Institute of Mathematics, Physics and Chemistry

Department of Chemistry

Laboratory of fuels, oils and lubricants

Laboratory exercise

Determination of water content in petroleum products

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Szczecin

EXERCISE SHEET

<table>
<tr><td>1</td><td colspan="3">Relation to subjects: Marine Power Plant Operation/28</td></tr>
<tr><td></td><td>Specialty/Subject</td><td>Learning outcomes for the subject</td><td>Detailed learning outcomes for the subject</td></tr>
<tr><td></td><td>MPPO – Chemistry of fuels and lubricants.</td><td>EKP3
K_U014, K_U015, K_U016.</td><td>SEKP12 – Performing determinations of selected quality indicators of petroleum products;</td></tr>
<tr><td>2</td><td colspan="3">Purpose of the exercise:
teaching the student how to independently determine the water content in petroleum products using the distillation method and determine the type of water (fresh or sea water);</td></tr>
<tr><td>3</td><td colspan="3">Prerequisites:
the student is trained in the occupational health and safety regulations in a laboratory workplace, which he confirms with his signature on the appropriate form, knows – the sources of water in the oil and its types, the form of water occurrence, methods of qualitative and quantitative analysis of water content, operational significance and limit values of water content in lubricating oils, methods of removing water from oil used on ships, cases of oil degradation and the need to change oil due to the presence of water in the oil;</td></tr>
<tr><td>4</td><td colspan="3">Description of the laboratory workplace:
Dean-Stark apparatus, analytical balance, basic laboratory glassware, silver nitrate solution, samples of used lubricating oils or other lubricating products;</td></tr>
<tr><td>5</td><td colspan="3">Risk assessment*:
azeotropic distillation in a Dean-Stark apparatus (possibility of the flask breaking with boiling liquid and thermal burn), contact with extraction gasoline used to wash the measuring apparatus and laboratory glass – there is a possibility of a fire hazard due to the presence of solvent vapours.
Final assessment – CONSIDERABLE HAZARD, SERIOUS EFFECTS
Security measures required
a. lab coats, protective glasses,
b. health and safety cleaning products, cleaning cloths, paper towels,
c. petroleum products waste container (for disposal),
d. container for waste gasoline beakers (for regeneration);</td></tr>
<tr><td>6</td><td colspan="3">The course of the exercise:
a. Read the workplace manual (appendix 1) and familiarize with the laboratory kit for the exercise,
b. Perform a determination of the water content in the tested lubricating oil,
c. If the permissible water content in the tested oil is significantly exceeded, test for the presence of sea water (i.e., the presence of chloride ions).,</td></tr>
<tr><td>7</td><td colspan="3">Exercise report:
a. Develop the exercise in accordance with the instructions contained in the workplace manual,
b. On the basis of the determined water content in the oil and possibly the type of this water (fresh, sea), determine the quality and operational suitability of the tested oil and propose appropriate corrective actions;</td></tr>
<tr><td>8</td><td colspan="3">Archiving of research results:
Submit a written report on the performed exercise to the academic teacher.</td></tr>
</table>

9	**Assessment method and criteria:** a. EKP1, EKP2 – tasks given for independent solution and development: mark 2.0 – the student has no basic chemical, physicochemical and operational knowledge regarding the presence of water in lubricating oils and the ability to solve simple tasks in this field; mark 3.0 – has basic chemical, physicochemical and operational knowledge regarding the water content in lubricating oils and the ability to calculate and solve simple tasks in this field; mark 3.5 – 4.0 – has extended chemical, physicochemical and operational knowledge regarding the determined performance parameter of lubricating oils and the ability to solve complex tasks in this field; mark 4.5 – 5.0 – has the ability to apply complex chemical, physicochemical and operational knowledge to a partial evaluation of the quality and usability of the tested lubricating oils due to the determined parameter and the ability to make operational decisions on this basis. b. EKP3 – control works: mark 2.0 – does not have the ability to analyse and evaluate the results of the performed analyses and determinations and to draw conclusions; mark 3.0 – has the ability to analyse the obtained results, interpret the laws and phenomena, transform formulas, and interpret charts and tables; mark 3.5 – 4.0 – has the ability to broaden the analysis of results, apply laws, construct monograms and charts; mark 4.5 – 5.0 – has the ability to comprehensively analyse the obtained results, make generalizations, detect cause-and-effect relationships and make the right operational decisions.
10	**Literature:** 1. Krupowies J., Wiznerowicz Cz.: Oznaczanie zawartości wody w produktach naftowych. Instrukcja stanowiskowa do ćwiczenia, AM, Szczecin 2013. 2. Barcewicz K.: Ćwiczenia laboratoryjne z chemii wody, paliw i smarów. Wyd. AM w Gdyni, Gdynia 2006. 3. Podniało A.: Paliwa oleje i smary w ekologicznej eksploatacji. WNT, Warszawa 2002. 4. Przemysłowe środki smarne. Poradnik. TOTAL Polska Sp. z o.o., Warszawa 2003. 5. Urbański P.: Paliwa i smary. Wyd. FRWSzM w Gdyni, Gdańsk 1999. 6. Krupowies J.: Badania zmian parametrów fizykochemicznych silnikowych olejów smarowych eksploatowanych na statkach Polskiej Żeglugi Morskiej. WSM w Szczecinie, Studia nr 27, Szczecin 1996. 7. Krupowies J.: Badania zmian właściwości oleju obiegowego okrętowych silników pomocniczych. WSM w Szczecinie, Studia nr 40, Szczecin 2002. 8. PN/EN/ISO standards for the testing of petroleum products. 9. Oil product catalogs of oil companies. 10. Dudek A.: Oleje smarowe Rafinerii Gdańskiej. „MET-PRESS", Gdańsk 1997. 11. Baczewski K., Biernat K., Machel M.: Samochodowe paliwa, oleje i smary. Leksykon, Wydawnictwa Komunikacji i Łączności, Warszawa 1993. 12. Herdzik J.: Poradnik motorzysty okrętowego. Wydawnictwo TRADEMAR, Gdynia 1995.
10	Notes

APPENDIX 1 – MANUAL

1. SCOPE OF THE EXERCISE

- getting acquainted with the workplace instructions for the exercise,
- determination of the presence and content of water in oil, determination of the type of water,
- evaluation of usability of exploited oil on the basis of water content and its type.

2. THEORETICAL INTRODUCTION TO THE EXERCISE

Water can get into marine engine oils during transport, storage and use. It can be both fresh and sea water. The main reasons for the ingress of water into the ship's oil are: fuel combustion, air moisture condensation, failure of coolers and heating steam pipelines, leaks with faulty piston cooling, incorrect operation of centrifuges and many others. Water can also be found in freshly bunkered fuels and oils. Therefore, its presence in oil products on ships should always be taken into account.

The presence of water in the lubricating oil is a factor that significantly worsens its operational properties. One of the most unfavourable factors is the strong corrosive effect of water-saturated oil, which not only does not protect against corrosion, but can cause it itself. Water may additionally wash out oil refining additives, create permanent emulsions, change the viscosity and lubricity of the oil, reduce its resistance to aging and disrupt the operation of the oil system.

It should be noted, however, that the presence of water in the oil cannot be a reason that disqualifies its suitability for further operation. There are, for example, sediment tanks or centrifuges in oil systems on board ships. Only the water content of the oil in the form of a stable emulsion, which cannot be removed by the equipment installed on the ship, or the presence of sea water, makes the oil unsuitable for further operation.

The presence of water in the oil is not a sign of poor oil quality, but a defective operation of the oil preparation and cleaning system. Therefore, determine the causes of water entering the oil, remove them, check the operating parameters of the purification devices and correct them accordingly.

Due to the negative effect of water in engine oils, it is recommended to mark it directly on the ship. For this purpose, simplified test methods are used, e.g., using portable laboratory kits.

When assessing very low water contents, the slight water solubility in oils must be taken into account. This solubility depends on the temperature and air humidity, and for engine oil operating conditions it is from 0.005% to 0.03% by mass.

3. DETERMINATION OF THE WATER CONTENT

The water content in petroleum products should be understood as the percentage by mass or volume of water present in the tested sample.

The **qualitative method** is used to detect the presence of water in liquid petroleum products. It should be ascertained that the tested product, heated to a certain temperature, does not foam and does not make any characteristic crackles.

Performing a water-in-oil test

Fill a clean and dry test tube (dimensions: 15 mm in diameter and 150 mm in length) with the tested oil to the height of about 80 mm. Then close the test tube with a stopper with a thermometer inserted in it, which should be installed in the hole of the stopper so that its end is at a distance of 20 mm from the bottom of the test tube. Then, place the test tube in an oil bath, heated to 175 °C, in such a way that the level of the sample in the test tube is 10 mm higher than the level of the oil in the bath. While the temperature of the test sample rises from 100 °C to 150 °C, be sure to observe the reaction of the petroleum product.

Elaboration of the results

If the tested sample foams and you hear characteristic crackling sounds, assume that the oil is filled with water. Repeat the tests three times.

Determination of water content in petroleum products by distillation method

The **distillation method** is used for quantitative determination of the water content of the liquid petroleum products and consists in removing the water contained in the tested sample with a solvent, i.e., first creating an azeotropic liquid and then distilling off the water from it. The appropriate solvent should be selected from table 1.

Table 1

Selection of the solvent depending on the tested product

Solvent	Tested petroleum product
toluene, xylene	bitumens, crude oil of the asphalt type, heavy fuel oils (residual fuels)
xylene	crude oil, liquid asphalts, residual fuel oils, diesel oils, lubricating oils
extraction gasoline[1], isooctane	lubricating grease
xylene	carbon products

Preparation of the sample

A sample of the liquid product should be thoroughly mixed by shaking for 5 minutes in a vessel filled to no more than 3/4 of its capacity. High-viscosity products and petroleum products with a high paraffin content should be heated to 40 ÷ 50°C before mixing. Solid products should be crushed and thoroughly mixed. When testing plastic greases, remove the top layer of them, and then take equal amounts of products from at least three places away from the walls of the vessel and mix them in an evaporating dish.

When testing low-viscosity liquid products, use a cylinder to measure 100 cm^3 of the sample and pour it into the distillation flask – 1 (fig. 1).

[1] extraction gasoline mix with a small amount of water and shake for 1 minute, leave to stand layer separation. After separating the water layer, dry the gasoline with anhydrous calcium chloride and filter through a pleated filter.

Using the same cylinder, without washing it, measure 50 cm^3 of xylene into the flask, and then twice 25 cm^3 of xylene in order to rinse the sample from the cylinder.
When testing highly viscous liquid products or solid products, weigh 100 g of the tested product and transfer quantitatively to the distillation flask, then add 100 cm^3 of solvent according to table 1.

When testing products with very low or very high-water content, the size of the sample and the volume of the azeotropic liquid should be suitably reduced or increased so that the volume of water collecting in the receiver is greater than 0.1 cm^3, but does not exceed the capacity of the receiver used.

After thoroughly mixing the contents of the distillation flask, add a few pieces of porous material (e.g., porcelain), and in the case of a liquid prone to foaming, add a few drops of silicone oil, then assemble the distillation set as shown in Fig. 1. Turn on the cooling water circuit to the cooler – 2 and heat the distillation flask on an electric plate with a mesh so as to obtain a distillate condensation rate in the amount of 2 ÷ 4 drops per second. Carry out distillation for about 1 hour counting from the moment the receiver is filled – 3 with distillate to the point of overflow. Finish the distillation when the liquid in the receiver is completely transparent. If water droplets appear on the walls of the condenser during distillation, stop heating (moving the electric plate from under the flask) and wash the condenser several times with the solvent used for distillation in small portions. Bring the liquid in the flask back to the boil and distil.

After cooling the contents of the receiver to the ambient temperature, disassemble the set (in the presence of the teacher). Read the amount of water from the graduation of the receiver. If some water remains on the walls of the receptacle, use a glass rod to push the water to the bottom of the receptacle. If the upper layer of the liquid in the tank is not completely clear or the amount of separated water is small (up to 0.03 cm^3), place the collecting tank in a water bath at a temperature of about 60 °C for 30 minutes, and then cool the distillate again from receiver to ambient temperature and read off the volume of water collected.

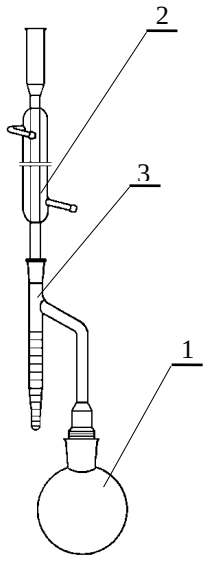


Fig. 1. Set for the determination of water in petroleum products using the distillation method (apparatus according to Dean Stark). 1 - distillation flask, 2 - condenser, 3 - receiver

Elaboration of the results

Depending on the method of determining the water content $Z_{\%wt.}$ or $Z_{\%vol.}$ calculate its content according to the following equations:

$$Z_{\%mas.} = \frac{V \cdot \rho_w}{m} \cdot 100$$

$$Z_{\%obj.} = \frac{V}{V_1} \cdot 100$$

where:

V – the volume of water in the receiver [cm^3];
ρ_w – water density at reading temperature [g/cm^3], table 2;
m – sample weight [g];
V_1 – sample volume [cm^3]

The result of the determination should be the average value of two measurements differing from each other by no more than 0.03 cm^3.

Table 2

The density of air-free water at 0 to 40 °C [g/cm^3]

°C	0.0	0.1	0.2	0.3	0.4	0.5
0	0.9998396	0.9998460	0.9999528	0.9998591	0.9998653	0.9998713
1	0.9998985	0.9999035	0.9999082	0.9999128	0.9999172	0.9999214
2	0.9999399	0.9999431	0.9999461	0.9999489	0.9999516	0.9999554
3	0.9999642	0.9999657	0.9999670	0.9999682	0.9999692	0.9999701
4	0.9999720	0.9999718	0.9999716	0.9999711	0.9999705	0.9999698
5	0.9999637	0.9999620	0.9999602	0.9999582	0.9999560	0.9999537
6	0.9999999	0.9999367	0.9999334	0.9999299	0.9999262	0.9999224
7	0.9999011	0.9998964	0.9998916	0.9998866	0.9998815	0.9998762
8	0.9998477	0.9998416	0.9998353	0.9998289	0.9998223	0.9998157
9	0.9998701	0.9997726	0.9997649	0.9997571	0.9997492	0.9997411
10	0.9996987	0.9996898	0.9996808	0.9996717	0.9996624	0.9996530
11	0.9996029	0.9995937	0.9995834	0.9995729	0.9995623	0.9995516
12	0.9994961	0.9998486	0.9994730	0.9994612	0.9994494	0.9994374
13	0.9993756	0.9993628	0.9993500	0.9993370	0.9993239	0.9993106
14	0.9992427	0.9992287	0.9992146	0.9992004	0.9991861	0.9991717
15	0.9990977	0.9990826	0.9990673	0.9990519	0.9990364	0.9990208
16	0.9989410	0.9989247	0.9989083	0.9988917	0.9988751	0.9988583
17	0.9987728	0.9987553	0.9987378	0.9987201	0.9987023	0.9986845
18	0.9985934	0.9985748	0.9985562	0.9985374	0.9985185	0.9984995
19	0.9984030	0.9983833	0.9983636	0.9983438	0.9983238	0.9983037
20	0.9982019	0.9981812	0.9981604	0.9981395	0.9981185	0.9980973
21	0.9979902	0.9979685	0.9979467	0.9979247	0.9979027	0.9978805
22	0.9977683	0.9977456	0.9977227	0.9976998	0.9976767	0.9976536
23	0.9975363	0.9975126	0.9974887	0.9974648	0.9974408	0.9974166
24	0.9972944	0.9972697	0.9972449	0.9972200	0.9971950	0.9971699
25	0.9970429	0.9970172	0.9969914	0.9969655	0.9969396	0.9969135
26	0.9967818	0.9967551	0.9967284	0.9967016	0.9966477	0.9966477
27	0.9965113	0.9964837	0.9964561	0.9964284	0.9964005	0.9963726
28	0.9962316	0.9962032	0.9961746	0.9961460	0.9961172	0.9960884
29	0.9959430	0.9959136	0.9958842	0.9958546	0.9958250	0.9957953
30	0.9956454	0.9966152	0.9955848	0.9955544	0.9955239	0.9954934
31	0.9953391	0.9953080	0.9952768	0.9952456	0.9952142	0.9951828
32	0.9950243	0.9949923	0.9949603	0.9949282	0.9948960	0.9948637
33	0.9947010	0.9946682	0.9946353	0.9946024	0.9945693	0.9945362
34	0.9943694	0.9943358	0.9943021	0.9942683	0.9942345	0.9942005
35	0.9940296	0.9939952	0.9939607	0.9939261	0.9938915	0.9938567
36	0.9936819	0.9936467	0.9936114	0.9935760	0.9935406	0.9935050
37	0.9933263	0.9932903	0.9932542	0.9932181	0.9931818	0.9931455
38	0.9929629	0.9929261	0.9928893	0.9928524	0.9928154	0.9927784
39	0.9925920	0.9925545	0.9925169	0.9924792	0.9924415	0.9924037
40	0.9922136					

Table 2 cont

°C	0.6	0.7	0.8	0.9
0	0.9998771	0.9998827	0.9998882	0.9998934
1	0.9999254	0.9999293	0.9999330	0.9999365
2	0.9999565	0.9999587	0.9999607	0.9999625
3	0.9999708	0.9999713	0.9999717	0.9999719
4	0.9999689	0.9999678	0.9999666	0.9999652
5	0.9999513	0.9999457	0.9999459	0.9999430
6	0.9999184	0.9999143	0.9999101	0.9999057
7	0.9998708	0.9998652	0.9998595	0.9998537
8	0.9998088	0.9998019	0.9998947	0.9998785
9	0.9997329	0.9997246	0.9997161	0.9997015
10	0.9996434	0.9996337	0.9996239	0.9996140
11	0.9995408	0.9995298	0.9995187	0.9995074
12	0.9994253	0.9994130	0.9994007	0.9993882
13	0.9992973	0.9992838	0.9992702	0.9992565
14	0.9991571	0.9991424	0.9991276	0.9991127
15	0.9990051	0.9989892	0.9999733	0.9989572
16	0.9988414	0.9988244	0.9998073	0.9987901
17	0.9986665	0.9986483	0.9996301	0.9986118
18	0.9984804	0.9984612	0.9994419	0.9984225
19	0.9982836	0.9982633	0.9992429	0.9982224
20	0.9980761	0.9980548	0.9980334	0.9980119
21	0.9978583	0.9978360	0.9978135	0.9977910
22	0.9976303	0.9976070	0.9975835	0.9975600
23	0.9973924	0.9973680	0.9973436	0.9973191
24	0.9971446	0.9971193	0.9970939	0.9970685
25	0.9968873	0.9968611	0.9968347	0.9968083
26	0.9966206	0.9965934	0.9965661	0.9965388
27	0.9963446	0.9963165	0.9962883	0.9962600
28	0.9960595	0.9960305	0.9960014	0.9959722
29	0.9957655	0.9957356	0.9957056	0.9956756
30	0.9954627	0.9954319	0.9954011	0.9955701
31	0.9951512	0.9951196	0.9950879	0.9955561
32	0.9948313	0.9947988	0.9947663	0.9944337
33	0.9945030	0.9944697	0.9944364	0.9944029
34	0.9941665	0.9941324	0.9940982	0.9944640
35	0.9938219	0.9937870	0.9937521	0.9933170
36	0.9934694	0.9934438	0.9933980	0.9933622
37	0.9931092	0.9930727	0.9930362	0.9929996
38	0.9927412	0.9927040	0.9926668	0.9926294
39	0.9923658	0.9923279	0.9922899	0.9922518

4. DEVELOPMENT OF THE EXERCISE

1. Compare the obtained results with warning values for the tested oil.
2. On the basis of the water content and its type evaluate the operational suitability of the tested petroleum product.
3. In case of exceeding warning values of water content. provide corrective actions.
4. Report the effect of water and the type of this water on the operational parameters of the oil.
5. Figures 2 – 3 show the cross sections of marine engines (trunk piston engine and crosshead engine).
6. The warning values for Elf. Castrol and Mobil lubricating oils as well as the limit values recommended by marine engine manufacturers are given in auxiliary tables 3 – 6 at the end of the manual.

5. THE FORM AND CONDITIONS FOR PASSING THE LABORATORY EXERCISE

1. passing the so-called "entry" before starting the exercise.
2. submission of a correct written report on the performed exercise. which should include:

   - short theoretical introduction.
   - operational significance of the measured parameter.
   - processing of the obtained results according to the position manual.

3. final credit for the test at the end of the semester.

I. Example of task with solution

Calculate how much water is formed as a result of complete combustion of 1000 kg of cetane (hexadecane $C_{16}H_{34}$) and determine the ratio in relation to the mass of burnt hydrocarbon.

The reaction equation on the basis of which we calculate is as follows:

$$\begin{array}{ccccccc} 2C_{16}H_{34} & + & 49O_2 & \rightarrow & 32CO_2 & + & 34H_2O \\ 452 & & \multicolumn{3}{c}{\text{———————————}} & & 612 \\ 1000 & & \multicolumn{3}{c}{\text{———————————}} & & x \end{array}$$

$$x = \frac{1000 \cdot 612}{452} = 1353{,}98 \text{ kg}$$

Answer: As a result of burning 1000 kg of cetane. about 1354 kg of water is produced. And therefore the ratio of the mass of water formed as a result of this reaction to the mass of burnt hydrocarbon is 1.35. i.e. for 1000 kg of cetane burned. 1354 kg of water are produced.

II. Tasks and questions to be completed by the student

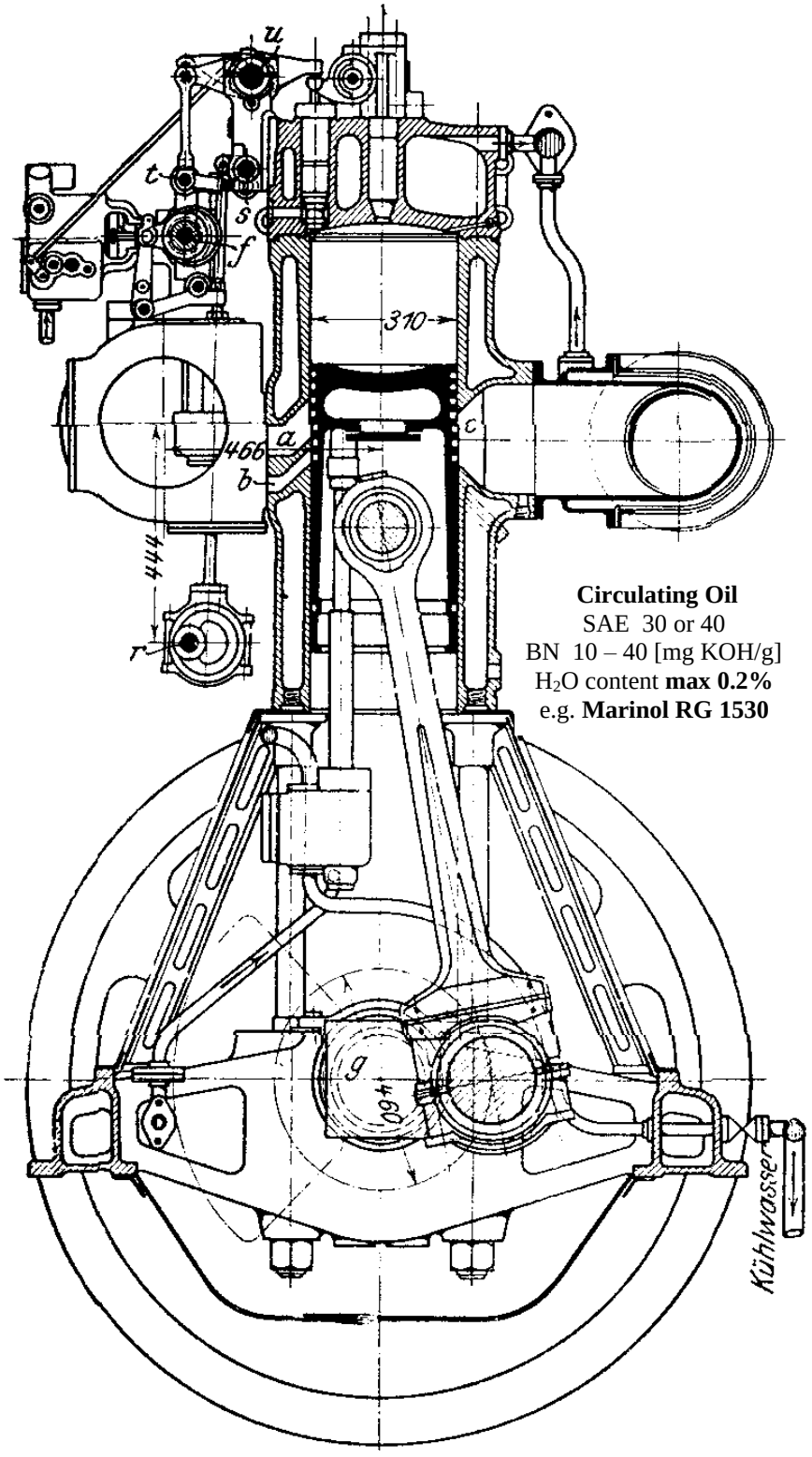
Tasks

1. The water content of Marinol RG 1530 oil taken from the cycle of a trunk piston engine is 0.35% by mass. Determine the operational suitability of this oil and provide any corrective action.
2. The water content of Marinol RG 2030 oil taken from the cycle of a trunk piston engine is 0.85% by mass. Determine the operational suitability of this oil. What additional tests should be performed to complete the evaluation of the operational suitability of this oil? Report any corrective action.
3. The water content of Marinol RG 4040 oil taken from the cycle of a trunk piston engine is 0.15% by mass. Determine the operational suitability of this oil and provide any corrective action.
4. The water content of the Marinol RG 630 oil taken from the crosshead engine cycle is 0.45% by mass. Determine the operational suitability of this oil and state whether it requires corrective action.
5. The water content of the Marinol RG 630 oil taken from the crosshead engine cycle is 0.85% by mass. Determine the operational suitability of this oil and state whether it requires corrective action.

Questions

1. What are the sources of origin, types and forms of water occurrence in lubricating oils used on ships.
2. What are the methods of detecting the presence of water in petroleum products and testing its type (fresh water – sea water) on ships?
3. Explain how the presence and content of water affects the performance quality of lubricating oils.
4. How is water removed from lubricating oils on ships?
5. When does the water content and its type eliminate lubricating oil from further use?
6. What are the permissible water contents in the lubricating oils of trunk piston and crosshead engines?
7. When does the presence of water in an oil decrease and when does it increase the viscosity of a water-oil mixture?

TRUNK PISTON ENGINE

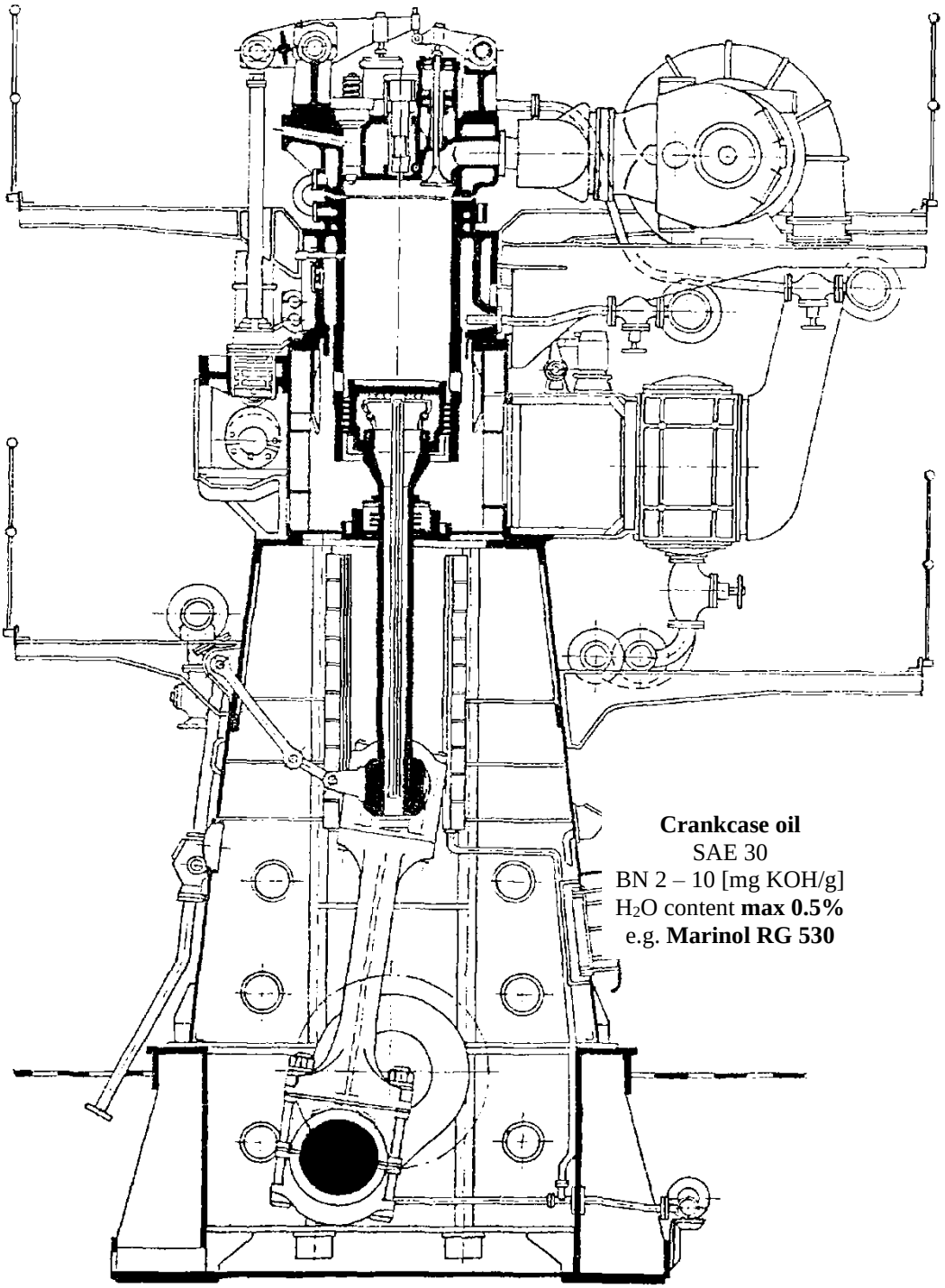


Circulating Oil
SAE 30 or 40
BN 10 – 40 [mg KOH/g]
H_2O content **max 0.2%**
e.g. **Marinol RG 1530**

Fig. 2. Cross-section of a trunk piston engine (380 HP)

CROSSHEAD ENGINE

Cylinder oil
SAE ≥ 50 (50+, 60)
BN ≥ 50 [mg KOH/g]
– 120 [mg KOH/g]
e.g. **Marinol RG 7050**



Crankcase oil
SAE 30
BN 2 – 10 [mg KOH/g]
H_2O content **max 0.5%**
e.g. **Marinol RG 530**

Fig. 3. D 55 type engine - cross-section

Auxiliary tables

Table 3

Warning values for the basic physicochemical parameters of some Elf oils

Markings	Disola M3015 Disola M4015	Aurelia XT4040
Kinematic viscosity at 40 °C [mm^2/s]	+30% –20%	+30% – 20%
Base number [mg KOH/g]	> 8	> 15
Flash point in a closed cup [ºC]	> 180	> 180
Water content [%]	< 0.3	< 0.3
Contents of impurities insoluble in n-pentane [%]	< 2	< 2

Table 4

Warning values for the basic physicochemical parameters of some Castrol oils

Markings	Castrol MPX 40 Castrol MLC 40	Castrol MXD 303
Kinematic viscosity at 40 °C [mm^2/s]	± 25%	± 25%
Base number [mg KOH/g]	– 50%	–50%
Flash point in a closed cup [°C]	> 180	> 180
Water content [%]	< 0.2	< 0.2
Contents of impurities insoluble in n-pentane [%]	< 2	< 4

Table 5

Warning values for the basic physicochemical parameters of some Mobil oils

Markings	Mobil 312	Mobil 412	Mobil 442
Kinematic viscosity at 40 °C [mm^2/s]	min mm^2/s max 143 mm^2/s	min 102 mm^2/s max 218 mm^2/s	min 102 mm^2/s max 218 mm^2/s
Base number [mg KOH/g]	– 50%	– 50%	– 50%
Flash point in a closed cup [ºC]	> 190	> 190	> 190
Water content [%]	< 0.2	< 0.2	< 0.2
Contents of impurities insoluble in n-pentane [%]	< 2	< 2	< 2

Table 6

Limits for the basic physicochemical parameters of lubricating oils recommended by Western manufacturers of marine engines

Compression ignition engines			Kinematic viscosity [mm^2/s] w at 100°C		Flash point FP	Water content max	Contaminant content	BN
manufacturer	type	model	min	max	[°C]	[% wt.]	[% wt.]	[mgKOH/g]
1	2	3	4	5	6	7	8	9
Daihatsu	four-stroke	all	–20%	+30%	180	0.1% vol.	2.5	3.0 for fuel (MDO) 5.0 for fuel (LMFO) 10.0 for fuel (HFO)
Deutz-MWM	four-stroke	D/TBD 234 TBD 604 B S/BAM 816	9 (SAE 30) 11 (SAE 40)	+25%	190	0.2	2.0	min 50%
	four-stroke	D/TBD 440 S/BAM 628 TBD 645 R/S/BVM 640	9 (SAE 30) 11 (SAE 40)	+25%	190	0.2	2.0	min 60%
Krupp MaK	four-stroke	all	80 at 40°C (SAE 30) 130 at 40°C(SAE 40)		180	0.2	2.0	min 15* min 18**.*** min 50% for fuels MDO/MGO
MAN B&W	four-stroke two-stroke	20/27 to 58/64	±1 degree SAE		185	0.5	1.5	min 50%* min 70%**
MTU	four-stroke	all	9.0 (SAE 30) 10.5 (SAE 40)	+25%	190	0.2	2.5	min 50%
Wartsila	four-stroke	VASA 46	11.5 for40°C 95	19 for 40°C 212	170	0.3 (0.5)	2.0	50% min 15
Sulzer	two-stroke (piston oil cooling)	RTA 84 C/M/T 72. 62. 52 48. 38	–10%	+20%	180	0.5	0.5	min 5
	two-stroke (water cooling of the pistons)	RTA 84. 76. 68. 58 and all RND. RLA and RLB	–10%	+20%	180	0.5	0.5	min 5
	four-stroke	Z40. ZA40. ZA40S	–20%	+30%	180	0.5	2.5	min 60%
	four-stroke	type-A andS20	–20%	+30%	180	0.5	2.5	min 50%
Yanmar	four-stroke	all	–20%	+30%	180	0.3% vol.	2.0	4 (for fuel MDO) 15 (for fuel HFO)

* engines with separate cylinder oil circuit. fuelled by HFO.
** HFO fuelled engines without separate circulation of cylinder oil.
*** applies to the MaK 453 C engine.