/cm^2 . If the pressure drops lower the auxiliary compressor must be started and the bottles filled up again to 100 kg/cm^2 . If there is no possibility to start the compressor, the third battery which always should be at 100 kg/cm^2 can be used.

6.3. Filling of the bottles with air.

Check that the valves T 23, T 25, T 26, T 29, T 30, T 34, T 20, T 22, T 28, T 32, T 35 are closed.

Open T 36, T 37, T 38 on the bottles and T 27, T 24, T 39, T 21.

Start the auxiliary compressor following separate instructions,

When the pressure in the bottles has reached 100 kg/cm^2 (M 40) switch off the compressor and close T 24, T 27 and T 38. The battery connected to T 38 is kept as reserve. Close T 21.

6.4. Supplying the N_2 and propane rack with compressed air for standby.

Check that all valves on the N_2 rack are closed and the propane rack is in such condition that pressure can be put on.

Switch on the voltage for the regulation rack and open the valve which supplies the rack with compressed air from the common line.

Push the reset button on the regulation rack. Since the main compressor is not in operation, and since there is no pressure in the supply line from the auxiliary compressor these two fault signals will stay on.

Check that T 23, T 24, T 25, T 26, T 30, T 32, T 20 are closed.

Open T 27, T 29, regulate the pressure with V 8 about 40 atm, open T 31.

The pipe from the auxiliary compressor supply to the N_2 rack will fill itself.

Check the pressure (M 46). The fault signal PS 2 for lack of pressure in the supply line from the auxiliary compressor must disappear, green light on.

6.5. Putting of the N_2 rack in standby.

The closing of the main valves G 1 and G 2 is achieved by putting a pressure on the pilot volumes of G 1 and G 2, respectively on inner and outer Barksdale (M 16, M 17), which is sufficiently higher than the freon pressure.

Check that T 61, T 62, T 63, T 64, T 65, T 66, T 68, T 69 are closed.
Open T 74, Check the pressure (M 13).

Open T 64 and T 65 slowly, watch the manometers (M 16, M 17). When the given pressure is reached, close T 64, T 65.

When the pressure in the Barksdale reservoirs drops, bring it up again by operating T 64, T 65.

When the pressure in the auxiliary compressor supply line drops below a certain value a signal will be given by PS 2. Check the pressure (M 12) and the pressure on the high pressure side of V 8 (M 40). Start the auxiliary compressor or open T 38, when the pressure difference (M 40 - M 46) is below 10 kg/cm^2 , to raise the pressure in the bottles. If the pressure difference is higher than 10 kg/cm^2 , check the setting of V8.

6.6. From standby to "air-cycles".

"Air-cycles" are intended to check the operation of the N_2 - system and the expansion - system at a pressure lower than the operating pressure, such that limited danger should arise from incorrect operation of any component.

a) Close T 64, T 65, T 74.

Let off the pressure in the collector pipe, by opening T 69 to the exhaust.

Check that manometer M 13 goes to zero. Close T 69.

Check that all valves including V 1, V 2, V 3, P 1, P 2 are closed.

- b) Start the main compressor with T 3 and T 4 closed. When the compressor works alright and the correct pressure on the high pressure side is reached open T 3 and T 4. The signal for compressor fault on the regulation rack must disappear.
- c) Fill the Barksdale expansion reservoir by opening T 58.
- d) Open T 50.
Open T 55 and V 3 Barksdales with the "Sollwertgeber".
Set it for the given pressure.
Open the bypass Barksdale T 76.
Check the pressure and if necessary adjust it.
- e) Fill the main expansion volume by opening T 57.
- f) Open T 56 just a little to prevent overshooting of the regulation valve V 1.
Open V 1, main compression. Caution : OVERSHOOTING
Open the bypass of the main compression T 75 completely.
Adjust the pressure to the given value which should be at least 2 atm lower than the Barksdale pressure.
Open T 56 completely.
- g) Open V 2, Barksdale pilots.
Open the bypass Barksdale pilot, T 77, just a little.
Adjust the pilot pressure 2 atm higher than the Barksdale pressure.
- h) Raise the pressure in the main expansion volume, by adjusting P 1.
The pressure will increase only slowly since the bypass is very small, compared with the volume. Watch the pressures, main compression, main expansion.
- i) To raise the pressure Barksdale expansion, regulate P 2. This pressure should be 2 atm below the pressure of the main expansion.
- j) Switch on the heater if required.

6.7. From "air-cycles" to operation.

Raise inner and outer Barksdales compression pressures.

Raise main expansion pressure.

Raise Barksdale expansion pressure.

Raise main compression pressure.

Raise pilot pressure.

When pressures are stable at the values suitable for the liquid used in the chamber, open T 71 to compress slowly the chamber.

Close T 71.

6.8. From operation to standby.

Switch off the heater.

Close the bypass Barksdale T 76.

Close T 55 and V 3 by turning the "Sollwertgeber" anti-clock wise.

Close V 2, Barksdale pilots.

Close T 56, T 50 and V 1 main compression.

Reduce the pressure in the Barksdale and main expansion volume, by opening P 1 and P 2. This operation should be done very carefully because the pressure in the return line of the main compressor should not rise above 5.5 atm. If it rises higher the compressor will be switched off.

When the pressures for the Barksdale pilot, main compression, Barksdale expansion and main expansion have decreased to 5 atm shut the bypass Barksdale pilot T 77 and main compression T 75.

Close T 57, T 58, check if all valves are closed.

Open T 74, check (M 13).

Switch off the main compressor, close T 3, T 4.

6.9. Shut down.

This means that the chamber is cold and the liquid drained, or alternatively, that the chamber is full and moderately warm, but one is afraid that cracks in the valve membranes could allow a sudden pressure build-up behind the chamber membrane which could damage it when the liquid is removed. One wants to let off the pressure in the N₂ - rack and in the supply and return lines of the auxiliary and main compressor.

Close T 31, T 64, T 65.

Open T 69, T 68, T 67, T 66, T 63, T 57, T 73.

When the pressure is zero, close all valves except T 69.

Open T 64, T 65.

Close T 64, T 65, T 69.

Open T 73, and T 17 in the power house, so that if T 3 would leak this would not lead to a pressure rise in the main supply line.

6.10 Gas heater.

When the bubble chamber runs continuously the temperature of the N_2 heater can be regulated by changing the relation of the "on-off" period of the flip-flop which is inside of the regulation box. Up to $60^{\circ} - 70^{\circ} C$ it is sufficient to leave the "off" period as long as possible and just change the "on" period.

7. FAULTS IN THE N_2 - SYSTEM.

There are three classes of faults :

- a) Faults that are indicated by a flashing red light on the regulation rack and in certain cases by a bell but do not stop the cycle. The red light keeps flashing until the fault is removed. The bell can be stopped by pushing the white "alarm reset" button on the regulation rack.

These faults are :

- i) Main compressor on "no-load" - bell ringing.
- ii) Supply pressure to safety tank low (PS 2) - no bell.

- b) Faults that stop the cycle. They are indicated by a flashing light and in certain cases by a bell. The light keeps flashing until the fault is removed. The bell can be stopped by pushing the white "alarm reset" button on the regulation rack. The operator should decide whether to put the system in emergency.

These faults are :

- i) Main compression stopped - bell ringing.
- ii) Main compressor return pressure high (PS 3) - no bell.

- iii) Air supply to regulation rack low (PS 1) - no bell.
 - iv) Main compression high (M 18) - no bell.
 - v) Membrane pressure high (M 19) - no bell.
 - vi) Membrane pressure low (M 19 A) - no bell.
 - vii) Main expansion high (M 20) - no bell.
 - viii) Main expansion low (M 20 A) - no bell.
 - ix) Barksdale expansion high (M 21) - no bell.
 - x) Barksdale pilot - Barksdale compression difference low (D 1) - no bell.
 - xi) Barksdale compression - Main compression difference low (D 2) - no bell.
 - xii) Main expansion - Barksdale expansion difference low (D 3) - no bell.
- c) Faults that put the system in emergency :
- i) Pushing the emergency button by accident.
 - ii) General CERN power failure. Since all the interlocks of the bubble chamber are connected to the CERN emergency supply one expects the system to be again under control (but in emergency) within a few seconds.

8. EMERGENCY.

8.1. Going into N₂ emergency.

When during normal operation a serious fault occurs on the bubble chamber, for instance indications of possible failure of the membrane, or on the N₂ - system, for instance stopping of the main compressor, one must press the emergency button.

If the emergency button is pressed the following things happen.

The cycling of the bubble chamber is stopped.

The magnetic valves E 1, E 2, E 3, in the bypass lines are closed.

V 2 opens completely since its "Sollwertgeber" is by-passed by the magnetic valve E 5 and full pressure is put on the Barksdale valves to keep the main valves G 1 and G 2 closed.

The pneumatic valve K 2 in the compressor return line is closed.

Within a few minutes after pushing the "nitrogen emergency" button one must close T 56, T 57, T 58 and the bypasses T 75, T 76, T 77. One must also put the cycling control switch on STOP.

8.2. How to control pressures during emergency.

If the pressure in the main compression reservoir decreases slowly, and one wants to keep it constant, one must open T 56 periodically to add some gas. If the pressure behind the membrane drops, and one wants to keep it constant, one should open T 71.

8.3. Starting up of the compressor in emergency.

If the reasons for the emergency is that the compressor has stopped close T 4 and check what has caused the fault.

- a) When the fault is such that the compressor can be started again, check that the pressure in the main return line (M 45) and at the compressor inlet (M 4) is not higher than 5 kg/cm^2 .

If the pressure of M 45 is too high, one can blow it off through T 17.

If the pressure of M 4 is too high, close T 14, open T 18 until the pressure has decreased to 4.5 kg/cm^2 , close T 18 and open T 14. This is necessary to avoid to bleed all the gas of R 6 through the bypass V 5.

- b) When the fault is such that the compressor cannot be started put the system on standby.

8.4. Restarting normal operation from emergency.

- a) Cycling control switch on STOP.
- b) Open T 57, T 58 slowly, pay attention to the pressure in the return line.
- c) Open T 76 (Barksdale bypass).
- d) Push the "reset" button on the regulation rack.
- e) Open T 77 (pilot bypass).
- f) Open T 56 just a little. Caution: OVERTSHOOTING.
- g) Open T 75 (main compressor bypass).

- h) When the pressures are stable, open T 56 completely.
- i) Reduce the pressures in Barksdale compression reservoirs, by opening T 69, T 64, T 65, to the value of M 22.

8.5. Important !

In case the chamber membrane is broken, or shows to be about to break, keep the N_2 - system in emergency with the compressor running, until other orders are given.

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Revised on 15th July, 1963 by P. G. Innocenti

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