REPORT

“SYNTHETIC AND MINERAL CRUDE OILS

COMPATIBILITY STUDY”

Moscow - 2013

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INTRODUCTION

As written in clause 5 of the Design Specification, the purpose of this project is to evaluate the compatibility of synthetic crude oil and mineral crude oil when mixed together. This is the first time such synthetic crude oil and mineral crude oil compatibility studies are performed in Russia. A variety of sources suggest that synthetic liquid hydrocarbons (SLH) are manufactured and, apparently, used in some countries (for example, in South Africa), however no data have been found so far with respect to SLH detailed characteristics and application conditions.

The concerns about mixing synthetic products with natural oil are caused by the following reasons. Crude oil is a relatively balanced complicated irreversible disperse system of several hundreds of hydrocarbons and heteroatom compounds, including true solutions, colloidal solutions and suspensions, a system formed in quite different conditions (in the reservoir) over a very long period of time. The system's balance can be disturbed not only by changing the external effects (such as temperature, pressure, electrical current, etc.), but also by introducing small amounts of substances (for example, pour-point depressants). In this project we are to introduce a synthetic component in an amount of 2% to 50% into mineral crude oil and evaluate the stability of the mixtures qualitatively and quantitatively and their behavior during 7 days.

The crude oil samples for testing were obtained from INFRA Technology LLC:

- INFRA - VDR2 synthetic crude oil – 9 liters;
- Mineral crude oil – 10 liters.

This report represents the findings of the integrated study of mixed synthetic crude oil and mineral crude oil compatibility and the results of evaluation of the chemical and physical stability of the mixtures after one week storage in glass containers at the temperatures of 5 °C and 20 °C.

1. Selecting and adapting the existing methods of compatibility study for mixed synthetic and mineral crude oils with reference to STO 11605031-034-2009 and GOST R 51858-2002

Technical standard documents for crude oils and gas condensates contain no special methods for evaluating the physicochemical stability of the raw materials or their mixtures. In this study, compatibility and physicochemical stability of synthetic and mineral crude oil mixtures should be understood as the ability of crude oils to form homogeneous mixtures with the synthetic ingredient concentrations ranging between 2% and 50% by weight and the ability of the mixtures to retain their properties as well as avoid de-mixing and sedimentation on the bottom and the walls of a glass vessel for 7 days at the storage temperatures of 20 °C and 5 °C.

The most important components in the structure of crude oils are:

- Asphaltenes – brittle solid substances with the molecular weight of 1000 to 5000, density over 1.0, contained in crude oil in the form of colloidal rather than ideal solutions, prone to precipitation upon addition of light hydrocarbon solvents, which is actually the basis for their determination method per GOST 11858 and the oil residue deasphaltenization process.

- “Hard paraffins” (GOST 11851) – paraffins and ceresins with the melting point of 50 °C or higher that form “mesh structures” in the oil, which reduce the oil fluidity.

To evaluate the properties of synthetic and mineral crude oil mixtures, oil quality indicators have been examined that are most essential for the specialists and present in practically all standards for the raw materials. The following quality indicators have been selected:

- From GOST 51858 “Crude oil. General specifications”: density, fractional composition per GOST 2177, paraffin content (Appendix 1);

- From STO 11605031 “Crude oil and gas condensates. Unified research program”: kinematic viscosity, pour point, and asphaltene and (silica-gel) resin content.

Crude oil quality indicators

GOST Name	GOST no.	Scope	Accuracy characteristics (reproducibility)
Methods for determination of density	3900	The method is used for determination of density of crude oil and oil products	Two results are deemed true if the discrepancy between them does not exceed 0.001 g/cm^3
Method for determination of kinematic viscosity and calculation of dynamic viscosity	33	The standard establishes the method for determination of kinematic viscosity by glass viscosimeter of oil products liquid at the test temperature for which the shear stress is proportional to the deformation rate	Discrepancy in the results obtained in different laboratories shall not exceed 0.72% of the arithmetic average value
Methods of pour point determination	20287	Determination of pour point by method B	Discrepancy in two parallel results shall not exceed 2°C
Method for determination of fractional composition	2177	The standard establishes method B for determination of fractional composition of crude oil and dark oil products	Two results are deemed true if the discrepancy between them does not exceed: 7°C for IBP, 6°C for 10% distillation, 3°C for 50% distillation, 7°C for 90% distillation, 10°C for 96%-98% distillation
Method of determination of asphaltic-resinous substances content	11858	The standard covers crude oil, oils and liquid dark oil products additive-free	Allowable deviation from the lowest result value is 10%-20% depending on asphaltene and resin content
Method of paraffin determination	11851	Determination of paraffin mass fraction of crude oil by method A of this standard	Reproducibility of the results is 68% of the arithmetic average

Preliminary tests of applicability of the selected analysis methods for evaluation of properties of synthetic crude oil and its mixtures have been conducted with 50/50 mixture, where the mineral crude oil was represented by marketable oil – raw material of Nizhny Novgorod Refinery, well studied and by its properties (except the pour point) close to the representative sample of oil of the year 2013. Table 1.1 shows the results of performance of intensity and duration of mixing components to obtain homogeneous mixture. The tests have shown that, in order to obtain a homogeneous mixture, after 10 minutes of stirring, some time is required for the mixture to achieve complete equilibrium. Normally, to speed up mixture homogenization, heating is used, but in this case such technique was not possible due to the danger of losing highly volatile components of the synthetic and mineral crude oils; therefore, instead of heating, the mixture was held at the indoor temperature overnight (for 14 hours). After the mixing method was selected, the mixture was put to storage at the temperature of 20°C. The near-bottom sample analysis was carried out after three, six, and seven days. The test results (Table 1.2) have shown that:

- Viscosity, density and asphaltene content of the near-bottom sample tend to rise;
- Sensitivity of the selected methods of analysis is sufficient for the evaluation of the mixture conditions.

It should be noted that the additive properties of crude oil, density, viscosity at 50°C, and asphaltene content retain additivity for mixtures as well, that is the experimental results are close to the estimated values. Non-additive properties such as pour point, viscosity at 20°C, “paraffin melting temperature” show greater differences from the initial values and therefore evidence the change in the mixture structure as compared with the mineral crude oil structure.

In accordance with the preliminary tests and observations, a uniform procedure has been established for preparation of mixtures, delivery for or removal from storage, and assessment of sedimentation rate.

Table 1.1

Changes in the properties of synthetic and mineral crude oil mixture in the process of preparation

Indicators	CRUDE OILS		Mixture of synthetic and mineral crude oils in 50% to 50% mass ratio after 10-minute stirring					GOST
	Synthetic	Mineral	Start of analysis	After one hour	After five hours	After fourteen hours	Maximum possible calculated values*	
Density at 20°C, kg/m^3	740.4	861.6	758.1	765.2	775.0	778.5	797.0	3900
Kinematic viscosity at 20°C, mm^2/sec	1.36	21.35	2.34	2.41	2.65	2.70	3.83	33
Kinematic viscosity at 50°C, mm^2/sec	0.91	8.10	1.45	1.51	1.58	1.62	2.15	33
Pour point, °C	-17	-30	-24	-24	-25	-27	-22	20287

*) Excluding the gas cut

Table 1.2

Physicochemical characteristic of synthetic and mineral crude oils and their 50/50 mixture

Indicators	CRUDE OILS		Mixture of synthetic and mineral crude oils in 50% to 50% mass ratio					GOST
	Synthetic	Mineral	Initial	Near-bottom sample				
				After three days	After six days	After seven days	Maximum possible calculated values*	
1	2	3	4	5	6	7	8	9
Density at 20°C, kg/m^3	740.4	861.6	778.5	793.9	808.2	812.2	797.0	3900
Kinematic viscosity at 20°C, mm^2/sec	1.36	21.35	2.70	2.86	4.12	4.15	3.83	33
Kinematic viscosity at 50°C, mm^2/sec	0.91	8.10	1.62	1.69	2.30	2.38	2.15	33
Pour point, °C	-17	-30	-27	-26	-18	-19	-22	20287
Sulfur content, total % mass	0.0008	1.35	-	-	-	-	-	R51947
Content of, %: asphaltenes	0	1.82	0.88	1.10	1.10	1.09	0.91	11858
silica-gel resins	0.2	11.3	5.0	-	-	4.9	5.5	11858
paraffin with melting temperature, °C	1.2 50	4.8 53	2.8 51	-	-	2.7 51	3.1 50	11851

Table 1.2 - continued

1	2	3	4	5	6	7	8	9
Sedimentation after storage	-	-	-	-	-	black deposit on bottom and walls	-	visually
Fractional composition: IBP, °C	69	53	58	-	-	-	61	2177
Boiling out, % vol. to temperature: 80°C	1.5	3.0	2.5	-	-	-	2.5	
100°C	6.5	5.5	5.5	-	-	-	6.0	
150°C	34.5	12.0	23.0	-	-	-	23.0	
200°C	60.0	20.5	39.0	-	-	-	40.2	
240°C	75.5	25.5	49.5	-	-	-	50.5	
300°C	89.0	37.0	65.0	-	-	-	63.0	
EBP (336°C)	96.0	-	-	-	-	-	-	
350°C	-	48.0	69.0	-	-	-	70.0	

*) Excluding the gas cut

2. Practice of preparing mixtures of synthetic and mineral crude oils and evaluating the physicochemical stability of the mixtures during storage

The mixture is to be prepared in the amount of 1500 g in a glass container with mechanical stirring during 10 minutes followed by maturation at the indoor temperature during 14 hours. After that, the mixture is to be intensively stirred again for 5 minutes and poured in three vessels:

- Take 300 ml of the mixture from the middle with a pipette and into an individual container for immediate determination of initial quality indicators of the mixture.

- Pour 600 ml portions of the mixture into two cylinders and place for storage at the temperatures of 5 °C and 20 °C.

A mineral crude oil sample was placed for storage in the same conditions as a reference sample.

After 7 days, pipette the upper sample from each cylinder in the amount of 200 ml, and then sample the lower (near-bottom) sample in the amount of 300 ml. The near-bottom sample is to be analyzed first. If its asphaltene content does not exceed the initial value, this indicator needs not be determined for the upper sample. Turn over the cylinder with the remnants of the mixture and place it into a jar for the night (14 hours).

The next morning, examine the cylinder's bottom and walls in transmitted light and describe the observations. If a deposit or sediment exists, pour 50 ml of toluene into the cylinder, dissolve the sediment and drain the solution into a constant-weight jar, which is then to be put on a tray with sand preheated up to 105 °C in order to evaporate the solvent. The jar with the sediment after evaporation is to be brought to the constant weight. The sediment amount is to be weighed with accuracy to four digits. The sediment amount determination result is to be expressed as mass percentage in relation to the stored amount of the liquid and rounded up to three decimals.

3. Determination of physicochemical characteristic of initial synthetic and mineral crude oil samples

Table 3.1 represents the physicochemical properties of the initial synthetic and mineral crude oils as determined by the selected standard methods of analysis of the indicators listed in para. 1.2 of the Design Specification.

Table 3.1

Physicochemical characteristic of synthetic and mineral crude oils

Indicators	Oils		GOST
	Synthetic	Mineral	
1	2	3	4
Density at 20°C, kg/m^3	740.4	869.5	3900
Kinematic viscosity at 20 °C, mm^2/sec	1.36	25.78	33
Kinematic viscosity at 50 °C, mm^2/sec	0.91	9.58	33
Pour point, °C	-17	-10	20287
Sulfur content, % mass	0.0008	1.5	R 51947
Content, % of: asphaltenes	0	2.04	11858
silica-gel resins	0.2	10.7	11858
paraffin with melting temperature, °C	1.2 50	4.0 56	11851
Fractional composition:			2177
IBP, °C	69	49	
Boiling out, % vol. to temperature: 80 °C	1.5	3.5	
100 °C	6.5	7.5	
150 °C	34.5	15.5	
200 °C	60.0	23.5	

Table 3.1 - continued

1	2	3	4
240 °C	75.5	30.0	
300 °C	89.0	41.5	
EBP (336 °C)	96.0	-	
350 °C	-	55.0	

By its physicochemical properties, the synthetic crude oil sample is somewhat differing from the sample examined in 2011 (Appendix 2). The mineral oil's properties are close to those of the typical marketable West Siberian (sour) crude oil.

Increased volatility of the samples during weighing was noted while making analysis of the synthetic crude oil, which could have somewhat reduced the measuring accuracy. This noticeable evaporability of the crude oil samples is attributed to their significant content (4.9% to 5.5%) of light hydrocarbons up to C_5 inclusive (Table 3.2).

Table 3.2

Content and individual SG of gases to C_4 and C_5 dissolved in synthetic and mineral crude oils

Synthetic crude oil					Mineral crude oil				
Hydrocarbons	to C_4, %		to C_5, %		Hydrocarbons	to C_4, %		to C_5, %	
	for oil	for gas	for oil	for gas		for oil	for gas	for oil	for gas
Methane	-	-	-	-	Methane	-	-	-	-
Ethane	-	-	-	-	Ethane	0.07	2.62	0.07	1.35
Propane	0.03	4.02	0.03	0.66	Propane	0.89	31.35	0.89	16.17
Isobutane	0.27	33.46	0.27	5.50	Isobutane	0.46	16.26	0.46	8.39
N-butane	0.51	62.53	0.51	10.28	N-butane	1.42	49.76	1.42	25.67
Isopentane	-	-	1.82	37.02	Isopentane	-	-	1.11	20.11
N-pentane	-	-	2.29	46.54	N-pentane	-	-	1.55	28.30
Total:	0.81	100.00	4.92	100.00	Total:	2.84	100.00	5.50	100.00

4. Preparation and analysis of synthetic and mineral crude oil mixtures

In accordance with the procedure described in the “practice”, mixtures were prepared from the mineral crude oil with the synthetic crude oil content of 2%, 7%, 15%, 25%, and 50%. The physicochemical properties of the mixtures were determined for all of the selected quality indicators and represented in Table 4.1. With the increase in the synthetic crude oil concentration the change of properties (except for the pour point) was occurring gradually, without jumps. The basic properties of the mixtures – density, kinematic viscosity at 50 °C, content of asphaltenes, resins, and paraffin, as well as fractional composition – were close to the estimated values. Abnormal pour point behavior of the mixtures was noticed: the growing content of the synthetic component in a mixture scarcely affected its pour point, which, strangely enough, was close to the pour point of the mineral crude oil. This fact evidences considerable influence of the synthetic component on structuring of oil, for which reason the behavior of the “pour point” of the mixture becomes unpredictable. It should also be noted that kinematic viscosity at 20 °C is to a greater extent differing from the estimated values than kinematic viscosity at 50 °C is, which, in all appearances, is also related to the mixture structure change. Moreover, in all mixtures, i.e. with a synthetic component present, the paraffin melting temperature is lowering (when determined as per GOST 11851) in comparison with the melting temperature of the paraffin extracted from the initial mineral crude oil.

Table 4.1

Physicochemical characteristic of synthetic and mineral crude oils and their mixtures in various ratios

Indicators	OILS		Synthetic and mineral oil mixture in the ratio:					GOST
	Synthetic	Mineral	2/98	7/93	15/85	25/75	50/50	
1	2	3	4	5	6	7	8	9
Density at 20 °C, kg/m^3	740.4	869.5	868.3	860.1	847.8	830.9	799.9	3900
Kinematic viscosity at 20 °C, mm^2/sec	1.36	25.78	22.94	19.75	13.22	8.87	4.09	33
Kinematic viscosity at 50 °C, mm^2/sec	0.91	9.58	8.75	7.80	5.73	4.21	2.20	33
Pour point, °C	-17	-10	-10	-10	-11	-11	-11	20287
Sulfur content, total % mass	0.0008	1.5						R 51947
Content, % of: asphaltenes	0	2.04	2.00	1.89	1.73	1.53	1.00	11858
silica-gel resins	0.2	10.7	10.5	9.9	9.1	8.12	5.28	11858
paraffin with melting temperature, °C	1.2 50	4.0 56	4.0 54	3.9 53	3.6 54	3.3 53	2.8 54	11851

Table 4.1 - continued

1	2	3	4	5	6	7	8	9
Fractional composition: IBP, °C	69	49	50	49	55	56	56	2177
Boiling out, % vol. to temperature: 80 °C	1.5	3.5	3.5	3.5	3.5	3.0	2.5	
100 °C	6.5	7.5	7.5	7.5	6.5	7.0	7.0	
150 °C	34.5	15.5	15.5	17.5	18.5	25.0	27.0	
200 °C	60.0	23.5	24.0	27.0	28.5	37.5	43.5	
240 °C	75.5	30.0	30.0	35.0	37.0	44.0	54.5	
300 °C	89.0	41.5	42.0	47.0	49.0	58.5	67.5	
EBP (336 °C)	96	-	-	-	-	-	-	
350 °C	-	55.0	55.0	64.0	67.0	72.5	77.0	

5. Storage. Analysis of results and conclusions

Tables 5.1 to 5.7 show the results of analysis of five synthetic and mineral crude oil mixtures and of mineral crude oil (reference test) after storage at 5 °C and 20 °C.

The objective of this work phase was to obtain the necessary input for evaluating separating ability of synthetic and mineral crude oil mixtures as well as for assessing possible sedimentation upon short-term storage of the mixtures at positive temperatures. Examination of the experimental analysis findings for the mixtures of different composition before and after storage allowed us to come to the necessary intermediate conclusions.

- For all samples, including the reference sample, the near-bottom layer becomes somewhat “heavier” after storage while the upper layer becomes “lighter” at the same time as compared with the quality indicators of the initial mixture.

- All samples demonstrate higher stability of mixtures when stored at the temperature of 5 °C rather than at the temperature of 20 °C. However, the differences in the density and viscosity values of the near-bottom and the upper layers before and after storage at different temperatures are minor and basically fall into the allowable reproducibility limits.

- The results of direct determination of asphaltenes in the sample’s strata after storage (at 20 °C) have shown that only for the near-bottom sample of the 50/50 mixture (Table 5.6) the asphaltene content exceeds the allowable deviation value. The same was observed in the preliminary tests (Table 1.2).

- Paraffin and resin content of the near-bottom sample were generally unchanged quantitatively during storage, but the melting temperature of the paraffin extracted during the process of its determination as per GOST 11851 after storage was also 2 °C to 4 °C lower than in the initial mineral crude oil.

- As expected, the fractional composition of the mixture samples did not change after storage (Table 5.7).

- Observation of the formation of sediment (or deposit) on the bottom and walls of vessels after storage of the initial mineral crude oil (reference test) and mixtures of diverse composition has allowed for evaluating and substantiating the choice of the permissible synthetic component content of the mixtures with mineral crude oil. In the vessels, after the storage of the initial mineral crude oil, 2/98 and 7/93 mixtures, no deposit or sediment was observed that would be discernible with bare eye in transmitted light. In a vessel, after the storage of 15/85 and 25/75 mixtures, a slight dark deposit was observed on the bottom and walls partially or on the whole phase boundary. In a vessel, after the storage of 50/50 mixture, denser dark sediment was found on the bottom and walls of the vessel with a sharp line along the phase boundary. For 15/85, 25/75, and 50/50 mixtures, the quantity of sediment in the vessel after the storage was determined by the procedure mentioned in the "Practice" (Tables 5.4 and 5.5). As could be expected, the maximum quantity of sediment was found in the vessel after the storage of 50/50 mixture (Table 5.6). Theoretically, the sediment could contain not only asphaltenes but also resins, carbenes, carboides, and mechanical impurities. In this case, direct determination of asphaltenes in the sediment per GOST 11858 could not be performed due to little amount of the sediment.

Table 5.1

Results of mineral crude oil analysis before and after storage (reference sample)

Indicators	OILS					GOST
	Initial	After storage at 20 °C		After storage at 5 °C		
		near-bottom	upper	near-bottom	upper	
Density at 20 °C, kg/m^3	869.5	872.6	865.3	870.0	869.1	3900
Kinematic viscosity at 20 °C, mm^2/sec	25.78	25.90	25.58	25.89	25.81	33
Kinematic viscosity at 50 °C, mm^2/sec	9.58	9.61	9.49	9.62	9.59	33
Pour point, °C	-10	-4*	-5*	-6*	-5*	20287
Content, % of: asphaltenes	2.04	2.05	2.03	2.00	2.04	11858
silica-gel resins	10.7	10.6	-	10.6	-	11858
paraffin with melting temperature, °C	4.0 56	-	-	4.0 56	-	11851
Sedimentation after storage	-	none	-	none	-	visually

*) Pour point without heat treatment

Table 5.2

Results of 2/98 synthetic and mineral crude oil mixture analysis before and after storage

Indicators	Synthetic and mineral crude oil mixture					GOST
	Initial	After storage at 20 °C		After storage at 5 °C		
		near-bottom	upper	near-bottom	upper	
Density at 20 °C, kg/m^3	868.3	869.2	866.8	868.5	866.8	3900
Kinematic viscosity at 20 °C, mm^2/sec	22.94	23.01	22.89	23.02	22.99	33
Kinematic viscosity at 50 °C, mm^2/sec	8.75	8.80	8.77	8.79	8.81	33
Pour point, °C	-10	-7*	-7*	-5*	-6*	20287
Content, % of: asphaltenes	2.00	2.03	1.99	2.00	2.00	11858
silica-gel resins	10.5	10.5	-	-	-	11858
paraffin with melting temperature, °C	4.0 54	4.0 54	-	-	-	11851
Sedimentation after storage		none	-	none	-	2477

*) Pour point without heat treatment

Table 5.3

Results of 7/93 synthetic and mineral crude oil mixture analysis before and after storage

Indicators	Synthetic and mineral crude oil mixture					GOST
	Initial	After storage at 20 °C		After storage at 5 °C		
		near-bottom	upper	near-bottom	upper	
Density at 20 °C, kg/m^3	860.1	860.4	859.3	860.8	860.8	3900
Kinematic viscosity at 20 °C, mm^2/sec	19.75	19.80	19.71	19.80	19.73	33
Kinematic viscosity at 50 °C, mm^2/sec	7.80	7.85	7.78	7.85	7.80	33
Pour point, °C	-10	-6*	-7*	-6*	-6*	20287
Content, % of: asphaltenes	1.89	1.90	1.90	1.90	1.90	11858
silica-gel resins	9.9	9.9	-	9.9	-	11858
paraffin with melting temperature, °C	3.9 53	3.9 53	-	3.9 53	-	11851
Sedimentation after storage		none	-	none	-	2477

*) Pour point without heat treatment

Table 5.4

Results of 15/85 synthetic and mineral crude oil mixture analysis before and after storage

Indicators	Synthetic and mineral crude oil mixture					GOST
	Initial	After storage at 20 °C		After storage at 5 °C		
		near-bottom	upper	near-bottom	upper	
Density at 20 °C, kg/m^3	847.8	848.5	846.5	848.0	847.1	3900
Kinematic viscosity at 20 °C, mm^2/sec	13.22	13.30	13.18	13.28	13.10	33
Kinematic viscosity at 50 °C, mm^2/sec	5.73	5.75	5.70	5.75	5.72	33
Pour point, °C	-11	-5*	-5*	-4*	-5*	20287
Content, % of: asphaltenes	1.73	1.72	1.70	1.70	1.70	11858
silica-gel resins	9.1	9.1	-	9.1	-	11858
paraffin with melting temperature, °C	3.6 54	3.6 53	-	3.6 53	-	11851
Sedimentation after storage		sediment on bottom and partially on walls	-	sediment on bottom and partially on walls	-	visually
Sediment amount, % mass		0.076		-		“Practice”

*) Pour point without heat treatment

Table 5.5

Results of 25/75 synthetic and mineral crude oil mixture analysis before and after storage

Indicators	Synthetic and mineral crude oil mixture					GOST
	Initial	After storage at 20 °C		After storage at 5 °C		
		near-bottom	upper	near-bottom	upper	
Density at 20 °C, kg/m^3	830.9	833.0	829.8	832.6	830.0	3900
Kinematic viscosity at 20 °C, mm^2/sec	8.87	9.02	8.72	8.94	8.78	33
Kinematic viscosity at 50 °C, mm^2/sec	4.21	4.45	4.18	4.30	4.18	33
Pour point, °C	-11	-4*	-5*	-5*	-5*	20287
Content, % of: asphaltenes	1.53	1.55	1.52	1.53	1.53	11858
silica-gel resins	8.12	8.15	-	8.20	-	11858
paraffin with melting temperature, °C	3.3 53	3.2 52	-	3.4 52	-	11851
Sedimentation after storage		slight deposit on bottom and dark strip on walls	-	slight deposit on bottom and dark strip on walls	-	visually
Sediment amount, % mass		0.080				“Practice”

*) Pour point without heat treatment

Table 5.6

Results of 50/50 synthetic and mineral crude oil mixture analysis before and after storage

Indicators	Synthetic and mineral crude oil mixture					GOST
	Initial	After storage at 20 °C		After storage at 5 °C		
		near-bottom	upper	near-bottom	upper	
Density at 20 °C, kg/m^3	799.9	807.1	794.4	801.6	798,5	3900
Kinematic viscosity at 20 °C, mm^2/sec	4.09	4.79	3.95	4.38	4,05	33
Kinematic viscosity at 50 °C, mm^2/sec	2.20	2.31	2.18	2.27	2,19	33
Pour point, °C	-11	-8*	-10*	-8*	-8*	20287
Content, % of: asphaltenes	1.00	1.14	0.95	0.98	0,98	11858
silica-gel resins	5.28	5.25	-	5.30	-	11858
paraffin with melting temperature, °C	2.8 54	2.7 52	-	2.7 53	-	11851
Sedimentation after storage		continuous dark deposit on bottom and walls	-	continuous dark deposit on bottom and walls	-	visually
Sediment amount, % mass		0.094				“Practice”

*) Pour point without heat treatment

Table 5.7

Fractional composition under GOST 2177 of synthetic and mineral crude oil mixture after storage at 20 °C

Indicators:	Synthetic and mineral crude oil mixture ratio				
	2/98	7/93	15/85	25/75	50/50
IBP, °C	51	48	54	56	58
Boiling out, % vol. to temperature: 80 °C	3.5	3.5	3.5	3.0	2.5
100 °C	7.5	7.5	7.0	7.0	6.5
150 °C	15.0	17.0	18.0	24.5	26.5
200 °C	24.5	26.5	29.0	37.0	43.5
240 °C	30.0	35.0	37.0	43.5	54.0
300 °C	42.0	47.5	49.0	59.0	68.0
350 °C	55.0	64.5	67.5	73.0	77.0

Conclusion

The objective of this study was to evaluate compatibility of synthetic and mineral crude oils when mixed together. In full compliance with the Design Specification to this contract, comprehensive study was carried out to investigate compatibility of synthetic and mineral crude oils mixed together and results were obtained of evaluation of physicochemical stability of the mixtures after one-week storage in a glass reservoir at the temperatures of 5 °C and 20 °C.

In this study, compatibility and physicochemical stability of synthetic and mineral crude oil mixtures are understood as the ability of the crude oils to form homogeneous mixtures with the synthetic ingredient concentrations ranging between 2% and 50% by weight and the ability of the mixtures to retain their properties – not to break down and not to form sediments on the bottom and walls of a vessel during short-time storage. Preliminary tests were performed in order to select and approbate the methods of analysis on synthetic and mineral crude oil mixtures. Most common and illustrative methods of mixture analyses, conditions of mixing and storage, sampling and testing were selected. The “Practice of preparing mixtures of synthetic and mineral crude oils and evaluating the physicochemical stability of the mixtures in storage” was developed especially for this study. Conformity to a single procedure of mixtures research and utilization of standard analysis methods allowed receiving comparable results carefully checked for integrity. The summation of the data obtained from the synthetic and mineral crude oil mixture research suggest the following conclusions:

- For all the samples, including the reference sample, the near-bottom layer becomes somewhat “heavier” after storage while the upper layer becomes “lighter” at the same time as compared with the quality indicators of the initial mixture.

- All samples demonstrate higher stability of mixtures when stored at the temperature of 5 °C rather than at the temperature of 20 °C.

- Differences in the density and viscosity values of the near-bottom and the upper layers before and after storage at different temperatures are minor and basically fall into the allowable reproducibility limits.

- The results of direct determination of asphaltenes in the sample's strata after storage (at 20 °C) have shown that only for the near-bottom sample of the 50/50 mixture the asphaltene content exceeds the permissible deviation value. The same was observed in the preliminary tests.

- Paraffin and resin contents of the near-bottom sample of all mixtures were generally unchanged quantitatively during storage.

- Fractional composition of the mixture samples did not change after storage.

- Results of storing mixtures at positive temperatures have shown than the synthetic crude oil addition influences noticeably the change in the crude oil disperse system structure but does not cause abrupt changes of the phase equilibrium.

- Onset of sedimentation process is noticed in the mixture that contains 15% of the synthetic component.

- Amount of sediment after storage increases for 25/75 and 50/50 mixtures as compared with 15/85 mixture.

Therefore, the findings of the study suggest that, in order to obtain homogeneous stable mixtures, the admixture of synthetic crude oil to the mineral crude oil (in its composition and properties close to the marketable West Siberian (sour) crude oil) should not exceed 15% by weight.

For industrial conditions it is recommendable to specifically prepare the synthetic and mineral crude oil mixture in a tank. The synthetic crude oil should be fed from the bottom of the tank, with mineral crude oil already inside, followed by 3 to 5 recirculation cycles. Such method will allow receiving homogeneous mixture while keeping valuable light hydrocarbons in the mixture.

Analysis of synthetic and mineral crude oil mixtures is made in accordance with GOST R 51585-2002, which is typical for marketable oil.

Appendix 1 GOST R 51858

Table 2 – Oil types

Indicator	Rate for oil type										Test method
	0		1		2		3		4		
	Inside Russia	For export	Inside Russia	For export	Inside Russia	For export	Inside Russia	For export	Inside Russia	For export	
1. Density, kg/m^3 at temperature:	Up to 830.0		830.1 to 850.0		850.1 to 870.0		870.1 to 895.0		Over 95.0		In accordance with GOST 3900 and 9.3 of this standard
20 °C											
15 °C	Up to 833.7		833.8 to 853.6		853.7 to 873.5		873.6 to 898.4		Over 898.4		In accordance with GOST R 51069 and 9.3 of this standard
2. Fractional yield, % vol. min to temperature:											In accordance with GOST 2177 (method B)
200 °C	-	30	-	27	-	21	-	-	-	-	
300 °C	-	52	-	47	-	42	-	-	-	-	
3. Mass fraction of paraffin, % max	-	6	-	6	-	6	-	-	-	-	In accordance with GOST 11851

Notes:
1. If by one of the indicators (density or fractional yield) oil belongs to a lesser number type and by other, to a greater number type, such oil is to be considered belonging to the greater number type.
2. Oil of types 3 and 4 when taken into pipeline transportation system for further delivery to export must have the rate under indicator 3 “max 6%”.

Appendix 2

Physicochemical characteristic of synthetic crude oil

INFRA Technology LLC, 2011

Indicators	Values	GOST or practice
Density at 20 °C, kg/m^3	745.6	3900
Kinematic viscosity at 20 °C, mm^2/sec	1.57	33
Kinematic viscosity at 50 °C, mm^2/sec	1.03	33
Pour point, °C	-5	20287
Content, % of: asphaltenes	0.03	11858
silica-gel resins	0.4	11858
paraffin with melting temperature, °C	2.4 52	11851
total sulfur	0.001	R 51947
Fractional composition:		2177
IBP, °C	78	
Boiling out, % vol. to temperature: 80 °C	 2.5	
100 °C	4.0	
150 °C	30.0	
200 °C	56.0	
240 °C	72.0	
300 °C	88.0	
EBP (345 °C)	96.5	