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Sectional Centrifugal Pump with Air-Cooling Oil System

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***Abstract* — The article considers sectional centrifugal pump (SCP) designed to pump liquids into the reservoir to maintain reservoir pressure. The article justifies the use of air-cooling of the oil system of the pump major nodes, which decreases the material and energy costs and reduces the repair time of the cooling system.**

Keywords* — *modular injection station; sectional centrifugal pump; oil cooler; air-cooling; blower.

I. Introduction

At present, oil field exploitation using oil reservoir stimulation techniques to increase oil production, in particular, the flooding of oil reservoirs, has been successfully introduced. For this purpose, modular cluster pump stations (MCPS) are mainly used. MCPS units are produced and equipped with all necessary equipment at manufacturing plants. The units are sized so that they can be transported by common transport. The installation of unit equipment is 8-10 times less time-consuming than the construction of permanent structure [1-2].

Modular cluster pump station (MCPS) consists of the following units: pumping unit, low-voltage apparatus, control unit and comb. Each of the units has a foundation bed, where the whole complex of equipment and shelter is installed. Some equipment, e.g. some high-voltage equipment, is installed without shelter, if the installation and operation conditions and safety requirements allow. MCPS are equipped with SCP (Figure 1). Supply of modular cluster pump station with SCP pumps can reach 160000 m^3/ day [3-5].

II. Methods and materials

To ensure proper pump operation, the construction includes an oil system to lubricate the pump shaft bearings.

When in real exploitation, almost all the shaft bearings of the pump become defective due to various factors:

- incorrect choice of shaft bearing construction,
- lack of concentricity between the guide pulley and the pump itself,
- shaft deformation,
- unbalancing of rotating parts and nodes,
- changing the shaft geometry due to thermal effects,
- cooling of the shaft bearings by splashing water on the shaft bearing body, which is a senseless, as it leads to the drying of the lubricant layer of the shaft bearing and deterioration of its parameters, as well as to the increase of the friction coefficient and additional load on the shaft bearing,
- cavitation attack,
- intermittent changes in water flow pressure,
- axial pressure,
- changing the shape and size of the bearing body,
- all kinds of vibrations,
- long distance between impeller and bearing,
- faulty shaft bearing installation.

If the load capacity of the shaft bearing is exceeded, the shaft bearing starts to become very hot, and heating itself is a common cause of the early failure of the shaft bearing. The reduction in the viscosity of the lubricants during the heating process leads to a loss of the load capacity of the shaft bearing.

The designers of the shaft supports state that the service life of the oil in the shaft bearing in most cases depends on the thermal impact.

Clean oil does not dry out and its useful life is almost thirty years at 30^0C., meanwhile an increase in the oil temperature of 10^0C reduces the service life of the oil by half. This means that oil temperature monitoring is crucial when trying to increase the service life of the shaft bearing. The main reasons of the early failure of the shaft bearing are foreign liquids and mechanical impurities. Practice shows that with 0.002% water in the lubricant, the service life of the shaft bearing is almost halved, and the presence of 6% water in the oil reduces the service life by 80%.

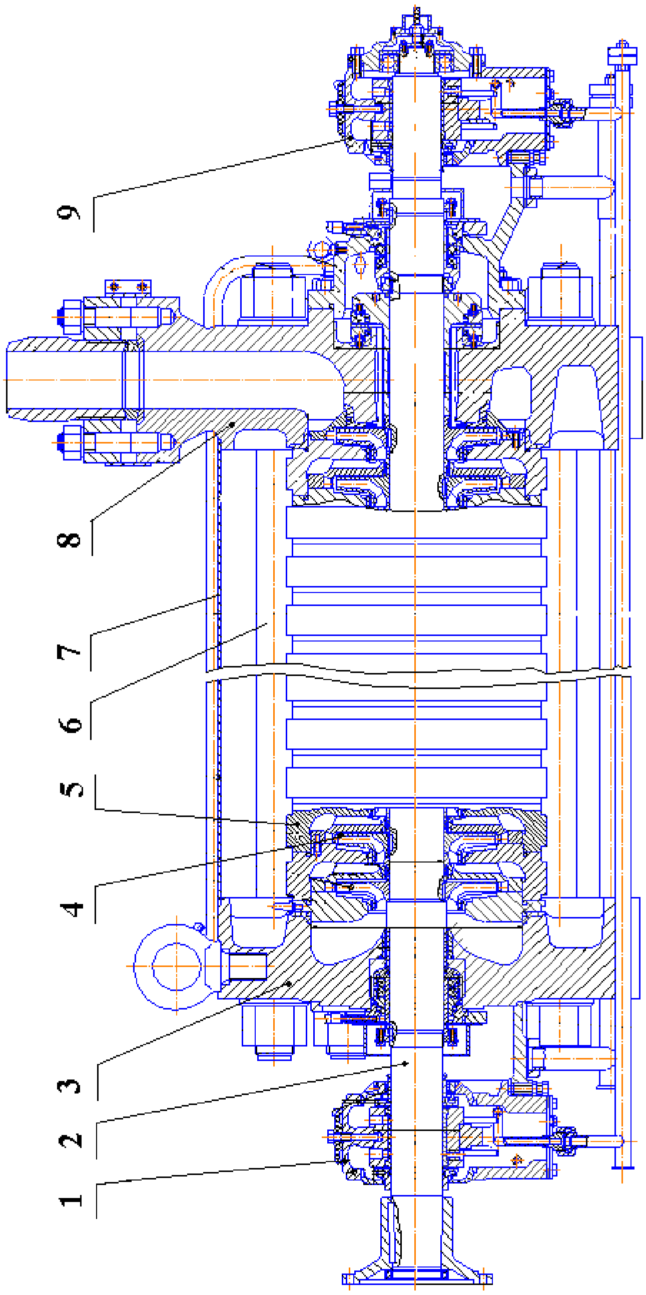

Fig. 1. Sectional centrifugal pump: 1 – shaft bearing; 2 – shaft; 3 – suction bonnet; 4 – blower; 5 – guide apparatus; 6 – locking pin; 7 – guard; 8 – discharge bonnet; 9 – shaft bearing

According to the current schemes of thermal agents in oil coolers, cooling systems are classified into three groups: 1) with a constant temperature of both thermal agents; 2) with a constant temperature of one of the thermal agents; 3) with a variable temperature of both thermal agents.

By directions, the flows are divided into: 1) forward flow; 2) backflow; 3) cross flow; 4) mixed flow.

By the heat agent, cooling systems are classified into: 1) oil-water cooling system; 2) oil-air cooling system.

Oil-water circulation cooling is used in modern designs of pump units such as SCP. The pump cooling system includes one or more oil coolers, electric pumps and a piping line.

The whole system is installed in a special closed space with an internal temperature of at least 0°C in winter to protect the water from freezing. The pump cooling system provides free flow and access to various nodes to conduct repair and revision works. An oil-conducting line is made as short as possible, without sharp drops and local hydraulic resistances, in which air could be formed. If such spots do exist, they are equipped with air vent plugs to remove the "air bags". In order to reduce the hydraulic resistance in the oil line, the number of slide valves and flange connections must be limited.

The SCP pump bearings are lubricated with a ring lubrication system. Cast iron rings, rotating together with the shaft, grip oil from the bearing crankcase (crankcase volume is 1.5-2 dm^3). The oil in the crankcase is cooled down through the oil cooler, which is cooled by fresh water in its turn, installed in the territory of MCPS, and then comes back to the main oil tank.

The oil circulation is carried out by oil pumps connected to the electrical drive shaft by means of a clutch. Heated oil flows into the oil tank after the SCP pump shaft bearings and its electrical drive, then the oil flows through the oil cooler, cools down there and then flows to the SCP pump. In order to pump oil through the cooler and thus overcome its resistance as well as the resistance of the entire system, the pump is installed in front of the oil cooler, i.e. the pump delivery pipe faces the oil cooler. This also allows the oil pressure in the oil cooler to exceed the water pressure in the oil cooler, in order to prevent water from entering the oil in case of small, so called "hair" cracks in the oil cooler pipes. The oil overpressure under the water pressure is accepted within the range of 0.07...0.15 mPa.

The oil cooling is based on the "backflow" method, i.e. oil and water in the oil cooler are moving towards each other. Heated oil enters the top of the oil cooler, passes through the space between the pipes and comes out of the bottom of the oil cooler. The water, on the other hand, enters the bottom of the upper part of the oil cooler, rises through the pipes upwards and comes out of the top of the oil cooler.

There are two-way coolers on the water side: the water enters the lower part of the cooler, rises in the first compartment through the pipes up, into the upper water box, and enters the second compartment pipes, going down again, and then comes out of the branch pipe, located next to the inlet pipe. Cooling water supplied to the oil cooler must be free of mechanical impurities (sand, gravel, etc.) and chemicals (salts, alkalis, etc.). When supplying water with a pressure of about 0.1 mPa from the water supply network, no special pumps for pumping water are required.

The oil system includes a working oil pump NMSH-25-3,6/4 installed on the oil tank with the flow rate of 3,6 m^3/h and the discharge pressure of 0,4 mPa. NMSH-25-3,6/4 pump has the AOL2-31-4 electric motor; BM-0,32 oil tank with the capacity of 0,32 m^3; MH-4 oil cooler with the cooling surface of 4 m^2; double FDM-32 oil filter with the filtration surface of 0,13 m^2 and the throughput capacity of 7,4 m^3/h; safety valve and isolation valve.

Lubrication of the slide bearings is fored, it is carried out by the pressure lubrication installation. The pump unit has a ring bearing lubrication. Lubrication of clutches of the pump is consistent. The bearings are lubricated with turbine oil Tp 22, that can be replaced by the turbine oil T22, T30 and industrial oil I20A, I25A, I30A. Lithol 24 or CIATIM-221 [6] are used to lubricate the clutches.

The water cooling system provides water supply to the oil cooler MH-4, cooling and packing box when operating at less than atmospheric inlet pressure. The water consumption for the oil cooler is 6 m^3/h, the same amount of water is used for cooling and packing box [4]. In a pumping unit with ring lubrication of the slide bearings, the cooling water consumption is 7 m^3/h. The pressure lubrication installation includes an emergency tank and two gear pumps NMSH-5-25-3,6/4-5 (one of them is a backup pump) with the electric motor 4AH80V4UZ, installed on a common bedplate [7-8].

In a closed circulation, the oil has a significant heating effect, which has an adverse impact on the system as a whole. To reduce the temperature in the oil system, a liquid oil cooling system is used. A ring lubrication system is used to lubricate the SCP pump bearings.

Cast iron rings, rotating together with the shaft, grip oil from the bearing crankcase (crankcase volume is 1.5-2 l). The oil in the crankcase is cooled down through the oil cooler, which is cooled by fresh water in its turn, installed in the territory of MCPS, and then comes back to the main oil tank. Practice shows that the company bears significant operating costs when servicing this system [9-10].

III. Results and Discussions

The technical measure is aimed to replace the liquid oil cooling system with the air system, which has a number of advantages, such as: reduction of material consumption, energy consumption, occupied surface area, better installation capacity, increase of pump service life.

The improvement of the construction requires the replacement of the usual cooling system of the lubrication system (bearing node) by fresh water with the air cooling system (Figure 2). For this purpose, the hydraulic piping system is dismantled. Instead, it is replaced by an industrial airmover, and an air duct system, and the inlet elements of the oil cooler are changed. For this purpose, the hydraulic piping system is dismantled. Instead, it is replaced by an industrial rotary blower and air duct system, and the inlet elements of the oil cooler are changed.

Oil-air cooling is an effective way to cool the oil in SCP-type pumps with forced oil circulation and oil cooler of blowers (Figure 3).

Blowers installed on the oil cooler direct the airflow through it. The number of oil coolers installed in the system depends on the rated capacity of the system or the amount of deprivations in it. The system is very efficient. This is achieved through the high oil speeds and relatively high cooling air speeds (Figure 4).

However, when the blowers are switched off, the cooling efficiency is insignificant due to the high aerodynamic resistance of the oil cooler. This means that, regardless of the load, even when idling, a certain number of blowers and pumps for air supply and oil circulation must be switched on. Due to the high efficiency of the air-cooled oil coolers, its use reduces the weight, size and cost of the cooling system.

The oil cooler consists of several lines of pipes, welded or rolled into tube sheets. At the top and at the bottom of the coolers there are oil boxes with pipe junctions. An electric pump is connected to the pipe junction of the upper box and a jet relay is connected to the pipe junction of the lower box. Axial blowers are installed on the brackets mounted on the cooler. In most cases, the cooler is supplied with three blowers with airflow diffusers (Figure 5).

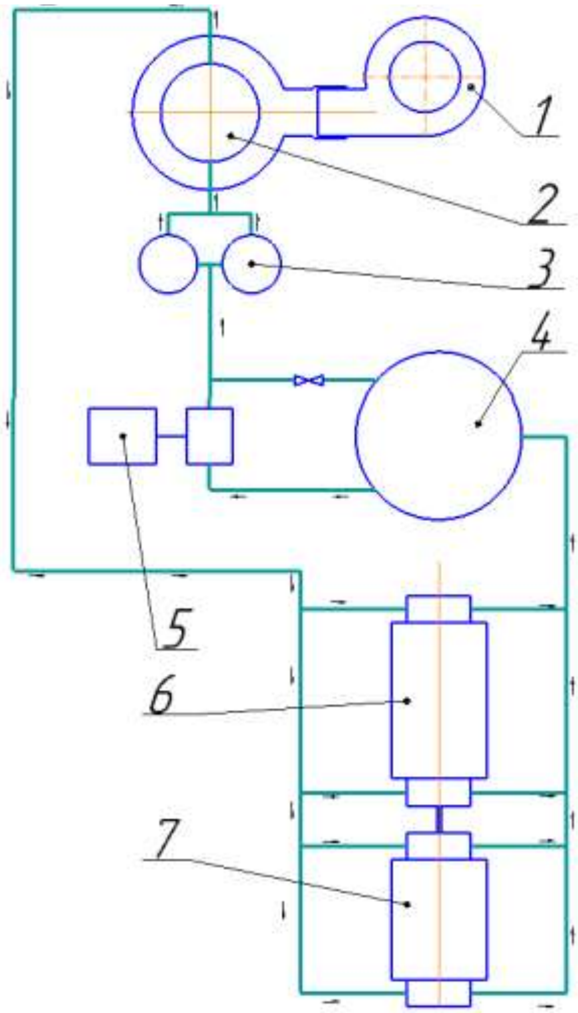

Fig. 2. SCP pump unit with air-cooled oil system: 1- blower; 2 – oil cooler; 3 – oil filter; 4 – oil tank; 5 – oil pump; 6 – SCP pump; 7 – SCP pump driver

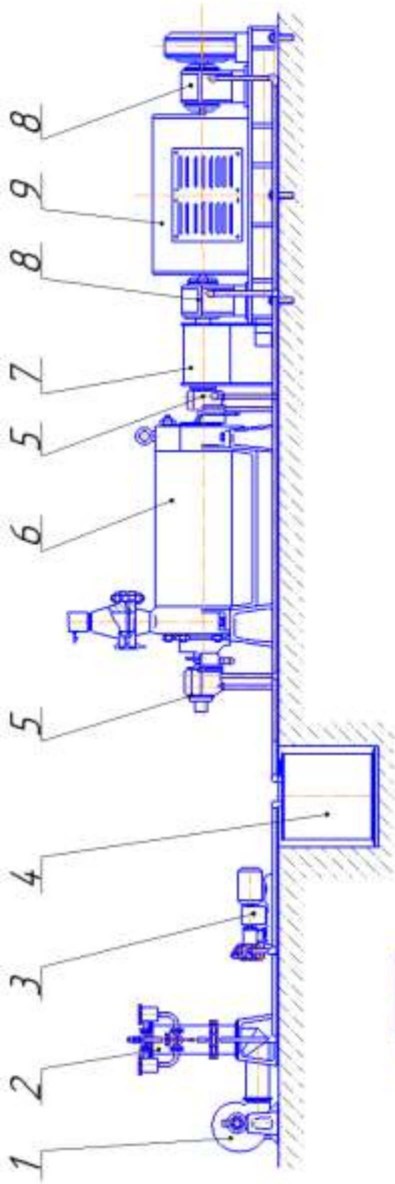

Fig. 3. SCP pump unit with air-cooled oil system: 1- blower; 2 – oil cooler; 3 – oil pump; 4 – oil tank; 5 – SCP pump bearing; 6 – SCP pump; 7 – clutch; 8 – SCP pump driver bearing; 9 - SCP pump driver

The oil in the cooler is circulating through the pipes. In order to create a large cooling surface with relatively small dimensions of the cooler, the tubes are finned.

Various finning constructions are used: thin steel plates with 2.5 mm pitch are placed on the steel pipes; winding on pipes, i.e. steel pipes, wrapped with a thin steel band of 10 mm width, which is welded to the pipes; other winding on steel pipes, but with a rolling on of a wire spiral made of steel wire with a diameter of 0.5 mm and spirally rolled pipes, i.e. aluminium pipes, on which fins of 10 mm height are also being cut (rolled) on a special machine. Winding the wire on the pipes is the most advanced way of the finned pipes producing.

The inner diameter of the pipes does not exceed 20 mm; the thickness of the pipes is 1.5-2 mm. The use of small diameter tubes has been made possible by the forced circulation of oil in them. Intensive blowing of the cooler allows to use a small pitch of fins of 2.5-5 mm. The sum of the outer surfaces of the finned pipes represents the full cooling surface.

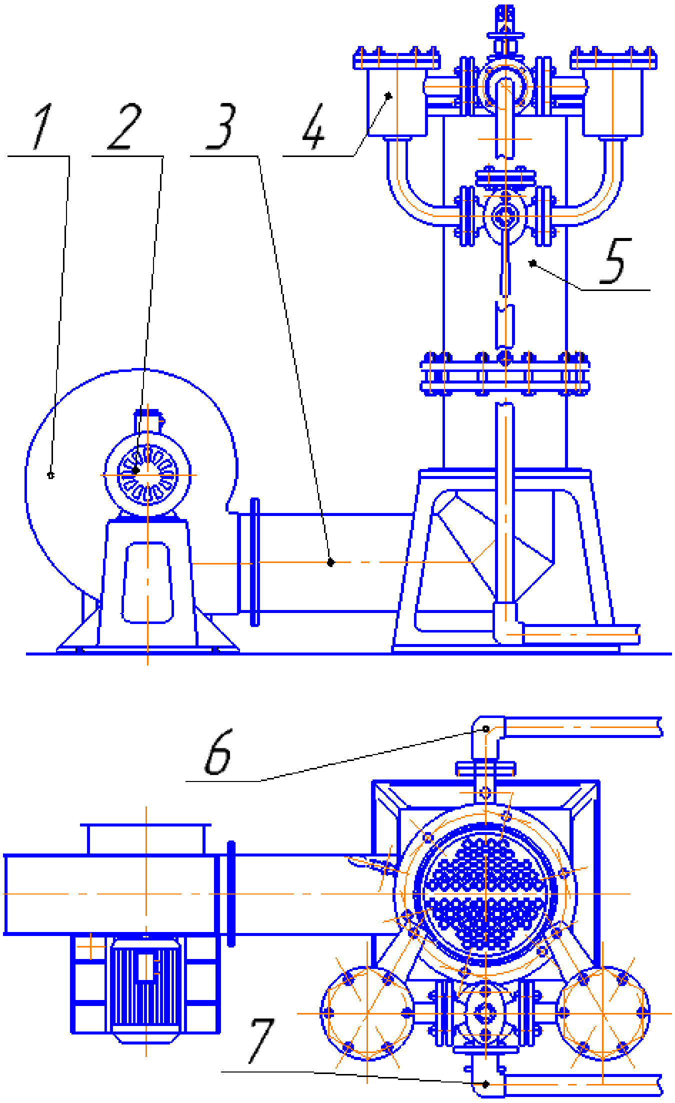

Fig. 4. Air cooling system of the oil system of the pump unit: 1- blower; 2 – blower driver; 3 – air piping; 4 – oil filter; 5 – oil cooler; 6 – oil pipeline (exit); 7 – oil pipeline (entrance)

The SCP pump unit can only be serviced if it is used as intended. When used, it is necessary: 1) to monitor the temperature of the pump shaft bearings, which should not exceed 80°C. The applicable registration devices are temperature relays RT3033; 2) to maintain the required amount of lubricants in the shaft bearings, to clear periodically from lubricants, wash and fill with fresh lubricants the body of the shaft and the shaft bearings during the first month of operation once in 10 days, and every 1000 hours of operation of the pump in the following period. CIATIM-201 GOST6267-74 is used as a lubricant in shaft bearings; 3 to monitor the leaks on the pump shaft and if necessary to control the operation of the packing elements. The leakage through the stuffing box packing must be between $5 \ldots 10 \cdot 10^{-3}$ m^3/h; 4) to record once a week in the journal of observations the following parameters: a) inlet pressure; b) outlet pressure; c) suction water temperature; d) pressure of the barrier (coolant) fluid supply; e) number of hours of pump operation.

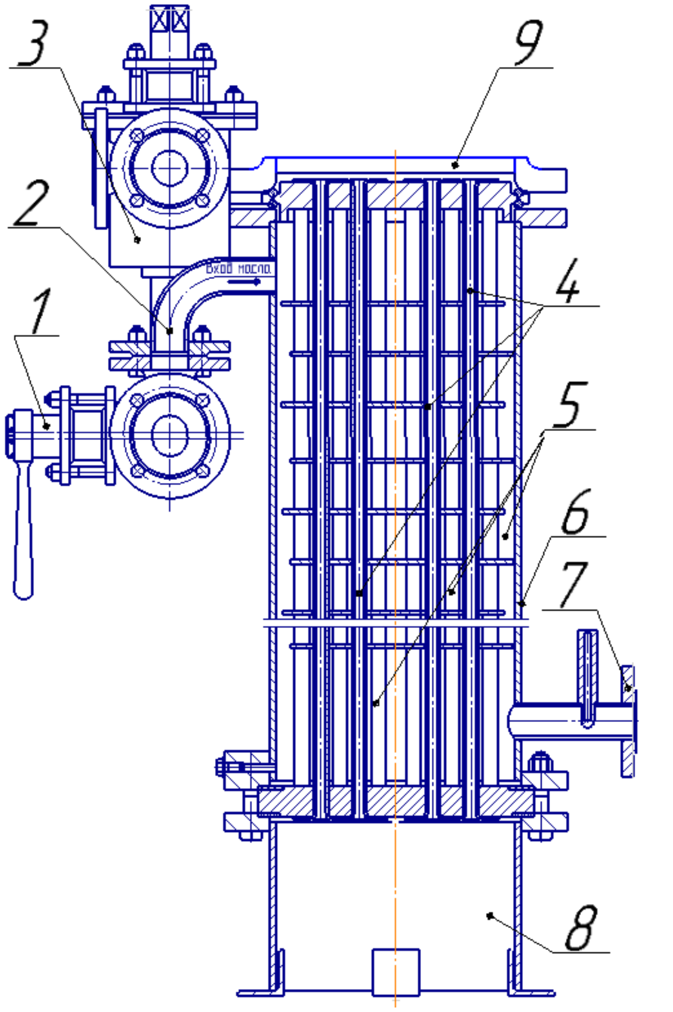

Fig. 5. Oil cooler: 1 – oil regulator; 2 – oil inlet; 3 – oil filter; 4 – cooling air tubes; 5 – oil circulation channels; 6 – oil cooler body; 7 - oil flow outlet; 8 – air inlet module for airflow; 9 – airflow output channel

Oil replacement is conducted in the following cases: 1) in case of water ingress into the oil system; 2) in case of viscosity index increase in comparison with the initial one by more than 25%; 3) in case of significant decrease in demulsifying ability.

From an environmental point of view, the proposed solutions reduce the environmental impact:

- in case of refusal of forced oil supply by means of an oil line with an oil pump, there willl be no problems with leaks in the system connections and therefore no environmental pollution from the used oil;
- lubrication of the bearings after reconstruction requires much less oil and therefore there will be no problem with the disposal of the used lubricant.

Reliability of the pump unit depends on the timely oil replacement. During its operation, the oil temperature should be about 50° C and its viscosity should be 7-9.3 m/s.

The consumption of oil for bearings with forced lubrication is 10% of the total amount per year, the period of the complete oil replacement varies after 800-15000 hours of pump operation and depends on the specific conditions of its operation.

Therefore, the proposed solution allows to reduce the harmful impact on the environment and, consequently, to raise the level of organization of labor safety and environmental protection measures in compliance with all safety measures.

IV. Conclusion

This suggestion allows:

1) to eliminate complex hydraulic communication and the use of fresh water;

2) not to import large amounts of fresh water to MCPS, as the presented cooling system works with a radiator and a blower;

3) to avoid frequent requests for transport for delivery and disposal of fresh water, as at the moment, due to the restructuring of Oil-and-Gas Production Department, these requests are serviced by third party service organizations;

4) the heat released during oil cooling can be redirected to the MCPS heating during winter operation, and to the atmosphere during summer operation;

5) to reduce maintenance and repair costs of the oil cooling system.

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