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# Characteristics, Rules of Replacement and Operation of Vacuum Pump Oils

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**Abstract.** This paper is devoted to the questions about the difference between mineral and synthetic vacuum oils, determining how often should the oil in the vacuum pump be changed, can the motor oil be poured into the vacuum pump and how to diagnose the pump by a color of the oil. Also the characteristics of vacuum oils, rules of replacement and operation of oils are described.

## INTRODUCTION

Vacuum oil is used as a lubricant and sealing agent in backing vacuum pumps (such as a rotary vane pump) and as a working fluid in oil diffusion and booster pumps [1–3].

Typical oils for applications in backing vacuum pumps are hydrocarbon-based mineral oils. Special applications, such as pumping of active gases, oxygen, acid vapors in the semiconductor industry, refrigeration and food industries require use of the more expensive synthetic oils. In the diffusion and booster pumps synthetic oils resistant to high operating temperature are used.

Communication with specialists operating vacuum pumps revealed a number of problems with the use of domestic vacuum oils. According to the documents provided by suppliers of VM series oil, it is produced outside Russia. According to a survey of participants of the advanced training course "Fundamentals of leak detection and vacuum technology" in Saint Petersburg Electrotechnical University "LETI" there were cases of obtaining low-quality VM oils at the enterprises.

The culture of use and timely replacement of vacuum oils is low even in large organizations. This paper aims to eliminate illiteracy in the use of vacuum oils and to assist in determining the frequency of oil change for a particular workflow.

## KEY CHARACTERISTICS OF OILS FOR BACKING VACUUM PUMPS

Oils for vacuum pumps differ from other technological oils in the following set of characteristics:

- low saturated steam pressure at operating temperature, which determines the maximum residual pressure of the pump;
- low tendency to oxidation and decomposition, affecting resistance to oxygen and mixtures with chlorides and fluorides. It is this property that distinguishes the synthetic oil, which is used in pumping aggressive media, from the mineral oil;
- viscosity, stable over a wide temperature range;
- oil produces no foam, is non-toxic and inert, which ensures the absence of oil degradation and wear of the pump evacuation chamber during the period of operation;
- sufficient temperature resistance with regard to possible overheating of the pump;
- low tendency to dissolution of gases and vapors that affect the maximum residual pressure of the pump.

The use of motor, industrial, hydraulic oils, as well as counterfeit vacuum oils in pumps, based on the experience of service work, can lead to sedimentation in a pump, decomposition of oil due to temperature exposure or chemical reaction with the pumped medium. This leads to loss of lubricating properties of the working fluid, jamming and overheating of the pump.

## SELECTION OF A VACUUM OIL

When choosing a vacuum oil, for example, when searching for an analogue of an unavailable oil, you should pay attention to two important parameters:

- viscosity matching. Only a small increase in viscosity adjustment is allowed for pumps with a large number of operating hours. This improves the uniformity of the coating of the working surfaces, taking into account the wear of the pump parts;
- type of oil matching: mineral or synthetic. In vacuum pumps, it is not allowed to mix mineral and synthetic oil or replace one with another, because this can lead to sedimentation in a pump and other chemical reactions that occur during operation.

When choosing an oil analog, it is necessary to follow the recommendations of the pump manufacturer. At the first filling of oil of other manufacturer it is necessary to preliminary check an absence of sedimentation at mixing with the oil used earlier.

## OILS FOR BACKING VACUUM PUMPS

Japanese company “Ulvac Inc.” recommends the oils under the brands Ulvoil and Moresco Neovac. These oils are produced and bottled at Matsumura plants in Japan. “Ulvac Inc.” guarantees the availability and presence of oils Moresco Neovac and Ulvoil from an authorized dealer “Ulvac Russia” (LLC “Vactron”). In turn, preserving the warranty on the Ulvac pumps is only possible when consumer uses the original vacuum oil.

Ulvoil SMR-100, Moresco Neovac MR-100 and Ulvoil R-4 oils (Table 1) are recommended for small sized backing rotary pumps with a pumping speed of less than 500 liters per minute.

**TABLE 1.** Mineral oil for pumps with pumping speed less than 500 l/min.

<b>Brand</b>	<b>Ulvoil SMR-100</b>	<b>Moresco Neovac MR-100</b>	<b>Ulvoil R-4</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	48	44.6	47
Type of oil	Mineral laboratory and general industrial		
Volume of cans, l	1; 4; 18	1; 4; 20; 200	2; 20; 200

These oils are suitable for Ulvac pumps and pumps of other manufacturers. They are used for general applications and in most industries. The oils are made with low viscosity for smooth start-up at low temperatures. The oil should be changed with a frequency corresponding to the pump operation area and the order of replacement, according to the operating manual.

Into the pumps Ulvac GLD and G oil is filled in the following volumes: G-101D – 800 ml; GLD-051 – 500–800 ml; GLD-137AA – 1000 ml; GLD-137CC – 1000 ml; GLD-202AA – 1100 ml; GLD-202BB – 1100 ml.

Ulvoil MR-200, Moresco Neovac MR-200 and Ulvoil R-7 oils (Table 2) have an average viscosity and are intended for backing vacuum pumps with pumping speed from 500 to 10000 liters per minute, for example for Ulvac GLD-280B in the volume of 700–1100 ml. Also these oils are recommended for use in the bearing unit of the Roots blower type Ulvac MBS-052 pump in the volume of 60 ml and in other two-rotor booster pumps.

**TABLE 2.** Mineral oil for pumps with pumping speed from 500 to 10000 l/min.

<b>Brand</b>	<b>Ulvoil MR-200, SMR-200</b>	<b>Moresco Neovac MR-200</b>	<b>Ulvoil R-7</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	70.4	71	69
Type of oil	Mineral general industrial and laboratory		
Volume of cans, l	1; 4; 18	1; 4; 20; 200	2.2; 8; 20; 200

Neovac MR-250 (Table 3) is the standard vacuum oil for large vacuum pumps for universal purposes. The oil has a high viscosity and is intended for backing vacuum pumps with a pumping speed of more than 10000 liters per minute. It is produced by fractional distillation of highly refined mineral base oil in the Moresco molecular distiller in Japan.

**TABLE 3.** Mineral oil for pumps with a pumping speed more than 10000 l/min.

<b>Brand</b>	<b>Moresco Neovac MR-250</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	105
Type of oil	Mineral
Volume of cans, l	1; 4; 20; 200

Moresco Neovac MR-200A and MR-250A oils (Table 4) are characterized by resistance to oxidation and decomposition, high temperature resistance.

These oils are resistant to a high-temperature degradation. They are needed when it is necessary to guarantee the life of the lubricant under severe operating conditions, such as high system load and elevated operating temperatures (100–130 °C). It is recommended to use them when the pump is installed in the device body and its cooling is limited.

**TABLE 4.** Mineral oil with increased oxidation stability for operation at elevated temperatures and loads.

<b>Brand</b>	<b>Moresco Neovac MR-200A</b>	<b>Moresco Neovac MR-250A</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	105	105
Type of oil	Mineral MR-200 with the addition of the antioxidant	Mineral MR-250 with the addition of the antioxidant
Volume of cans, l	4; 20	4; 20

Moresco Neovac SA-L and Ulvoil R-2 (Table 5) are synthetic oils for small-sized rotary vane pumps with a pumping speed of less than 500 liters per minute. They differ from the mineral oils by a greater stability of chemical composition during operation, the presence of antioxidant additives and resistance to active gases.

**TABLE 5.** Synthetic oil for pumps with a pumping speed less than 500 l/min with antioxidant additives and resistance to active gases.

<b>Brand</b>	<b>Ulvoil R-2</b>	<b>Moresco Neovac SA-L</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	26	32
Type of oil	Synthetic with antioxidant, resistant to active gases	
Volume of cans, l	1; 4; 20	1; 4; 20

Synthetic oil has a longer service life compared to mineral oil and does not form a resinous sediment on the pump parts, the so-called lacquer deposits, due to high thermal stability.

Oil of these brands is recommended for the most modern pumps – Ulvac GHD and GLD in the following volumes: GHD-031 – 370 ml, GHD-100 – 1000 ml, GLD-040 – 550–800 ml.

Ulvoil SO-M and Moresco Neovac SO-M oils (Table 6) are working fluids with anti-corrosion properties. They are designed for rotary vane pumps of low and medium pumping speed, including used in the refrigeration industry.

**TABLE 6.** Synthetic oil with high chemical resistance for pumps with a pumping speed from 500 to 10000 l/min.

<b>Brand</b>	<b>Ulvoil SO-M</b>	<b>Moresco Neovac SO-M</b>	<b>Ulvoil Super R-7000, R-7500</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	63.7	64	68; 82
Type of oil	Synthetic oil with antioxidant, resistant to the active gases		Synthetic for the semiconductor industry
Volume of cans, l	1; 4; 18	1; 4; 20	4

SO-M oil is recommended by Ulvac for use in the GCD pumps in the following volumes: GCD-051 – 500–800 ml, GCD-136 – 1000 ml, GCD-201 – 1100 ml.

For pumps with a pumping speed from 500 to 10000 l/min there is a modification of Moresco Neovac SA-M oil, which differs from SO-M in greater oxygen resistance.

Neovac SA-H oil (Table 7) is a synthetic oil for large backing vacuum pumps with a pumping speed of 10000 liters per minute. The oil has a high viscosity. Neovac SA-H provides low saturated steam pressure and has a long service life due to its thermal and oxidative stability.

This oil is used in pumps with oil seals for pumping active gases, acid vapors during etching processes, in chemical vapor deposition processes from steam phase (LPCVD) and at high temperatures and loads.

**TABLE 7.** Synthetic oil for pumps with a pumping speed more than 10000 l/min with antioxidant additives and resistance to active gases.

<b>Brand</b>	<b>Moresco Neovac SA-H</b>	<b>Ulvoil Super R-8000</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	95	101
Type of oil	Synthetic oil with antioxidant, resistant to the active gases	Synthetic for the semiconductor industry
Volume of cans, l	1; 4; 20	4

## OILS FOR JET VACUUM PUMPS

Oils for jet pumps should be selected especially carefully. In this area, silicone oils are almost exclusively used. The main requirements are low vapor pressure, high thermal stability, high resistance to atmospheric oxygen when heated, high molecular weight, absence of flammability and toxicity.

Booster oil pumps are used in the vacuum furnaces and installations that require pumping large flows and maximum performance in the working vacuum pressure range up to 0.1 Pa. These pumps are widely used in metallurgy, as well as in the chemical production and in spraying installations for roll materials.

For pumping large flows of gases using the ejector booster pumps oils Ulvoil B-6 and Moresco Neovac DB-12 (Table 8) are recommended. Features of such oils are: high chemical resistance, absence of reaction with catalysts (iron and copper) at high temperature and long service life due to its thermal and oxidative stability. These oils are used for Ulvac PBL pumps.

**TABLE 8.** Oils for booster ejector pumps.

<b>Brand</b>	<b>Ulvoil B-6</b>	<b>Moresco Neovac DB-12</b>
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	22	22
Vapor pressure	1.2·10 <sup>-5</sup> Pa at 25 °C	< 6.7·10 <sup>-4</sup> Pa at 20 °C
Type of oil	Synthetic hydrocarbon	
Volume of cans, l	18	20

Diffusion pumps differ from booster ejector pumps in the ability to pump to a lower limit residual pressure. Therefore, the oil vapor pressure requirements for diffusion pumps are higher.

In the diffusion pump, the vapor jet of the working fluid captures the molecules of the pumped gases due to mixing and mutual diffusion. The vapor-gas mixture at the exit from the ejector comes to the walls of the pump casing with a water cooling jacket, where the oil vapor condenses and flows back down into the oil tank, and the pumped gases enter the exhaust of the auxiliary booster pump, which is connected to the backing vacuum pumping units. The condensed oil is distributed over the fractional grid at the bottom of the oil tank depending on the vapor pressure. This achieves high efficiency of cyclic heating of the working fluid for the constant flow of the vapor jet through the pump stages.

Oils Ulvoil D-11 and Moresco Neovac SX (Table 9) are used for pumps Ulvac PFL, F and ULK. Ulvoil D-31 and Moresco Neovac SY (Table 10) are synthetic silicone oils that are resistant to oxidation at high temperatures

and to small contamination of the pumped medium. The operating temperature for these brands is 180–235 °C. They are used for Ulvac U and ULK pumps.

**TABLE 9.** Oils for diffusion pumps of general application.

Brand	Ulvoil D-11	Moresco Neovac SX
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	32	22
Vapor pressure	7.3 · 10 <sup>-5</sup> Pa at 25 °C	< 1.3 · 10 <sup>-6</sup> Pa at 20 °C
Type of oil	Synthetic hydrocarbon	
Volume of cans, l	1; 18	1; 4; 20

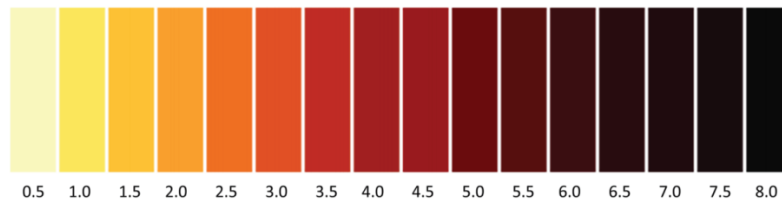
**TABLE 10.** High temperature resistant oils for diffusion pumps.

Brand	Ulvoil D-31	Moresco Neovac SY
Kinematic viscosity at 40 °C, mm <sup>2</sup> /s	170	22
Vapor pressure	2.1 · 10 <sup>-8</sup> Pa at 25 °C	< 7 · 10 <sup>-6</sup> Pa at 20 °C
Type of oil	Synthetic silicone	
Volume of cans, l	0.5	1; 4; 20

## REGULATIONS OF THE OIL REPLACEMENT IN A VACUUM PUMP

Vacuum oil degrades during the operation of the pump, so it is necessary to monitor the condition of the oil. This can be done visually, focusing on the color of the working fluid. In the laboratory, periodic measurements of the working fluid viscosity are additionally carried out.

For the convenience of visual inspection, the comparative color scale shown in Fig. 1 is used. It helps determining the recommendations for the maintenance of the pump, depending on the shade of the working fluid (Table 11).



**FIGURE 1.** Color scale for determining the condition of oil.

**TABLE 11.** Recommendations for the maintenance of the pump depending on the oil color.

Mineral oil	Synthetic oil	Vacuum pump condition
0.5–1.5	0.5–2.5	Good condition of both the oil and vacuum pump
2.0–3.5	3.0–5.0	Vacuum oil change is required
4.0–4.5	5.5–6.5	It is necessary to wash the pump with vacuum oil and change the oil
5.0–8.0	6.5–8.0	Immediate maintenance or repair of the pump is required

During long-term operation of the pump in conditions with high moisture content and dirt lubrication of the pump deteriorates, and there are prerequisites for increased wear of rotating parts. This may cause the pump to fail due to mechanical damage.

The regularity of oil change depends on the operating conditions and features of the process. In addition to the recommendations specified in the pump operating instructions, the oil change interval should be determined by a practical method. To do this, after ten days from the start of the pump in operation, it is necessary to check the oil level, fixing its consumption. Then drain the oil and determine the degree of degradation for the reporting time using

the color scale. This check of the oil condition, the presence of technological contaminants and foreign inclusions will make it possible to predict the frequency of oil change in specific operating conditions.

## CONCLUSION

Ulvoil and Moresco Neovac vacuum pump oils, manufactured in Japan, are suitable for use in Ulvac pumps and pumps of other brands. Lines of oils Ulvoil and Moresco are identical; meanwhile the cost of Moresco oil in Russia is lower.

For general industrial and laboratory applications mineral oils Ulvoil SMR-100, Moresco Neovac MR-100 and Ulvoil R-4 should be used in pumps with a pumping speed of less than 500 l/min. In pumps with a pumping speed from 500 to 10000 l/min Ulvoil MR-200, Moresco Neovac MR-200 and Ulvoil R-7 oils should be used. They are also suitable for use in the bearing assembly of two-rotor Roots blower pumps.

Neovac MR-250 is a standard vacuum oil for large vacuum pumps with a pumping speed of more than 10000 l/min. If it is necessary to use economical oil with increased oxidation resistance for operation at elevated temperatures (from 100 to 130 °C) and loads, it is recommended to use mineral oil Moresco Neovac MR-200A or MR-250A.

Synthetic oils with antioxidant additives and resistance to active gases for small-sized modern pumps GHD and GLD are Neovac SA-L and Ulvoil R-2.

Fluorine-free synthetic oils with corrosion-resistant properties for pumps with a pumping speed from 500 to 10000 l/min are Ulvoil SO-M, Ulvoil Super R-7000, Super R-7500 and Moresco Neovac SO-M.

When pumping active gases, acid vapors during etching or chemical deposition with pumps with a pumping speed of more than 10000 l/min Ulvoil Super R-8000 or Neovac SA-H oils should be used.

Standard oils for Ulvac diffusion pumps are Ulvoil D-11 and Moresco Neovac SX.

To achieve ultra-high vacuum at high pumping speed, oils for diffusion pumps with increased temperature resistance Ulvoil D-31 and Moresco Neovac SY should be used.

For Ulvac booster ejector pumps Ulvoil B-6 and Moresco Neovac DB-12 oils are recommended.

The oil must be replaced according to the pump operating instructions, taking into account the specific features of the application. In pumps used in analytical equipment in laboratory conditions it is recommended to change the oil every six months. This is true for mass spectrometric leak detectors [4], microscopes, spectrometers, chromatographs and other high-tech equipment working with non-aggressive gases. Industrial application and active pumped medium determine the need for a more frequent change of the working fluid of the vacuum pump.

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