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UNIFICATION OF GRADES OF DIESEL FUELS FOR HIGH-SPEED ENGINES

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The need for improvements in fuel quality and in the efficiency of fuel utilization is becoming more and more urgent, owing to the rapid growth in fuel consumption, the need for developing new types of fuels, and the increasing dependence of advances in equipment design on fuel quality and on rational utilization of the fuel. Of extreme importance in the national economy is the matter of curtailing the number of products and unifying the various fuel grades, particularly for diesel engine fuels.

Diesel fuels are currently produced in eight grades in accordance with two standards, for use in different engines under various conditions. Grades L, Z, Zs, and A are covered by the standard GOST 305–73, and grades DL, DZ, DA, and DS by GOST 4749–73. The existence of two standards complicates the planning of fuel production and the distribution, storage, transport, and supply of fuels to the consumers, and may not at all rarely leads to cross-hauls. Fuels conforming to GOST 305–73 are divided into two groups according to sulfur content, the first containing up to 0.2% and the second from 0.21 to 0.5%; fuels conforming to GOST 4749–73 are limited to 0.2% sulfur. A certain quantity of diesel fuel is produced with sulfur contents up to 1%.

The widespread use of hydrotreating processes has made it possible to lower the sulfur content in GOST 305–73 diesel fuels produced from medium-sulfur crudes down to the level of 0.2-0.5%. The increased processing of medium- and high-sulfur crudes has made it necessary to hydrotreat fuels produced to meet GOST 4749–73. Currently, 94% of all diesel fuels are produced with sulfur contents no higher than 0.5%, and 85% of these fuels have sulfur contents below 0.2%. The resources of crude oils that can be used to produce fuels meeting GOST 4749–73 are extremely limited; the production of these fuels has dropped off very sharply, currently amounting to only 2.5% of the total diesel fuel production, with prospects of a further drop.

Diesel fuels produced to meet GOST 305–73 and GOST 4749–73, particularly those with sulfur contents below 0.2%, are no different from each other in basic physicochemical quality indices, end-use, or service properties. As shown by many years of experience in application of these fuels, either will provide normal and reliable operation of diesels as in automotive vehicles, tractors, locomotives, and ships, and are also suitable for use in gas turbines. In tests on the operating life of one of the highest-performance high-speed transport diesels, using DZ fuel (GOST 4749–73) or Z (GOST 305–73) with a sulfur content below 0.5% in the latter fuel, no differences in terms of fuel effects on parts wear or on engine deposits could be detected. The results from these tests, the actual values of the physicochemical quality indices (Table 1), and data on extended storage of fuels under realistic conditions have led to the conclusion that fuels conforming to GOST 305–73 and GOST 4749–73 are equivalent.

According to the requirements of GOST 4749–73, fuel that is used in specially designed diesels has a more severe requirement on flash point and cetane number (DS grade). However, as shown by actual test results, diesels of these types can be operated successfully on summer-grade diesel fuel with sulfur content below 0.2% and flash point no lower than 61°C; hence there is no justification for any future production of a separate grade of fuel. Thus, at the present time there is no need and no economic justification for the production of diesel fuel to meet two different standards.

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TABLE 1. Characteristics of Diesel Fuels Conforming GOST 4749−73 and GOST 305−73, as Determined by Qualification Test Sequence

Characteristic	Diesel fuel	
	GOST 4749−73	GOST 305−73
Cetane number	45-55 (50 for DS)	45-57
Distillation, °C		
50%	255-290	240-280
96%	340-360	330-360
Viscosity at 20°C, mm^2/sec	1.5-6 4.5-8 (for DS)	1.5-6
Flash point, °C	35-36 (90 for DS)	30-61
Sulfur content		
total sulfur, mass %		
in group 1 fuel	0.05-0.2	0.05-0.2
in group 2 fuel	−	0.21-0.5
mercaptan sulfur, mass %	0.0001-0.1	0.0001-0.1
Existent gum content, mg/100 ml	30-60	30-40
Temperature, °C, Max.		
solid point		
for summer	−10	−10
for winter	−45	From −45 to −35
for arctic	−60	−55
cloud point		
for summer	−5	−5
for winter	−35	From −35 to −25
for arctic	Not standardized	
Carbon residue of 10% bottoms, %	0.01-0.3	0.01-0.3
Ash content, %	0-0.01	0-0.01

In other countries, diesel fuels are being produced and used in three or four grades. In most countries, two grades of fuel are being used, with significant gradations in low-temperature properties depending upon the season of the year and the area in which the fuels are used [1]. An NATO specification calls for a unified fuel grade F-75 that can be used year-round in high-speed diesel engines (including marine diesels) in areas in medium latitudes. Diesel engines in all climatic zones of the USSR can be operated successfully on one of three grades of diesel fuel: DL summer grade for air temperatures down to 0°C, DZ winter grade for air temperatures down to −20°C, and DA arctic grade for temperatures down to −50°C. For the most effective utilization of low-power diesel fuels, the solid point of winter-grade diesel fuel may be anywhere from −35 to −45°C, depending on the requirements of the user.

According to calculations performed by economists [2], the demand for winter-grade diesel fuel with a solid point of −35°C is at least 37% of the total demand for winter-grade diesel fuels, and the demand for fuel with −45°C solid point is 63% of the total. In order to fully satisfy the demands of users for winter-grade diesel fuel, the growth rate in the production of this material must be 1.7-2.5 times that for summer-grade fuels. In the immediate future, however, despite the introduction of Parex zeolite dewaxing units, a shortage of winter diesel fuels will be experienced. The demands of the western, central, and eastern regions of the country for fuel can be met more fully by the wintertime use (at temperatures down to −15°C) of summer-grade diesel with the pour-depressant additive VÉS-238. The results of test-stand and service evaluations performed in manufacturing plants, equipment testing stations, and collective farms have demonstrated the feasibility of using such fuel in areas in the temperature climatic zone. The addition of the pour-depressant to the fuel provides flexibility in production and in the output of diesel fuels with good low-temperature properties; also, the practice of diluting diesel fuels with kerosine can be eliminated. If this changeover can be made, then the standard winter-grade diesel fuel will be used only in districts with cold climates such as Altai, eastern Siberia, and the northern ural area. The additional supply of winter-grade diesel fuel to these districts will amount to about 30% of the total volume of these fuels produced.

TABLE 2. Specifications for Certain Foreign Diesel Fuels

Characteristic	NATO			Gr. Britain		W. Germ.
	F-54	F-75	F-76	Shell automotive transport diesel fuel	BS 28–69 Fuel,	DIN 51601
Cetane number Min	45	47	47	45	45	45
% distilled below 357°C	90	90	90	90	90	90
Viscosity at 37.8°C, mm^2/sec	—	1,8—7,5	1,8—7,5	1,6—5	7,8	1,8—10
Sulfur content, %, Max.	1	1	1	—	—	0,7
Flash point, °C, Min.	56	66	66	57	54	55

As a result of the greater numbers of engine-powered equipment operating in the USSR, the production of diesel fuels during the past seven years has increased by a factor of 1.5. In connection with the future dieselization of the automotive vehicle fleet, the demand for these fuels will increase by a factor of 1.7-1.9 in comparison with the present demand. These demands can be satisfied by raising the fuel end point to 380-390°C, in line with diesel fuel specifications in most European countries and the NATO specification (Table 2). The increase in the end point of the diesel fuel will involve certain changes in other properties. The 50% distillation point will be limited to a 290°C maximum instead of 280°C, and the 90% point to a 360°C maximum instead of 330-340°C; the solid point no higher than 5°C instead of 0°C; the existent gum content will be limited to a maximum of 50 mg/100 ml instead of 40 mg/100 ml; and the filterability factor will be limited to a maximum of 5 instead of 3.

The additional production of diesel fuel when the end point is raised will amount to 3-5% of the total output of summer-grade diesel fuel in many refineries. In view of the considerable increase in relative consumption of diesel fuels with higher cetane numbers, and in view of certain provisions that are made for cold-starting diesel engines, in particular by the use of flame preheating of the air, the cetane number specification for winter and arctic diesel fuels must be reduced to 40. This will make it possible to eliminate the use of isopropyl nitrite additive, which increases the carbon residue and lowers the flash point of the fuel. Moreover, when winter and arctic fuels are used, a reduction of cetane number from 45 to 40 shows very little effect on the starting of modern transport diesels at subfreezing temperatures.

The increasingly severe requirements on diesel fuel quality can be met to a considerable degree by the use of additives. In the current development stage are certain multifunctional additives, as well as additives to improve the combustion process, pumpability, protective properties, and stability of diesel fuels.

In the new standard, it will be desirable to reduce the number of property indices that must be determined. In particular, the present standards call for the determination of three different property indices to characterize the degree of diesel fuel cleanliness: the water content in accordance with GOST 2477−65, the content of solid contaminants in accordance with GOST 6370−59, and the filterability factor in accordance with GOST 19006−73.

The filterability factor reflects the influence of the other two quality indices, and it correlates well with service properties that determine the filter element life. Numerous studies of the causes for premature plugging of filter elements in diesel engines, these studies having been carried out at TsNITA [Central Scientific-Research and Design Institute of Fuel Systems and Tractor and Stationary Engines], NAMI [Central Scientific-Research Automotive Vehicle and Engine Institute], YaMZ (Yaroslavl' Engine Plant], and various machinery and vehicle testing stations have confirmed that fuel filterability at above-freezing temperatures depends on the contents of water, solid contaminants, and naphthenic acid soaps. However, any one of these properties indices by itself will not fully characterize the filterability of diesel fuels. Hence, it is advisable to replace these three quality indices by the determination of a single combination index, the filterability factor.

There is a need for a more objective evaluation of diesel fuel pumpability at subfreezing temperatures. In the existing standards, the low-temperature properties of fuels are rated in terms of the solid point [analogous to the pour point] and the cloud point. The solid point characterizes the mobility or fluidity of the fuel in relation to filling and emptying operations in storage tanks and tank cars or trucks; the cloud point characterizes a condition caused by crystallization of paraffinic hydrocarbons, such that the fuel loses its transparency. However, the cloud point does not give any idea of the degree of dispersity of the system consisting of fuel and precipitated wax crystals. Therefore, in order to evaluate the pumpability and circulation of fuels, particularly those with pour-depressant additives, a method has been developed and standardized in the Soviet Union and in other countries for the determination of low-temperature filterability (method for determination of the Limiting Temperature of Fuel Filterability, GOST 22254–76). The determination of this limiting temperature instead of the cloud point will undoubtedly bring the rating of low-temperature properties into closer conformance with the actual conditions encountered by fuels and service.

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UNIFICATION OF GRADES OF LUBRICATING OILS FOR AVIATION GAS-TURBINE ENGINES

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The high temperatures and operating loads on moving parts in gas turbines, the extremely high rotating speeds, and the continuous presence of oxygen in contact with the oil are factors contributing to the extremely severe operating conditions that lubricating oils encounter in modern gas-turbine engines. The suitability of oils is determined to a great degree by such high-temperature service properties as thermal-oxidative stability, lubricity, and corrosion properties. No less important are the operating characteristics of aviation oils at low temperatures, which must be such that aircraft gas-turbine engines can be started rapidly and reliably during the winter, particularly in the extreme northern and eastern areas of the USSR.

Advances in the design of jet aircraft have raised the level of requirements placed on the oils currently produced, and these oils will not provide reliable operation of the new engines that operate at a higher level of thermal stress. Therefore, new oils must be developed. However, even when new oils have been developed, the existing aviation oils have remained in service. The following factors also contribute to the expansion in the number of different aviation oil products: design differences in jet engines installed in modern aircraft, each of which imposes very different demands on the lubricating oil; the use of special-purpose synthetic oils in certain components of airborne equipment (36/1, VNII NP-5, and VNII NP-75A); and the lack of any standardization documents (up to 1972) limiting the selection of oils in the design of new engines and components.

As a result, we now find more than 20 different grades of oils and oil blends used in gas-turbine engines and aircraft equipment, including the comparatively inexpensive petroleum oils that have been used very widely in gas-turbine engines in subsonic aircraft, along with synthetic oils for supersonic aircraft. This proliferation of products has made it necessary to unify the grades of lubricating oils, on the basis of the best and most promising grades. Such unification will accomplish the following: The oil drain periods for the various engines can be extended, and in many cases the life of the engine between overhauls can be extended as a result of the use of high-quality oils; labor costs in aircraft servicing and maintenance can be reduced; the lube oil stock and supply system can be simplified and lowered in cost; and the oil consumption can be reduced.

Since the requirements imposed on oil quality by different turbojet and turboprop engines cannot be brought to a common ground without extreme difficulty, the unification of the oils used in these engines is best carried out individually, depending on the type of engine and aircraft. In turbojet engines, the oil operating

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