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8 January 1980

USSR Report

RESOURCES

(FOUO 1/80)

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USSR REPORT

RESOURCES

(FOUO 1/80)

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FUELS AND RELATED EQUIPMENT

UDC 622.276.6

PLANNING OF SYSTEMS FOR CARBON DIOXIDE INJECTION INTO A BED

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 5-7

[Article by B. M. Vladimirov and G. N. Yemel'yanov, Bashkir State Scientific Research and Planning Institute of the Oil Industry, submitted for publication 21 Dec 78]

[Text] For the purposes of a more complete extraction of oil from the depths of the earth it is planned to widely introduce new methods for working the fields with the use of chemical reagents.

Abroad work on carbon dioxide injection into a bed to increase the oil output has been done since 1949, whereby positive results have been obtained. Experimental industrial work to estimate the effectiveness of using carbon dioxide to increase the oil output was carried out at the Aleksandrovskiy area in the association "Bashneft'" [1].

Carbon dioxide is not an active compound, it is thermally stable, does not burn, and partially interacts with water, forming carbonic acid that possesses the properties of a weak acid [2]. The physical properties of carbon dioxide depend on the temperature, pressure and phase state. Under normal conditions (0° and 760 mm Hg) carbon dioxide is a gas with density of 1.9769 kg/m^3 and molecular weight 44.

The indices for injection into a bed (discharge, pressure, cycle of operations, sequence of connection, etc.) are taken according to the data of the production plan or the plan for development of the formation. Injection of carbon dioxide into the bed, as a rule, is done through injection wells cyclically (alternately with water). Therefore the systems of flooding of the bed and injection of carbon dioxide into the bed must comprise a unified system of maintaining formation pressure (MFP) of the field.

In the development of new oil fields or in the case where the active system of flooding meets the requirements set for the systems of carbon dioxide injection into a bed, certain elements in the MFP system (wells, injection pipelines and distributing points) can operate both on water and on carbon dioxide.

The requirements for the quality of the product to be pumped are taken from the condition of complete solubility in liquid carbon dioxide of gaseous admixtures and prevention of internal corrosion of the pipes.

The maximum permissible content of admixtures in carbon dioxide that is designed for injection into a bed is given below

water,%	0.02
Hydrogen, %	0.15
carbon monoxide,%	0.15
hydrogen sulfide, mg/m^3	20
other admixtures	traces

The optimal working parameters of the pipeline transport of carbon dioxide in a certain phase are defined by the temperature of the environment (soil, air), physical properties of the transported product, presence of effective thermal insulation structures, and the pumping indices (output, distance).

Thus, for example, the main pipelines and intrafield systems of carbon dioxide that are planned for construction extend from several tens to hundreds of kilometers. The output of the pipelines changes from 0.2 to 4.0 million T/year.

Under conditions of the Ural-Volga region the soil temperature in the zone of carbon dioxide pipeline laying (depth of occurrence 1.5-1.7 m) in winter is plus 1-1.5°C, and in summer plus 10-13°C. For the indicated temperatures the absolute saturation pressure of carbon dioxide (elasticity of vapors) is in winter 35-37 $kg\text{-}f/cm^2$, and in summer 46-48 $kg\text{-}f/cm^2$. To preserve the one-phase state of carbon dioxide its pressure at any point must differ from the saturation pressure by no less than 5-6 $kg\text{-}f/cm^2$.

Transporting of carbon dioxide on pipelines can be implemented as follows.

First method--transporting of carbon dioxide in a gaseous state under pressures up to 35 $kg\text{-}f/cm^2$ on anisothermic pipelines. The density of the product here will be altered in limits 30-90 kg/m^3, which results in large metal outlays for the construction of the linear section of the gas pipelines, increase in the equipment and consumption of electricity for driving the compressors. Before injecting the carbon dioxide into the wells it is necessary to raise the pressure to 150-200 kg/cm^2.

Second method--transporting carbon dioxide in the liquid state under pressures over 54 $kg\text{-}f/cm^2$ on anisothermic pipelines is the most efficient. This is evident from the following: the carbon dioxide with pressure above the critical (over 75 $kg\text{-}f/cm^2$) can be injected in a relatively broad range of temperatures without the danger of phase conversions. Here the density of carbon dioxide in the temperature interval 0-15°C will be altered insignificantly.

Pressure, kg-f/cm^2	Density, kg/m^3
80	952-870
150	1000-935
200	1020-960

With this method it is recommended that the carbon dioxide be transported from the site of its production to the fields under pressure up to 100 kg-f/cm^2, and at the oil fields under pressure 150-200 kg-f/cm^2.

Third method--transporting carbon dioxide in the liquid state under pressures up to 54 kg-f/cm^2. The temperature of the product to be pumped here must not be above the temperature of condensation (minus 20°C-minus 5°C) in order to prevent the separation of the gaseous phase. In this case the liquid carbon dioxide can be pumped on isothermic pipelines.

In order to maintain the heat content of the medium to be pumped on the required level on the linear section of the pipeline in 40-60 km the product must be cooled to the initial temperature with the help of cooling units.

With the given method of pumping carbon dioxide complexities arise in the operation of the structures and it is necessary to employ cooling units and effective hydrophobic thermal insulating materials.

Fourth method--transporting of carbon dioxide in the supercritical state at a temperature to prevent condensation above plus 31°C. The starting pressure of pumping for economic considerations is taken as 140-180 kg-f/cm^2. Pumping of the product in this case is possible on isothermic pipelines.

In order to maintain the heat content of the medium to be pumped on the required level on the linear section of the pipeline in 40-60 km the carbon dioxide must be heated in heat generators.

This method of transporting carbon dioxide can be very effective in pumping on standard (anisothermic) pipelines in cases where the specific local conditions guarantee the product temperature at the end of the pipeline not lower than 35-40°C.

The indicated temperature can be obtained during pumping of carbon dioxide with relatively high starting temperature (40°C and higher) on pipelines of small length, and also in supplying additional quantities of carbon dioxide in a number of intermediate points of the pipeline of great length. In the latter case the heat losses of the pipeline into the environment must be compensated for by the heat introduced by carbon dioxide in intermediate points of feeding the product into the pipeline.

Technical and economic comparisons of the methods described above for transporting carbon dioxide demonstrate that the most economical for the conditions of the Ural-Volga region and the technically feasible is the second method--transporting of carbon dioxide in the liquid state under high pressures on anisothermic pipelines. This method makes it possible to pump carbon dioxide in a broad range of temperatures without the danger of phase conversions and the density of the product is altered insignificantly. The latter affects the stability of operation of the pumping equipment.

Taking into account the high pressures of pumping under which it becomes inexpedient to set up intermediate storehouses to regulate the nonuniformity in consumption, the carbon dioxide must be fed from the site of its production to the injection wells on pipelines according to the "rigid" plan from pump to pump. Therefore regulation of the output of the system will be carried out by means of changing the operating pattern of the pumping stations, and the number of wells connected for injection.

The liquid carbon dioxide that is obtained based on the recovery of gaseous wastes of ammonium production is fed along the main pipeline to the field. The liquid carbon dioxide with pressure 55 kg-f/cm^2 enters the buffer tanks through the connection block and further to the intake of the centrifugal pumps.

The pumps raise the pressure of the carbon dioxide to the required amount (150-200 kg-f/cm^2), after which it enters the collector block from which it is sent along the distributing pipelines to the distributing pipes and further along the injection pipelines to the wells.

The buffer tanks are designed for regulation of the output of the pumps and the main pipeline, and for preventing possible entrance into the pumps of gaseous admixtures released from the carbon dioxide. To stabilize the operating patterns the production plan provides for the possibility of injecting carbon dioxide into the buffer wells connected directly to the collector block.

The carbon dioxide is injected into the bed with the help of the resources of control, automatics, interlocking, remote control that provide the normal operation and localization of possible deviations in the operation of the technological equipment with the minimum participation of the service personnel. The rate of carbon dioxide injection is guaranteed by the flow rate regulators that are installed at the opening of the well. Automatic regulation of the maximum permissible pressure is provided for injection and the maximum permissible pressure for suction of the pumps. For this purpose a pressure regulator "before itself" is installed on the pressure side of the pumps that maintains the minimum permissible carbon dioxide pressure on the final segment of the main pipeline, and a pressure regulator "after itself" on the suction side of the pumps to limit the possible increase in carbon dioxide pressure above the calculated value.

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FUELS AND RELATED EQUIPMENT

UDC 622.276.522

MEANS FOR PERFECTING GAS LIFT METHOD OF OIL EXTRACTION

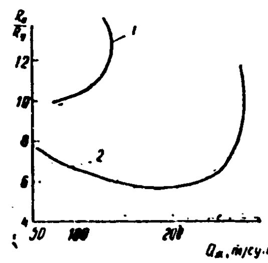
Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 15-19

[Article by N. S. Marinin, V. A. Popov and Ye. P. Erte, Siberian Scientific Research Institute of the Petroleum Industry, submitted for publication 16 Apr 79]

[Text] At the fields of West Siberia the gas lift method of oil extraction is being widely employed. At the Pravdinsk field oil wells are being operated with a compressor gas lift. At the Samotlor field plans of a compressorless gas lift developed by the Siberian Scientific Research Institute of the Petroleum Industry and Glavtyumenneftegaz have been introduced; they include withdrawal of gas for the gas lift from the gas cap and for elevation of the liquid directly from the gas bed by an intrawell overflow (IWO). As a result of this there is no need to lift the gas to the surface, prepare and withdraw the gas and oil in one well equipped according to the plan of intrawell gas lift-gas (IWO-gas), on independent channels. Here the gas is lifted on pump-compressor pipres (PCP), heated by the ascending flow of oil through the ring space up to 40-50°C and is fed to the gas lift wells.

According to the data of field studies of gas wells in the Samotlor field, the gas temperature at the head is 3-20°C, and the dew point temperature is +20°C, i.e., the feeding of gas to the gas lift wells without preparation is impossible. The use of the IWO-gas plan in withdrawal of oil over the pipe space with output of 300, 600 and 900 T/day makes it possible to heat the gas withdrawn on the PCP to t=40-60°C, and to feed it to the gas lif wells even beyond the limits of the cluster without preparation. According to the given plan wells 390 and 2048 of the Samotlor field were equipped. It is recommended that single wells be operated on the IWO plan. Eight wells have been equipped and are operating on this plan. Complete use of energy of the compressed gas and the absence of surface lines are the most promising for the introduction of the gas lift.

A necessary condition for the efficient operation of the gas lift wells is determination of the optimal parameters of their operation and establishment of the assigned pattern. The most widespread method for solving this



m/day

Figure 1. Example of Processing Results of Study for Well 473 (1) and 463 (2)

problem is the method of studying the gas lift wells proposed by the Azerbaijan State Scientific Research and Planning Institute of the Oil Industry that stipulates that the amount of the head pressure in studying the wells be constant. The field tests of the gas lift wells demonstrated that the head pressure in the process of the study is considerably altered, which impairs the use of this method. Therefore the possibility was studied of determining and selecting the optimal conditions for the operation of gas lift wells by processing the results of field studies. Figure 1 presents an example of the processing of results of studies on compressor wells 473 and 463 of the Pravdinsk field. The complex parameter R/P_y represents the ratio of the specific discharge of gas to the head pressure whose minimum value serves as the criterion of optimality. Thus, for well 463 the minimum value R/P_y is 5.6. With the known amount of head pressure, for example, 15 kg-f/cm^2, the specific discharge of gas in the optimal pattern will be 84 m^3/T with output of 170 T/day.

In order to select the operating pattern of the wells equipped according to the IWO plan, a method was developed for studying and processing its results in the coordinates P_y-$Q_ж$ which makes it possible to select the operating pattern of the wells with any values of the determining parameters (figure 2).

One of the main characteristics of the gas lift method of extraction is its efficiency. Based on the field tests and calculations made the efficiency of the gas lift system and its individual objects can be characterized by averaged data given in the table.

From the table one can define the two directions for increase in the efficiency of the gas lift. The first direction is linked to a reduction in the objects of the gas lift system, and the second--with an increase in the efficiency of each object.

The limit reduction in objects was achieved with the intrawell gas lift where all the technological operations (withdrawal of compressed gas, its transport, preparation, regulation and use) are implemented in the limits of one object, the gas lift well. The low efficiency of gas lift wells is explained primarily by the large losses for slipping of the gas in the lift.

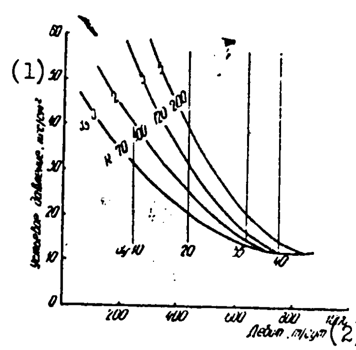


Figure 2. Example of Processing Results of Studies on Plan IWO (d_3 and d_v--Diameters Face and Head Flow Regulators Respectively, R--Specific Discharge of Gas).

Key:
1. Head pressure, kg-f/cm^2
2. Output, T/day

The colleagues of the Siberian Scientific Research Institute of the Oil Industry jointly with the workers of NGDU [Oil and Gas Mining Administration] "Pravdinskneft'" developed, tested and introduced a removable device for gas dispersion that makes it possible to considerably reduce the losses of gas for slipping. The removable device of gas dispersion can be installed in the sleeve connection of the PCP at any depth by a cable tool. With passage of the gas-liquid mixture through the flow regulator the gas phase is split up, the relative velocity of the gas is decreased and the losses for slipping are reduced, which results in an increase in the efficiency of the gas lift well and decrease in the specific gas consumption.

In 1976-1977 the economic effectiveness from introducing the devices of gas dispersion according to the NGDU "Pravdinskneft'" were 738,000 R. The results of field tests indicate the high effectiveness of using deep flow-regulator disperser, the sufficient reliability of its design and the operations for installation in the PCP. It is necessary to develop for different designs of wells and parameters of their operation a measuring order, methods of computation and to organize series output of the dispersing devices.

The ever increasing volumes of introducing the gas lift at the fields of Glavtyumenneftegas [Main Administration of the Tyumen' Oil and Gas Industry] advance in the number of main tasks the selection of the system of start-up of the gas lift wells. In this respect a set of field studies was formulated and a study was made on the effect of different types of gas lift

Objects of gas lift mixture	Gas lift		
	compressor	compressorless	intrawell
Gas engine	0.43	-	-
Piston compressor	0.85	-	-
Gas-withdrawing well	-	0.85	0.85
Gas pipeline	0.98	0.98	-
Gas-distributing booth	0.94	0.94	-
Gas-lift well	0.41	0.41	0.41
System of gas-lift as a whole	0.14	0.32	0.35

valves on the operating pattern of the gas lift wells. According to the test results it was established that the use of spring-bellows valves with light pressure of nitrogen by the bellows made it possible to reduce the specific consumption of gas by 10-25%, increase the output by 20-30%, and improve the efficiency of the gas lift wells by 7-10%. The effect was obtained as a result of the maximum use of the pressure of the injected gas. Further it is necessary to continue the studies of the spring-bellows valves with light bellows in order to study their characteristics, in particular the performance capacity of the spring, in a broad range of discharges of gas and outputs of liquid, and to determine the expediency of their mass use in the systems for starting-up the gas lift complexes.

Certain peculiarities of the start-up of gas lift wells under conditions of the West Siberian fields are associated with the curvature of their shafts. The laboratory and field studies showed that for successful start-up the distances between the valves must be reduced as compared to the distance for the vertical lift by 10-27% depending on the angle of curvature of the shaft of the gas lift well. In accordance with the indicated recommendations the start-up gas lift valves were arranged in the inclined gas lift wells of the Pravdinsk field, which promoted an increase in the depth of gas input into the hoist, increase in output and reduction in specific discharge of gas. Based on the studies made in the institute a "Technique for Arrangement of Start-up Valves in Inclined Gas Lift Wells" was developed and approved by the Ministry of the Oil Industry which was recommended for computation of the start-up patterns in the inclined gas lift wells at all the fields.

In the operation of the gas lift wells the problem arises of the optimal distribution of gas of high pressure for the wells. The task of the optimal distribution of gas is reduced to the maximization of oil withdrawal with limited discharge of gas or minimization of gas discharge with the assigned withdrawal of liquid. As a result of the resolution of the indicated problem a technique was developed for distributing gas by the analytical method. The field tests of the efficient distribution of gas for the gas lift wells were made on a group of 13 wells in the NGDU "Pravdinskneft'." It was established that with the individual selection of the operating pattern of the gas lift wells for the least specific discharge of gas the withdrawal of liquid is 20% lower than that obtained by the analytical method.

In addition to the examined one of the important tasks of the research is an increase in the reliability of the functioning of the gas lift complex. In field practice the reliability is evaluated based on the period between repairs and the operating coefficient of the gas lift wells.

The main types of major repairs on the gas lift wells of the Pravdinsk field in 1973-1977 are presented below in percentages of the total balance.

Transfer of wells to gas lift,%	46
Repair of gas lift well, %	32
Including repair of the operating column,%	1
perforation	3
isolation of water	7
intensification of influx	19
other work on the bed	2
Repair of gas lift equipment	22
Including elimination of accidents of underground equipment,%	2
elimination of hydrate plug in well	10
revision and replacement of gas lift equipment	10

Since the equipment of the well for the gas lift is included in the cycle of construction of wells, then further the work for transfer to the gas lift can be excluded from the volume fulfilled by the major repair teams. The repair work for change in the characteristics of the critical zone (perforation, isolation, intensification) is carried out on wells regardless of the method of operation. A reduction in the number of these repairs is linked to the development and introduction of more advanced systems of development.

Of the amount of work on repair of underground gas lift equipment about half is elimination of hydrate plugs in the wells. Elimination of these repairs is possible based on a more thorough preparation of the gas before feeding it into the well, and development and introduction of measures for preventing hydrate-formations in the shafts of the gas lift wells. Only a tenth of all the repairs are linked to elimination of accidents, inspection and replacement of the gas lift equipment. This indicates that further increase in the reliability of the standard set of underground gas lift equipment does not have a significant effect on the reliability of the gas lift system as a whole.

However the attained period between repairs cannot be implemented on all fields. For example, the repair of wells with compressorless gas lift is linked to deposits of salts in the equipment and imperfection in the throttle valve in the experimental design of the unit for intrawell gas lift. To increase the period between repairs it is necessary in the first place to develop and introduce effective methods for combatting salt deposits.

We will analyze for the wells of the Pravdinsk field the operating coefficient for the period 1973-1977; on the average it is 0.97 Half of the time of inactivity is linked to the repair of wells, a third part--to a shortage of gas and repair of collectors, and a fifth part--with research. A reduction in the number of repairs of wells, idle time of the compressors and use of methods of research that exclude stopping of the wells, will make it possible to obtain an operating coefficient that is close to a unit.

Thus, the studies on the development, testing and introduction of the compressorless gas lift at the Samotlor field, search for and introduction of methods for increasing the efficiency of the gas lift wells (devices for gas dispersion, optimization of gas distribution over the gas lift wells, selection of efficient designs of gas lift valves, arrangement of start-up valves with regard for the curvature of the shaft of the gas lift wells) guaranteed the successful introduction of the gas lift method of operation at the Pravdinsk and substantiation of the selection of gas lift extraction of oil at 48 fields in West Siberia, including the Samotlor, Fedorovskiy, Bystrinskiy, Tagrinskiy, Lyantorskiy and Var'yeganskiy fields. The introduction of the gas lift method of operation in broad scales will permit an increase in the period between repairs of the gas lift wells by 3-4-fold as compared to the pump method, and to bring the operating coefficient to 0.97-0.99, which will provide a reduction in the need for repair teams of the wells 2-3-fold, and losses for extraction of oil due to idle times of the wells by 5-10%.

A further increase in the effectiveness of gas lift oil extraction is determined by the development and selection of economically expedient and reliable systems of gas lift, type, design and drive of the compressors, characteristics of the cable tool for conducting maintenance, selection of the appropriate parameters of the equipment, study and selection of efficient conditions for start-up and operation of the gas lift wells, search for effective methods of controlling salt deposits in the gas lift system, and development and introduction of methods that make it possible to bring the efficiency of the gas lift wells to 0.6-0.8.

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FUELS AND RELATED EQUIPMENT

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CONTROL OF SALT PRECIPITATES AT FIELDS OF WEST SIBERIA

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 25-27

[Article by S. A. Mihlaylov, Siberian Scientific Research Institute of the Petroleum Industry, submitted for publication 16 Apr 79]

[Text] The operation of the majority of oil fields of the oil-extracting regions is complicated by the precipitation of inorganic salts in the underground and surface oil field equipment. Salt precipitation sharply reduces the period between repairs of the equipment which results in losses in oil extraction.

At 14 facilities of the Trekhozernyy and Mortym'ya-Teterevskiy fields in 1971 salt precipitates were found for the first time. In 1978 for all the fields of West Siberia over 250 facilities were noted that were subject to salt precipitation. The dynamics of salt precipitation for years and fields is given in table 1.

The salt precipitates are mainly represented by carbonates of calcium and magnesium, however sulfates of barium and calcium are also encountered, products of corrosion, mechanical admixtures, petroleum products.

The problem of salt precipitation can be conditionally divided into two parts. The first--study of the causes, conditions and mechanism for salt precipitation on the surface of the oil field equipment. The goal of the given work is to prepare and issue the initial data for planning the schemes to develop the fields, guaranteeing their salt-free operation, as well as predicting salt precipitation, selection of sources of water-supply for systems to maintain the formation pressure and methods to control salt precipitation. The second part is development, creation and use of methods and resources for controlling salt precipitation in the underground and surface oil field equipment.

One of the main reasons causing salt precipitation is the use of fresh water of surface sources to maintain the formation pressure. The mean composition of the bed and injected water is presented in table 2, from which it is apparent that the closest in its composition to the bed water is the water of the apt-senomanskiy complex and waste water.

Table 1

(1) Месторождения	(2) Годы 1971	1972	1973	1974	1975	1976	1977
(3) Шаимской группы	14	53	68	80	98	95	65
(4) Самотлорское	—	—	1	7	21	83	104
(5) Усть-Балыкское	—	2	6	14	20	27	31
(6) Западно-Сургутское	—	1	—		—	1	2
(7) Мегионское	—	—	—		—	3	3
(8) Советское	—	—	—		—	—	9

Key:
1. fields
2. years
3. Shaimskaya group
4. Samotlor
5. Us'-Balykskoye
6. West Surgut
7. Megion
8. Sovetskoye

Table 2.

(1) Месторождение, источник	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ + K^+$	(2) Минерализация, г/л
(3) Самотлорское	195 / 3,2	16728 / 471,2	—	2290 / 114,26	48 / 3,94	8192,6 / 356,2	27,45
(4) Трехозерное	2293,6 / 37,6	9121,0 / 256,93	12,4 / 0,26	153,9 / 7,68	43,2 / 3,55	6521,8 / 283,56	18,14
(5) Сеноманская	159,0 / 2,6	11197 / 315,4	—	641 / 31,9	127 / 10,4	6340,0 / 275,6	18,46
(6) Пресная (речная)	70,2 / 1,15	7,1 / 0,2	—	16,0 / 0,8	8,5 / 0,7	—	0,10
(7) Сточная (подтоварная)	354,0 / 5,8	8971 / 252,7	—	64,3 / 32,1	10,0 / 0,8	5188,8 / 225,6	15,16

Key:
1. Field, source
2. Mineralization, g/l
3. Samotlor
4. Trekhozernoye
5. Senomanskaya
6. Fresh (river)
7. Waste water (lumber)

Note: Numerator--mg/l; denominator--mg-equiv/l.

Injection into the productive beds of water that is close in its chemical composition to the bed water, to a lower degree disrupts the steady-state saline equilibrium in the complex system bed water-rocks of collector-oil, than injection of fresh water from the surface of sources, rivers and lakes. The given situation is confirmed by the experimental operation of such fields as the West Surgut and Pravdinsk, where in the system of PPD water of apt-al'b-senomanskiy water-bearing levels is used.

In predicting the salt precipitation at the oil fields the selection of the optimal (from the viewpoint of salt precipitation) plans for development of deposits one needs to know all the hydrochemical and hydrogeological peculiarities of each specific field. The water to be injected in the process of its movement over the bed from the injection to the extracting wells enters a complex interaction with the container rock, oil, bed and connate water. A study of these processes and their consequences is one of the most urgent problems in the area of salt precipitation.

The studies made in the Siberian Scientific Research Institute of the Petroleum Industry made it possible to propose the following simplified plan of processes that result in salt precipitation or influence them.

At the first stage of oil removal by water the pattern of oil-displacement can be assumed to be the piston. Here the injected water creates in the beginning a swell of the mixture of connate and bed water of increased mineralization which also can promote salt precipitation, however it does not have a noticeable negative effect on the operation of the wells due to the low degree of flooding and the gusher pattern of operation of the wells.

On the second plan the process of"depletion" of the film oil by carbon dioxide occurs due to its transfer into the injected water. Here the aggressiveness of the injected water is considerably increased in relation to the carbonate cement of rocks in the productive levels. The injected water at this stage has little contact with the rock of the bed that is covered with a film of oil. Only after multiple washings of individual pore channels and washing off of the film do direct contact and saturation of water by ions of calcium occur to equilibrium under conditions of the bed. Such water during its elevation over the well shaft promotes the salt precipitation during degassing as a consequence of the isolation of carbon dioxide into the gas phase.

With a sufficient degree of "washing" of the oil bed by the injected water the process of salt precipitation can cease spontaneously. The proposed plan is only a hypothesis and requires a strict theoretical and experimental substantiation.

The methods for controlling salt precipitation at the oil fields can be divided into chemical, physical and technological.

The chemical methods are based on the use of reagents, inhibitors of salt precipitation that prevent the settling out of salts from the oversaturated solutions. The physical--on the use of magnetic and acoustic fields. The technological methods include the use of equipment with coatings on which precipitation of salts does not occur, as well as different devices that affect the dynamics and structure of the water-oil flow and the operating conditions of the oil field equipment.

The most widespread is the chemical method. Highly effective inhibitors have been created for salt precipitation that make it possible with feeders of roughly 5-30 g/T of extracted water to completely prevent precipitation of salts. In recent years the Siberian Scientific Research Institute of the Petroleum Industry jointly with the production enterprises of Siberia have conducted extensive work to develop the technology for application of salt precipitation inhibitors. In addition, highly effective inhibitors of salt precipitation were successfully created. Currently, two of them are passing field tests --OEDP (oxyethylidenediphosphonic acid) and PAP (polyethylenepolyamine-N-methylphosphonic acid).

Work has also been done to create reagents of multi-functional action, for example, corrosion inhibitor-inhibitor of salt precipitation-bactericide. Studies on the effect of certain inhibitors of salt precipitation on the processes of dehydration of oil demonstrate that a number of reagents, in particular OEDP and PAP improve the processes of oil preparation. Compositions have been developed based on PAP and OEDP that make it possible to successfully employ the given reagents under the climate conditions of West Siberia, i.e., under low temperatures.

The magnetic and acoustic methods for controlling salt precipitation are passing experimental and industrial tests on the fields of West Siberia. In the process of application of the magnetic methods positive results have been obtained at the fields of Azerbaijan, and at the fields of West Siberia--indefinite. The hydrodynamic acoustic emitters of the type "Sirena" and others demonstrate positive results at the Samotlor field.

The Siberian Scientific Research Institute of the Petroleum Industry has developed and is making experimental and industrial tests on polymer coatings that possess low adhesion to the salt precipitates. Two electrical-immersion pumps were assembled with polymer sleeves and guide apparatus with polymer coatings. Preliminary results demonstrate their high performance capacity under conditions of salt precipitation.

Thus, one can note that many phenomena, processes and conditions that result in the appearance of salt deposits on oil fields are already known. However, there are certain unsolved questions: the mechanism for formation of the chemical composition of water in the process of movement over the bed, the mechanism for formation of salt deposits on the surface of equipment, the mechanism for the action of salt precipitation inhibitors, and others.

9035
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FUELS AND RELATED EQUIPMENT

UDC 622.276.72

CONTROL OF PARAFFIN DEPOSITS AT UDMURTIYA FIELDS

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 27-29

[Article by F. A. Kamenshchikov, Ya. L. Smirnov, B. M. Suchkov, V. Ye. Yupashevskiy, and Z. A. Gumerova, Tatar Scientific Research and Planning Institute of the Petroleum Industry, submitted for publication 20 Dec 78]

[Text] The operation of the Urdmurtiya fields is complicated due to the isolation of paraffin from the highly viscous oil. In the pumping wells particles of paraffin adhere to the rods and walls of the pumping-compressor pipes (PCP) reducing their flow section and creating additional resistance to the movement of the liquid. Paraffin is deposited especially intensively in the discharge lines of the pumping wells in the winter. Here the pressure in the PCP is sharply increased, which causes leaks in the pump, pipes, head oil seal, and sometimes breaks in the rods occur. In certain wells the paraffin is deposited on the face and reduces the influx of oil from the bed.

According to its physical and chemical properties the oil of the Udmurtiya fields belongs to the highly sulfurous (over 2%), paraffin-base (3.6-9.5%). The total content of asphalt-resin substances changes from 17 to 75%. The viscosity of the oil reaches 100-160 cP.

To control deposits of paraffin mechanical, thermal, chemical methods are used, as well as pumping-compressor pipes with protective coatings. The mechanical methods include the use of different weights, scrapers, sweeps, spheres designed to clean the PCP and discharge lines. In the thermal methods the precipitated paraffin is heated, it floats and is removed together with the ascending stream of liquid. The chemical methods consist of the use of different solvents.

The most widespread method of deparaffinization of wells under conditions of field development of Udmurtiya is the thermal method, i.e., treatment of the wells with hot oil or steam. Washing of the wells with hot oil done through the pipe space is carried out with different volumes, 7.5-35 m^3, therefore the effect from them also varies. As a result of the thermal treatment on the wells of the Mishkinskiy fields the dependence was defined for the mean

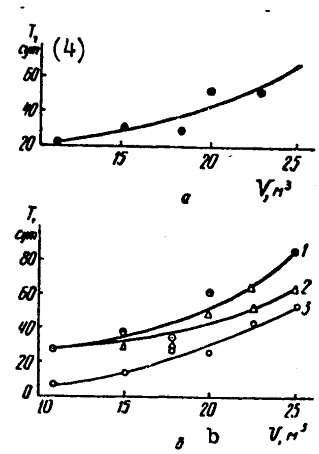

Figure 1. Dependence of Interpurification Period on Volume of Injected Liquid in Thermal Treatment of Wells of Mishkinskiy Field for All (a) and Individual (b) Levels

Key:
 1,2,3--Bashkir, Vereian, Cherepetskiy
 4--days

interpurification period on the volume of injected hot oil (fig 1,a). It is easy to note that with an increase in the volume of injected hot oil the interpurification period increases.

Analysis of the factual materials made it possible to approach thermal treatments from a more differentiated viewpoint. The action of the same volume of injected hot oil on the paraffin deposits varies, especially for wells that use different levels (fig 1,b). The thermal treatments have the greatest effect on wells that use the deposits of the Bashkir stage, and the least effect on wells of the Cherepetskiy level.

Besides the treatments of the paraffin-covered cages with hot oil at the fields the pumping-compressor pipes are steam treated with the help of a steam-generating unit, less often in combination with a compressor. The effect from such a method of deparaffinization is also not the same. In contrast to the thermal treatments the best results from steam treatment are obtained in wells of the Cherepetskiy level. Periodic deparaffinization of the lifting pipes with hot oil for many wells is a labor-intensive process, since it must be heated in measured tanks by superheated steam from the steam-generating units or with the help of mobile steam decontamination units. A shortcoming of this method is the need to stop the wells.

The indicated shortcomings are not inherent to the method that is based on the use of a protective coating applied to the PCP. One of the methods for creating a protective coating is lining the pipes with glass [1]. The paraffin is poorly adsorbed and crystallized on the glass coating which prevents precipitation of the paraffin in the process of oil extraction.

An important index in evaluating the effectiveness of the operation of pipes with protective coating is the inter-repair period of well operation. In the analysis it is difficult to differentiate maintenance according to types of work, i.e., it is impossible in a number of cases to determine what are the reasons for it: due to a disruption in the coating, coating with paraffin, etc. For comparative characteristics of the amount of the inter-repair period of operation of the wells with different coatings all the repairs are considered that are made on the wells.

The data on the amounts of the averaged inter-repair period of operation of wells equipped with sucker rod pumps, with enamel and vitrified cages for the Mishkinskiy and Chutyrsko-Kiyengopskiy fields are given in the table.

Indices	Type of coating		
	without coating	enamel	glass
Chutyrsko-Kiyengopskiy field			
Number of repairs for one well	2.83	2.77	-
Number of treatments for one well	8.51	7.02	-
Inter-repair period	129.20	131.70	190*
Mishkinskiy field			
Number of repairs for one well	-	2.6	-
Number of treatments for one well	-	7.58	-
Inter-repair period	-	140.30	210*

* The inter-repair period for the wells equipped with vitrified pumping-compressor pipes is computed for an incomplete calendar year.

It is apparent from the table that the amount of the inter-repair period for wells equipped with cages covered with enamel is commensurate with the amount of the inter-repair period of pipes without coating, while for wells equipped with vitrified cages, it is considerably higher. The analysis of the inter-repair period of well operation took into account all types of treatment done on the wells, including acid that produces a partial (sometimes also complete) deterioration of the enamel coating. Therefore acid treatments must be carried out with the use of a special complex of pipes without coating.

The vitrified cages in the association "Udmurtneft'" were lowered into wells 1724 of the Mishkinskiy field, well 847 of the Chutyrskiy and 380 of the Kiyengopskiy fields. Wells 1724 and 380 were equipped with deep sucker rod pumps, and well 847--with an immersed electrical-centrifugal pumping unit. During their operation no treatments or maintenance work because of deterioration in the coating itself were carried out. As a result of the introduction ofsuch pipes it was no longer necessary to conduct hot treatments, and the inter-repair period was considerably increased.

In addition to the use of pumping-compressor pipes with the protective coatings, thermal deparaffinization of the wells and pumping equipment, recently ever more attention has been focused in the control of paraffin deposits on methods directed towards the creation of conditions that prevent their formation. Such methods include the methods of regulation growth of crystals in the volume of the extracted oil by using various types of depressing agents, adsorption of specially selected surface-active substances (SAS), or compositions based on them, etc.

Making the ineer surface of the PCP hydrophilic with the help of SAS is becoming ever more widespread; for this purpose polyacrylamides are also used which possess the best properties for making a substance hydrophilic as compared to other polymers [2]. An aqueous solution of polyacrylamide applied to the walls of pipes in the form of a protective film, thanks to the long-chain globular-branched structure reduces the near-wall friction of the layers of liquid and prevents further precipitation of paraffin [3].

In order to implement a number of measures to control paraffin and prevent its precipitation on the walls of the pumping-compressor pipes at the Mishkinskiy field tests were made of a 0.1% solution of polyacrylamide. The solution of the hydrophilic-making solution of varying volume was injected into the PCP of wells 1811, 1438, 1954, and 1723 through the pipe space. The volume of injected solution significantly affects the inter-purification period of well operation. It is apparent from figure 2 that with an increase in the volume of solution of polyacrylamide the inter-purification period increases.

An important fact that affects the amount of the inter-purification period is the degree of purification of the pipes from the paraffin that has been precipitated during the operating period before the injection of the hydrophilic-making reagent. The more thoroughly the pipes are cleaned, the more stable the film of polyacrylamide is and the longer the inter-purification period.

In August 1976 at wells 1328, 1329, 1343 and 1740 of the Mishkinskiy field a two-component mixture was tested of polyacrylamide with liquid glass. The latter was introduced to stabilize the polyacrylamide film. At wells 1343 and 1740 the composition was injected through the pipe space, and at wells 1328 and 1329, directly into the pumping-compressor pipes.

The greatest effect was obtained during injection of the two-component mixture of polyacrylamide and liquid glass directly into the PCP in wells recently drilled. Therefore one can recommend the application of polyacrylamide treatment to all the wells just drilled, as well as those operating after maintenance and thorough cleaning of the inner surface of the pipes and rods of resin-paraffin deposits. In treatment with the two-component mixture of polyacrylamide with liquid glass the pumping-compressor pipes and rods are covered with a solid, stable protecting film that reduces or prevents precipitation on them of resin-paraffin formations and guarantees a longer period of operation of the wells without treatments.

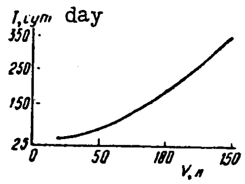

Figure 2. Duration of Well Operation depending on Volume of Injected Polyacrylamide

Thus, the most effective method for increasing the inter-purification period of well operation is the use of a protective glass coating. It makes it possible to increase the inter-repair period 1.5-2-fold.

The selection of the method for deparaffinization of wells depends on the employed level. It is expedient to treat wells of the Bashkir level with hot oil in a volume of 22-25 m^3. It is preferable to equip wells of the Cherepetskiy level with vitrified pumping-compressor pipes, and also to employ steam treatment with the help of a steam-generating unit.

Making the inner surface of pipes hydrophilic with the help of SAS is a promising method for preventing paraffin precipitation. It is recommended that polyacrylamide treatments be carried out in a volume of 150-200 l and concentration of 0.1-0.15% at wells just drilled, as well as those operating after maintenance.

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9035
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FUELS AND RELATED EQUIPMENT

UDC 622.276.8:665.625.001.8

STABILIZATION OF OIL AT WEST SIBERIAN FIELDS

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 32-33

[Article by M. G. Ibragimov, E. Sh. Telyakov, R. Sh. Salakhutdinov, S. M. Yumasheva, All-Union Scientific Research Institute of Hydrocarbon Raw Material, submitted for publication 19 Jan 79]

[Text] The oil of West Siberia in a small quantity is stabilized at two units of complex oil preparation (UKPN) of the association "Bashneft'": the UKPN of the oil and gas extracting administration "Oktyabr'skneft'" and the oil and gas extracting administration"Tuymazaneft'." In 1976 the VNIIUS [All-Union Scientific Research Institute of Hydrocarbon Raw Material] and the association "Bashneft'" examined the operation of the oil-stabilizing unit of the UKPN of the oil and gas extracting administration "Oktyabr'sk-neft'", and in 1977 the operation of the unit of the oil and gas extracting administration "Tuymazaneft'."

In the oil entering the unit of stabilization of "Tuymazaneft'" the content of light hydrocarbons differed insignificantly from the content of these components in the oil of the Bashkir and Tatar ASSR (table 1).

The material balance given in table 2 was compiled from the results of an examination of the unit of the oil and gas extracting administration "Tuymazaneft'" where the output of a wide fraction of light hydrocarbons (WFLH) is low.

The reason for the low yield of WFLH is the imperfect technological plan and outdated equipment of the unit that do not provide a high temperature of oil entering for rectification. The main parameters of the technological pattern according to the data of the examination are given below.

Temperature, °C	
Of oil	
after furnace	160-165
of top of column	100-120
stable	41-45
WFLH	51-50

Pressure, $kg\text{-}f/cm^2$	
in column	4.3-4
in gas-separator	3.6-2.5

TABLE 1.

(a) Компоненты	(b) Углеводородный состав нефти по районам, %		
	(c) Западная Сибирь	(d) Башкирская АССР	(e) Татарская АССР
CH_4	0,02	0,01	0,01
C_2H_6	0,06	0,10	0,10
C_3H_8	0,64	0,80	0,90
(f) изо-C_4H_{10}	0,42	0,33	0,35
н-C_4H_{10} (h)	1,37	1,35	1,40
(f) изо-C_5H_{12}	1,02	0,90	0,95
н-C_5H_{12} (h)	1,47	1,39	1,25
C_6H_{14}+выше (g)	95,00	95,12	95,04

Key:
- a. Components
- b. Hydrocarbon composition of oil by regions, %
- c. West Siberia
- d. Bashkir ASSR
- e. Tatar ASSR
- f. iso-
- g. above
- h. n-

The yield of WFLH at the unit of "Tuymazaneft'" equal to the yield at the unit of "Oktyabr'skneft'" was possible with a higher (166°C) temperature for feeding the column.

In the recommendations worked out in the examination of the unit of "Oktyabr'skneft'" a more advanced plan was suggested with topping of the bottoms of the column. The suggested plan was very effective with temperature of feeding the column above 170°C. However on the units where it is impossible to reach this temperature, the proposed method of oil stabilization insignificantly increases the output of WFLH. They include the majority of UKPN put into operation over 15 years ago, including the examined units. Intensification of the process of oil stabilization on these units is possible with the introduction of a plan given in figure 1 that permits the use of the heat of condensation of the steam phase of secondary topping. Comparison of the operating indices of the latter plan with the previous was made on a mathematical model based on computation of rectification by the relaxation method.

Figure 2 presents the depencence of the WLFH yield (D) on the temperature of the condensate in the tank of secondary topping (t_k). The output of WLFH according to the proposed plan is increased by more than 10% in relation to the previously examined method of stabilization. The increase in WLFH output, increase in the output from the potential of target

TABLE 2

(1) Потоки	(2) Компонентный состав, т/ч							
	C_1	C_2	C_3	(3) изо-C_4	(4) н-C_4	(3) изо-C_5	(4) н-C_5	$C_{6+в}$
(5) Приход (6) обессоленной нефти	0,07	0,18	2,03	1,32	4,37	2,80	4,26	284,08
(7) Расход (8) стабильной нефти	—	0,06	0,93	0,73	2,67	2,00	3,16	280,46
(9) ШФЛУ	—	0,01	0,33	0,30	1,17	0,67	0,99	3,53
(10) Газ стабилизации	0,07	0,11	0,77	0,29	0,53	0,13	0,11	0,09

Key:

1. Streams
2. Component composition,T/h
3. iso-
4. n-
5. Influx
6. of salt-free oil
7. Discharge
8. of stable oil
9. WFLH
10. Gas of stabilization

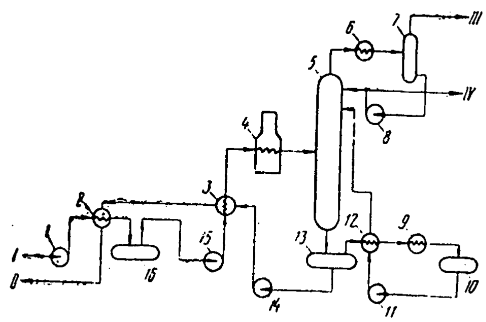

Figure 1. Plan of Oil Stabilization

Key:

1,8,11,14,15. pumps
2,3,9. heat exchangers
6,12. condensers
4. furnace
5. rectification column
7. separator
10. reflux tank
13. tank of topping
16. settling tank of salt elimination and dehydration
I. extracted oil
II. stable oil
III. gas of stabilization
IV. WFLH

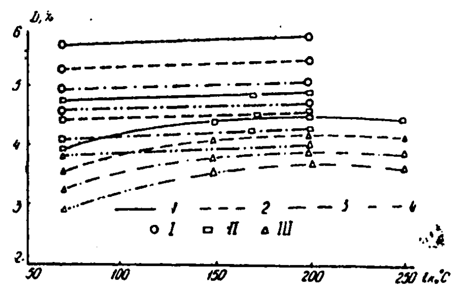

Figure 2. Dependence of Output of WFLH on Parameters of Pattern and Quality of Product with Content in WFLH 25(1), 20 (2), 15 (3) and 11% (4) of Hydrocarbons C_{6+B} and Feeding Temperature 240 (1), 210 (II) and 190°C (III).

components of petrochemistry in the use of the examined plan make it possible to reduce the outlays for conducting the process.

Thus, intensification of the process of stabilization of the West Siberian oil with the use of the examined plan makes it possible to significantly increase the output of raw material for petrochemistry.

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FUELS AND RELATED EQUIPMENT

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OIL PREPARATION AT PRAVDINSK FIELD

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 40-41

[Article by V. S. Ambros and G. A. Atanov, production association "Yuganskneftgas", submitted for publication 19 Jan 79]

[Text] The Pravdinsk field has been built up on the pressure-tight plan with gas lift method of operating the oil wells. On this plan the first stage of separation is implemented directly at the field under pressure 10-12 kg-f/cm^2. The separated oil and gas are sent on independent collectors to the central collection point (CCP) for further preparation. At the CCP (figure 1) the oil is separated from the gas that was isolated with reduction in pressure to 4-5 kg-f/cm^2, in separators C=1,2. A reagent is fed into the stream of oil before and after the separators. From these separators the oil enters the slag-settling tank (not shown in the figure), then to the flow-divider Д-1, in which it is separated to heaters П-1 and П-4. The oil heated in П-4 passes gas-separator Д-26, settling tank of dehydration Д-27, and terminal separator Д-2 that fulfills the role of the buffer tank. In the second stream the heating, separation and dehydration are combined in one apparatus П-1. From tank Д-2 the prepared oil is pumped by pumps H-1 to the reservoirs, and from the reservoirs by pumps H-2 to the main oil pipeline. The possibility is provided for pumping out the oil to the main oil pipeline by pumps H-2 directly from separator Д-2, by-passing the reservoirs. The gas from all collection points (C-1,2, Д-1, П-1, Д-26, Д-2) enters for reception of the compressors and is fed to the natural gasoline unit that is located in this same area.

The water separated from the oil in the apparatus Д-1, П-1, Д-27 and Д-2 and the reservoirs is fed to the purification plants. The unit for oil preparation is distinguished by compactness of the equipment arrangement with the minimum length of the production pipelines. The entire process of oil collection is carried out by means of the energy in the bed without the use of pumping aggregates to transport the water-oil emulsion over the production chain. The oil fed for treatment has density of 0.85-0.87 g/cm^3, viscosity at 20°C 12-15 cP, degree of flooding 5-6%, it contains 1% sulfur 4-5% resin, 2-3.5% asphaltenes, 4.5-5% paraffins. According to the

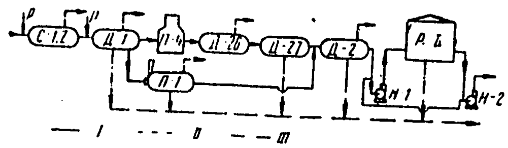

Figure 1. Production Plan of Oil Preparation

Key:
- I. oil
- II. gas
- III. drainage water

Siberian Scientific Research Institute of the Petroelum Industry this oil refers to the first group. The necessary heating temperature for preliminary discharge of water is 22-25°C, and for final dehydration 45-50°C.

The main factors that affect the quality of the prepared oil are the time of contact between the reagent and the emulsion, and the presence of free gas, as well as the time for presence of the emulsion in the settling apparatus.

The plan provides for the feeding of the reagent-demulsifier before the apparatus Д-1. However its contact time with the emulsion before the heating is several seconds, which is not sufficient for complete mixing. By using the recommendations of the Siberian Scientific Research Institute of the Petroleum Industry the introduction of the reagent was transferred to before the separator C-1,2 which increased the contact time to 10-12 min. The reagent was intensively mixed with the emulsion in the turbulent gas-saturated stream, in the gas separators C-1,2, as well as due to the available local resistances of varying type. With introduction of the reagent before the apparatus Д-1 the degree of flooding W in the apparatus Д-27 fluctuated in limits 1-1.8% with mean degree of flooding 1.33% (fig 2). An increase in the time of contact between the reagent and the emulsion, and its intensive mixing resulted in a decrease in the degree of flooding to 0.5-1%, which makes it possible in certain cases to yield the oil, by-passing the reservoirs.

After heating in П-4 the emulsion enters in a quantity of 410-430 m^3/h into two settling apparatus Д-27 with volume of 128 m^3 each. The emulsion enters in an amount of 650-660 m^3/h into 7 heaters-demulsifiers П-1 with volume of 156 m^3 each (the settling chamber of one П-1 is 40-50 m^3). Having the same load the apparatus Д-27 and П-1 operate in different patterns. In the apparatus Д-27 only separation of the processed emulsion occurs: in П-1 additional gas is collected in a quantity of 2-5 m^3/T. From the results of analyses with the help of the method of mathematical statistics it was determined that the mean indices in oil preparation in the gas-saturated state are somewhat better. The average-monthly water-contamination of oil in the apparatus Д-27 is 0.84-1.33%, in the heater-demulsifier П-1--0.76-1.24%.

The gas separated from the oil in small quantities with respect to the entire volume of П-1 promotes the merging of small drops of water and accelerates their settling out.

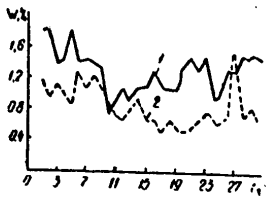

Figure 2. Change in Residual Content of Water in Oil depending on Point of Input of Reagent

Key:
1. Input of reagent before -1
2. Input of reagent before C-1,2.

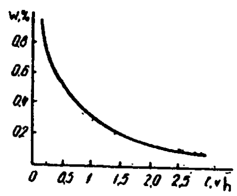

Figure 3. Effect of Settling Time on Residual Content of Water in Oil

However, in all cases water-contamination below 0.5-1% is impossible to obtain. This is explained by the increased velocities of movement of the finely-dispersed emulsion (1.5-1.6 m/s) in the production pipelines, which results in its additional dispersion. As a result of this the rate of settling is considerably slowed down, and to obtain high quality oil it is necessary to increase the settling time t to 1.5-2 h (fig 3). As a consequence of this, in order to obtain oil with water-contamination 0.2% and with salt content up to 40 mg/l it is sent additionally to reservoirs that operate in dynamic settling.

Thus, analogous oil of West Siberia can be prepared in the gas-saturated state. In the block units where the time for the passage of emulsion from the heating furnace to the settling apparatus is insignificant, the residual content of water, apparently, will fluctuate in limits 0.5-1%. The settling process can be accelerated by the use before the settling tanks of devices that make it possible, by using re-drainage water to coalesce the finely-dispersed drops, accelerate stratification of the emulsion, and improve the operation of the settling tanks. The use of such a preparation plan is preferable at the central collection points located near the gas refineries which are capable of receiving gas of all stages of separation without additional compression.

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FUELS AND RELATED EQUIPMENT

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CONTROL OF CARBONATE SALT PRECIPITATES IN OIL FIELD EQUIPMENT

Moscow NEFTEPROMYSLOVOYE DELO in Russian, No 9, Sep 79 pp 44-45

[Article by F. M. Sattarova, Tatar State Scientific Research and Planning Institute of the Petroleum Industry, submitted for publication 25 Sep 78]

[Text] In the equipment of oil preparation units there are cases of precipitation of mineral salts, mainly consisting of calcium carbonate.

The water used in the units of oil preparation for cooling the condenser-coolers and salt elimination is fresh or slightly mineralized. The table gives the chemical composition of the water used in the oil preparation units.

This is medium-hard and hard water. The carbonate hardness is governed by the presence of cabonate ions; the pH of this water is above the pH of the equilibrium saturation, consequently, when this water is used salt precipitates should be expected.

According to the technology of oil preparation the water used in the units is heated to 60-70°C. With an increase in the temperature the dissolved carbon dioxide is separated from the water and the pH rises. All of this results in a disruption in the carbonate equilibrium. Part of the bicarbonate ions become carbonate ions, which, in connecting with the calcium ions form calcium carbonate that is difficult to dissolve.

For a more complete washing of the salts from the oil a water-oil emulsion before the second phase of salt elimination is passed through the fresh water. It was noted that in mixing the simultaneously extracted and the fresh water the intensity of salt precipitation depends on the correlation of the waters. With a reduction in the quantity of fresh water and an increase in the bed water the precipitation of carbonate salts ceases.

The bed water of the Devonian and Carboniferous levels of the oil fields of Tataria is characterized by a low content of bicarbonate ions, and a high content of ammonium ions. During mixing of the water the bicarbonate ions

(1) Место отбора пробы	(2) d_{20}, г/см³	pH_{20}°C	(3) Химический состав, г/л							Σ R, г/л (4)	Равновесие при 80°C (5)			Избыточное количество HCO_3', г/л (6)
			Cl'	SO_4''	CO_3''	HCO_3'	Ca''	Mg··	K + Na·		pH	HCO_3', г/л (4)	CO_3'', г/л (4)	
(7) Азнакаево, УКПН-1	1,0013	8,8	0,2603	0,6296	0,0096	0,2684	0,2184	0,0596	0,2156	1,6617	8,55	0.793	0,0063	0,1891
(8) Карабашская УКПН	1,0001	8,6	0,1426	0,0897	0,0024	0,2196	0,0782	0,0289	0,0756	0,6370	8,85	0,1159	0,0189	0,1037
(9) о. Кама, Исмагиловская УКПН	1,0004	8,45	0,1654	0,0848	—	0,2135	0,0839	0,0284	0,0784	0,6544	9,2	0,1769	0,0180	0,0549
(10) Горкинская УКПН	1,0004	7,45	0,1021	0,1201	—	0,1281	0,0706	0,0179	0,0572	0,4960	8,75	0,0793	0,0021	0,0732

Key:
1. Site of sample taking
2. g/cm³
3. Chemical composition, g/l
4. g/l
5. Equilibrium at 80°C
6. Excess amount of HCO_3', g/l
7. Aznakayevo, UKNP-1
8. Karabashkaya UKPN.
9. Kama Island, Ismagilovskaya UKPN
10. Gorkinskaya UKPN

Note. Samples were taken on 30 May 1978.

of the fresh water, bonding with the ions of ammonium of the bed water form ammonium bicarbonate. With a temperature above 36°C the ammonium bicarbonate is broken down with the release of carbon ioxide and ammonia gas.

In order to prevent precipiation of carbonate salts from the water of the circulating water system dosing of ammonium salts can be used, such as ammonium chloride and ammonium nitrate. The mechanism for prevention, as in the case of water mixing, consists of a reduction in the pH and breakdown by the ammonium ions of part of the bicarbonate ions.

Besides prevention of salt precipitates the solutions of ammonium salts can be used to remove the already precipitated carbonates. The mechanisms for dissolving of the carbonate salts consists of the formation of ammonium carbonate from the carbonates and the ammonium ions. With a temperature above 60°C the ammonium carbonate is broken down with the release of ammonia gas and carbon dioxide.

With an increase in the concentration of ammonium salts and temperature of the solution the solubility of the calcium carbonate rises. The quantity of reagent for removal of the broken down carbonate salts is computed according to the formula

$$X=\frac{S\cdot h\cdot d\cdot 160}{100},$$

where X--quantity of ammonium nitrate, kg;
S--area of apparatus from which it is necessary to remove the salts, m^2;
h--thickness of salt precipitate, m;
d--density of precipitate, kg/m^3.

Removal of the precipitates of carbonate salts from the equipment can be carried out without stopping the unit of gas preparation, directly during operation. The calculated amount of reagent in this case should be introduced both for prevention and for removal of salts.

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FUELS AND RELATED EQUIPMENT

UDC 622.692.4:620.193

STUDY OF PIPELINE FAILURES AT SAMOTLOR FIELD

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 9, Sep 79 pp 45-48

[Article by E. P. Mingalev, V. N. Kushnir, O. N. Kuz'micheva, B. V. Yevdokimov, and A. A. Silayev, State Institute for Planning of Tyumen' Oil and Gas Plant, submitted for publication 2 Apr 79]

[Text] The KSP-3 region of the Samotlor field belongs to the category of increased corrosion danger. From July 1977 to June 1978 in this region there were 17 cases of rupture in the oil collectors (see table).

The collectors were put into operation in 1972-1974 and after 3-5 years failed. In the analyzed period the system of oil collection at KSP-3 switched from separate to the stage of one-pipe, although in the majority of cases the products are transported simultaneously over two parallel oil conductors.

A three-phase medium, gas-oil-water under pressure about 0.8 MPa is delivered to the oil collectors. The collectors are made of pipe steel with territorial unification of the clusters, and are telescopic with junctions 426-530-720-820 mm in diameter. A large number of accidents occurred on collectors 530 and 820 mm in diameter. The telescopic design of the collectors is made in order to obtain the same amounts of velocities of motion and creation of the necessary pressure of the liquid at each section of the collector. However, comparative analysis of the throughput of the oil collectors under real conditions demonstrated that sections of the collectors with the same diameters operate with different discharges of liquid and rates of flows. This is explainable by the absence of equality in the correlations of phases of the transported mixture. In addition, the medium has a high temperature (30-40 °C) and increased gas factor (mean value 73 m^3/T).

Accidents occurred on the sections of under-loaded collectors where the flow rate fluctuated from 0.03 to 0.86 m/s. On the sections of the collectors 820 mm in diameter operating with greater load, with rate of flow 1.64-1.70 m/s the emergency situations were not observed. Evidently, the change in

(1) Диаметр/длина трубы, мм (место аварии, куст скважин)	(2) Дата ввода в эксплуатацию, год	(3) Дата аварии	(4) Причина порыва	(5) Длина замененного участка, м
820×10/2750 (к. 65, 64, 63, 62, 42)	1974	27/VII 1977 г.	(6) Внутренняя коррозия в виде канавки $l=12$ м	20
219 (к. 46)	1972	23/VIII 1977 г.	(7) Не установлена	—
530×9/1450 (к. 61)	1972	8/IX 1977 г.	(6) Внутренняя коррозия в виде канавки $l=8$ м	40
820×10/2600 (к. 39)	1972	28/IX 1977 г.	(6) Внутренняя коррозия в виде канавки $l=10$ м	50
		22/II 1978 г.	(6) Внутренняя коррозия в виде канавки $l=8$ м	1130
426×8/1200 (к. 39)	1972	24/XI 1977 г.	(7) Не установлена	—
720×10/734 (к. 42)	1974	1977	(8) Внутренняя коррозия	50
530×8/4170 (к. 61)	1974	18/I 1978 г.	(6) Внутренняя коррозия в виде канавки $l=8$ м	10
530×8 (к. 87)	1976	18/I 1978 г.	(9) Микротрещины	—
820×10/1500 (к. 74)	1974	18/I 1978 г.	(8) Внутренняя коррозия $l=12$ м	100
530×8/4700 (к. 63)	1974	4/II 1978 г.	(6) Внутренняя коррозия в виде трещины $l=2$ см	—
530×8/1700 (к. 88)		4/II 1978 г.	(7) Не установлена	—
530×8/1500 (к. 88)		7/II 1978 г.	»	—
426×8 (к. 88)	1975	7/II 1978 г.	(10) Колебания трубы	—
820×9/2600 (к. 44)	1974	22/II 1978 г.	(7) Не установлена	—
820×9/2600 (к. 39)	1972	5/III 1978 г.	(11) При опрессовке трубы	—
426×8/1842 (к. 89)	—	—	(7) Не установлена	—
426×8 (к. 86)	—	3/VI 1978 г.	(12) Свищ	—

Key:

1. diameter/length of pipe mm (site of accident, cluster of wells (k))
2. date put into operation, year
3. date of accident
4. reason for rupture
5. length of replaced section, m
6. inner corrosion in form of groove
7. not established
8. inner corrosion
9. microfissures
10. oscillations in pipe
11. during pressurizing of pipe
12. air hole

the hydraulic pattern of the pipeline sometimes results in accidents. To clarify the causes of the emergence of accident situations conditions for the operation of oil collectors of the KSP-3 and other collection points were compared (DNS-1, DNS-4, KSP-5, KSP-9) of the Samotlor field.

The collectors of the same diameters with equal operating periods were considered to be of one type. The comparison was made according to the water-contamination of the oil, output of the collector, quantity of treatments of the clusters of wells by reagents of salt precipitates and acid.

In the comparison the differences were especially noticeable in the output of the single-type collectors whose product has roughly the same water-contamination. The collectors from the cluster of wells KSP-3 have a load for liquid and gas that is several times lower than the collectors of other collection points. If one considers the greatest load of the single-type collector at which accidents were recorded to be the critical, then the overwhelming majority of values of loads of KSP-3 collectors are below the critical, when the loads on the other collectors are 2-3 times higher.

The appearance of corrosion in the system of collection and transport of oil should be linked to the increase in water-contamination of the well product. The average water contamination of the product does not exceed 20%, however the water content in certain sections of the collectors reaches 60-65%. The bed water that is separated from the oil, in moving over the bottom of the collector and accumulating in the reduced sections (dead zones) produces intensive corrosion of the lower forming pipe. The composition of water in the collector is not uniform, its mineralization fluctuates in limits 8-27 g/l. The ion composition of water (mg/l): Ca^{2}-- 280-850; Na^{+},K^{+}--3000-10,000; Mg^{2+}--30-300; Ca^{2+}--7000-16,000; SO_4^{2-}--5-120; HCO_3^{-}--200-700. In addition the water contains (mg/l): iron 0.05-4.2; hydrogen sulfide 0.15-4.0; carbon dioxide 10-80, mechanical admixtures up to 140; SVB up to 10^6 cells per 1 ml. The factor that intensifies the process of corrosion can be the hydrochloric acid that is used in hydrochloric acid treatments of wells. From 1977 to July 1978 45 such treatments were carried out at the KSP-3.

Corrosion is unique and has the appearance of a groove of rectangular section 20-60 mm wide, up to 20 m long with variable depth (figures 1,2). At the sites of the greatest deepening longitudinal ruptures occurred up to 10-12 m long. The shape of the corrosion damages, as well as their localization in the lower part of the pipe indicates that the process of failure has an electromechanical nature.

Based on an analysis of the reasons for the ruptures in the oil collectors one can suggest the following mechanism of corrosion. The mechanical admixtures that accumulate in the lower sections of the pipeline form strong precipitates that, as the analysis showed, are mainly represented by carbonates, iron sulfides and also an increased quantity of microcomponents: Al,Mn and Fe. The formed dense layer of precipitate increases the electrochemical heterogeneity of the surface along the lower forming pipeline.

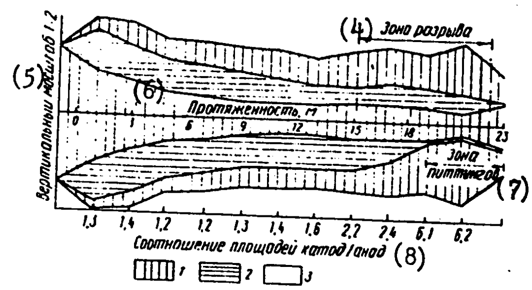

Figure 1. Plan of Failures in Metal of Inner Surface at Lower Forming Pipe on Accident Section

Key:

1. areas with carbonate precipitate
2. regions of metal failure (groove)
3. oil film
4. zone of rupture
5. vertical scale 1:2
6. extent, m
7. zone of pittings
8. correlation of areas of cathode/anode

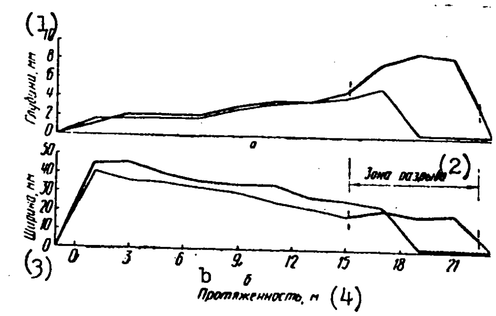

Figure 2. Depth (a) and Width (b) of Breakdown of Inner Surface of Pipe 820 x 10 in Diameter on Accident Section (thickened line shows metal failure)

Key:

1. depth, mm
2. zone of rupture
3. width, mm
4. extent, m

The sections under the precipitate become anodes, while the precipitate itself becomes the cathode. Between the anode and the cathode a powerful macrocell develops;as a result of its work the collector is destroyed. Intensification in the work of the macrocell can be promoted by the concentration heterogeneity of the ion composition of water along the collector. The ascending and descending streams of liquid, forming the edge of the precipitate, give form to the breakdowns as a groove.

The proposed mechanism for corrosion of steel under a precipitate was simulated in the laboratory in the presence of SVB with temperature of 40°C. The tests were made on flat samples 28 x 28 mm in size on which the precipitate was applied in a strip, mixture of sand and clay. The medium used was oil accumulated from a collector containing 20% mineralized water. The test samples were placed in hermetically-sealed vessels to which 2 ml of SVB culture were added (to 1 ml of 10^6 units). Two series of experiments were conducted lasting 1104 and 3336 h.

The results of the tests indicate that in its appearance the corrosion under artificial precipitate is similar to the nature of breakdown of the surface of the oil conductor. A strip of destruction under the precipitate is clearly traced. The control samples (without precipitate) were characterized by small amounts of uniform corrosion.

The addition of corrosion inhibitors IKB-4 (150 mg/l) and Sever-l (600 mg/l) to certain vessels did not promote a retardation of the process, since the formation of an inhibitor film under the precipitate was impaired by its dense structure and the good adhesion to the metal.

Thus, the most effective method is inhibition. In the process of corrosion under the precipitate the proposed method for protection of oil conductors with the help of inhibitors can be ineffective if the inhibitor does not penetrate under the precipitate. Therefore before using the inhibitor it is very important to mechanically clean the collectors of precipitates. However, as shown by the analysis of the causes of accidents of collectors in a number of complex collection points of the Samotlor field the operating life of the collectors can be prolonged if their load is increased and a flow rate of liquid above 2 m/s is created.

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FUELS AND RELATED EQUIPMENT

NEW APPROACH TO CLASSIFICATION OF OIL RESOURCES

Moscow GEOLOGIYA NEFTI I GAZA in Russian No 9, Sep 79 pp 7-12

[Article by E. M. Khalimov, Ministry of the Petroleum Industry and M. V. Feygin, Institute of Geology and Development of Mineral Fuels]

[Text] The early 1960's witnessed enormous progress by Soviet geologic science and practice. Our country took first place in world crude production, thanks to the discovery of the Western Siberian basin and its accelerated development.

Future development there will involve, first, more complete involvement in the development of existing crude reserves and the utilization of residual reserves in depleted oil fields; second, new progress in geologic prospecting work and new discoveries. How the proportions between these two trends will be determined will govern to a great extent the rate of growth not only of sectors directly involved in petroleum production (crude, gas and geologic), but also of allied sectors that comprise the foundation for the development of oil production (the machine building industry, metallurgy, chemical industry, etc.).

Substantial progress in science and technology in the field of geologic research and prospecting operations notwithstanding, positive results will continue to be of a probabilistic nature. Therefore the evaluation of possible increments of reserves and of the even more uncertain recovery of petroleum from them is especially probabilistic.

The accuracy of calculations during the planning of production from discovered deposits and prospected reserves of petroleum is determined not only by the reliability of the latter (as was assumed for a long time), but also by a complex of factors that characterize the conditions of development and construction of oil wells and the feasibility of using new technology and techniques.

No importance was attached to these factors during future planning in individual regions with heavy production and substantial petroleum reserves, in which there apparently existed the conditions necessary for continued increase of production, the growth of production slowed down and ceased in many cases and oil production declined. The inaccuracy of planning calculations is a result primarily of the failure to take into account the qualitative characteristics of reserves.

Petroleum production in the country as a whole, given the current high level, cannot be increased by way of the discovery and development of new deposits and more complete utilization of existing petroleum reserves in an effort to maintain production levels in some regions and to slow down the rates of decline in others. The indispensable condition of optimum industry development planning here is the correct assessment of overall petroleum resources in the ground, especially in that part of the resources (reserves), from which crude can be extracted with existing technology.

The first classification of petroleum reserves in the USSR was developed by a commission of the Geological Committee in 1928. Reserves were supposed to have been differentiated in accordance with the principle of reliability (amount of knowledge available) into three categories: A -- prepared, B -- prospected, C -- presumed. Then the classification was improved considerably by I. M. Gubkin, D. V. Golubyatnikov, V. V. Bilibin, M. V. Abramovich, M. A. Zhdanov and others. All subsequent classifications (1932, 1937, 1942, 1953, 1959) were based on the very same principle.

The present classification of reserves in the USSR (1970) is also based on the principle of differentiation in accordance with how much is known about the geology of fields and deposits and individual parts thereof, and of structures that show promise of containing petroleum (traps). There are four categories of reserves (A, B, C_1 and C_2), in addition to a quantitative petroleum forecast evaluation group (D). The reserves in categories A, B and C_1 are figured within a proven petrolifer, but they differ from each other in terms of how accurately the calculated parameters are determined. The reserves of category C_2 are extremely diversified in terms of composition and include unprospected portions of discovered deposits, promising formations with unverified petrolifers in known fields, and promising petroleum structures (traps) in a region with a proven commercial petrolifer [1].

The development of classification on this principle was no accident. At the same time the promise of many tracts and even of geologic provinces, which are now recognized oil centers (Uralo-Povolzh'ye and Western Siberia) have not yet been proved. Development under these conditions was completely justified. And for many long years it promoted intensified analysis of the petroleum content of the depths and objective evaluation of petroleum reserves.

Today our country has a strong raw materials base, which provides for stable development of oil production; the commercial importance of many petroleum deposits has been proved. At the same time the diversity of deposits, differing in terms of grades of crude and reservoirs, character and depth of deposition, conditions and methods of development, accessibility, geographic and weather conditions, remoteness from consumers, development cost and cost effectiveness, has been established. Problems of correct economic and technological evaluation of resources and their complete utilization must be solved under these conditions. Therefore the classification should take into account not only the reliability of the assessment of reserves, but also the factors mentioned above.

On the basis of the proposed classification of petroleum resources and their evaluation it is recommended that the following four principles be utilized: 1) the amount of available knowledge of resources; 2) the economic desirability of developing resources at the present time (profitability); 3) the commercial importance of resources; 4) the possible completeness of the utilization of deposits and of the recovery of the resources of oil fields.

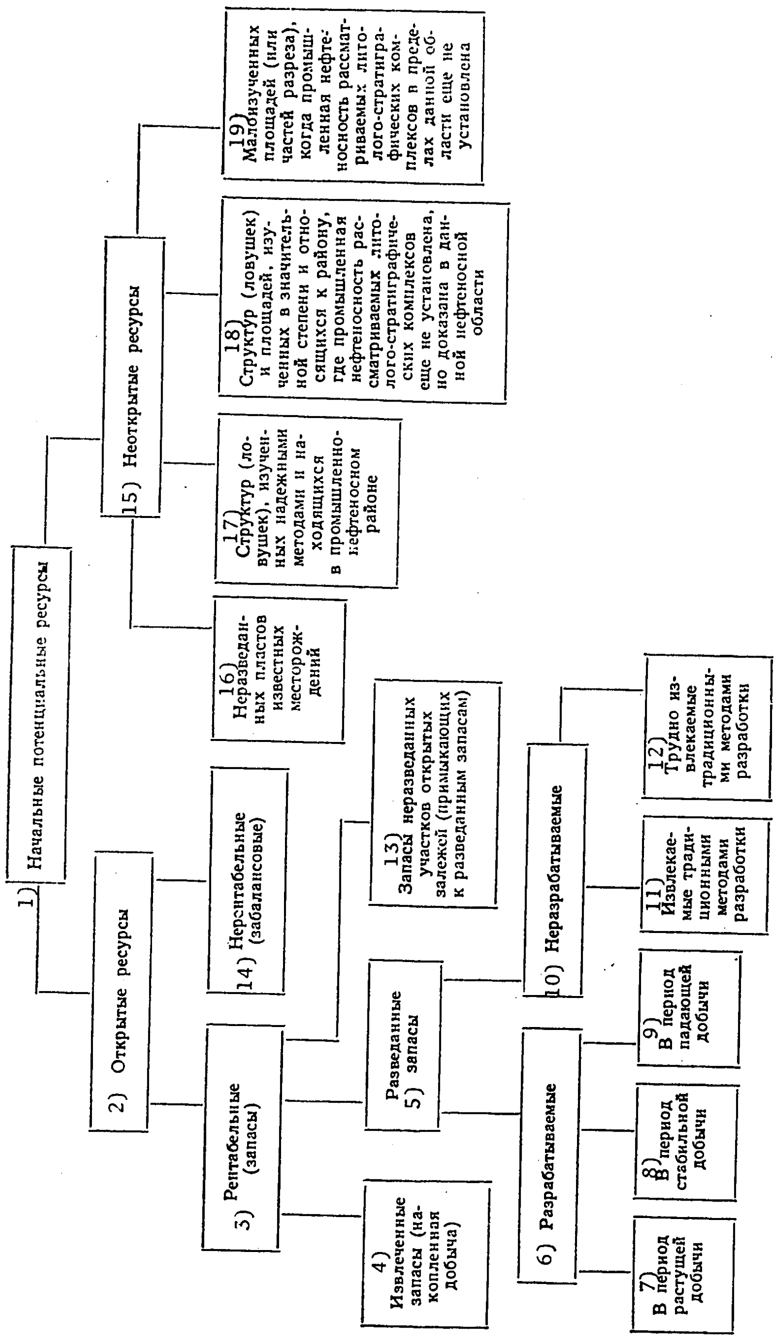
It is desirable to refine certain terms to preclude contradictory interpretation of individual classes.

Utilization of the term "reserves" must be restricted [3]. It is recommended that just the amount of petroleum that has already been prospected (or discovered and deposited next to prospected reserves), and which can be extracted with existing technological, technical and economic capabilities, be called reserves. Then all the rest of the petroleum, which has not yet been discovered or even prospected, but which cannot yet be extracted, should be called "resources."

The term that expresses the total amount of petroleum in the ground is also ambiguous. The term "geologic reserves" is used today, but in reality reserves refer only to the recoverable fraction (on the average 30-60% of the oil in the ground). The term "oil in place," which is also imprecise, is used in the United States.

It would be better to use the term "total volume of petroleum in formation," since it most completely expresses the semantic meaning of the examined concept. However, this term is unsuitable for statistics and is inconvenient to use. Therefore it is recommended that the term "formation resources" be used as a conditional synonym. Then the term "recoverable" can be used in reference both to reserves and to resources, whereas the term "formation" refers only to resources. Thus, petroleum formation resources contain a recoverable fraction and an unrecoverable fraction. The recoverable fraction of petroleum formation resources of prospected and profitable (at the present time) oil fields and deposits is defined as reserves. The remaining fraction of formation resources is called unrecoverable resources (given present technological and economic capabilities).

It is better to discuss other terms and concepts in the presentation of the meaning of the proposed classification of petroleum resources, which may be used for characterizing both recoverable and formation resources (see the chart).



Classification of petroleum resources.
[Key on next page]

KEY:
1. Initial potential resources
2. Discovered resources
3. Profitable (reserves)
4. Recoverable reserves (cumulative yield)
5. Prospected reserves
6. Developed
7. In increasing yield stage
8. In stable yield stage
9. In declining yield stage
10. Undeveloped
11. Extractable with traditional development methods
12. Hard to extract with traditional development methods
13. Reserves of unprospected parts of discovered deposits (adjacent to prospected reserves)
14. Unprofitable (balance)
15. Undiscovered resources
16. Unprospected formations of known deposits
17. Structures (traps) investigated by reliable methods and located in commercial oil field
18. Structures (traps) and areas, investigated to a considerable extent and located in region where commercial petroleum content of examined litho-stratigraphic complexes not yet established but proved in given oil province
19. Little-investigated tracts (or parts of cross section), where commercial petroleum content of examined litho-stratigraphic complexes in given oil province not yet established

The term "discovered resources" refers to resources of already discovered oil deposits. It takes into account reliable data on formation parameters, the quality of petroleum and development conditions. "Undiscovered resources" are only presumed to exist on the basis of favorable results of geophysical analyses of individual structures (traps) and territories, and of theoretical representations. Undiscovered resources are identified as a result of a quantitative evaluation of a forecast of the existence of a petrolifer.

As a term that combines the two indicated groups of resources (discovered and undiscovered) it is recommended that the term "initial potential resources" be used, and the term "current potential resources" should be used in cases when already extracted reserves (cumulative yield) are excluded.

The "discovered resources" group, when the economic principle of the profitability of their development at the present time is used, is divided into "profitable" and "unprofitable."

The industrial utilization of "unprofitable" (balance) resources is possible only in the future, since their development is uneconomical at the present time for a number of reasons. We refer here to resources that may become recoverable (i.e., reserves) with the improvement of existing development systems. The main factor here is cost effectiveness. Systematic accounting and analysis of petroleum resources of this subgroup focus greater attention on measures to increase the recovery of petroleum from formations of developed fields. The possible completeness of the utilization of formations and of the development of petroleum resources is determined on the basis of technological and technical-economic calculations of several different ways of developing oil fields.

"Discovered profitable resources" correspond to the term "reserves" and include: 1) "recoverable reserves" or "cumulative yield"; 2) "prospected reserves" (current); 3) "reserves of unprospected parts of discovered deposits" (next to prospected reserves).

The "recoverable reserves" subgroup is a part of "discovered resources," and it must be singled out for the correct characterization of the overall status of resources and completeness of their utilization.

The "prospected reserves" subgroup is the basis of the classification, since it determines recovery capabilities that exist today. It essentially should include reserves that have been prospected to a degree sufficient for drafting a technological plan of development of an oil field.

This subgroup is divided into "developed" and "undeveloped" reserves, depending on the stage of industrial utilization. This distinction provides an opportunity to characterize the degree of involvement of prospected reserves in development and the availability of ready reserves for increasing national oil production.

A more detailed evaluation of prospected petroleum reserves in terms of commercial importance may be recommended [2]. As is known, the first stage of development of oil fields (until the time the planned yield is reached), during which the yield increases, is brief. Usually 20-30% of the initial recoverable reserves are produced during that time. Much of the life of an oil field, during which the basic volume of its reserves is recovered, nearly always proceeds under conditions of stable or declining yield. Therefore the separation of petroleum reserves into those developed during the "rising," "stable" and "declining" stages of production significantly clarifies the status of the production capabilities of producing fields.

"Undeveloped" reserves similarly also can be differentiated in terms of their commercial importance as "extractable by traditional development methods" and "hard to extract by traditional development methods." The latter include reserves of heavy crude, subgas deposits, water-petroleum zones, reservoirs of complex structure, etc., and also deposits of insignificant size.

The "reserves of unprospected parts of discovered deposits" subgroup includes reserves calculated to exist between a section with prospected reserves and a discernible petrolifer contour. This subgroup is the next reserve for the preparation of new prospected reserves. According to the current Soviet classification it should include the most reliable part of the reserves of category C_2 (and perhaps some of C_1).

"Undiscovered resources" are classified on the basis of a quantitative evaluation of a forecast of the petroleum prospects of variously analyzed and substantiated geologic formations.

It is suggested that the following four subgroups of resources be classified on the basis of the indicated principles.

1. Unprospected formations of known oil fields. The commercial petroleum reserves of these formations are forecast on the basis of geologic analogy with productive formations of a given or adjacent fields.

2. Structures (traps) investigated by reliable methods and located in a commercial petroleum region. The promise of these formations is forecast by geologic analogy with adjacent fields. The success of their prospecting usually varies from 30-60%. Therefore the appropriate correction factor for this should be introduced during the determination of the total petroleum resources of a large region as a whole.

3. Structures (traps) and tracts that have been analyzed to a considerable extent and are located in a region where the commercial importance of the examined litho-stratigraphic complexes is not yet established, but is proved in a given petroleum province. The existence of petroleum resources is forecast on the basis of geologic analogy with some region of a given oil province, where commercial reserves have been established in the same litho-stratigraphic complex.

4. Little-investigated tracts (or parts of a cross section), when the commercial importance of the examined litho-stratigraphic complexes within a given province (or large tectonic formation) is not yet established. In this case petroleum is forecast on the basis of analysis of the general geologic criteria of the existence of petroleum and on the basis of theoretical representations. Also used here is geologic analogy with other large tectonic formations, where the evaluated litho-stratigraphic complex is a petrolifer.

The main criterion for distinguishing between the last two subgroups is establishment of the commercial significance of a given litho-stratigraphic complex within a large tectonic formation, or first-order structure (the latter is conditionally equated with an oil province).

Thus, the suggested classification of petroleum resources, without changing existing requirements on the individual categories of reserves, accurately describes their position in the general scheme and sufficiently completely characterizes the status of the prospecting and utilization of petroleum resources.

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FUELS AND RELATED EQUIPMENT

COMMERCIAL RESERVES OF GAS

Moscow GEOLOGIYA NEFTI I GAZA in Russian No 9, Sep 79 pp 27-30

[Article by I. N. Malinovskiy, A. S. Panteleyev, Ye. S. Grishin, D. S. Golovastov, South Ural Branch (YuUO) of the All-Union Petroleum Scientific Research Institute of Geological Exploration (VNIGNI) and V. V. Popovin (VNIGNI): "Assessing Commercial Gas Reserves in Oil-Gas and Oil-Gas Condensate Fields"]

[Text] Several oil-gas and oil-gas condensate fields have been discovered in recent years in Orenburgskaya Oblast. The total reserves of petroleum in these fields now amount to about 10% of the calculated balance of the oblast. The prospects of the discovery of new oil-gas deposits are quite good.

The development of oil fringes poses a difficult problem. The deposition of petroleum along with gas, their mutual subordination and the common practice of developing gas first detract so much from the technological and economic indices of the development of the oil part of a deposit that fringe reserves are often relegated to the balance group.

Under these conditions it is very important to objectively evaluate commercial reserves of gas dissolved in oil.

In most cases the saturation pressure of gas in oil in oil-gas deposits is equal or nearly equal to the initial formation pressure. Consequently, during the process of the development of an oil-gas deposit dissolved gas is inevitably released from an oil fringe (whether or not it is commercial) as the formation pressure decreases.

The amount of this gas, released and recovered along with free dissolved gas, depends on the final fluid dynamic conditions of the development of the deposit.

Consequently, the practice of placing the reserves of an oil fringe in the balance group should not be applied to the gas dissolved therein.

The experience of the development of the Sovkhoz field is an example that confirms the above theoretical premises.

The oil-gas condensate deposit of the Sovkhoz field is confined to a Riffian formation of the Sakmaroartinskiy age. The gas portion of the deposit overlies a type "A" oil fringe, which accounts for about half of the effective volume of the deposit. The fringe is 85-100 m thick. Two wells are producing commercial oil yields, but test operations disclosed that the fringe is not of commercial importance. Based on data from an analysis of surface tests, its density varies from 0.8725-0.8920 t/m^3, and its viscosity is 10-20 centipoise.

The development of the gas deposit was completed in 1974. The total gas yield exceeded the initial reserves, calculated by the volumetric method, by nearly a factor of two.

The degree of analysis of the field was sufficiently high at the time of calculation of the reserves, and the gas reserves were confirmed as category B by GKZ [State Commission on Mineral Resources] USSR.

The large discrepancy between the confirmed reserves and the recovered gas cannot be attributed simply to miscalculations during the determination of the effective gas-saturated volume. Some gas undoubtedly came from degassing of the oil fringe. According to calculations dissolved gas (which was not figured in during calculation of the reserves) accounted for 15% of the total yield.

Similar conditions existed in the Orenburg gas condensate field, where an oil fringe, accompanying the Artinskiy-Middle Carboniferous gas deposit, was disclosed as the result of prospecting operations.

The fringe oil has the following properties: surface density 0.84 t/m^3, formation viscosity 2 centipoise, gas factor 176-204 m^3/m^3 at a saturation pressure of 19.9 MPa.

The gas factor, calculated on the basis of M. Stending's empirical formula [4], is 160 m^3/t.

A technical-economic evaluation of the commercial development of the Artinskiy-Middle Carboniferous oil fringe, completed by YuUO VNIGNI, indicated that the development of the biggest part of it (90% of the reserves) is characterized by poor indices, in which connection it was recommended that these reserves be placed in the balance group.

It is methodologically more correct to place the gas dissolved in the oil in commercial categories, since degassing of oil during the development of a deposit is inevitable, and this gas can be recovered along with free gas.

It is recommended in the literature [3] that the formula

$$v_0 = Q_b r_0 - Q_{rec} \cdot b_0 \cdot p_f \alpha_f f - Q_{nr}(b_0 - b_f) \cdot p_f \alpha_f \cdot f - Q_{nr} \cdot r_f \quad (1)$$

be used for calculating recoverable dissolved gas reserves in the gas cap mode. Here Q_b are balance oil reserves; Q_{rec} are recoverable oil reserves; Q_{nr} are nonrecoverable oil reserves; b_0 is the initial volume ratio; b_f is the volume ratio of formation oil on the final development date; r_0 is the initial gas factor; r_f is the residual quantity of gas at the final pressure; p_f is the residual formation pressure; α_f is the correction factor for compressibility at pressure p_f; f is a correction factor for temperature.

Since in the case at hand it is not planned to recover the oil from the fringe formula (1) acquires the form

$$v_0 = Q_b r_0 - Q_{nr}(b_0 - b_f) p_f f - Q_{nr} r_f. \quad (2)$$

The development of deposits in the depletion mode also causes complex behavior on the part of multicomponent mixtures in a porous medium, accompanied by phase conversions. Formulas (1) and (2) do not take into account the dynamics of the liberation and filtration of gas in a reservoir in the presence of the liquid (oil) phase. Gas that saturates a porous medium to less than 20-30% is known to lose its mobility in the presence of liquid phase. This phenomenon undoubtedly will occur during the development of gas-oil fields and should be taken into account.

All the diverse factors that influence the gas yield of oil fringes should be analyzed in each specific case on the basis of geologic data and analytical investigations, during which the processes that take place during development are modeled.

To calculate recoverable gas reserves in a fringe it is recommended that a correction factor of 0.7-0.8 be introduced in formulas (1) and (2). This correction factor, in the first approximation, takes into consideration the influence of actual formation conditions on filtration in a porous medium.

Another important means of improving the accuracy of gas reserve calculation is to consider the residual oil saturation in the gas part of a deposit.

Studies have established that in many gas and gas condensate fields of Orenburgskaya Oblast the porous part of the gas-saturated volume, along with bonded water, contains a certain amount of heavy hydrocarbons in the form of bitumens and lighter mobile components.

An analysis of core samples from 11 wells in Kalinovsko-Novostepanovskiy field established that the residual oil in the gas part of the Kalinovskaya suite deposit occupies 2.1 to 20.6% of the pore volume and the average content is 10.5% [1].

The gas-saturated volume of the Artinskiy-Middle Carboniferous deposit of the Orenburg gas condensate field contains hydrocarbons (heavy fractions). The average content is estimated at 13.5% of the pore volume.

The existence of residual oil has been noted in the gas-saturated cross section of the Sakmaro-Artinskiy deposit of the Sovkhoz field and of fields outside of Orenburgskaya Oblast [2]. The above data indicate that residual oil saturation of the gas part of the deposits is quite often encountered in a wide stratigraphic range.

A certain amount of the heavy hydrocarbons that saturate the pores of gas deposits is close to petroleum in terms of physico-chemical properties and undoubtedly exhibits all the features of the thermodynamic transformations of multicomponent hydrocarbon systems.

According to calculations gas reserves are greatly affected by the volumetric expansion of residual oil as a result of the dissolving of a certain amount of gas in it under the initial thermodynamic conditions. This circumstance reduces the amount of free gas, but a certain amount of gas dissolved in the residual oil is added, and during the development of a deposit in the gas mode this gas escapes from the oil and is recovered along with the free gas. Calculations have shown that when the volume ratio is taken into consideration the total amount of free gas and of gas dissolved in residual oil is larger than when just the free gas is considered, when the volume ratio is ignored.

The dynamics of the relative increase (in percent) of gas reserves is shown in Figure 1 as a function of the volume ratio. Empirical relations between the gas saturation of oil and the volume ratio for crudes with a density of 0.78 to 1 were used for the calculation. The utilization of the volume ratio for residual oil with any density leads to an increase of the calculated gas reserves, and the difference gets greater as the oil gets lighter, and consequently as its gas saturation increases.

Porosity, water saturation, amount of oil and thermodynamic conditions, corresponding to point c in Figure 1, were calculated for the purpose of analyzing the influence of residual oil saturation on gas reserves.

The results of the calculations (Figure 2) show that the magnitude of gas reserves decreases significantly as oil saturation increases, whether or not the volume ratio is taken into account. The summary reserves of free and dissolved gas (curve a -- the volume ratio of petroleum is considered) exceed the reserves of free gas (curve b -- the volume ratio is not considered) in the entire investigated range of oil saturation values. As the oil saturation of a reservoir increases the difference between them gets larger and the fraction of dissolved gas increases (curve c).

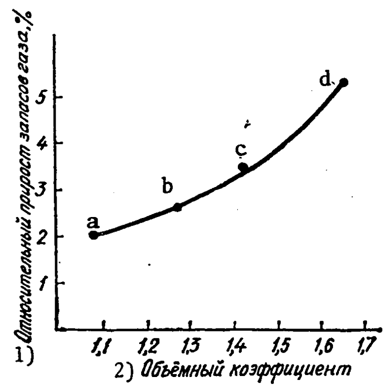

Figure 1. Relative increment of gas reserves as function of volume ratio. Density of oil in g/cm^3: a -- 1.00; b -- 0.91; c -- 0.84; d -- 0.78.

Key: 1. Relative increment of gas reserves, %
2. Volume ratio

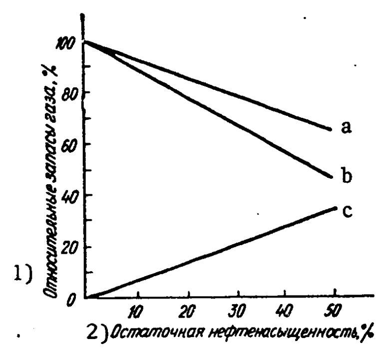

Figure 2. Dynamics of change of relative gas reserves as function of residual oil saturation: a -- in consideration of dissolved gas; b -- dissolved gas not considered; c -- fraction of dissolved gas in total gas reserves.

Key: 1. Relative gas reserves, %
2. Residual oil saturation, %

Gas reserves in reservoirs with residual oil saturation should be calculated by the formula

[г=g; н=o; н=f]

$$Q_г = Fhm\{[\beta_г f(p_н\alpha_н - p_к\alpha_к)] + [\beta_н \cdot r_0 - \beta_н\eta b_0 p_к\alpha_к f - \beta_н(1-\eta) \times (b_0 - b_к) \cdot p_к\alpha_к f - \beta_н(1-\eta) \times r_к]\}, \quad (3)$$

where Fhm is the effective reservoir volume; β_g is the gas saturation of a reservoir in consideration of the volumetric expansion of the residual oil; p_o is the initial formation pressure of a deposit; α_o is a correction factor for compressibility at pressure p_i; β_o is the residual oil saturation coefficient; η is the oil yield coefficient. The other symbols are the same as in equation (1).

Under conditions when petroleum is not recovered and remains entirely in pores (η = 0) formula (3) acquires the simpler form

$$Q_г = Fhm\{[\beta_г f(p_н\alpha_н - p_к\alpha_к)] + [\beta_н r_0 - \beta_н(b_0 - b_к)p_к\alpha_к f - \beta_н \times r_к]\}. \quad (4)$$

This version of the formula apparently is the best one, since the theoretical prerequisites of the formation of residual petroleum in gas deposits and development practice indicate that residual petroleum, as a rule, will not come out, since it loses its mobility as a result of degassing.

The following conclusions are offered by way of summary.

1. The gas dissolved in fringe oil classified as balance reserves must be considered in terms of commercial categories.

2. Gas dissolved in residual oil should be taken into consideration, in addition to free gas, during calculation of gas reserves in reservoirs with residual oil saturation.

3. Special studies must be conducted for the purpose of estimating the amount of gas dissolved in residual oil and fringe oil during the preparation of a field for the calculation of reserves.

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FUELS AND RELATED EQUIPMENT

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UNDERGROUND GASIFICATION OF COAL DISCUSSED

Kiev UGOL' UKRAINY in Russian No 10, Oct 79 pp 5-6

[Article by V.A. Kushniruk, doctor of geological-mineralogical sciences, and candidates of geological-mineralogical sciences Ye.S. Bartoshinskaya and S.I. Byk, Institute of Geology and Geochemistry of Mineral Fuels of the Ukrainian SSR Academy of Sciences: "Underground Gasification of Coals of the L'vovsko-Volynsk Basin"]

[Text] The L'vovsko-Volynsk coal basin with an area of 10,000 square kilometers is an important energy base for a number of oblasts of the Ukraine, Belorussia and the Baltic region. The lower and middle coal deposits are coal-bearing. The geological reserves of the basin come to more than 3 billion tons, approximately one-third of which can be extracted through mines. Out of the 88 beds and interstratifications of coal established in the basin at the present time 6 are being worked and two more beds are being prepared for exploitation in the near future. The remaining layers are mainly of substandard or insufficiently aged capacity, but they are mixed with coals of good quality.

Thus, remaining in the earth is more than 70 percent of the coalreserves, in connection with which the question of the study of the possibilities of recovering the deposits using underground gasification of coal becomes an urgent one. This method is generally accepted for working coals that are inaccessible for extraction by the open pit or mine method, although it has not received wide distribution.

Underground gasification is a physico-chemical process of turning the coal into gaseous fuels using free or bound oxygen in the depths of the earth. The gases produced are used as an energy fuel or as a chemical raw material. Suitable for gasification are non-caking or slighty-caking brown or hard coals and anthracites, which are characterized by a relatively high mechanical strength and thermal stability, a low ash content A^c, and an insignificant content of sulfur S^c_{tot}.

The thickness of soft layer y should not exceed 12 millimeters, and the ash melting temperature in the half-reduction medium should be in the limits of t_a=1200...1250°C [1]. Suitable for gasification are

Donets coals or coals of the eastern regions of the USSR with parameters cited in table 1. If a positive solution is found to the problem of underground gasification of goals of the L'vovsko-Volysnk basin, the need will arise to work out a GOST [All-Union State Standard].

Table 1.

Description of the Coal	Donets Hard Coals	Coals of Eastern Regions of the USSR	
		Hard	Brown
A^c, %, not more than	20	20	25
S^c_{tot}, %, not more than	4	1.2	1.2
t_a, °C, not less than	1250	1200	1250

According to quality indicators the coals of the basin are not uniform. But on a rather large area of development of a number of beds they satisfy the demands made and can be regarded as targets for underground gasification. Cited in table 2 are the basic parameters of the coals being considered for gasification of certain layers of the Vizeyskiy (index of the beds, v), Serpukhov (n) and Bashkir (b) stages. The coals of the indicated beds in the northern part of the basin (Volynskoye and Zabugskoye deposits) and its southern half (Mezhrechenskoye, Tyaglovskoye, Karovskoye) are medium-ash and medium-sulfurous, with y=5...18 millimeters, and are related to brands Г and Ж. Making use of the empirical relation of oxides of silica and alumina to the oxides of iron, magnesium, and calcium, and keeping in mind the prevalence of the sum SiO_2+Al_2O_3, it is possible to come to a conclusion about the refractoriness of the ash of coals of the majority of the beds [2] which, apparently, fluctuates in the limits of 1300-1400°C.

The mining and geological conditions of the basin are as follows. The beds of the Vizeyskiy age lie among clayey and clayey-carbonaceous formations. Most often the soil is composed of argillites and aleurolites, local sections have sandstones and clayey limestones, and the roof has argillites and clayey limestones, and very rarely sandstones. The Serpukhov coal beds lie among terrigenous rocks--argillites, aleurolites, and sandstones are encountered in the roof and the soil. Clayey limestones are noted only in the roof of several beds, and the area of their development is small. The beds of the Bashkir age most often are also floored with clayey formations--with argillites and aleurolites, and often sandy soil is also encountered. Terrigenous and carbonaceous rocks are developed in the roof in equal measure.

Table 2.

(1) Индекс пласта	A^c, %	(2) $S^c_{общ}$, %	y, мм	(3) $t_з$, °C	(4) Марка (код)
(5) *Волынское месторождение*					
v_1	18	3,2	7—9	—	$Г_6$
v_3^3	18	3,1	7—10	—	$Г_6$
v_4^3	10	3,4	7—10	—	$Г_6$
n_7	15	2,7	5—8	1430	$Г_6$ (711)
$n_7^в$	9	2,7	6	1340	$Г_6$ (711)
n_8	11	2,9	5—8	1420	$Г_6$ (711)
b_1	10	2,8	7—9	—	$Г_6$
b_4	10	4,4	7	1365	$Г_6$
(6) *Забугское*					
v_0^4	11	2,2	8—9	—	Ж
v_4^3	13	1,8	7—10	—	Ж
v_5	17	2,9	9—14	—	Ж
n_7	18	3,4	7	—	$Г_6$
$n_7^в$	13	3,1	7—12	—	$Г_6$—$Г_{12}$
n_8	7	1,1	5—12	—	$Г_6$—$Г_{12}$
n_9	12	2,7	10—13	—	$Г_{12}$
b_1	9	2,4	7—18	—	$Г_{12}$
(7) *Межреченское*					
v_1	20	2,5	9—11	—	Ж
v_3^3	13	2,0	7—10	—	Ж
v_4^3	11	2,2	8—11	—	Ж (535)
v_5^3	9	1,1	11—13	—	Ж (535)
$n_7^в$	8	2,3	12—14	1400	$Г_{12}$ (633)
n_8	9	0,9	12—14	—	$Г_{12}$
n_9	19	2,3	12	1395	$Г_{12}$ (634)
(8) *Тягловское*					
v_1	12	3,0	—	—	Ж
v_3^3	20	1,9	—	—	Ж
v_4^3	14	1,8	—	—	Ж
n_7	19	3,8	12—15	—	Ж
(9) *Каровское*					
n_7	10	2,3	11—16	—	Ж

Key:

1. Index of bed
2. S^c_{tot}, %
3. t_a, °C
4. Brand (code)
5. Volynsk deposit
6. Zabugskoye
7. Mezhrechenskoye
8. Tyaglovskoye
9. Karovskoye

According to structural features the basin can be included among regions of average complexity. There are several large dislocations here--faults with an amplitude of 200-300 meters and a large number of small ones with an amplitude of from 0.1 to several meters, which often are not established by the test pits. These dislocations should be considered when developing the technology of underground gasification of coals, since some of them, obviously, can affect the given process. The cited lithological make-up of the soil and the roof of the beds, and the relatively rare large dislocations, which make it possible to single out sites that are favorable in a tectonic respect, can be regarded as a positive factor for underground gasification of coals.

Good studies have been made of the hydrogeological conditions in the basin. The deposits of hard coal age have a low water content. The carboniferous rocks are separated from the basic Upper Cretaceous water-bearing layer by a thick mass of close-grained and practically water-free rocks of the lower part of the Upper Cretaceous and Turonian layers [2]. Consequently, the water content of the deposits will not hinder the process of underground gasification.

Thus, the necessary prerequisites exist for underground gasification of the coals of the L'vovsk-Volynsk basin that are inaccessible for mine working. The gas produced can be used for energy purposes and as a chemical raw material for producing a number of valuable products, including high-quality liquid fuel. In considering the L'vovsko-Volynsk basin as a possible target for development by the underground gasification method, also considered was that circumstance that in the not-distant future the mines of the basin will fall into disuse, and the released productive forces and resources can be used for creation of coal-chemistry enterprises. The know-how for such exploitation of the beds exists in our country: three industrial stations for underground gasification of brown and hard coals [3] are producing 1.5 billion cubic meters of gas per year (according to data for 1974).

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