CHAPTER 12

Auxiliary Equipment

Introduction

The auxiliary equipment for the mechanical systems in water power plants comprises

- oil pressure system
- air pressure supply system

12.1 Oil pressure system

The oil pressure system has to supply pressurised oil energy for the turbine governor system[/1/,/2/]. Different types and sizes of these systems are in use and they exist for pressures between 25 and 40 bar. The pressure tank which is designated accumulator, is of the oil-air type for pressures of these levels.

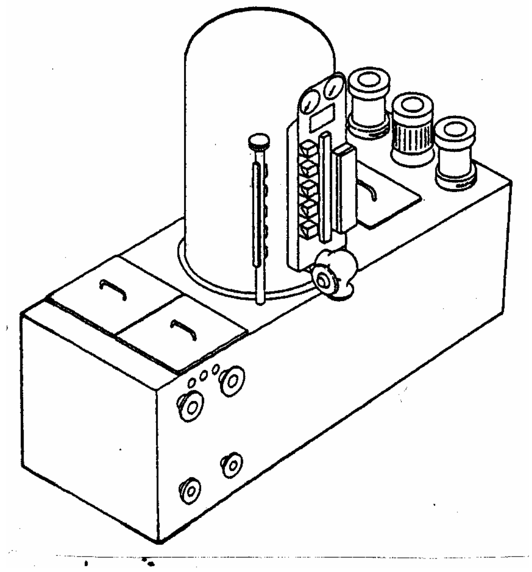

Fig.12.1 Oil pressure system, 40 bar design pressure of the air/oil pressure accumulator /2/

Some small governor systems have been designed also for operation at oil pressures as high as 100 bar. In this case the oil and air in the accumulator must be separated. The usual applications then are off the shelf bladder or piston accumulators. The limitation in the design of these higher oil pressure systems is not only the accumulator size but also the availability of big size control valves.

Oil pressure systems for operation of the shut off valves in main water conduits to the turbines are also found as optional installations in some power stations. These are however, simple power packs which are individually dimensioned and installed for the respective valves. Such power packs are not further described in this book.

An oil pressure system for 40 bar[/2/] which is common and up to date for medium and big size turbine governors, is described in the following section. Fig. 12.1 gives an overlook of a such oil pressure system.

12.1.1 System construction

A general function diagram of the oil pressure system[/2/] is shown in Fig. 12.2. The corresponding hydraulic circuit diagram is shown in Fig. 12.3.

The main components can be summarised as follows:

- oil sump tank
- switches and indicators
- accumulator, e.g., oil pressure tank
- oil pump units
- unloader valve
- check valves
- main oil valve
- relief valve
- oil cooler

Fig. 12.2 Oil pressure system. Function diagram /2/

General

The accumulator is filled with oil and air under pressure. This energy storage allows a short time high oil consumption which is much higher than the capacity of the oil pumps.

The energy storage is also sufficient for the oil consumption during a stop sequence of the turbine unit without the oil pumps in operation

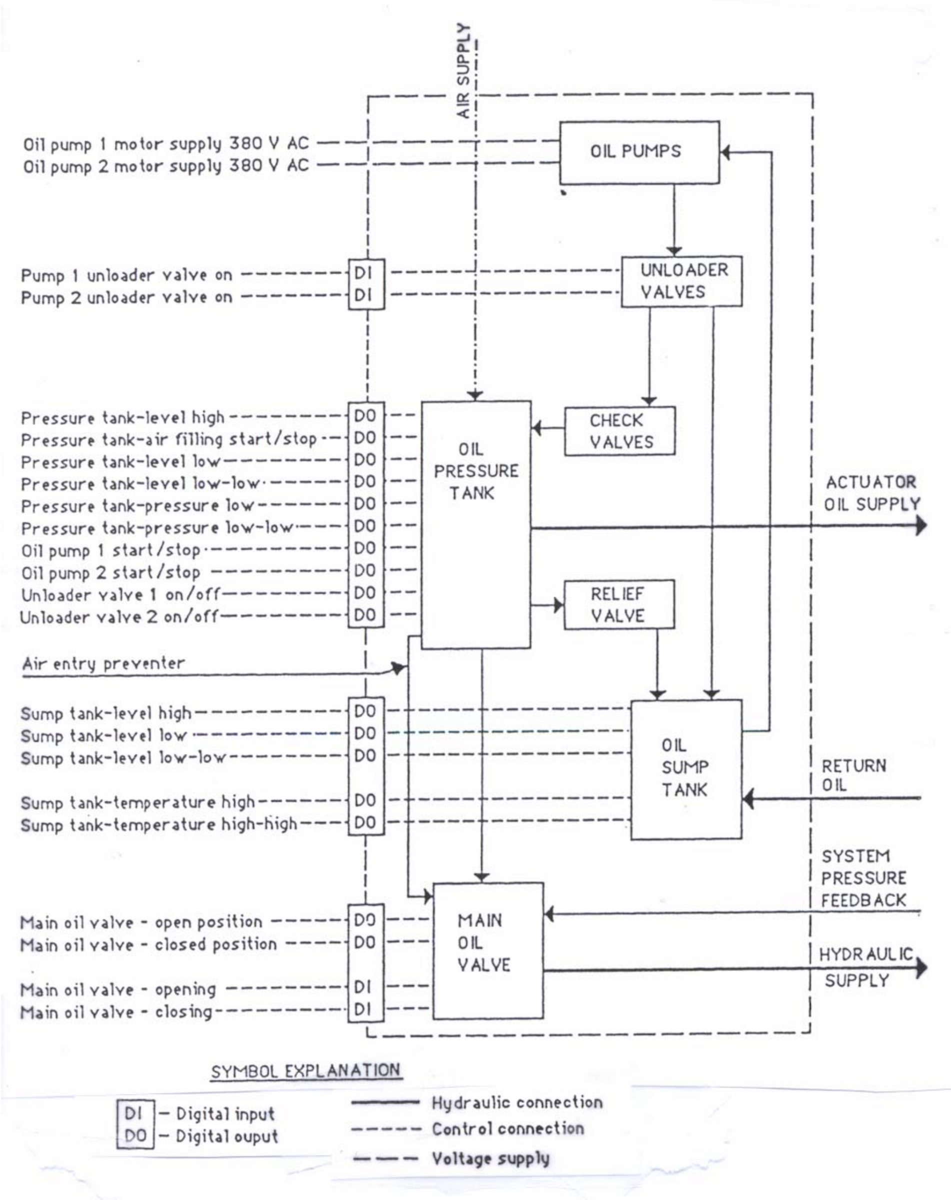

Fig. 12.3 Oil pressure system. Hydraulic circuit diagram /2/

The system is designed for a maximum working pressure of 40 bar.

An oil cooler may be connected to the oil return line.

The system is designed for complete remote control with necessary indicators and signal transmitters for safe operation.

Oil sump tank

The oil sump tank is designed with a volume sufficient for the amount of oil in the system. The tank has inspection openings to give access for service and routine inspections.

The oil sump tank contains a special arrangement with strainers to ensure deaeration of the oil. The separation of air entrapped in the oil prevents rapid oxidation and ensures long service life of the oil and also of the components in the system.

Accumulator

The accumulator is mounted on the top of the oil sump tank. A man hole gives access for inspection and service.

The oil level in the tank is controlled by refilling of compressed air. Correct oil level is important to obtain necessary energy storage and necessary amount of oil. Refilling of air is necessary because that pressurised oil absorbs air linearly dependent on the pressure. The absorbed air releases from the oil during the passage of the oil sump tank.

Oil pump unit

The oil pressure system is equipped with two equal oil pump units.

Each pump unit consists of a screw pump, flexible shaft coupling, distance piece, tube/fittings and an electric motor. It can be removed as a separate unit for overhaul. One pump unit may even be dismantled for service and overhaul when the turbine is operating.

The pump is of the self priming positive displacement type. The main parts in the pump are the three rotating screws, e.g., one power rotor and two idler rotors. The power rotor is the only driven element and the idler rotors turn due to the action of the driven rotor. Their thread surfaces are shaped to form a tight seal both in relation to each other and the surrounding rotor housing. The fluid is transported axially and quite uniformly according to the screw rotation.

The pump units are equipped with a fluid trap on the suction side to ensure that the pump remains filled with oil in the stand by mode. This fluid trap shall be filled with oil before the pump is started after overhaul.

The oil pump units are driven by alternating current (AC) motors.

An oil pressure system with two pump units has one pump running continuously while the other pump is in stand by. The stand by pump will start automatically at low pressure in the accumulator. The control of the oil pump units permits the selection of either pump as the preferred unit.

As an option a direct current (DC) motor driven oil pump can be supplied.

A DC motor driven pump is operating only if the AC supply fails. The pump will then start and stop via a pressure switch control which keeps the pressure below but close to the normal oil pressure.

Due to the pump start and stop automatic control the DC motor driven pump unit has no unloader valve system.

Unloader valve

The unloader valve is installed to prevent a fast degradation of the oil quality. A relatively fast degradation will happen if the relief valve (11), Fig. 12.3, is in continuous operation and thereby cause unwanted oxidation and cavitation.

The unloader valve pos. (6) on Fig. 12.3, is installed in the pipeline between the oil pump unit and the inlet check valve of the accumulator.

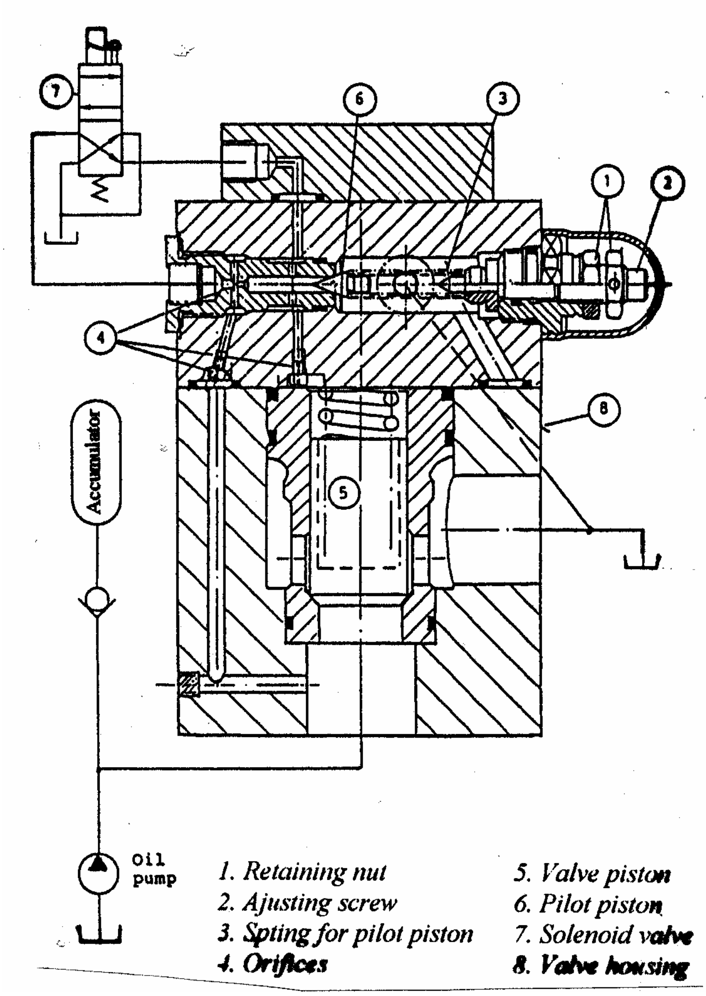

Fig. 12.4 Unloader valve /2/

The design of an unloader valve is shown on Fig. 12.4. This valve is operated when the solenoid valve (7) is being activated by a pressure switch.

At low pressure in the accumulator, the oil is fed from the pump to the accumulator. As soon as the oil pressure has reached the upper set point, the pressure switch activates the unloader valve. The pressure on the top of the unloader valve piston is then decreased, the piston moves upwards and the oil flow is led to the oil sump tank.

In this mode the pressure in the accumulator will decrease due to the oil consumption in the governor system and no oil supply from the pump. When the pressure reaches the lower setting level, the solenoid valve closes. The pressure on each side of the valve piston equalises and the unloader valve closes due to the force from the spring in the valve piston.

The unloader valve works only when the oil pump is running.

Energy is saved as long as the unloader valve delivers the oil directly to the oil sump tank. The unloader valve also reduce the demand for cooling of the oil.

The unloader valve may also be operated as a pilot controlled pressure relief valve.

Check valves

Between each oil pump unit and the accumulator a check valve is installed as shown on Fig. 12.3. These valves prevent pressure oil to flow back to the oil sump tank through the oil pump.

The valve piston is spring loaded to ensure that the valve is closed during pressurising the oil pressure system. The oil pump unit, the oil pipe and other equipment between the pump and check valve may be dismantled without depressurising the accumulator.

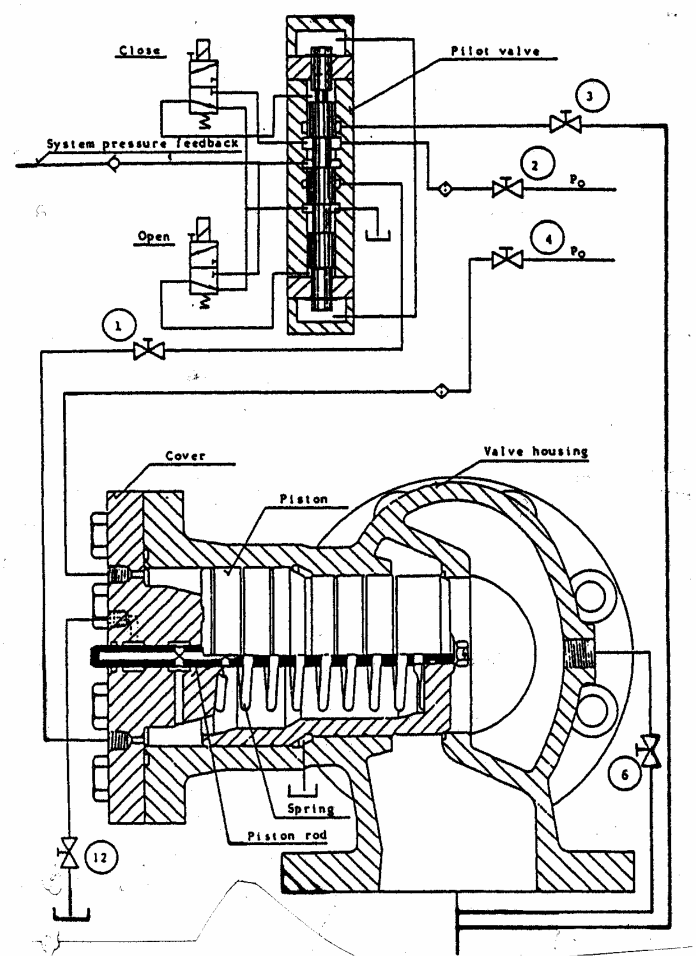

Fig. 12.5 Main valve with pilot valve (schematically drawn) /2/

Main oil valve

The main valve (12) on Fig. 12.3, is the shut off valve between the accumulator and the main oil piping system.

The design of the main oil valve is shown on Fig. 12.5. The closing/ opening member is a differential piston. For equal hydraulic pressure on the two sides of the piston, the valve therefore remains in closed position. Also at zero pressure on the piston sides the valve is kept closed due to the spring force.

Opening and closing of the main oil valve is controlled by the pilot valve. This valve drains or pressurises respectively the piston chamber.

This opening and closing sequence can be done by remotely controlled solenoid valves.

The main valve will be closed automatically at critical low oil level in the accumulator to prevent air from entering the main piping system. This process occurs independent of the manual or automatic sequence control

Manually operated valves are supplied for the by-pass function (6) on Fig. 12.5, and for the opening and closing sequence.

Relief valve

The relief valve (11) on Fig. 12.3, protects the accumulator against unintended high pressure. The design of the valve is shown in Fig. 12.6.

The relief valve shall not open before the pressure in the accumulator exceeds normal working pressure.

The oil begins to flow through the valve when the oil pressure on the lower side of the valve piston balances against the spring pressure.

The design of the valve with a long coil spring and a large valve piston gives a very accurate flow - pressure characteristic. The valve is adjusted by turning the top cover.

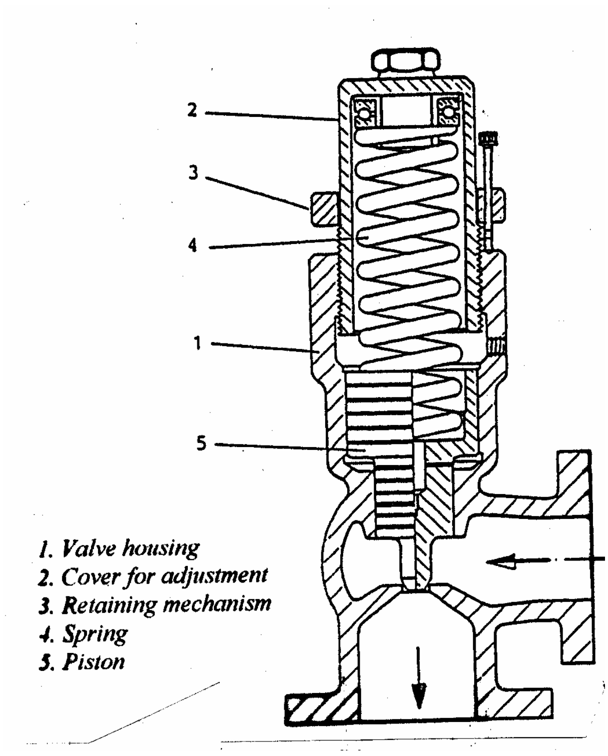

Fig. 12.6 Relief valve /2/

If the oil pressure system has no unloader valves or if the valves are out of function, the relief valve can work as a pressure control valve.

Oil cooler

The hydraulic circuit diagram Fig. 12.3 shows the cooling principle for the oil pressure system. The cooling is being done in the return line. Some oil pressure systems do not need oil cooling when the temperature conditions are favourable.

Cleaning of the internal cooler surfaces which are in contact with water, can easily be done by removing the end covers. This may be done during normal operation of the system.

Oil temperature control is accomplished by a thermostatic valve. An automatic control as well is applied. It is based on the oil temperature being sensed in the sump tank to control the water flow through the oil cooler in accordance with the adjustable temperature setting on the valve.

12.1.2 System operation

Opening sequence

The main valve shall not be opened without a preceding careful pressurising and deaeration of the main piping system[/2/]. The pilot valve has this function. When the solenoid valve for opening is activated, the spool in the pilot valve moves to the first stage and oil passes through the by-pass line (3) to the main piping system.

As soon as the system pressure feedback in the main piping system is high enough, the spool in the pilot valve moves to the second stage, the piston chamber in the main oil valve is then drained and the main oil valve opens. In open position the piston chamber will remain drained through the bore in the piston rod. The control voltage to the solenoid valve is switched off and the spool in the pilot valve will move back to the neutral position.

The limit switch on the main oil valve indicates open and closed position.

Closing sequence

When the solenoid valve for closing is activated, the spool in the pilot valve moves to the closed position. Pressure oil flows to the piston chamber in the main oil valve. Together with the inlet oil through pipe (4) the necessary pressure is being built up to close the valve. In closed position the outlet from the valve chamber will be closed and the control voltage to the solenoid is switched off. The spool in the pilot valve moves back to neutral position.

Automatic emergency closing

The orifices in the inlet pipe (4) and outlet pipe (12) in Fig. 12.5, respectively are adjusted so that the main oil valve closes if the oil level in the accumulator becomes extremely low.

Emergency closing

By closing the manually operated valves (1) and (2) in Fig. 12.5, respectively, the outlet from the piston chamber is being closed, the oil pressure increases and the main oil valve closes.

Instrumentation

The oil pressure system is designed for complete remote control with necessary indicators and signal transmitters for safe operation according to up to date standards.

The function diagram Fig. 12.2 shows all in and out going signals and power supply.

The hydraulic circuit diagram Fig. 12.3 shows the instrumentation and the control functions.

Precautions to be taken by start at zero pressure

The oil level in the sump tank has to be checked.

Manual valves for pressure gauge, pressure switches, air supply and pressure to closing side of the main valve piston are to be opened.

Manual valves for air draining, oil draining, pressure to actuator and manual by-pass are to be closed.

One oil pump unit has to be started and run until the oil level can be seen at the lower end of the level indicator.

Air pressure is to be supplied until approximately 2/3 of nominal pressure p_o is reached. It must be checked that the level in the oil sump tank is not too low. One oil pump unit is then started and run until correct level in the accumulator is reached.

Nominal pressure is obtained by filling or draining of air.

Before switching to automatic operation the relief valve, the unloader valves and the instrumentation have to be checked and adjusted if necessary.

12.2 Air supply system

The air pressure system serves to refill the accumulator in the oil pressure system with air.

The air in the accumulator is in direct contact with the oil. With pressurised accumulator, the oil absorbs air linearly with the pressure. In the sump tank the absorbed air releases again during the pressure relief to atmospheric pressure. This process however, takes some seconds to be fulfilled, but the passage time for the oil flow through the sump tank is longer than for the air release process

A function diagram of a typical air pressure system[/2/] is shown in fig. 12.7. The corresponding pneumatic circuit diagram is shown in fig. 12.8. The system shown is designed with two

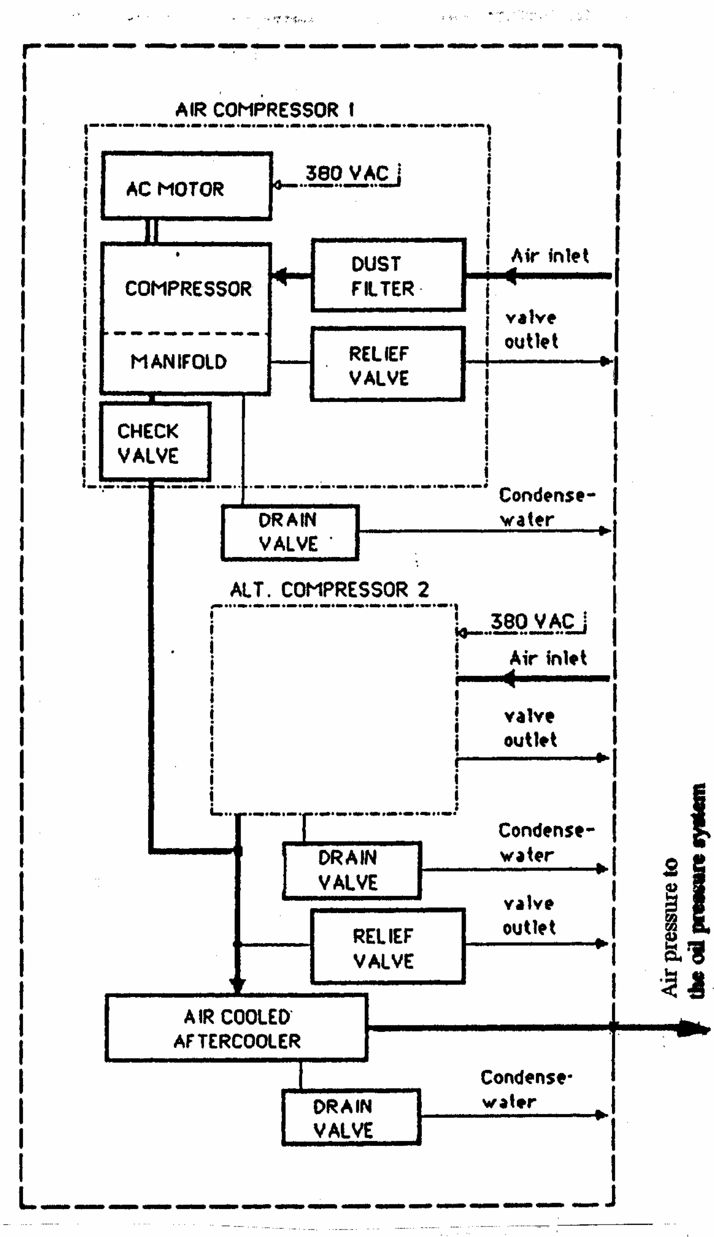

Fig. 12.7 Function diagram /2/

compressors. However, systems with only one compressor are common as well.

The main components are:

- one or two AC powered high pressure air compressors with inlet filter
- relief valve mounted on the compressor
- air cooled aftercooler with condensate trap
- valves

The start and stop of the refilling cycle is controlled by a level switch on the accumulator.

To avoid short cycles for start and stop of the compressor, the stop command is normally delayed to obtain a minimum of working time. This logic is a part of the main control system.

The compressor utilised for the air supply system is an air cooled two stage compressor. Fig. 12.9 shows the compressor with motor assembled on a subbase.

The condensate trap on the compressor is equipped with a manual or automatic drain valve for drainage of condensate.

An air-cooled aftercooler is normally installed on the tube between the compressor and the accumulator equipped with a manual or automatic drain valve.

A relief valve on the compressor is a system protection and is adjusted below the maximum allowable pressure of the system.

Air pressure systems with two compressors are equipped with two level switches on the accumulator. The level switch for compressor 1 is placed at normal oil level and the one for compressor 2 is placed 50 to 150 mm above the normal oil level making compressor 2 to start only if the system for compressor 1 is failing.

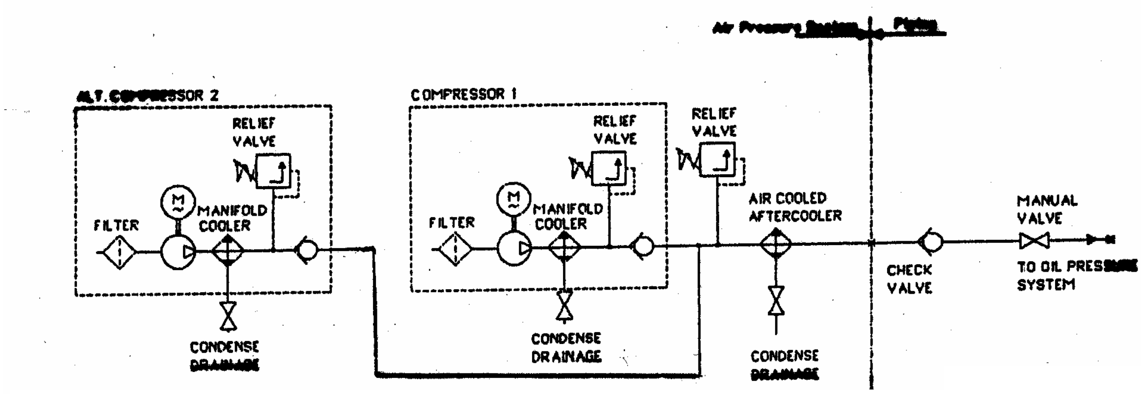

Fig 12.8 Pneumatic circuit diagram /2/

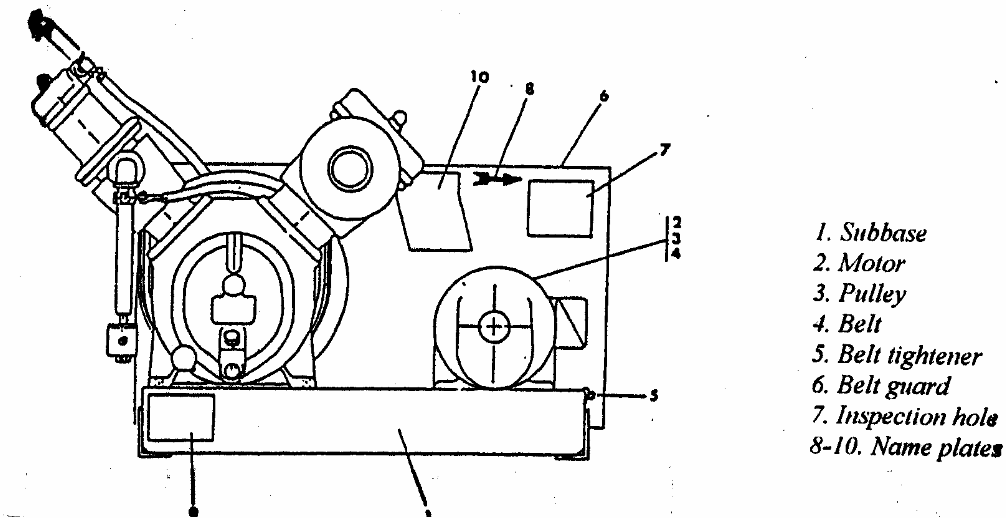

Fig. 12.9 Compressor /2/

References

1. Condition Control of Hydropower in Norway: Handbook – Governor (in Norwegian).
2. Kværner Brug: COURSE III, Lecture compendium, Oslo, 1986.