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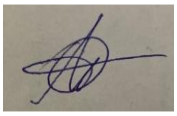

(Author signature)

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Abstract

Today, the development of oil and gas fields on the Arctic coasts and the continental shelf is an important and relevant direction in the development of the Russian oil and gas complex.

The shelf of the Kara Sea is one of the most promising areas of the Western Arctic. The largest discoveries of gas and gas condensate fields and highly promising structures have been made in the Kara Sea. At present, two deposits with unique reserves have been explored here - Rusanovskoye and Leningradskoye. They are the most studied in comparison with other deposits in the region.

Since a feature of projects for the development of fields on the Arctic shelf is the need to build and operate facilities in difficult climatic and ice conditions, the development of reasonable schemes for the development of fields in the Kara Sea is a top priority.

Due to the extreme natural and climatic conditions of the Kara Sea, the necessary scope of technical and technological work during the inter-ice period is significantly limited. Therefore, it is necessary to choose the type of field that allows year-round drilling and operation of the project gas well stock.

The purpose of the work is to select a promising design for the foundation of an offshore oil and gas production platform for the conditions of the deep-water shelf of the Arctic seas, using the Rusanovskoye and Leningradskoye fields in the Kara Sea as an example.

Research objectives:

• Studying the experience of exploration and development of offshore hydrocarbon fields in the Arctic seas.

• Study of conceptual options for the development of hydrocarbon deposits in the Kara Sea.

• Selection of a promising design for the foundation of an offshore oil and gas production platform for the conditions of the deep-water shelf of the Arctic seas.

Methods and objects of research

When performing the study, traditional design methods were used, as well as methods of mathematical modeling and statistical methods.

The object of research is the Rusanovskoye and Leningradskoye deposits.

The subject of research is the development of the Rusanovskoye and Leningradskoye fields.

Scientific novelty of the work

The scientific novelty of the work lies in the development and justification of the choice of development of the Rusanovskoye and Leningradskoye deposits, taking into account their technical accessibility.

The practical significance of the work

The results of scientific research can be used in the development of options for platform and underwater development of the Rusanovskoye and Leningradskoye fields.

The main provisions for defense:

Selection and justification of a promising design for the platform and underwater development of the Rusanovskoye and Leningradskoye fields in the Kara Sea.

Creation of a methodology for selecting platform and underwater facilities for the Rusanovskoye and Leningradskoye fields used in the development of offshore hydrocarbon fields in the waters of the Arctic (Arctic) seas.

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Table of Contents

List of acronyms

LNG – liquefied natural gas;

MODU - mobile drilling offshore;

IRP - ice-resistant stationary platform;

IBC - an ice-resistant block-conductor;

MDK - a mobile drilling complex;

MIRP - a mobile ice-resistant drilling platform;

UPC - an underwater production complex;

OPP - onshore product processing facility;

RSP - a remote single point berth;

CIDS - reinforced concrete drilling rig on artificial base

UDC – underwater drilling complex

UWF – underwater foundation

GCF – gas-condensate factor

GD – gas deposit

GWD – gas water deposit

IDC – ice resistant drilling construction

1. REVIEW OF METHODS FOR THE DEVELOPMENT OF OFFSHORE OIL AND GAS HYDROCARBON FIELDS IN THE SHELF CONDITIONS OF THE ARCTIC AND NON-ARCIC SEAS

1.1. Conditions of the Arctic and problems of development

The Arctic is a part of the globe adjacent to the North Pole, bounded from the south by the Arctic Circle, located at 66 ° 33 'N, within which the phenomena of the polar day and polar night are observed. Within these boundaries, the area of the Arctic is 21 million km2. The features of the nature of the Arctic are: low radiation balance, average air temperatures of the summer months close to 0 ° C at a negative average annual temperature, predominantly solid atmospheric precipitation during most of the year, year-round presence of ice on land in the form of glaciers, ground ice and permafrost , treeless land, as well as the ice cover of sea areas - all this makes it possible to distinguish the Arctic into a special natural landscape-geographical region. Its boundary is usually drawn along the southern limit of the tundra zone, which is close to the contours of the July isotherm of 10°C on land and 5°C at sea. In some places this border runs north of the Arctic Circle, in some places south of it. Within these limits, the area of the Arctic (including the water surface) is about 27 million km2 (5.3% of the earth's surface). On the continents, this boundary runs along approximately 70 ° N. (with the exception of the southern part of Greenland, the Labrador Peninsula and adjacent parts of the Atlantic Ocean), coinciding with the average position of the Arctic front. In this case, the area of the Arctic turns out to be smaller by approximately 10-15%. The Arctic land accounts for about 10 million km2. Within the Arctic, 2 natural zones are distinguished: arctic deserts and tundra

The main part of the Arctic Ocean is the Arctic Basin (in addition to the North European and Canadian). The Arctic shelf is a shallow part of the bottom of the Arctic Ocean, adjacent to land, including islands of continental origin and, in geological terms, being a continuation of the mainland. The shelf territories are the marginal seas: the Barents, East Siberian, Chukchi, Kara, and also the Laptev Sea. [3]

The average depth of the outer edge of the shelf of the World Ocean is 130-132 meters, the average width is about 80 km. The most extensive in the world are the shelves of the Barents Sea (1300-1700 km) and other Arctic seas, as well as the coast of Argentina. The shelf width of the Arctic Basin is on average 800 km. As for the depth, for the Barents Sea it is 100-350 meters, for the Kara Sea - an average of 100 meters. The depth of the shelf of the Laptev Sea is 10-40 meters, in the Chukchi Sea - 20-60 meters. For comparison, the average depth of the Arctic Ocean is 1.2 km, the greatest depth - 5.5 km - was recorded in the Greenland Sea, and at the North Pole, according to the measurements of the Mir deep-sea apparatus, the depth is 4,261 meters.

The development of oil and gas resources in the Arctic is associated with significant costs and a high level of risk. The main challenges faced by companies involved in the development of oil and gas fields include:

- harsh climate. Severe frost almost year-round, long polar nights, threat of damage to offshore drilling rigs by arctic ice, swampy tundra that causes seasonal activity in many regions, and limited biological activity have an extremely negative impact on personnel and equipment;

- undeveloped infrastructure. Development of new deposits "from scratch" is very expensive and subject to significant environmental risks. The Arctic will require special equipment (in particular, special tankers and icebreakers). At the same time, the summing up of extended communications, supply and logistics are complicated by harsh climatic conditions;

- competition from other gas sources. The growing supply of gas on the world market, both from traditional and non-traditional sources, casts doubt on the economic feasibility of developing Arctic fields. Competition may come primarily from shale gas, but also increasingly from coal seam gas and liquefied natural gas (LNG). Estimates of the resource potential of less extreme areas are constantly rising, the development of which can be economically justified and environmentally safe, rather than the development of Arctic natural gas fields.

- hydrolaccoliths (swellings formed in the permafrost zone, the core of which consists either of a continuous lens of ice or of frozen soil layered with ice up to 25-40 m high and more). They pose a great danger, as they grow and change rapidly. Strong watering of loose rocks of the seabed. When drilling in such rocks, to ensure the safety of the core and the stability of the walls of the wells, it is necessary to use special technical means and carry out technological measures that require additional material costs and meet stringent requirements for protecting the environment from pollution.

Offshore oil and gas production is also dangerous because even with high reliability of all links in the technological chains, the consequences of a single accident can be very severe due to the large scale of the facilities (offshore platforms, tankers, pumping stations) and their remoteness from rescue services. In the Arctic, pollutants will remain for a long time, deposited in the ice cover, and the possibilities for elimination are extremely limited.

Another unique natural feature of the region is stamuhi - ice blocks penetrating the ocean floor at shallow depths, capable of literally tearing through underwater communications.

The exclusive economic zones of the following countries are located in the Arctic: USA, Canada, Russia, Norway, Denmark, Sweden, Finland, Iceland. Russia has the longest border in the Arctic.

Today, the leaders of the oil and gas industry are increasingly turning their attention to the extraction of hydrocarbons on the Arctic shelf. Severe climatic conditions make their own adjustments to the technologies used for mining. Many deposits are so unique that they require significant refinement of equipment and production methods. The uncontrolled movement of ice masses creates a danger for standard types of platforms - they can simply be crushed. In addition, ice greatly limits the time available for drilling, at the same time, the detection of leaks and their timely elimination becomes especially difficult.

The study of all natural (climatic, geological, hydrological, biological) features of the Arctic shelf and the features of world experience in the design and construction of offshore oil and gas facilities can contribute to the accelerated development of oil and gas fields, which will thereby allow both science and the country's economy to advance.

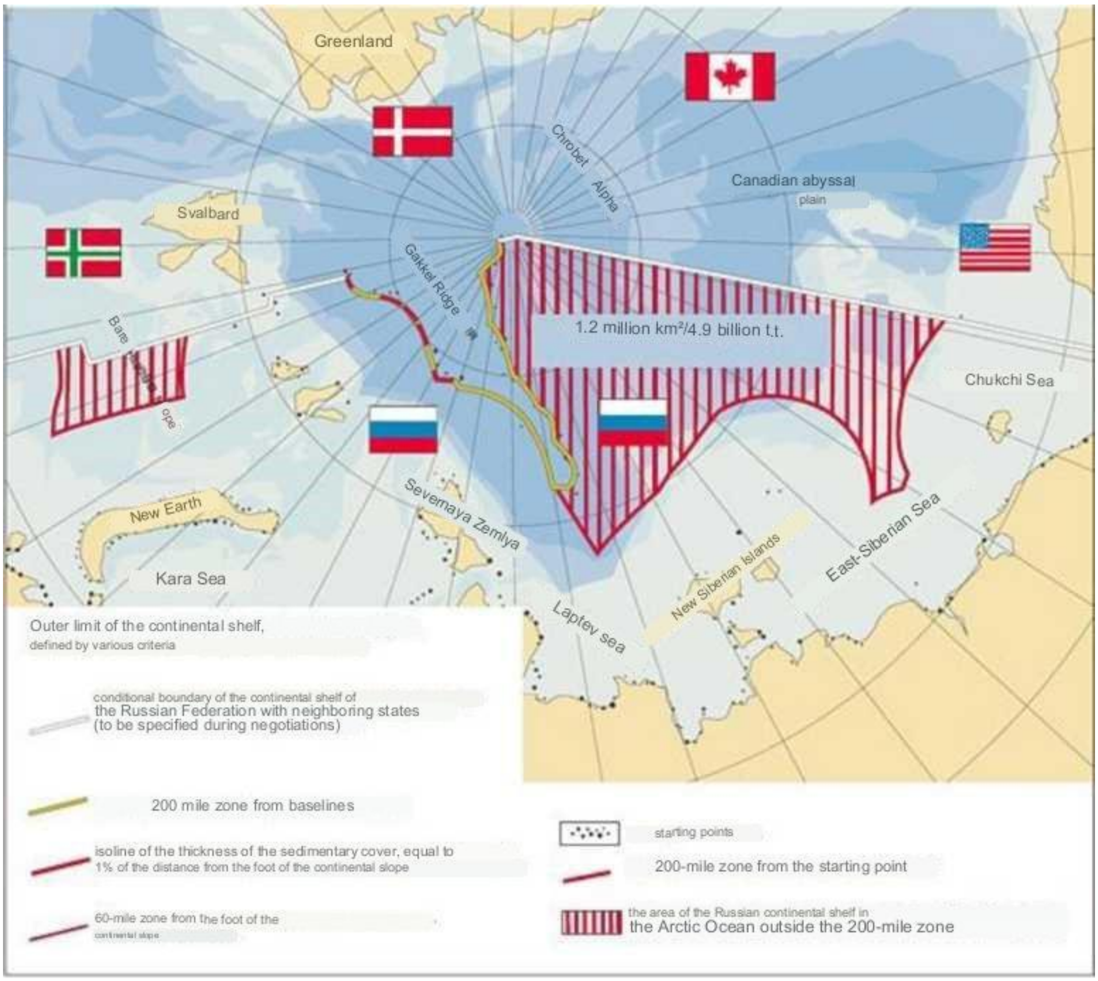


Figure 1.1 The area of the extended continental shelf of the Russian Federation In the Arctic Ocean beyond the 200-mile zone.

To date, the world has accumulated significant experience in the design, construction and operation of MNGS, which are used for drilling, production, storage, processing and transportation of oil and gas. Such structures have been built and are being built all over the world at different latitudes, in a variety of climatic, hydrological, engineering-geological, seismic and other natural conditions. Significant experience has been accumulated by American, Canadian, Norwegian, Japanese and other foreign companies. Until recently, domestic experience in the construction of offshore oil production facilities was mainly represented by facilities for oil production in the Caspian Sea.

According to the existing classification, offshore oil and gas production facilities are divided into three main groups:

- artificial alluvial and bulk islands made of sand, gravel or stone, with or without bank protection;

- stationary submersible platforms supported in the operational state on the seabed and having a gravity, pile or combined type of construction;

- floating complexes that are in a state of operation afloat and are held by anchor systems or have dynamic positioning systems [8].

1.2. World experience in the development of hydrocarbon fields

This section discusses examples of world experience in the development of various oil and gas fields located in the offshore area of both the Arctic and non-Arctic seas. Based on the above examples, it is possible to draw conclusions about the effectiveness of certain engineering solutions adopted in the design and construction and their possible application for the conditions of the Rusvnovskoye and Leningradskoye fields in the Kara Sea.

Some of the most famous projects for the development of oil and gas fields in the Sea of Okhotsk are Sakhalin projects, such as Sakhalin 1, 2,

Sakhalin-1 is an oil and gas project being implemented on Sakhalin Island under the terms of a production sharing agreement. As part of the project, work is underway to develop oil and gas on the northeastern shelf of Sakhalin Island. The project provides for the development of the Chaivo, Odoptu-Sea and Arkutun-Dagi fields, according to exploration, the volume of recoverable reserves is estimated at 2.3 billion barrels of oil (307 million tons) and 485 billion m3 of natural gas.

The companies leading the field development are Exxon Neftegaz Limited, a subsidiary of ExxonMobil (30%), other members of the consortium for its development - OJSC Rosneft (20%), ONGC (20%) and SODECO (30%).

ORLAN platform

Oil and gas production at the Chayvo field is also carried out from the Orlan offshore platform.

The North Chayvo field is geographically located in the Chayvo Bay of the Sea of Okhotsk, off the northern coast of Sakhalin Island.

Chaivo Bay is elongated from north to south, separated from the sea by a spit. It communicates with the Sea of Okhotsk through the Kleye Strait.

In general, the total recoverable reserves of the Chayvo-Sea field in categories

C1+C2 of the Russian classification are 17.1 million tons of oil and condensate and 9.9 billion m3 of gas. The reserves of the northern part of the tip of Chayvo are 9.356 million tons of oil in category C1, 5.482 million tons of oil in category C2.

The Orlan platform is a steel-concrete gravity-type structure, on which the drilling and accommodation modules are located. The platform is being used to develop the southwestern part of the Chayvo field.

The Chayvo field is located 12 km. from the northeast coast of Sakhalin. The produced oil and gas is delivered to the Onshore Product Processing Facility (OPP), where products are prepared and stabilized for further shipment. Oil is transported via a 226 km (140 mile) pipeline crossing Sakhalin and the Tatar Strait to Khabarovsk Krai, located on the Russian mainland, for temporary storage at the De-Kastri terminal. From the De-Kastri terminal, oil flows through an underwater pipeline about 6 km long to the world's largest tanker loading facility - a remote single point berth (RSP), where it is loaded into specially designed double-hull tankers for delivery to consumers in the world market. Natural gas is transported through a network of pipelines owned and operated by other companies for sale to customers in the Russian Far East.

The platform belongs to CIDS drilling rigs (CIDS - reinforced concrete drilling rig on artificial base), which is also a mobile offshore drilling rig (MODU - mobile drilling offshore). The platform is designed for offshore drilling in harsh arctic conditions at depths of 10.7 - 16.8 m.

The steel-concrete base of the Orlan easily withstands the onslaught of ice and giant hummocks, reaching the height of a six-story building. The mass of the platform is about 70 thousand tons. The length of the structure is 96 m, its width is 89.9 m, the total height of the base is 30 m. Orlan is able to withstand extremely low temperatures and seismicity up to 8 points, withstand waves up to 13 m high , ice and hummocks up to 6 m high. The power supply of 14 MW and the capacity of a heavy drilling rig up to 750 tons with a drive of 2300 horsepower will allow Orlan to achieve a maximum oil production of 23 thousand tons per day, ensuring the operation of 20 wells, each of which the horizon can deviate up to 13 km.

The platform consists of four main components: a steel base, a concrete middle section and two steel deck sections, which house a new world-class drilling rig, technology and accommodation modules of the platform.

The Orlan platform was originally called Glomar Beaufor sea I (Glomar Beaufort Sea I) and was built in 1983-1984. in Japan. In 1984, the platform was towed and installed in the Beaufort Sea (USA, Alaska). The platform was operated as an exploration drilling rig. As a result of its operation, it was practically proved that the platform design is adapted for year-round operation in harsh Arctic conditions. Between 1984 and 1997, the platform drilled 6 exploration wells. Further, the platform was purchased for the Sakhalin-1 project and converted from exploration to production.

After a global modernization, when the latest drilling equipment was installed on the platform (and, in fact, only the base remained of the old platform), the Orlan was towed to a permanent parking lot. Its pontoons were filled and the platform, forever, sank to the prepared bottom of the Sea of Okhotsk. At the installation site of the Orlan platform with drilling and residential modules, the sea depth

a)

b)

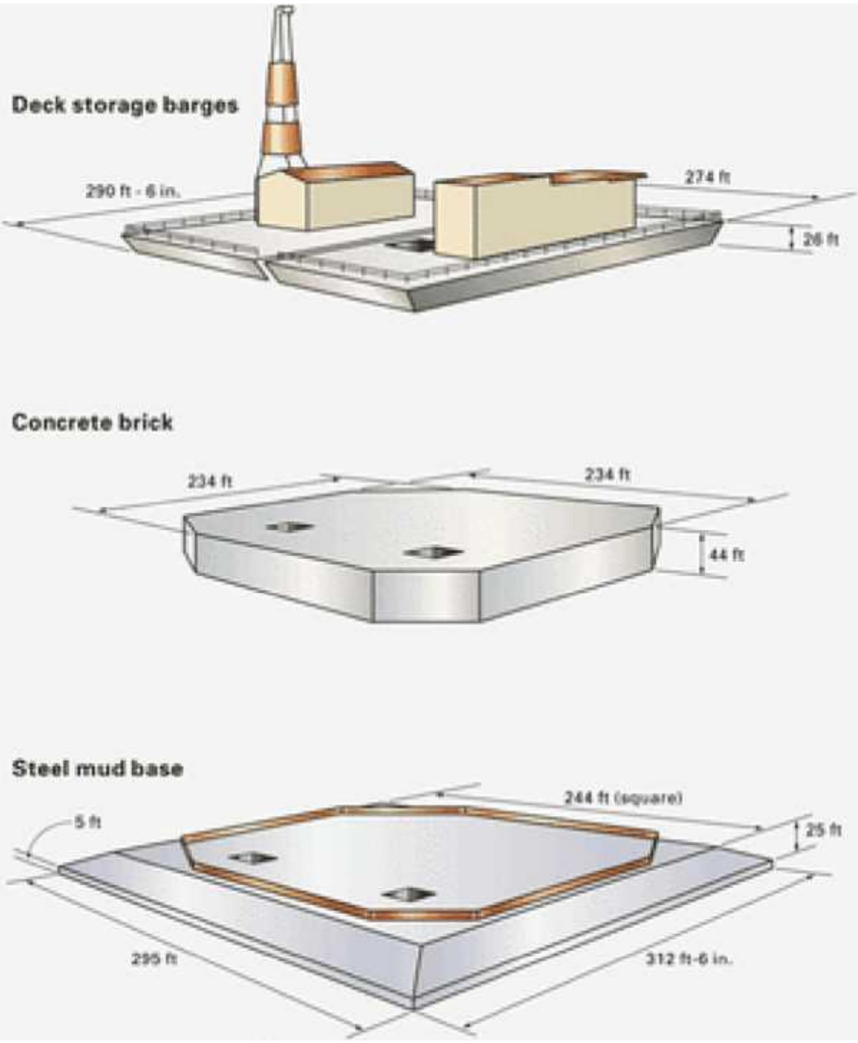


Figure 1.2 Orlan platform: a - photograph, b - diagram.

Platform "BERKUT"

The Arkutun-Dagi field is located at a distance of about 25 km from the coastline, in the northeast of Sakhalin Island, east of the Chayvo field. The field is being developed by Exxon Neftegaz Limited.

Oil and gas will be transported through the new field pipeline to the existing Chayvo Onshore Processing Facility and then through the existing pipelines for sale.

Hydrocarbon production takes place in the difficult subarctic conditions of the Sea of Okhotsk, where winter temperatures can drop to -44°C, wave heights reach 18 m with wind speeds up to 140 km/h, and sea ice thickness reaches 2 m. Dagi varies from 30 to 40 m. Therefore, the offshore ice-resistant drilling platform is designed with such a margin of safety to ensure year-round operation, despite difficult climatic conditions.

In addition, since Sakhalin is located in an area of high seismic activity, the operator of the Sakhalin-1 project equipped the platform with pendulum-type friction bearings to make the structure earthquake-resistant. The platform consists of 2 parts: a gravity-type base (GBS) and a topside housing drilling and production equipment, as well as living quarters.

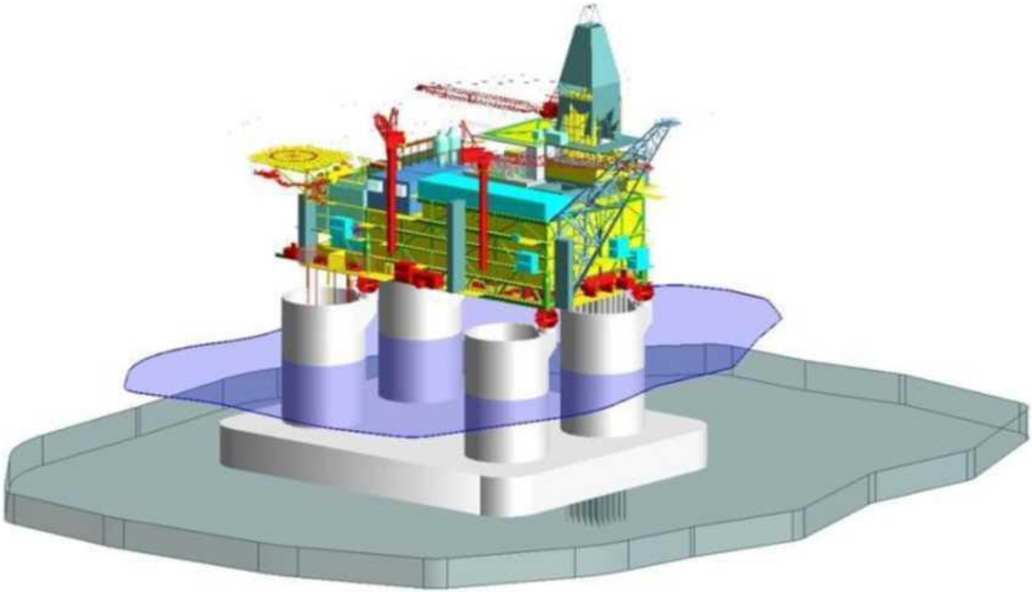
The Berkut platform is designed specifically to operate in harsh subarctic conditions and will be able to withstand waves up to 18 meters high, pressure from ice fields up to two meters thick and temperatures down to -44 C°.

Gravity type base (GBS) is a rectangular concrete caisson on which 4 concrete columns are installed to accommodate the topside. — Length of the caisson — more than 133 m — Width — 100 m — Height with columns — about 55 m Weight of the gravity-type base (CGT) — 160 thousand tons.

The topside is a huge 6-level structure with integrated technological, drilling, residential modules and other structures. Each level is comparable in size to a standard football field. The topsides and drilling rig of the Berkut platform are among the largest and most powerful in the industry. The platform has equipment for increasing wellhead pressure and injection of gas-lift gas, which allows for maximum oil recovery. Berkut is equipped with a powerful drilling rig designed to operate in harsh winter conditions, capable of drilling and completing the most complex wells with a vertical reach of more than 7 km (4.4 miles). A total of 45 drilling cuts are provided at the drilling rig. The rig is capable of moving in all directions between well drilling cutouts. The drilling rig of the Berkut platform will allow ENL drillers to apply advanced technologies, including a system of intelligent wells, completion of wells in two horizons and the installation of multilayer gravel packs.

Technical characteristics of the topside: length - about 100 meters, width - about 50 meters, height of the drilling rig - 129 meters above sea level. With 97 km of piping and 1,900 km of cables, this gigantic structure weighs about 42,000 tons. In May 2013, the topsides of the Berkut platform were lifted, weighing 42,760 tons.

a)



b)

Figure 1.3 Platform Berkut: a - scheme, b - general view.

Sakhalin-2 is an oil and gas project being implemented on Sakhalin Island under the terms of a production sharing agreement. The project provides for the development of two offshore fields: Piltun-Astokhskoye (mainly an oil field with associated gas);

Lunskoye (mainly gas field with associated gas condensate and oil rim). The total reserves are 182.4 million tons of oil and 633.6 billion m3 of gas (according to other sources - 150 million tons of oil and 500 billion cubic meters of gas).

PILTUN-ASTOKH-A (PA-A) platform (MOLIKPAK)

PILTUN-ASTOKHSKOYE field

The Piltun-Astokhskoye oil and gas condensate field (OGCF) is located on the continental shelf of Northeast Sakhalin, at the latitude of the southern end of Piltun Bay, at a distance of 15-20 km from the coast of the island, located at a sea depth of 24-48 m.

The reserves of the Astokhanskoye field are: free gas in category A + B + C1 - 73.6 billion cubic meters. m, condensate - 5.9 million tons, oil - 95.8 million tons of recoverable; category C2 - respectively, gas - 29.2 billion cubic meters. m, condensate - 2.4 and oil - 29.4 million tons.

Administratively, this section of the shelf is part of the Okhinsky and Nogliksky districts of the Sakhalin region. The nearest settlement on the adjacent land is the city of Okha, located 90 km to the north. Transportation of goods is possible by sea from the port of Moskalvo. located at a distance of about 280 km in the north of the island in the Baikal Bay, or from the ports of Kholmsk, Korsakov and Poronaysk, located in the southern part of the island, as well as by helicopters from the airport of the city of Okha

The shelf of the Sea of Okhotsk within the field is a flat plain of a modern abrasive-accumulative shoal. The sea depth varies smoothly from 0 to 30 m. The bottom relief is slightly wavy, with a gentle slope (i = 0.003).

The engineering and geological conditions of the Piltun-Astokhskoye field are characterized as difficult due to the presence of buried paleovalleys, the complex structure of metal complexes, a rather high seismic hazard and the active manifestation of mesodynamic processes.

The ice regime in the field area is complex. Fast ice is formed along the coastline, within which ice hummocks up to 5-6 m high are frequent. Ice 1.5-2 m thick often forms detached fields moving along the coast of the island from north to south at a speed of m/sec. This prevents drilling of wells with PBU in winter (within 6 ¬6.5 months) and endangers the OIRFP.

The Molikpaq platform is Russia's first ice-class offshore production and production platform installed on the shelf of the Sea of Okhotsk as part of the Sakhalin-2 project.

Platform "PILTUN-ASTOKHSKAYA - A" (PA-A)

The platform is a converted drilling rig that was previously used in Arctic waters off the coast of Canada. In 1998, the platform was towed from the Beaufort Sea in the Canadian Arctic across the Pacific Ocean to South Korea, where it was converted to work on the Sakhalin-2 project. Then she was towed from Korea to Russia and installed on a steel base made at the Amur Shipyard - so that the platform could be used in deeper waters offshore about. Sakhalin. The base was filled with sand, which ensured a strong fixation of the structure on the seabed.

The Molikpak platform (PA-A) was installed at the Astokhskaya area of the Piltun-Astokhskoye field in the Sea of Okhotsk in September 1998, 16 km from the coast, the sea depth at the installation site is 30 m. - extracting complex "Vityaz". Molikpaq is a modernized ice-class drilling platform. The name "Molikpaq" means "big wave" in the language of the Eskimos of northern Canada, where this platform used to be based (in the Beaufort Sea). In 1998, a 15m intermediate steel base was added to the base of the Molikpak platform to set it up in deeper waters off Sakhalin Island.

The Molikpaq consists of a caisson filled with sand in the center to effectively anchor the platform to the seabed.

The main working areas are closed, they provide for temperature control and ventilation. Equipment located outdoors is equipped with anti-icing and low temperature protection. Living quarters are designed for 132 permanent and 32 seasonal workers. On the Molikpaq platform, an extended reach drilling method was used in deviated wells with a maximum horizontal deviation of up to 6 km and a maximum well depth of up to 6650 m.

Base: 111 m x 111 m Weight: 54 kt Derrick height: 101 m Topsides: 73 m x 73 m Helideck height: 49 m Drilling windows: 32 drilling windows

Production wells: 13 oil producing wells, one gas injection well, four water injection wells and one cuttings injection well.

Production capacity of the Molikpaq platform: oil - 90 thousand barrels per day (11,538 tons per day); associated gas - 1.7 million m3/day. Previously, the platform operated only during the summer months; year-round production from Molikpaq began in 2008.

After the minerals are mined, they are sent via oil and gas pipelines to the LNG plant in Prigorodnoye. The plant itself is divided into two zones (gas and oil) by the so-called green belt.

Figure 1.4 Platform "Piltun-Astokhanskaya - A" (Molikpaq). PILTUN-ASTOKHSKAYA-B platform

The PA-B platform is the largest platform installed on the Sakhalin-2 project. Since the end of 2008, the platform has been producing oil and associated gas at the Piltun area of the Piltun-Astokhskoye oil field. Hydrocarbons are supplied through the trans-Sakhalin pipeline system to the LNG plant and the oil export terminal of the Prigorodnoye complex.

The base of the platform is a gravity-type reinforced concrete base with four supports, on which the upper structures of the platform with technological facilities are located. The southeast leg is used as a well pad, the northeast leg is for large radius offshore pipeline/pipe risers, and the other two legs are for pumps and tanks. The topside complex was built in South Korea. The topsides of the platform house drilling equipment and liquid hydrocarbon separation equipment, storage for chemicals and accommodation module. The main working areas are closed, they provide for temperature control and ventilation. Outdoor equipment is equipped with ice protection equipment.

The PA-B platform is designed for year-round operation under severe climatic, wave, ice and seismic loads.

The platform is installed approximately 12 km from the northeast coast of the island. Sakhalin in the open sea at a depth of 32 m.

Gravity-type concrete base with four legs - designed and built in Vostochny port in the Russian Far East by Aker Kvaemer Technology AS and Quattrogemmi OY. Installed in August 2005.

The fully integrated platform deck is built by Samsung Heavy Industries at shipyards in South Korea. The topsides were installed in July 2007 by thrusting on a pre-installed concrete base.

The height of the PA-B platform is 121 m from the seabed to the top of the deck, i.e. equivalent to the height of a 30-story building.

The platform is equipped with equipment for drilling, distribution of hydrocarbons, liquids/water, storage of chemical materials.

Staff accommodation: 100 permanent and 40 temporary workers. Base:

Height: 53 m

Weight: 90,000 tons

Dimensions: 94m x 91.5m x 11.5m

Support height: 56 m

Upper structure:

Flare stack height: 98.6 m Weight: 28,000 t Drilling windows: 45

The PA-B capacity is more than 70,000 barrels (11.1 thousand m3) of oil and 92 million standard cubic feet (2.9 million m3) of associated gas per day.

Figure 1.5 Piltun-Astokhskaya-B platform (PA-B)

Platform "LUNSKAYA-A" (LUN-A)

The Lunskoye oil and gas condensate field is located on the shelf of Northern Sakhalin, 12-15 km east of the coastline of the island. Sea depth at the field is 42-47 m.

The deposit was discovered in 1984, studied by seven exploratory wells. First-class gas reservoir with a thin oil rim: initial in-place gas reserves of 526.7 trillion. cube m (18.6 trillion cubic feet); balance reserves of commercial oil 124.465 million tons (931 million barrels).

The Lunskaya-A platform is a drilling and production platform installed 15 kilometers off the northeast coast of Sakhalin Island as part of the Sakhalin-2 project.

The Lunskaya-A platform (Lun-A) was installed in June 2006 at the Lunskoye gas field in the Sea of Okhotsk, 15 km from the coast at a depth of 48 m. The Lun-A platform is equipped with minimal technological equipment. It is designed for year-round production and produces most of the gas for the liquefied natural gas (LNG) plant. Primary gas treatment is carried out at the Onshore Processing Facility (OPF), after which the gas is transported to a liquefied natural gas (LNG) plant.

The base of the platform is a gravity-type reinforced concrete base with four supports, on which the upper structures of the platform with process equipment and structures are located. The southeast leg is used as a well pad, the northeast leg is for large radius offshore pipeline/pipe risers, and the other two legs will be used for pumps and oil transfer tanks.

The platform topsides were built in South Korea. The topsides of the platform house drilling equipment and liquid hydrocarbon separation equipment, storage for chemicals and accommodation module. For safety reasons, all technological and drilling equipment is located at the end of the platform opposite from the residential module. The main working areas are closed, they provide for temperature control and ventilation. Equipment located outdoors is equipped with anti-icing and low temperature protection.

LUN-A is used for extended reach drilling of deviated wells with a maximum horizontal deviation of up to 6 km and a maximum true vertical depth of 2920 m.

Staff accommodation: 126 workers, however, up to 140 people live on the platform

Base:

Height: 69.6 m Weight: 103,000 tons

Base plate: 88 m x 105 m x 13.5 m Pole height: 56 m

Pole diameter: 20 m

Weight: 21,800 tons

Flare stack height: 105 m

The estimated capacity of the Lun-A platform is more than 50 million m3 of gas, while the associated condensate and oil production is approximately 8,000 m3 (50,000 barrels) per day.

Figure 1.6 - Platform "Lunskaya-A" (LUN-A)

Pechersk Sea

OIRSP "PRIrazlomnaya"

The field is located on the shelf of the Pechora Sea, 55 km north of the village of Varandey and 320 km northeast of the city of Naryan-Mar (Pechora river). The sea depth in the area of the deposit is 19-20 meters.

The Prirazlomnoye oil field is the first domestic project to develop the resources of the Arctic shelf. The field was discovered in 1989 and is located on the shelf of the Pechersk Sea, 60 km from the coast (village Varandey). The reserves of the field are 46.4 million tons of oil.

The Prirazlomnaya offshore ice-resistant fixed platform ensures the performance of all technological operations: well drilling, production, storage, offloading oil to tankers, generation of heat and electricity.

The length and width of the platform are 126 m, the weight of the platform (without ballast) is 117 thousand tons, autonomy in terms of provisions and fuels and lubricants is 14 days, in terms of technological reserves and chemicals - 60 days, in terms of consumables for drilling operations - 40 days, residential the module is designed for year-round living up to 200 people. The platform meets the most stringent security requirements. It is adapted to work in harsh natural and climatic conditions, designed and built with the expectation of maximum ice loads in the region.

The platform operates in accordance with the "zero discharge" principle: used drilling fluid, cuttings and other process waste are pumped into a special absorption well. Prirazlomnaya is designed to ensure maximum safety of oil production.

The sea depth in the field area does not exceed 20 meters, so the platform is installed on the seabed and is securely held due to its weight (500 thousand tons) and a protective berm made of stone and crushed stone. A specially designed platform support base (caisson) is able to successfully withstand the arctic climate. For greater resistance to corrosion and wear, its walls are made of a four-centimeter layer of clad steel, a three-meter space between which is filled with heavy-duty concrete.

The design of the caisson part is designed so that it can withstand a direct torpedo attack. The margin of safety of the lower part of the platform many times exceeds the actual loads.

The supporting block of the platform is a steel caisson with dimensions of 126 m x 126 m, to the bottom of which corrugated steel skirts 35 mm thick are attached in the form of a lattice with a step of 25.2 m. The depth of immersion of skirts into the bottom soil is about 1.5 m. from the bottom to the upper deck is 24.3 m. The height of the platform, excluding the drill string and flare tower, is 40.5 m, and together with them 141 m.

The bottom of the 3 m high steel caisson has a cellular structure in the form of upper and lower skins supported by frame frames. The inclined surface of the sides contributes to the destruction of ice as it moves up the sides. In the area of contact with ice, the sides are covered with stainless steel. Cofferdam walls divide the interior of the caisson into 16 sections for storing oil and sea water. Oil is stored inside the caisson in 12 sections with a capacity of about 160 thousand m3. The upper deck of the caisson with a height of 2.3 m closes the storage of oil and outboard water. Inside the sides and walls of the cofferdams there is a concrete ballast.

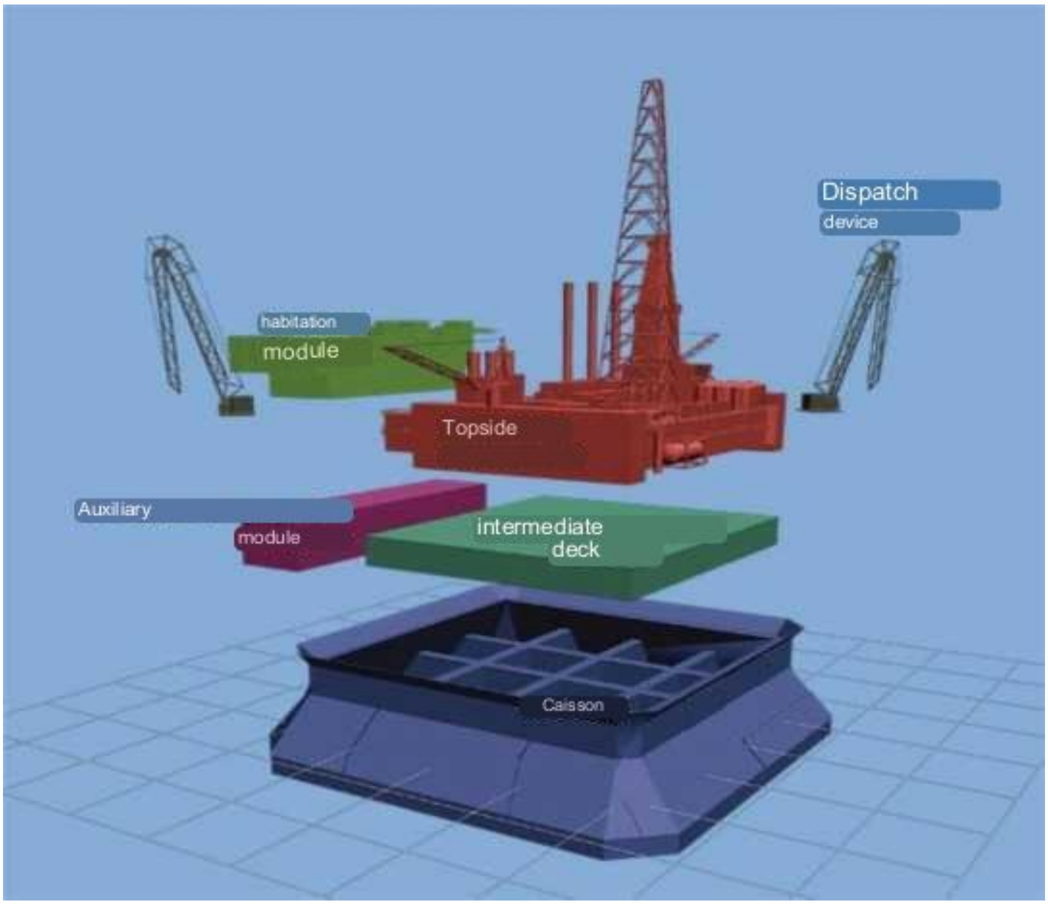


Figure 1.7 OIRFP "Prirazlomnaya"

North Sea TROLL-A platform

Field "TROLL"

The Troll oil and gas field is located in the North Sea on the shelf of the western coast of Norway, 100 km northwest of Bergen

The Troll field, Block 31/2 is a large offshore oil and gas field located on the Norwegian continental shelf. Opened in 1979. The depth of the sea here is approximately 350 m.

The Troll field consists of 2 structures - Western and Eastern Troll. The recoverable reserves of the field are estimated at 250 million to 750 million tons of oil, and natural gas is 1.3 trillion. m3. The density of oil is 0.845 g/cm3 or 35.9° API. The sulfur content is 0.14%. Productive deposits are located at a depth of 1.3-1.6 km. The deposit area is 710 km2.

Troll-A is an offshore natural gas platform in the Troll field off the west coast of Norway. Weighing 1.2 million tons loaded with ballast under tow, 472 meters tall, with a submerged concrete structure of 369 meters and a dry weight of 656,000 tons, the

Troll-A is a majestic marvel of engineering. Not only is the platform among the largest and most complex engineering projects in history, it is also the largest object ever moved by man on the surface of the Earth. The design was shown on television when it was towed into the North Sea in 1996, where it is now operated by Statoil.

The platform was towed over 200 kilometers from Watsa in the northern region of Rogaland, to the Troll region, 80 kilometers northwest of Bergen. The towing took seven days. Produced gas is carried through the pipelines of the platform at speeds up to 2,000 miles per hour (890 m/s). This speed is provided by two gas compressors in order to increase production volumes.

The platform sits on the sea floor 303 meters below the sea surface. One of the concrete cylindrical pillars has an elevator that takes workers and technicians to the seabed in nine minutes. The walls of the Troll's supports are over 1 meter thick, made of steel reinforced concrete formed in one continuous stream. Attached to these four posts is a reinforced concrete box that ties them together, which has the special function of dampening unwanted, potentially damaging resonances from earthquakes and waves. Each leg is also divided along its length into independent watertight compartments. A group of six 40-meter vacuum anchors is used, holding the installation on the seabed.

The platform, as an engineering structure, consists of two main components:

1. Concrete gravity base (mushroom stem on which the drilling-producing platform rests), 370 meters high.

2. Upper structures (actually, the platform itself, the hat of this mushroom, where mechanisms and people are placed)

Four cyclopean concrete pillars protrude from the sea. The drilling deck and the entire superstructure of the platform rests on four massive concrete pillars that go down to the seabed to a depth of 300 meters. The base of the platform is made of 19 prefabricated concrete blocks made on land. The base was towed on ropes and sunk in a deep fjord, where four high supports were attached to them. The total height of each support is 369 meters, exceeding the height of the Eiffel Tower. By the way, each of them has an elevator, the rise of which takes 9 minutes. The walls of the cylindrical legs are over 1 meter thick.

At the very base of the platform, pipelines bend around a corner and, passing along the seabed, deliver gas to Norway 60 kilometers from this place. And below is a concrete floor, and under it is sea silt, the platform goes deep into the seabed.

Down at the seabed, the main task is to cope with the pressure of the water column, and up close to the top, with the wind and waves that crash on the platform. During a storm, waves can reach the deck, located at a height of 30 meters above the sea. But this deck is large enough not to be flooded by the waves, and is securely attached to four pillars. They, in turn, are strong enough to withstand the impact of 5 million waves every year.

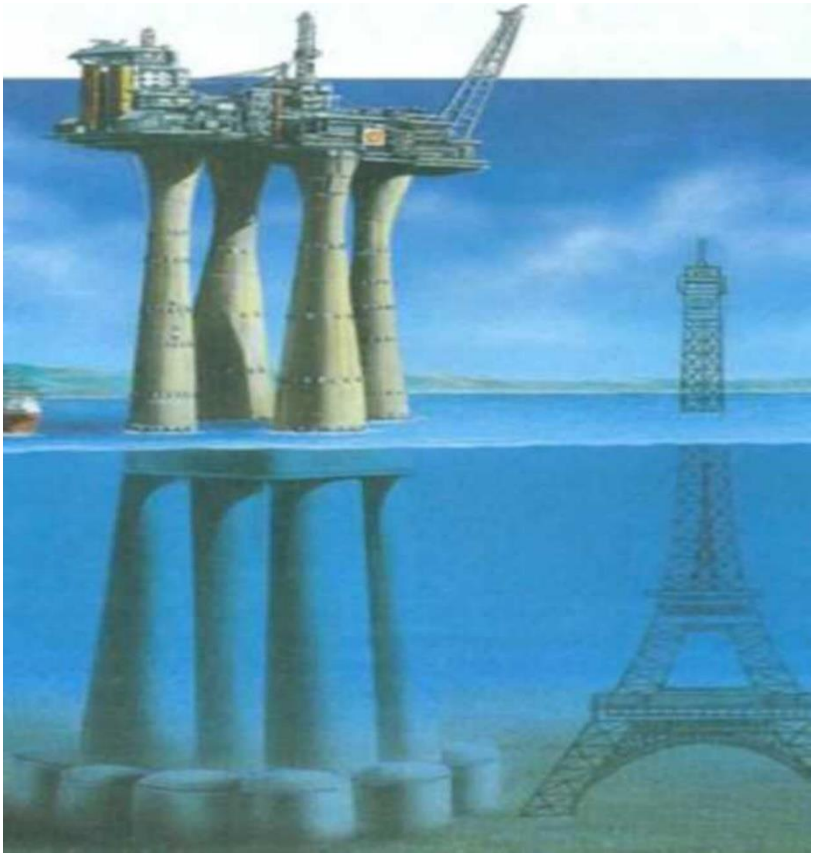


Figure 1.8 Troll – A

The Gullfaks deposit is located 160 km from Sognefjord, Norway.

Gullfaks, Block 34/10 (nor. Gullfaks) - a complex of oil and gas fields in the North Sea. Opened in 1978. Development began in 1986.

Oil and gas production in Gullfax is carried out using 3 platforms Gullfax A, Gullfax B and Gullfax C, as well as their satellites Gullfax South, Rimfax, Skinfax and Gullveig.

The oil and gas bearing layers are tied to the Paleogene deposits. Initial oil reserves at the complex are 200 million tons, and natural gas reserves - 200 billion m3.

Gullfaks is an offshore oil platform in Block 34/10 in the North Sea between the UK and mainland Europe. The platform is installed at a depth of 217 meters. The total height of the structure is 380 meters, making it taller than the Eiffel Tower. Gullfaks C produces 250,000 barrels of oil per day. Norway is 108 miles away from the complex. Workers get to work by helicopter. Gas was found in the North Sea in 1959 and oil was discovered in 1970. Gullfaks was completed in 1990.

The topside is made of steel structures and stands on four massive concrete columns, which in turn rest on a hollow concrete foundation. Caisson foundation. It consists of equipped cells designed to store produced oil. Crude oil is pumped from wells in the seabed and then pumped through pipelines through wellheads to the platform.

After oil is injected, underground caisson tanks are filled with water, and this cycle is repeated anew.

On the roof are cargo cranes, as well as a helipad. Oil production is provided by a drilling rig. Oil is delivered to the shore by tankers.

The mining company at Gullfax is the Norwegian company StatoilHydro (70%). Another project partner is Petoro (30%). The platform has the following options:

Total height - 380 m,

Length -142 m,

Width - 40 m,

Support height - 262 m,

Water depth - 217 m,

Storage tank (oil) - 300 thousand m3,

Living quarters (beds) - 300,

Base height - 19 m,

Figure 1.9 - Platform "GULLFAKS"

Field and platform "DRAUGEN"

Field development. Draugen by a consortium of companies, which included Petro AS (47.88%), A / S Norskoe Shell (26.2%), BP Norge AS (18.36%) and Chevron Texaco Norge AS (7.56%), began in 1993. Shell became the operator of the project.

The platform is a reinforced concrete base 280 meters high, which, by the way, was built without the participation of divers, and an integrated deck with topsides about 30 meters high.

The design is such that in the event of a storm the "leg" can stabilize the load and eliminate the possibility of refraction: almost the entire "leg" is filled with sea water and only the top three levels are working equipment.

However, even during the calm, a slight swaying is felt on the platform.

A distinctive feature of the field is a relatively small number of wells - only 12 producing. The field's peak production was 225 kb/d and peak production from a single platform well was 77 kb/d, which remains an unbeaten world production record for offshore wells. Today, the daily production of wells is 40 thousand tons. barrels, with 24 thousand barrels being water, and the total production volume is 140 thousand barrels per day.

The Draugen offshore oil platform has been operating in the North Sea since 1993, is the first oil platform built north of the 62nd parallel, and is also considered a real miracle of engineering - a multi-storey building stands on one 280 meter concrete "leg", of which 250 meters are in sea. The development is being carried out by the Dutch-British oil and gas company Royal Dutch Shell.

The original design of the Draugen platform, with a wide concrete footing, is designed to withstand the area's frequent storms. All produced oil is stored in tanks located in the underwater part of the structure (at the base of the "leg"). Periodically, it is pumped into a tanker moored at a special loading terminal, about 3 km from the platform. All produced gas is pumped into the underwater gas pipeline, which goes to the coastal station.

According to the original plans, Draugen was supposed to close back in 2010 - its upper part was to be dismantled, and the leg was partially disassembled and sealed, turning it into a kind of coral reef, but since the recoverable hydrocarbon reserves at this field have almost doubled, its service life extended for a certain time.

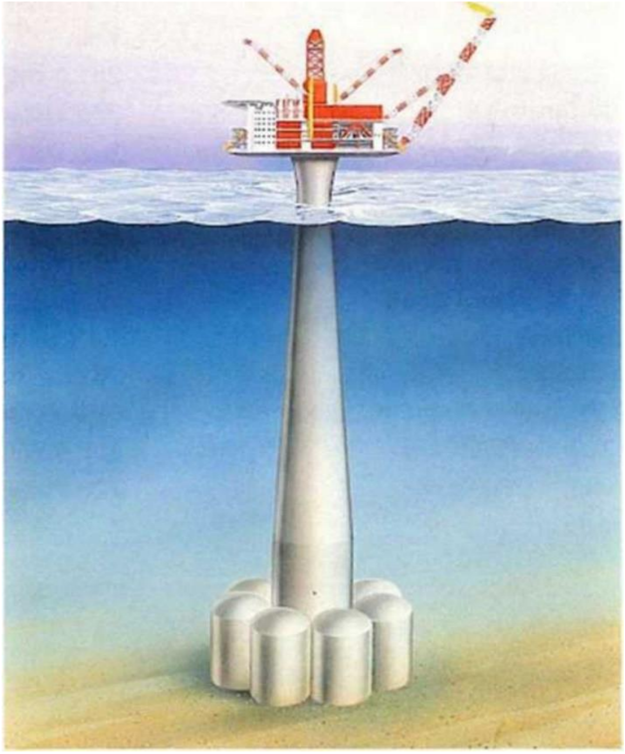


Figure 1.10 DRAUGEN platform, general view

STATFJORD platform.TATFJORD field

Statfjord, Blocks 33/9 and 33/12 (Norway), 211/25 (Great Britain) - a complex of oil and gas fields in the North Sea. Opened in 1974. Development began in 1979. One of the oldest large oil fields in Northern Europe.

Oil and gas potential was established in Paleogene deposits. Initial oil reserves at the complex are 500 million tons, and natural gas reserves - 200 billion m3.

The operator of Statfjord is the Norwegian company StatoilHydro (44.34%). Other project partners are ConocoPhillips (15.17%), ExxonMobil (21.37%), Shell (8.55%), Centric a Resources (9.68%), Enterprise Oil (0.89%).

Statfjord B

In Norway, in 1981, it was built, though not a ship, but a floating structure - a reinforced concrete base for the production and storage of oil "Statfjord B" with a displacement of 849 thousand tons. It is this artificial island that is still the largest engineering structure ever created by shipbuilders in the world.

The offshore platform Statfjord, with a concrete gravity base and a steel superstructure, is located in the center of the field, 200 km west of the city of Bergen in Norway and is located close to the border between British and Norwegian territorial waters.

The reinforced concrete giant Statfjord B is installed in the North Sea at a depth of 145 m, its height from the seabed to the top of the drilling rig is 271 m.

The massive bottom oil storage base with a length of 167 m, a width of 134 m and a height of 68 m consists of 20 giant cylindrical tanks made of reinforced concrete with a diameter of 24 m and a total capacity of 250 thousand cubic meters. meters.

Four reinforced concrete columns 110 m high are installed on them, on which the upper part of the base, made of steel, with an area of 116 X 88 m and a mass of 47 thousand tons, rests. On the decks of this upper structure (with an area

37.5 thousand sq. meters) there are 25 production modules with various technological and energy equipment and a seven-storey residential block for 250 people.

The lower deck of the building is 29 m from the sea surface. A power plant with a capacity of 38 thousand kW is provided to provide energy to various mechanisms.

With the help of the drilling rig installed at Statfjord B, 40 wells can be drilled to a depth of up to 2800 m. Annual oil production can be about 7.5 million tons

It took three years to build this unique structure. About 7 thousand concrete workers and shipbuilders took part in its construction. In total, 135 thousand cubic meters were spent. meters of concrete, 35 thousand tons of steel reinforcement, about 35 thousand tons of metal structures and 8 million people spent. hours. The cost of founding Statfjord B exceeds the cost of the aircraft carrier Carl Vinson and amounts to $1.8 billion.

The reinforced concrete base "Statfjord B" is a four-time record holder: firstly, it is the largest offshore floating structure in the history of shipbuilding; secondly, the largest of the facilities installed on the shelf; thirdly, the largest floating structure ever towed and, fourthly, the heaviest artificial object ever moved on the water surface.

Oil from Stafjorada is transported by tankers all over Europe. The gas is supplied via the Tempen Link pipeline to St. Ferguson (UK).

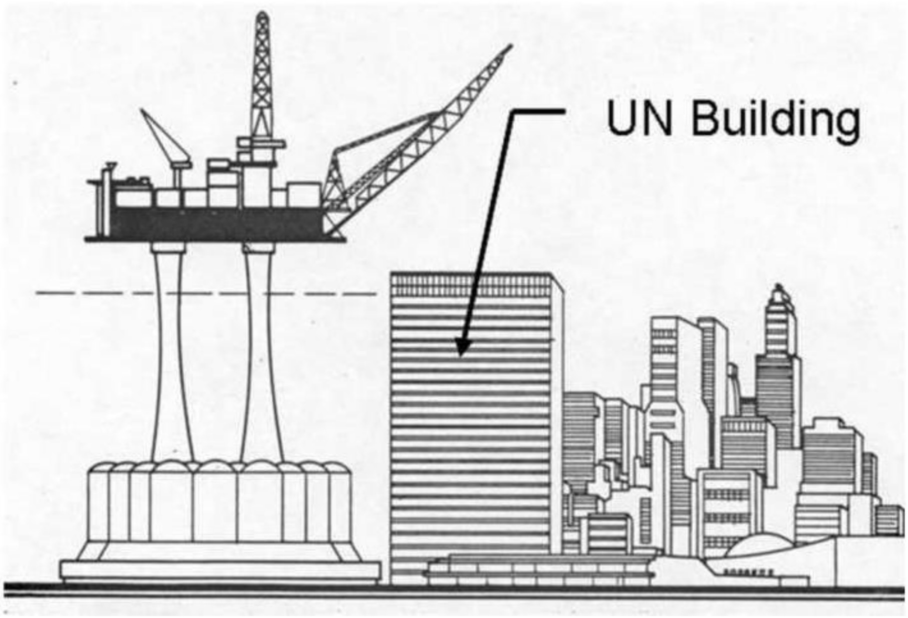


Figure 1.11 Statfjord B platform

Caspian Sea

Ice-resistant stationary platform (IRP-1, IRP-2)

The stationary offshore ice-resistant platform built at the Yury Korchagin field is located in the Caspian Sea, 180 kilometers from Astrakhan and 240 kilometers from Makhachkala. A production well was built at the field and a commercial oil flow was obtained. The field is being developed by OOO LUKOIL-Nizhnevolzhskneft, a subsidiary of OAO NK LUKOIL.

Information about the deposit. Yu. Korchagina: Sea depth in the field area: 11-13 m.

Recoverable oil reserves: 28.8 million tons

Recoverable gas reserves: 63.3 billion cubic meters m

Maximum oil production level: 2.5 million tons per year

Maximum level of gas production: 1 billion cubic meters m

Number of wells being drilled: 33 pcs.

Drilling is carried out from an offshore ice-resistant fixed platform (OIRFP).

The platform consists of production (IRP-1) and residential (IRP-2) modules connected by a 74.2 m long bridge. A drilling complex with a lifting capacity of 560 tons is installed on the production module for drilling wells with a maximum length along the shaft up to 7400 m.

IRP-1 is a platform created by reconstructing the basic supporting body of the Shelf-7 floating semi-submersible drilling rig. Complexes are located on IRP-1: drilling,

Operational and technological, energy, as well as a complex of ship

Main characteristics			IRP-1:	
Length	overall (with flare boom)	approx.	115	m,
Length	corps		95,5	m,
Width	overall (with brackets for piles)		72,2	m,
Width	corps		64,2	m,
Height	overall from sea level	approx.	90	m,
Weight	platforms (dry)	approx.	16000	t.

The mass of the platform when parked on the ground with liquid ballast is 25,655 tons.

The upper production building IRP-1 has a very dense saturation with equipment for the extraction and processing of oil and gas. Therefore, the placement of living quarters on the same platform created serious difficulties in ensuring the safety and comfortable living conditions of the crew. Despite the fact that the location of all complexes in the upper building ensured compliance with the requirements of regulatory documents on industrial safety, it became obvious that the removal of the residential module outside IRP-1 was an urgent need.

It was decided to build a free-standing stationary platform IRP-2 with a residential block designed for 105 people. IRP-2 is designed for year-round comfortable living for all personnel working at the facilities of the field named after. Y. Korchagin.

Main characteristics of IRP-2:

Number of residents: 105 people.

Weight about 2,780 tons.

Figure 1.12 Offshore ice-resistant platform (OIRFP (IRP-1 and IRP-2))

Atlantic Ocean HIBERNIA Platform

HYBERNIA field

Hibernia is an oil field located east of the island of Newfoundland in Canada. Opened in 1979. The field includes two early Cretaceous oil basins - Hibernia and Avalon, occurring at depths of about 3700 and 2400 meters, respectively. Hydrocarbon reserves are approximately 3 billion barrels (420 million tons).

The Hibernia gravity ice-resistant platform is located 315 km east of Newfoundland (Canada) at a sea depth of about 80 m.

The height of the gravity base of this platform exceeds 111 m, and the height of the entire structure is almost 224 m, the weight with ballast is 1.2 million tons. Hibernia is designed to withstand a collision with an iceberg weighing more than 1 million tons without damage and up to 6 million .t - with non-critical damage. But the owners of the platform prefer to avoid encounters even with ice blocks of harmless size, for which a specially hired ship intercepts approaching icebergs and drags them away from expensive structures.

The main advantage of this type is stability, due to the rigid attachment to the seabed, they are less susceptible to displacement under the influence of wind and water masses.

A special gravity submersible weighing 450,000 tons has been developed for the subsea base of the Hibernia platform. It is a 105.5-meter caisson-type base, constructed using high-strength concrete, stitched with steel gratings and tightened with tension cables that create additional strength. The base is protected by an anti-ice structure of 16 concrete teeth.

According to the structure, the anti-ice wall 1.4 meters thick consists of two layers: the outer one is a system of X- and V-shaped ceilings 0.7-0.9 meters thick, transferring the load to the inner part of the fence; the inner layer is less than 0.9 meters thick. The underwater base of the platform is limited from above and below and reinforced with round horizontal plates.

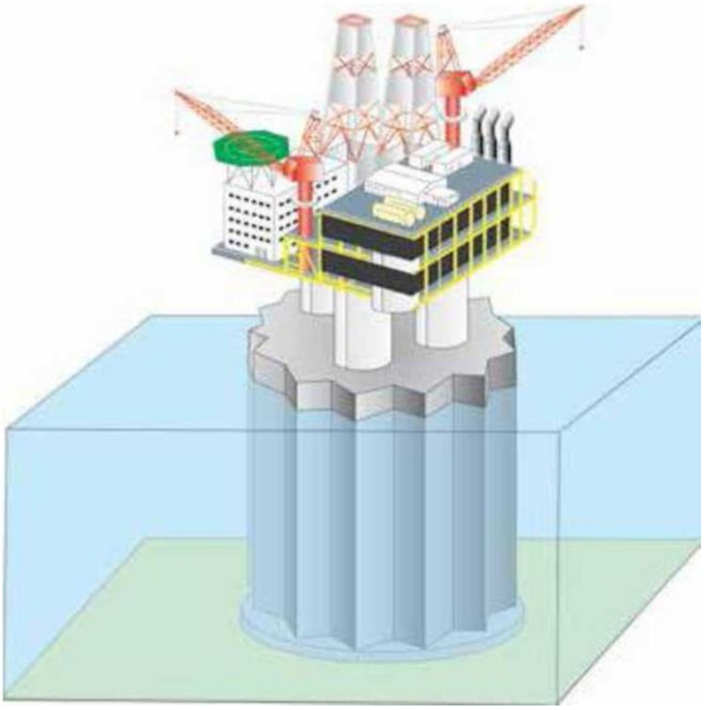
The lower base plate is 108 meters in diameter, the upper one rises 5 meters above sea level. Inside the gravity structure are oil storage facilities designed to hold 1.3 million barrels of crude oil. From the lower base plate, four shafts or columns extend through the gravity structure of the base, which support other internal structures, namely, an auxiliary shaft, a pipeline riser shaft and two production drilling compartments. Each of them is 17 meters in diameter and 111 meters high. Auxiliary shaft is also called utility shaft or supply systems shaft; it contains the automatic equipment necessary for the operation of the gravity base system, the piping network, the heating and air conditioning system, and the electrical controls. Two drilling shafts contain 32 production channels (mouths) leading to oil deposits at a depth of up to 3,700 meters below sea level.

The Hibernia topsides have a design capacity of 23,900 cu. m / d, include five main modules: production (processing), a module with wellheads (wellhead), slurry, utility and residential premises, which can accommodate 185 people, as well as seven overhead structures: a helipad, a flare boom, an overpass for pipes, main and auxiliary rescue stations, two drilling modules. The 37,000-ton complex top of the platform is transported by barges into deep waters and installed above the partially submerged gravity base shafts. The completed 600,000 ton platform was then towed to its final location and secured to the bottom with 450,000 tons of solid ballast.

Oil stored in the subsea caisson bed of Hibernia is exported using an offshore offloading system consisting of a subsea pipeline, a subsea buoy, a flexible oil loading hose and regular oil cargo tankers. A tanker loading point for added security is located two kilometers from the platform. Hibernia is served by three 127,000-ton tankers - Kometik, Vinland and Mattea, with a capacity of 850,000 tons each

a)

b)



c)

Figure 1.13 Hibernia platform: a - general view,b - scheme,c - foundation at the construction stage

Platform project "HEBRON". Field «HEBRON»

The Hebron field is located offshore Newfoundland and Labrador in the Jeanne d'Arc Basin, more than 350 km southeast of the provincial capital of St. John's and approximately 32 km southeast of the ExxonMobil-owned Hibernia facility. The water depth is approximately 92 m.

The Hebron oil fields on the Canadian shelf were discovered 30 years ago. Hebron is located 350 kilometers from St. John's - the capital of the province of Newfoundland and Labrador. The start of production at the site is planned for 2017. The expected daily production volumes are about 150,000 barrels (21,000 tons). The total estimate of oil reserves fluctuates around 700 million barrels (98 million tons)

The Hebron field will be developed using a self-contained offshore gravity platform made of reinforced concrete capable of withstanding sea ice, icebergs and difficult meteorological and oceanographic conditions. The base of the platform is designed to store approximately 1.2 million barrels of crude oil and will support the topside structures, which include living quarters and drilling and production equipment.

Preliminary engineering and design work has been completed and significant progress has been made in the engineering design. The current economic calculations reflect the outstripping pace of project preparation, current market conditions and exchange rates. Construction of an offshore gravity platform has already begun at the project's main site in Bull Arm, Newfoundland and Labrador. The beginning of the assembly of the upper structures will begin at the end of this year.

The Hebron field will be operated by an ExxonMobil subsidiary called ExxonMobil Canada Properties, which owns a 36% stake in the project. Field development partners include Chevron (26.7%), Suncor Energy (22.7%), Statoil (9.7%) and Nalcor Energy Oil and Gas (4.9%).

a)

b)

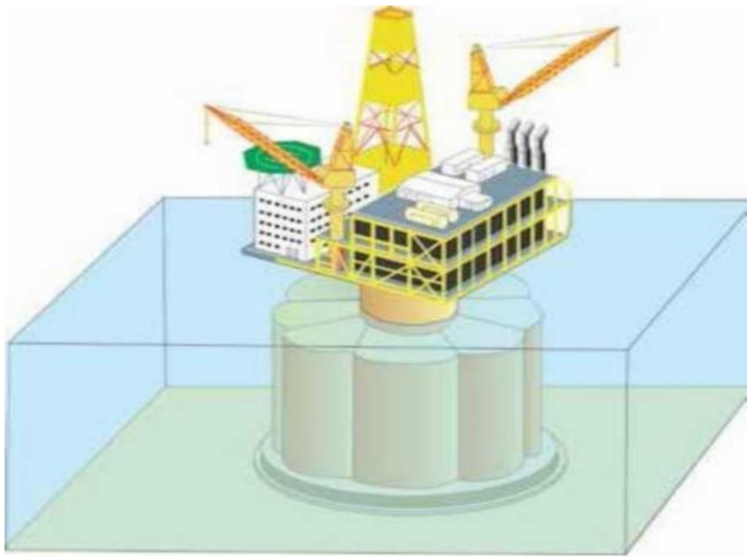


Figure 1.14 - Platform for the development of the Hebron field a and b - different views

Baltic Sea

Kravtsovskoye field

The Kravtsovskoye (D-6) field in the Baltic Sea was discovered back in 1983. According to the results of exploration work, geological reserves of C1 + C2 category oil here amounted to 21.5 million tons, recoverable reserves - 9.1 million tons. It took 7.7 billion rubles to develop the field. Over the entire period of operation of the platform, the volume of oil production amounted to about 3.6 million tons. Commercial oil production at the Kravtsovskoye field began in July 2004. Currently, 14 productive wells have been drilled at D-6, 13 of which are horizontal. Drilling and oil production are carried out from an offshore ice-resistant fixed platform, which was built at the plant for the production of steel structures of OOO LUKOIL-Kaliningradmorneft. This is the first production platform on the Russian shelf, designed and built by domestic design and production organizations.

Drilling and oil production are carried out from an offshore ice-resistant fixed platform (OIRFP), which was built at the steel structure plant LUKOIL-Kaliningradmorneft.

All production processes at the OIRFP are carried out in accordance with the principle of zero discharge, that is, all industrial and domestic waste will be taken ashore for disposal.

The platform is located near the Russian-Lithuanian border on the territory of the Russian Federation, 22.5 km from the coast of the Curonian Spit.

The depth in this place is 25-38 m.

Well depth - 2393 m.

The design is called precisely - OIRFP - offshore ice-resistant stationary platform. It (OIRFP) consists of two supporting blocks (modules - technological, where drilling is carried out, and residential, in which 90 people can live): existing (OB-1) and new (OB-2),

located 70 m apart and connected by a bridge

The support block OB-1 is a three-dimensional lattice structure of a pyramidal type, which is made of beveled tubular assemblies and straight inserts, which are interconnected by welding. The support block rests on the seabed and is attached to it with a system of piles that transfer the load to the ground

Also on one of the modules is a helipad. The modules are interconnected by a 70 m long bridge! A 47 km long pipeline stretches from the platform to land along the seabed to the oil gathering point in the village. Romanovo, from where oil and gas are already transported through an underground pipeline to the oil terminal in the village Izhevsk.

Figure 1.15 OIRSP D – 6

Conclusions on the first chapter

1. Basically, for the development of offshore fields in the Arctic and freezing seas, gravity, ice-resistant platforms with a caisson-type base are used.

2. According to their design, these platforms are divided into caisson-type gravity platforms in the form of artificial islands in steel-concrete design and gravity-type platforms in the form of reinforced concrete structures, having a base in the form of a caisson and a support block in the form of shell columns. The artificial islands are the Orlan platform, the Chaivo field in the Sea of Okhotsk, the Piltun-Astokhskaya-A (PA-A) (Molikpak) platform, the Piltun-Astokhskoye field in the Sea of Okhotsk, the Prirazlomnaya OIRFP, and the Prirazlomnoye field in the Pechersk Sea. The rest are reinforced concrete gravity platforms.

3. There is also the use of gravity platforms in the form of metal spatial structures fixed on the bottom with the help of piles and divided into two mining and residential

blocks, such as IRP - 1 and IRP - 2 in the Caspian Sea and MSLP D-6 in the Baltic Sea.

4. A separate group includes two gravity, reinforced concrete platforms, namely "Hybernia" and "Hebron" installed in the Atlantic Ocean not far from the coast of Canada. These platforms have a special reinforced structure capable of absorbing the loads that occur when colliding with icebergs.

5. So it can be distinguished that basically many platforms are used at shallow depths up to 30 m on average, some of the platforms at medium depths and some at large ones.

6. Due to the distance of many fields and platforms from the shore and communications, as well as due to the difficult navigation in the Arctic seas, the platforms are quite autonomous and have a large supply of both resources and energy. Most platforms have reservoirs for the accumulation of mined minerals, and some platforms are connected to the mainland by pipelines.

7. To reduce the impact of ice on the structure, some platforms use a narrowing of the hull near the waterline or tilting the walls of the block towards the top or bottom of the structure.

2. CONCEPTUAL OPTIONS FOR DEVELOPMENT OF HYDROCARBON DEPOSITS IN THE KARA SEA

2.1. Geological characteristics of the deposits of the Kara Sea

2.1.1. General information

On the shelf of the Kara Sea, tectonic structures of the Barents-Kara (Northern Kara shelf) and West Siberian (South Kara shelf) plates are located, separated by the sublatitudinal North Siberian Threshold, which is contrastingly expressed in the cover and in the basement topography, an uplift complicated by ruptures.

On the shelf continuation of the West Siberian plate, there is the South Kara syneclise, which includes the South Kara basin, and the structures framing it: the Vaigach-Novaya Zemlya monocline, the West Kara and East Kara terraces (Figure 5.1). The syneclise has a three-tiered structure: a foundation, an intermediate structural stage, and a sedimentary cover. The basement is composed of deeply metamorphosed Precambrian and Paleozoic rocks and is submerged in troughs to depths of up to 14 km.

In the central part of the syneclise there are raised basement blocks (Rogozinsky, Rusanovsky) with a cover reduced to 5–7 km. The blocks are separated by rift troughs, the strike of which is consistent with the generalized strike of the West Siberian and Yenisei-Khatanga rifts.

The intermediate (syn-rift) Paleozoic-Triassic stage is represented by a volcanic-sedimentary sequence with a thickness of 3–4 km on uplifts to 6–7 km in troughs. The sedimentary cover of the syneclise is represented, as on the adjacent land, mainly by Mesozoic-Cenozoic terrigenous formations up to 11 km thick.

The South Kara syneclise is bounded by folded formations of the Paikhoi-Novaya Zemlya zone in the west and northwest and of Taimyr in the east. Both folded systems articulate in the zone of block ledges of the North Siberian Sill with a sedimentary cover thickness of 1–2 km.

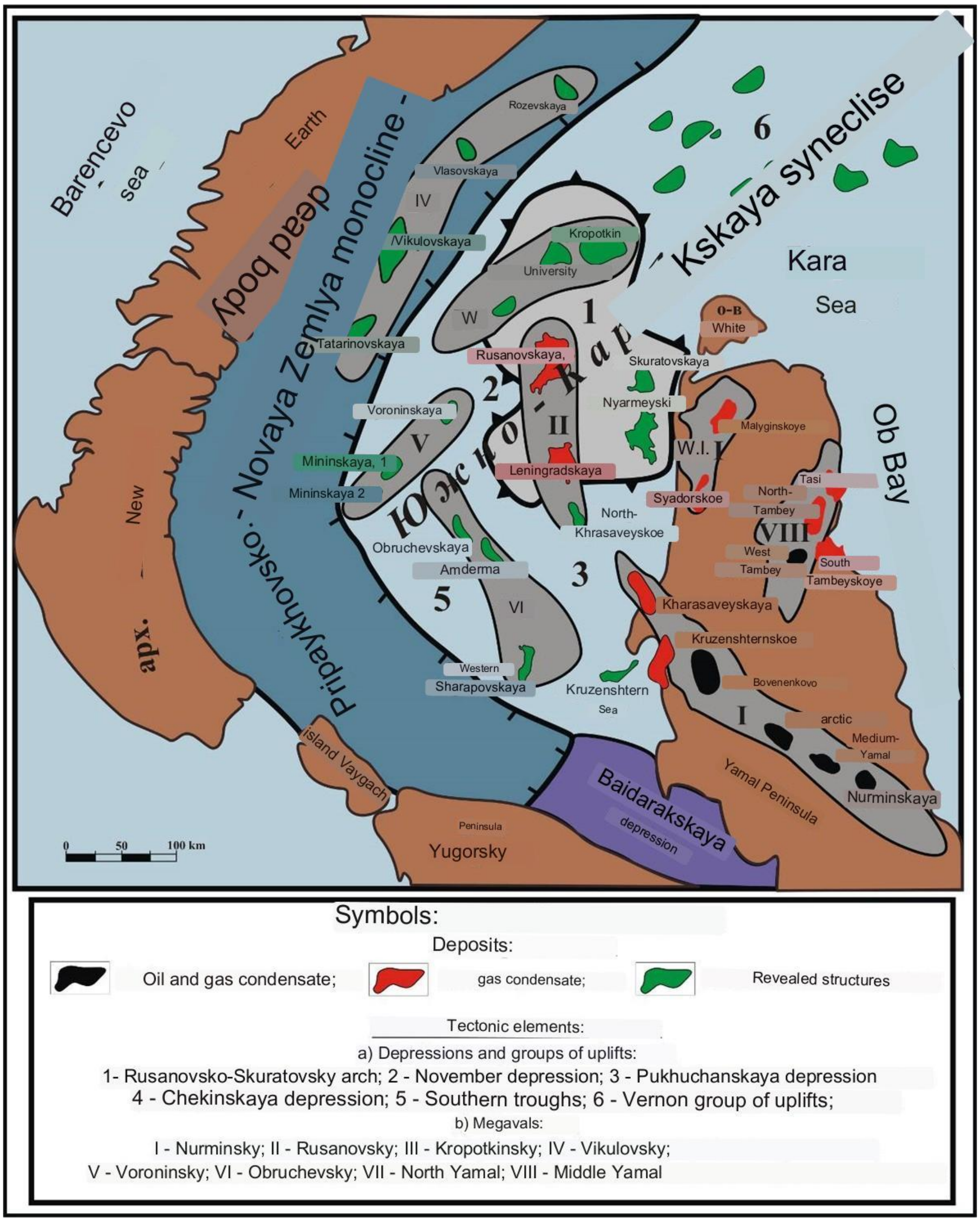


Figure 2.1 Tectonic scheme of the South Kara basin

In the western part of the water area (Vaigach-Novozemelskaya monocline, West Kara terrace) there is an area of swell-like uplifts subordinated to the strike of the Paikhoi-Novaya Zemlya zone, in the center is an area of isometric uplifts (Rogozinskoye, Rusanovskoye), where the influence of both framing systems is found. In the east (East Kara step) there are swell-like uplifts of sublatitudinal strike, subordinated to the strike of Taimyr structures. Structures of the second order in the cover of the megadepression of isometric (arches, troughs) and elongated (swells, troughs) forms inherit riftogenic horst- and graben-like basement blocks. They are separated in the south from the land tectonic structures by a transverse trough, where the northern periclinal ends of the swell-like land uplifts and the southern periclinals of the anticlines of the Rogozinsky and Rusanovsky uplifts die out. In riftogenic troughs normally oriented with respect to it, the thickness of the cover is 9–11 km.

Exploratory seismic exploration was not carried out at the Vaigach-Novaya Zemlya monocline.

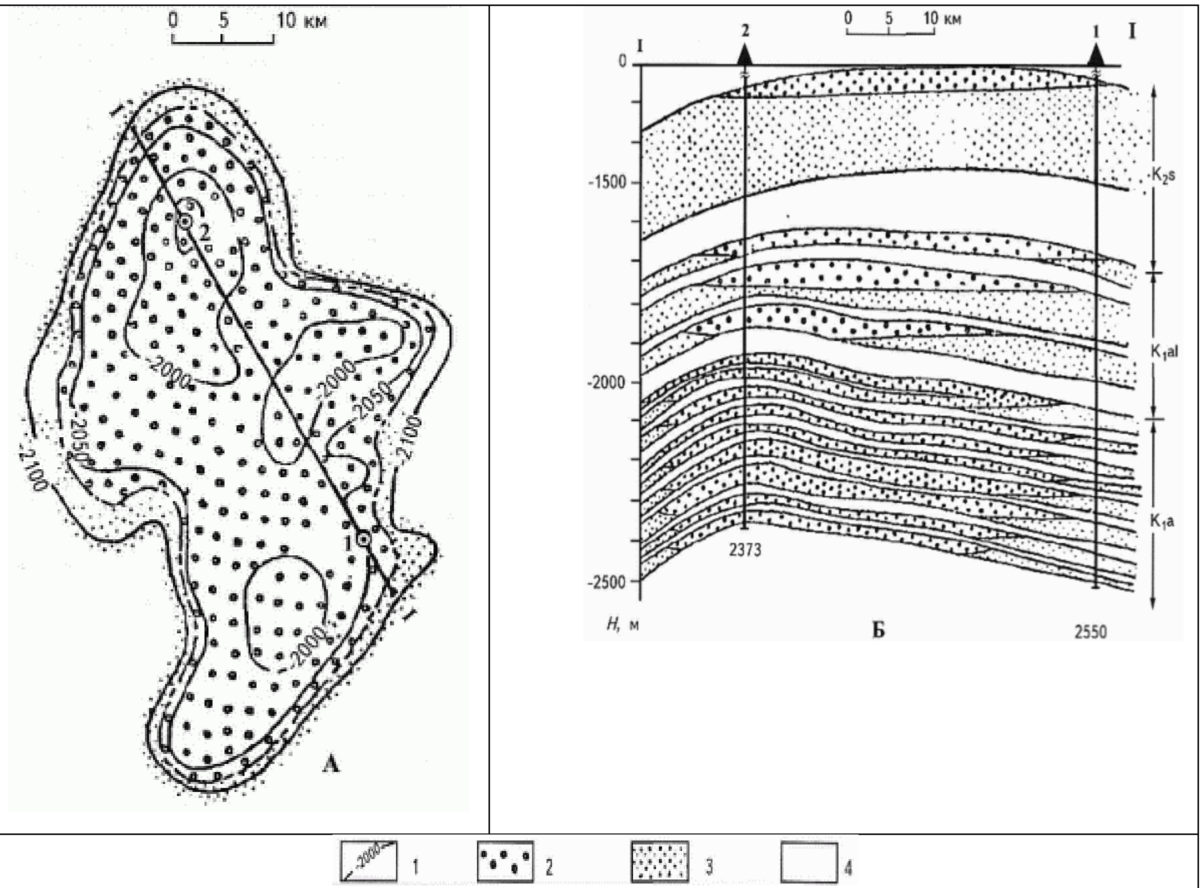
On the West Kara Terrace, 10 local structures were identified, zoning framing the central part of the syneclise.

On isometric uplifts and on the sides of the South Kara depression, 48 anticlines were identified, of which two (Zapadno-Sharapovskaya and Kharasaveyskaya) are in the fund of prepared ones, gas condensate fields were discovered on the Leningradskaya and Rusanovskaya anticlines introduced into drilling.

On the North Kara shelf there are depressions of St. Anna, Severo-Kara and the Central Kara Threshold separating them (Figure 5.1). The surface of the predominantly pre-Riphean basement here has a complex dissected relief, plunging from the periphery of the water area to the center (from 2–4 to 12–17 km). There are a number of deep riftogenic troughs filled with Riphean-Cenozoic deposits, incl. expressed at the bottom of the sea in the form of a neotectonic trough of the St. Anna trough. The upper part of the sedimentary section is represented by Triassic-Cenozoic terrigenous formations 2–3 km thick, the lower part is represented by the Late Paleozoic sequence 7–9 km thick. The latter is composed of carbonates, evaporites and terrigenous complexes with the participation of magmatogenic formations. These deposits are associated with the main prospects for the search for oil accumulations. Exploratory seismic exploration was not carried out.

As for the tectonic features of the Rusanovskoye and Leningradskoye gas condensate fields, the morphology of these anticlines is typical for platform folds of the passive shelf - these are brachianticlines with a length-to-width ratio of no more than 3:1, with gentle slope angles of the wings not exceeding a few degrees. Although uplifts are expressed throughout section of the sedimentary cover, however, from the bottom to the top, they are flattening. The uplifts under consideration are related to protrusions of the Proterozoic basement.

Rusanovskaya structure is a two-dome fold with a gentle arch (less than 1°) (Figure 5.2). The structure is located at a distance of 120 km from the coast, with sea depths of 100-120 m. In terms of development and internal structure, the Rusanovskoe uplift is a consedimentary structure of the cladding. Despite the general coincidence of structural plans for different horizons, in the structure of the Rusanovskaya structure, there are some differences in different horizons associated with structural rearrangements at the boundaries of the Triassic and Jurassic (seismic reflecting horizon T4), Jurassic and Cretaceous (seismic OG B), Neocomian and Aptian (OG M). These facts must be taken into account in development projects when justifying production well placement systems.



1 - isohypses of the top of the deposits of the Aptian stage, m; 2 - gas; 3 - sandstones; 4 - clay

Figure 2.2 Rusanovskoye gas condensate field in plan (A) and in section (B)

It also requires additional study of disjunctive dislocations at the level of the Albian - Paleogene. In addition, apparently, there are disturbances penetrating into the sedimentary cover from the pre-Jurassic basement, where intense riftogenic and disjunctive fragmentation of the basement of the earth's crust has been established. To the south of the Rusanovskoye field in the waters of the Kara Sea, the Leningradskoye field was discovered. The distance from the shore is 90 km, the sea depth is about 100 m. The productivity of the Lower Cretaceous complex on the Leningradskaya structure was confirmed by well No. 1, where seven gas-bearing objects were identified in the interval of the section with a thickness of about 500 m according to gas logging and well logging data. When testing a sandstone layer in the top of the Tanopchinskaya suite (interval 1895 - 1903 m), a free flow of gas with condensate was obtained with a flow rate of 402 thousand m3 / day. In deeper deposits, the formations are gas-water-saturated, low-rate or "dry".

At the Leningradskoye gas condensate field, in contrast to the Rusanovskoye field, the main deposits of gas and condensate were identified during testing of sandstone layers in the lower part of the Marresalinsky suite (Albian-Cenomanian). From four objects in the interval 1602 - 1780 m, dry gas inflows were obtained with a flow rate of 300 to 400 thousand m3 / day. In the top of the Cenomanian (upper part of the Marresalinsky formation) from two objects in the interval of 1097 - 1168 m, dry gas inflows were obtained with a flow rate of 235 to 253 thousand m3 / day. Gas deposits are predominantly structural massive type. The thickness of the complex reaches 500 m (Figure 5.3). In general, the structures under consideration, located within the South Kara syneclise, are confined to the Rusanovsko-Skuratov arch, which is a passive margin of the Permian-Triassic rift. The roof of the Jurassic deposits lies here at depths of 3.2–4.2 km with an amplitude of tectonic disturbances of about 350 m. . Another important point of tectonics is the assumption that the Rusanovskoe and Leningradskoe uplifts are actually part of a single arched multi-dome uplift with a single GWC (approximately at a depth of 2350 m) according to the Cenomanian-Aptian deposits. The basis for this is the detailed correlation of productive deposits, carried out along with a thorough analysis of the sampling data of the structures under consideration.

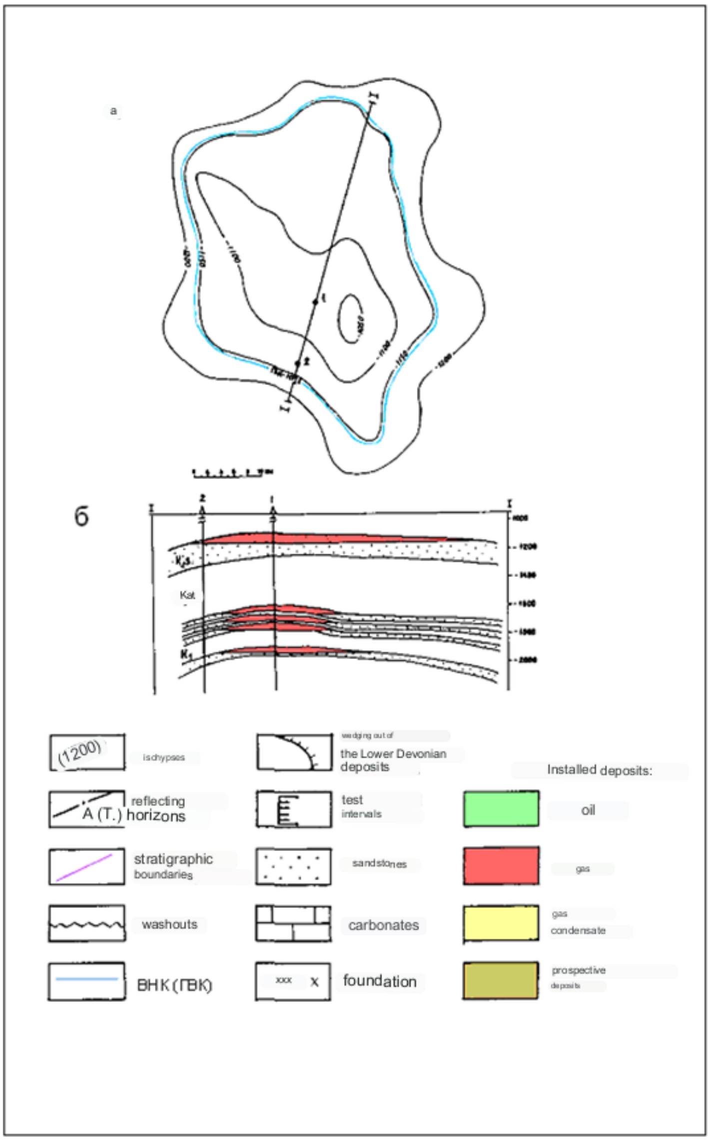


Figure 3.3 Leningradskoye field (a) structural map along the top of formation C (Cenomanian) b) section along line I – I)

In the water area of the Kara Sea, 58 promising structures have been identified; two of them were put into drilling and two unique gas condensate fields (Rusanovskoye and Leningradskoye) were discovered there. Two structures are a direct continuation of the land deposits (Kruzenshternskoye and Kharasaveyskoye). The fund prepared for exploration drilling includes one structure (Zapadno-Sharapovskaya).

Two exploratory wells each (four in total) with a total volume of 9.9 thousand meters were drilled at the Rusanovskoye and Leningradskoye offshore fields. In addition, a parametric well was drilled on the Bely and Sverdrup Islands (5.8 thousand meters). Drilling density is very low.

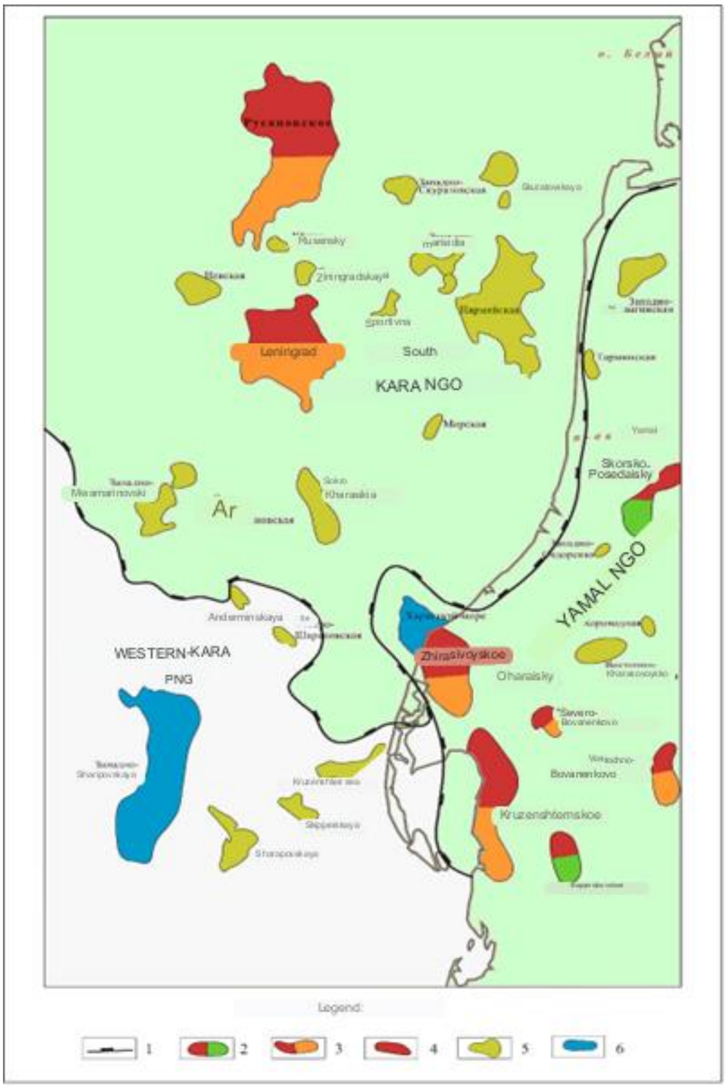
Among the identified structures, according to various estimates, up to 20 deposits with reserves of up to 100 million tons of oil equivalent are predicted. tons. The discovery of mixed oil and gas fields is also expected.

To date, out of the entire territory of the Kara Sea shelf, the oil and gas potential of the subsoil has been confirmed by drilling only on the structures of the West Yamal shelf.

According to the oil and gas geological zoning, the West Yamal shelf is mostly located in the southern part of the South Kara Oil and Gas Region and partially (in its southwestern section) within the West Kara Oil and Gas Region, identified in the water area of the West Siberian oil and gas province (Figure 5.4).

Similarly to the land part of the West Siberian province, in the water area of the Kara Sea in the Mesozoic section of the sedimentary cover, four regional oil and gas complexes are distinguished: Lower-Middle Jurassic, Neocomian, Barremian-Aptian, Albian-Cenomanian.

The Lower-Middle Jurassic oil and gas complex in the offshore part has not been studied by drilling. The industrial gas content of this complex has been established onshore in the South Yamal OGO at the Malyginskoye, Kharasaveyskoye, Novoportovskoye, and Bovanenkovskoye fields. Moreover, at the Bovanenkovskoye and Novoportovskoye fields, productivity is associated with the Lower-Middle Jurassic continental deposits of the Tyumen Formation, and at the Kharasaveyskoye and Malyginskoye fields, with coastal-marine and offshore formations of the Bolshekhetskaya series. It is assumed that the development of facies of the Bolshekhetskaya series also takes place within the West Yamal shelf.



Kara Sea. (1 - boundaries of oil and gas fields; 2 - oil and gas fields; 3 - gas condensate fields; 4 - gas fields; 5 - identified structures; 6 - structures prepared for drilling)

Figure 2.4 - Scheme of oil and gas geological zoning of the West Yamal shelf

At the Kharasaveyskoye field, in the sandy-silty deposits of the Lower-Middle Jurassic, two small gas condensate deposits were identified in the Yu2 and Yu3 formations (Malyshevskaya suite). Revealed reservoir type deposits with lithological limitation. Effective thicknesses are 2 - 4 m, open porosity of reservoirs is 13% - 18%, gas saturation is 70%. The content of condensate in the gas is 70 g/m3. Reservoir pressure exceeds hydrostatic pressure by 1.9 - 2.0 times.

At the Malyginskoye field, in the Lower-Middle Jurassic deposits in sandy-siltstone formations, two large gas condensate deposits were identified - in the Yu2-3 formation (Malyshevskaya suite) and in the Yu6-7 formation (Vymskaya suite). Revealed reservoir type deposits with lithological limitation.

Effective thicknesses are 20 - 25 m, reservoir open porosity values are 14% - 15%, gas saturation is 56% - 58%. The content of condensate in the gas is 120 - 282 g/m3. Reservoir pressure exceeds hydrostatic pressure by 1.9 - 2.0 times.

It should be noted that in the offshore part of the South Kara OGO, an increase in the degree of claying of the Lower-Middle Jurassic deposits and a deterioration in the reservoir properties of productive horizons relative to the adjacent land part are expected, which reduces the prospects for their oil and gas potential here.

The Lower-Middle Jurassic oil and gas complex is overlain by the clay strata of the Valanginian-Upper Jurassic deposits, which are considered on the adjacent land as a regional seal.

However, at the Kharasaveyskoye field, when testing the deposits of the Upper Jurassic Bazhenov formation in well No. 42 (from the Yu0 reservoir, composed of fine-grained sandy-silty varieties with interlayers of hard dark gray siltstones), an influx of gas condensate was obtained with a flow rate of 80 thousand m3/day.

The Neokomsky-Aptian oil and gas complex was discovered and studied in detail on the adjacent land at the deposits of the South Yamal oil and gas condensate area - Malyginskoye, Kruzenshternskoye, Kharasaveyskoye, Bovanenkovskoye, Novoportovskoye, etc. Rusanovskoe and Leningradskoe. This complex is the main productive complex in the section of most of the known fields of the Yamal Peninsula and on the shelf of the Kara Sea.

The section of the complex is characterized by the alternation of sandstones, siltstones, and clays; Deposits of the Akh Formation (age range Berriasian-Valanginian-Lower Hauterivian) are predominantly clayey in composition, include unevenly distributed beds and interlayers of clayed sandstones. Sandstones are developed mainly in the lower part of the formation (Achimovskaya Member) and in its upper part (Novoportovskaya Member). On the Yamal Peninsula, the deposits of the Achimov Member are poorly studied. No hydrocarbon deposits were found in them. Insignificant oil inflows were obtained in the Tambeyskaya and Neytinskaya areas. In the sediments of the Novoportovskoye unit, gas condensate deposits have been identified at the Kharasaveyskoye and Kruzenshternskoye fields. In the south of the

Yamal Peninsula, at the Novoportovskoye field, gas condensate and oil and gas condensate deposits have been established in these deposits.

Moreover, if at the Novoportovskoye field this unit is the main reservoir of hydrocarbons - 11 productive layers have been identified, then in the northern and northwestern directions the sandy layers are partially clayed. As a result, at the Kharasaveyskoye field, the number of productive layers in the deposits of the Akh suite is reduced to 6 (layers of the BYa group, confined to the upper part of the suite), and at the Kruzenshternskoye field, productivity is associated with only one horizon in the top part of the Akh suite (BYa2 layer).

At the Malyginskoye field, in the deposits of the Akh suite, three gas condensate deposits were identified in its roofing part (in the layers BYa2/0, BYa2, BYa3). At the same time, sandstone layers in the north-west of the area (toward the water area) are clayed.

At the Kharasaveyskoye field, when testing these productive strata in the deposits of the Akh suite, the flow rates were: gas - 150 - 300 thousand m3 / day, condensate - 160 - 216 m3 / day.

Reservoir pressures exceed the hydrostatic pressure by 1.75 - 1.86 times. Revealed reservoir type deposits. The values of effective thicknesses are up to 6 - 8 m, the values of open porosity of reservoirs are 14% - 20%, gas saturation is 60% - 70%. Condensate content 160 - 180 g/m3.

At the Malyginskoye field, when testing productive strata in the sediments of the Akh suite, gas flow rates amounted to 100 - 270 thousand m3 / day. Identified reservoir-type deposits with lithological limitation.

The values of effective thicknesses are up to 5 - 12 m, the values of open porosity of reservoirs are 16% - 20%, gas saturation is 55% - 73%. Condensate content 80 - 84 g/m3.

In the adjacent water area of the Kara Sea shelf, claying of the sandy layers of the Akh Formation is assumed.

The deposits of the Tanopchinskaya suite (Upper Hauterivian-Barrem-Aptian age) are characterized by a complex lithofacies structure and are represented by: the

Upper Terivskaya sequence - uneven alternation of interlayers of sandy-siltstone rocks, often lenticular; the Barremian sequence is predominantly mudstone with sporadically developed lenses and thin interlayers of sandy-siltstone rocks; the Aptian is the most sandy and is characterized by a more stable nature of the distribution of sandy and siltstone rocks.

In the deposits of the Tanopchinskaya suite at the Kharasaveyskoye field, 26 sand layers (layers TP1-26) were identified, most of which contained gas condensate deposits. At the Kruzenshternskoye field, the number of productive layers is less - only 9. At the Malyginskoye field, 19 gas condensate deposits have been identified in the section of the Tanopchinskaya suite.

It should be noted that the most significant reserves of hydrocarbons in the deposits of the Tanopchinskaya suite are confined to its roofing part (to the layers TP1-TP5) and are controlled by a regional seal represented by the Albian clayey sequence. Other deposits in the volume of the Tanopchinskaya suite are controlled by zonal and local seals and are mainly characterized by small reserves. According to the type of deposit, reservoir domed or massive reservoir (with a large level of productivity, uniting a group of hydrodynamically connected reservoirs). Gas flow rates in the best reservoir layers (in the upper part of the suite's sediment section) reached up to 1 million m3/day.

Gases are methane, sulfur-free. The content of condensate in deposits ranges from 2.5 - 4 g/m3 in the bedrock of the suite (layers TP 1-5, TP6, TP8) to 23.1 - 50 g/m3 (layers TP10-TP14) and up to 80 - 180 g/ m3 (layers TP21-26 of the Kharasaveyskoye field). For deposits in the lower part of the section of the suite (layers TP21-26), the excess of reservoir pressure over hydrostatic pressure is 1.7 - 1.86 times, higher along the section, the anomaly coefficient decreases to 1.10 - 1.05.

The reservoir properties of the rocks of the Tanopchinskaya suite change with depth and depend on the sand content (clay content) of the reservoir rocks. Thus, at the Kharasaveyskoye field in the deposits of the Aptian stage (layers TP1-TP14), the net-to-gross ratio is 56% - 68%, the average open porosity is 0.22% - 0.26%, the permeability is from 170 to 1150 mD. In the underlying Barreme-Hauterivian deposits

(TP16-TP26 plates), the net-to-gross ratio is 30% - 60%, the effective porosity is 12% - 18%, the permeability is 100 - 150 mD, rarely 300 - 500 mD.

On the shelf of the Kara Sea, the Neocomian-Aptian complex was discovered by drilling at the Rusanovskoye and Leningradskoye deposits. The exposed part of the section is represented by deposits of the Tanopchinskaya suite. The regional seal of the Neocomian-Aptian complex is the clay strata of the Yarong Formation of the Lower Albian.

The Alb-Cenomanian oil and gas complex was discovered and studied in detail on the adjacent land - at the deposits of the South Yamal oil and gas reclamation area - Malyginskoye, Syadorskoye, Kruzenshternskoye, Kharasaveyskoye, Bovanenkovskoye, Novoportovskoye and others. More than 25% of the identified hydrocarbon reserves on the Yamal Peninsula and the bulk of the reserves of the Leningradskoye field on the shelf of the Kara Sea are associated with this complex. The section of the complex includes deposits of the Yarong (Lower Albian) and Marresalin (Upper Albian-Cenomanian) formations. On land, in the sandy deposits of the Marresalinsky suite in the top of the Cenomanian, large deposits of dry methane gas have been identified (the Kruzenshternskoye, Kharasaveyskoye, Bovanenkovskoye, and other deposits). At the Malyginskoye field, a small gas deposit was discovered in this part of the section. At the Syadorskoye field, in the top of the Cenomanian, an average gas deposit was found (the only one in the section of the field).

The deposits are predominantly of a massive type, confined to the top of the complex (in the PK1 formation). The values of effective gas-saturated thicknesses reach 35-55 m (at the Malyginskoye field, the area-weighted average value of the effective gas-saturated thickness is only 3.4 m).

Sandstone formations are characterized by high reservoir properties - open porosity 19% - 35%, permeability 100 - 1000 mD, which ensures high gas flow rates reaching 500 - 1500 thousand m3 / day. (absolutely free).

The deposits are characterized by reservoir pressure close to hydrostatic. At a number of fields (Kruzenshternskoye, Bovanenkovskoye, Malyginskoye), sandstone layers are also productive in the lower part of the Marresalinsky suite (PK9, PK10 layers).

At the Malyginskoye field, in the section of the Yarong suite, three gas deposits were discovered in sandstone layers (in the KhM1, KhM2, KhM3 layers). The main large gas deposit is confined to the KhM3 reservoir. Reservoir type deposits. The area-weighted average value of the effective gas-saturated thickness for productive formations is 4-5 m. Sandstone formations are characterized by high reservoir properties - open porosity 23% - 24%, permeability 50 - 300 mD, which ensures high gas flow rates reaching 300 - 800 thousand m3 / day The deposits are characterized by reservoir pressure close to hydrostatic.

The clay stratum of the Kuznetsovskaya and Nizhneberezovskaya formations of the Upper Cretaceous serves as a regional seal of the complex.

2.1.2. Rusanovskoye field

Deposits of the Neocomian-Aptian oil and gas complex, or rather the upper and middle parts of the Tanopchinskaya suite (Aptian), were uncovered here. In this section, 7 productive sandy-siltstone formations (A1-A7) containing gas condensate deposits have been identified (Table 5.1). The flow rates during testing were: gas - from 192 to 377 thousand m3 / day. at the fitting 9.9 mm, condensate - from 2.8 to 12.3 m3 / day. Condensate content in gas – 20g/m3.

The gas of all productive formations is of the same type in terms of component composition and is classified as methane (methane content exceeds 90 mol.%), low nitrogen, sulfur-free, low carbon dioxide (CO2 content is 0.16% - 0.48%), low helium content, there is an increased content of ethane in the gas (3.38% - 3.51% mol.), which is higher than the standard (0.3%). Wellhead gas samples are characterized by slight variations in the component composition.

Thus, the content of methane varies from 92.45% to 94.27%, ethane from 3.38% to 3.51%, propane from 0.91% to 1.00%, butanes from 0.61% to 1 .83%, pentanes and higher homologues of methane from 0.61% to 1.83%, helium from 0.006% to 0.01%, carbon dioxide from 0.18% to 0.70%, nitrogen from 0.075% to 0.38%. The data are presented in table 5.2. A slight weighting of the gas is noted along the section from top to bottom (the relative density increases from 0.604 to 0.627).

Table 2.1 Characteristics of the productivity of the Rusanovskoye field

NGK / suite	Test interval m	gas flow rate, thousand m^3/day (nipple, mm)	Well logging productivity interval, m	Collector	Casing	Note
Well № 2						
Alb-Cenomanian (Marresalin Formation)			1273 - 1277	sandstone	Clay deposits of the Kuznetsovskaya suite (K2t)	
------//------			1277-1285	------//------		
------//------			1637-1652	------//------		
------//------			1708-1714	------//------		
------//------			1778-1783	------//------	Clay deposits of the Yarong Formation (K1at)	
Barrem-atskiy (tanopchinskaya suite)	1928-1950	197,8 (12,7)		siltstone		
------//------	1962-1999	239,3 (13,89)		------//------		
------//------	2011-2052	379,5 (13,9)		sandstone		
------//------	2037-2052	232,3 (11,9)		siltstone		
------//------	2065-2086	506,3 (15,1)		------//------		
------//------	2102-2125	364 (13,89)		sandstone		

Table continuation 2.1

------//-----	2147-2180	534 (15,08)		------//------		
------//------	2202-2232	520 (13,89)		------//------		
------//------	2235-2254	54 (5,95)		------//-----		
------//-----	2278-2310	216 (10,75)		------//------		

------//------	2329-2350	224,5 (11,9)		------//-----		
Well № 1						
Santon Cognac (Berezovskaya suite)	1000-1027	Qв=0,193		sandstone		
Barrem Aptian (tanopchinskaya suite)	2237-2253	Qг=1000 Qв=12,6		------//------		Produced water inflow with gas

Table 2.2 Composition of gases of the Rusanovskoye field

Perforation interval, m	Age of deposits	Gas composition,%						
		CH4	C2H6	C3H8	C4H10	C5+	CO2	N2
1928-1950	K1Sm	89,25	4,28	1,850	0,660	2,39	0,35	0,5
1962-1999	K1Sm	94,27	3,39	0,910	0,190	0,61	0,32	0,1
2011-2037	K1Sm	93,46	3,38	0,930	0,220	0,74	0,70	0,3
2147-2180	K1Sm	93,81	3,44	0,990	0,230	0,62	0,22	0,5
2235-2254	K1Sm	93,36	3,42	0,960	0,230	1,47	0,18	0,2
2320-2350	K1Sm	93,82	3,41	0,960	0,230	0,74	0,23	0,4

The content of methane in the composition of the gas is reduced (from 94.27% in the interval 1962 - 1999 m to 93.36% in the interval 2235 - 2254 m), and at the same time the content of heavy methane homologues (C5 +) increases from 0.61% to 1.47 %.

Revealed deposits are bedded arched. The effective gas-saturated thicknesses range from 5.4 m (formation A1) to 59.4 m (formation A5). The average values of open porosity of reservoirs are 20% - 21%, gas saturation from 48% - 54% (in the upper layers A1 and A2) to 61% - 72%. Reservoir pressure exceeds hydrostatic pressure by 1.06 - 1.10 times in the upper deposits and 1.18 - 1.19 times in the lower deposits. The proven by drilling stratigraphic range of gas content in the Aptian was 462 m. Alb-Cenomanian oil and gas deposits were not sampled at the Rusanovskoye field. According to well logging data from wells No. 1 and No. 2, gas saturation of sandstone layers in the Cenomanian deposits (1 layer) and in the Albian deposits (3 layers) is assumed here. According to the seismic data in the section of the Albian deposits, up to 5 intervals are distinguished with an anomalous record of the wave field of the "bright spot" type, associated with gas-saturated sandstones.

2.1.3. Leningradskoye field

Here, in the exposed upper part of the section of the Tanopchinskaya suite, one gas condensate deposit was identified (in the top of the Aptian deposits) (Table 5.3). When testing well No. 1, gas inflows were obtained - 402 thousand m3 / day. and condensate - 2.4 m3/day. on a 15.9 mm fitting.

The condensate content in the gas is 18.6 g/m3. Revealed reservoir type. Reservoir pressure exceeds hydrostatic pressure by 1.08 times. The average values of the reservoir parameters are - effective gas-saturated thickness - 8.3 m, porosity - 26% - 27%, gas saturation - 64%.

Table 2.3 - Characteristics of the productivity of the Leningradskoye field (well No. 1)

Test interval, m	OGC	Lithological characteristics of oil and gas	Gas flow rate, thousand m3/day (choke diameter, mm)	Gas composition	The nature of the manifestation of the inflow
2399-2333	Barrem-Aptsky (Tanopchinskaya)	Alternation of thin (1 - 3 m) sandy-silty layers (Кп=13 %-24 %, Кв=45 % - 67 %)	Qг=86,4 (8)	methane	Weak inflow of gas and produced water
2318-2280	------//------	Alternation of sandstones and siltstones (Kp=14%-17%, Kv=40%-59%)	Qг=14,9 (5,95)	-----//-----	Fountain inflow of gas

Table continuation 2.3

2198-2147	------//------	Medium cemented sandstone (Kp=16.5%, Kv=47%)	Qг=7,5 (3,96)	-----//-----	-----//------
2047-2112	------//-----	Sandstones strongly cemented with siltstone interbeds. and clays (Kp=17%-	Qг=62,5 (7,94)	-----//-----	------//-----

		19%, Kv=38%-55%)			
2047-2068	------//------	------//------	Qг=8 (5,95)	-----//-----	Fountain flow of gas with water
1932-1953	------//------	Fine-grained sandstone with siltstone	Qг=16,9 (3,96)	-----//-----	------//------
1895-1903	-----//------	Medium-grained quartz sandstone, loose Kp=14.5% - 23.5%	Qг=402,1 (15,8)	The gas is methane.Gas condensate is low-sulfur, low-paraffin.	Fountain inflow of gas with condensate
1761-1780	Alb-Cenomanian (Marresalian)	Sandstone quartz-feldspar, fine-grainedKп=23 %-27 %, Кв=13 %-38 %	Qг=377,9 (19,06)	methane	Dry gas fountain inflow
1725-1730, 1745-1755	------//------	Sandstones and siltstones Kp \u003d 17% - 26%, Kv \u003d 7% -54%	Qг=401,1 (19,05)	------//------	------//------
1673-1718	Alb-Cenomanian (Marresalian)	Sandstones and siltstones Kp \u003d 17% - 26%, Kv \u003d 7% -54%	Qг=358,6 (19,0)	methane	Dry gas fountain inflow
1602-1624, 1635-1644	------//------	Fine-grained sandstones from loose to moderately cemented Kp=19%-27%, Kv=21%-68%	Qг=323 (19,05)	------//------	------//----

Table continuation 2.3

1154-1168	------//------	Medium cemented sandstone	Qг=235,5 (19,05)	------//------	------//------
1097-1147	------//------	Medium cemented sandstone	Qг=252,9 (19,05)	------ //------	------//- -----

When testing the underlying sandstone formations in well No. 1, either small gas inflows (flow rate 14.9 thousand m3/day) or gas inflows (flow rate 16.9 - 62.5 thousand m3/day) with formation water were obtained.

Four deposits of gas were discovered in the deposits of the Cenomanian-Albian oil and gas complex at the Leningradskoye field - in the AC1, AC2, AC3 (Albian) and in the C (Cenomanian) reservoirs. The deposit in layer C is a massive waterfowl, the rest are reservoir arched. Effective gas-saturated thickness ranges from 17 m (AC1 formation) to 26-36 m. Productive formations are characterized by high reservoir properties - average values of open porosity are 26% - 27%. Gas flow rates ranged from 235 to 400 thousand m3/day. on the fitting 19 mm (absolutely free - from 461 to 3925 thousand m3 / day). Reservoir pressures in the Cenomanian and Albian deposits are close to hydrostatic, in the Aptian deposits they exceed hydrostatic pressure - from 1.08 in the top of the Aptian deposits to 1.23 in the bottom.

Thus, the identified stratigraphic level of gas content in the Aptian-Cenomanian was 939 m.

The gas obtained during testing of the Lower Cretaceous deposits is methane (methane content varies from 91.05% to 94.25%), low nitrogen (0.28% - 1.16%), sulfur-free, low carbon dioxide (0.12% - 0.94%), low helium content (0.003% - 0.0110%). The content of methane homologues (C2 + c) varies from 5.065% to 7.984%, and an increased content of ethane is noted (3.35% - 4.09%), the content of heavy methane homologues C5 + c is 0.44% - 1.507%. There is some lightening of the gas up the section (relative density varies from 0.638 to 0.600).

When testing the Upper Cretaceous deposits, a gas was obtained that is somewhat different from the gas sampled during the sampling of the Lower Cretaceous deposits. In the component composition of the gas, the content of methane varies from 94.82% to 99.26%, ethane - from 0.049% to 1.94%, pentanes and higher homologues - from traces to 0.304%, nitrogen - from 0.25% to 0, 80%, helium from 0.005% to 0.01%. According to the coefficient of fat content C2 + w / C1 * 100, the value varies - from 0.05 to 2.99 the gas is drier compared to the gas of the Lower Cretaceous, where this coefficient is 5.4 - 8.77. The gas sampled during sampling of the Upper Cretaceous deposits is characteristic of pure gas deposits. Characteristics of free gas sampled from various objects in well No. 1

Leningradskaya is shown in Table 2.4

Table 2.4 Characteristics of the free gas of the Leningrad field (well No. 1)

Sampling interval, m. (Object No.)	Sampling conditions	Density absolute, kg/m3 (relative)	Content, % mol.								ΣC_2+	C_2/C_3	Standardization coefficient	Fat coefficient
			methane	ethane	Propane	Butane	Methane + higher	helium	Carbon dioxide	nitrogen				
2333-2399 (K0) I object	on wellhead	0,79 (0,638)	91,63	3,35	1,46	0,83	1,255	0,011	0,94	0,52	6,895	2,29	146,3	7,52
2380-2318 (K0)(II object	on wellhead	0,762 (0,632)	91,05	4,04	2,03	1,17	0,744	0,006	0,45	0,51	7,984	1,99	126,25	8,77
2147-2198 (K0) IV object	on wellhead	0,739 (0,614)	92,18	4,09	1,01	0,56	0,623	0,007	0,37	1,16	6,283	4,05	260,51	6,82

Table continuation 2.4

2047-2112 (K0) V object	on wellhead	0,726 (0,602)	93,71	3,84	0,71	0,35	0,504	0,06	0,43	0,45	5,404	5,41	362,3	5,77
2047-2068 (K0) VI object	on wellhead	0,724 (0,601)	93,81	3,67	0,62	0,33	0,445	0,005	0,71	0,41	5,065	5,92	386,3	5,40

1932-1953 (K0) VII object	on wellhead	0,723 (0,600)	94,25	3,78	0,63	0,30	0,594	0,006	0,12	0,32	5,304	6,9	406,5	5,63
1895-1903 (K0) VIII object	on wellhead	0,753 (0,625)	93,41	3,63	0,64	0,32	1,507	0,003	0,21	0,28	6,097	5,67	378,1	6,53
1761-1780 (K0)(IX object	on wellhead	0,677 (0,562)	98,92	0,26	0,012	0,0118	0,0712	0,005	0,26	0,46	0,355	21,67	1092,4	0,36
1725-1730 1745-1755 (K1) X object	n wellhead	0,676 (0,561)	99,09	0,26	0,016	0,008	0,051	0,005	0,32	0,25	0,305	16,25	1083,3	0,31
1673-1718 (K1) XI object	n wellhead	0,677 (0,562)	98,81	0,136	0,0063	0,0015	0,0112	0,005	0,58	0,45	0,155	21,59	1743,6	0,16
1602-1644 (K1) XII object	n wellhead	0,719 (0,593)	94,89	1,94	0,45	0,14	0,304	0,006	1,84	0,43	2,834	4,31	328,8	2,99
1154-1168 (K1) XII object	n wellhead	0,674 (0,559)	98,89	0,049	0,008	0,0012	0,00008	0,01	0,25	0,80	0,05	61,25	5326,1	0,05
1097-1149 (K2) (XIV object	n wellhead	0,671 (0,557)	99,26	0,05	0,0009	0,0001	н/об	0,009	0,06	0,62	0,051	55,56	5000,0	0,051

2.2. Reserves and resources of hydrocarbons of the Rusanovskoye and Leningradskoye fields

2.2.1. Rusanovskoye field

The status of hydrocarbon reserves and resources on the shelf of the Kara Sea for the Rusanovskoye field is given in the following tables 2.5 and 2.6. Estimated parameters and results of estimation of hydrocarbon reserves of the Rusanovskoye field for reservoirs with established and estimated productivity according to well logging are given in Table 5.5. Estimated parameters and results of estimation of hydrocarbon resources of the Rusanovskoye field for formations not penetrated by drilling are given in Table 2.6.

Based on the results of exploratory drilling, the productivity of the Aptian subcomplex of the Neocom-Aptian oil and gas complex was established at the Rusanovskoye field. According to the results of testing well No. 2 in the Aptian section, corresponding to the upper and middle parts of the Tanopchinskaya suite, 7 gas and gas condensate deposits were identified (in the layers A1, A2, A3, A4, A5, A6, A7).

The results of testing well No. 1 (drilled on the eastern wing of the structural trap) turned out to be ambiguous and additional study of this part of the section is required.

Based on the results of the conducted prospecting work, an operational calculation of gas and condensate reserves of reservoirs A1, A2, A3, A4, A5, A6, A7 was carried out. The reserves were assessed in C1 and C2 categories. Category C1 reserves were identified around well No. 2 within the drainage zone - within an area with a radius of 4 km. For the rest of the field, the reserves were categorized as C2. Gas reserves amounted to 240.4 billion m3 in C1 category and 538.6 billion m3 in C2 category. Condensate reserves were (geological/recoverable): category C1 – 4.8/2.4 million tons, category C2 – 10.8/5 million tons.

In addition to the indicated reservoirs with proven gas content, an assessment of category C2 gas reserves was also performed for Alba-Cenomanian deposits and an assessment of gas and condensate resources of category D1l for conditional reservoir A8 in the bottom part of the Apt not drilled and for two conditional reservoirs (B1 and B2) in deposits barrema. Gas saturation in the Albian and Cenomanian deposits is assumed based on well logging data.

Table 2.5 Summary table of estimated parameters and estimation of free gas and condensate reserves of the Rusanovskoye field

Deposit age (reservoir type)	Reservoir, deposit, area	Stock category	Area of gas-saturated rocks, thousand m2	Weighted average gas-saturated thickness, m	Volume of gas-saturated rocks, thousand m3	Odds		Reservoir pressure		Reservoir pressure conversion factor into physical pressure, atm	Amend
						Open porosity fraction units.	Gas saturation fraction units.	Initial atm	final atm		On the deviati of the proper s of gases
Cenomanian Alb	WITH										
(G)	Sever-1	C2	32000	12,3	361600	0,27	0,54	128	1	0,968	1,20
	Sever-2		72600	12,3	820380	0,27	0,54	128	1	0,968	1,20
	Center + south	C2	666200	12,3	7528060	0,27	0,54	128	1	0,968	1,20
	Total C	C2									
(G)	AU										
	North	C2	292000	7,1	2073200	0,26	0,65	150	1	0,968	1,16
	Center + south	C2	610000	7,1	4331000	0,26	0,65	150	1	0,968	1,16
	Total AS	C2									
	Total										
	Cenomanian Alb	C2									
(GC)	A1	C1 gz	50240	5,4	271296	0,20	0,48	206	1	0,968	1,20
		C2 gz	480844	5,4	2596558	0,20	0,48	206	1	0,968	1,20
		gwz	359013	2,7	969335	0,20	0,48	206	1	0,968	1,20
(GC)	A2	C1 gz	50240	13,4	673216	0,21	0,54	210	1	0,968	1,20
		C2 gz	295692	13,4	39622673	0,21	0,54	210	1	0,968	1,20
		gwz	654772	6,7	4386972	0,21	0,54	210	1	0,968	1,20
(GC)	A3	C1 gz	50240	16,8	844032	0,20	0,65	217,2	1	0,968	1,16
		C2 gz	295692	16,8	4967626	0,20	0,65	217,2	1	0,968	1,16
		gwz	668066	8,4	5611754	0,20	0,65	217,2	1	0,968	1,16
(GC)	A4	C1 gz	50240	36,4	1828736	0,21	0,72	233,5	1	0,968	1,16
		C2 gwz	906515	14,64	13272610	0,21	0,72	233,5	1	0,968	1,16
(GC)	A5	C1 gz	50240	59,4	2984256	0,20	0,63	247,8	1	0,968	1,13
		C2 gwz	825095	14,24	11747852	0,20	0,63	247,8	1	0,968	1,13
(ГК)	A6	C1 gz	50240	13,4	673216	0,20	0,62	270	1	0,968	1,12
		C2 gz	353966	13,4	4743144	0,20	0,62	270	1	0,968	1,12

Table 2.6 Summary table of estimated parameters and estimation of free gas and condensate resources of the Rusanovskoye field for reservoirs not explored by drilling.

Deposit age (reservoir type)	Reservoir, deposit, area	Stock category	Area of gas-saturated rocks, thousand m2	Weighted average gas-saturated thickness, m	Volume of gas-saturated rocks, thousand m3	Odds		Reservoir pressure		Reservoir pressure conversion factor into physical pressure, atm	Amendments		Initial balance gas reserves, billion m3	Potential condensate content in formation gas, g/m3	Condensate recovery factor, units	Geological / recoverable condensate resources, million tons
						Open porosity, share of units.	Gas saturation, shares of units	Initial, atm	Final, atm		On the deviation of the properties of gases	For temperature				
Apt	A8	D1 gz	373978	17,6	6582013	0,18	0,60	295		0,968	1,10	0,825	184,2	20	0,5	3,7/1,8
(GK)		gvz	501356	8,8	4411933	0,18	0,60	295		0,968	1,10	0,825	123,5			2,5/1,2
		Total D1											307,7			6,2/3,0
Barrem	B1	D1	374600	9,5	3558700	0,18	0,60	328,3		0,968	1,14	0,814	113,0	39,5	0,92	4,5/4,1
(GK)	B2	D1	374600	20,4	7641840	0,18	0,60	344		0,968	1,14	0,798	249,2	130,5	0,7	32,5/22,8
	Total barrem	D1											362,2			37,0/26,9
	Total	D1											669,9			43,2/29,9

Three gas-saturated reservoir formations with a total total thickness of 26 m were identified in the deposits of the Marresalinsky suite (Albian) in the section of well No. 2 based on well logging data. .

In the lower part of the section of the Tanopchinskaya suite (Apt-Barrem), which has not been explored by drilling, several more gas condensate deposits are expected to be discovered. Calculation of resources in this part of the section was performed for the conditional layer A8 in the base of the Aptian deposits (analogue of the layers TP13-14 of the Kharasaveyskoye, Malyginskoye fields), for the conditional layer B1 in the Barrem deposits (analogue of the layers TP15-18 of the Kharasaveyskoye, Malyginskoye fields) and for the conditional layer B2 (similar to layers TP21-26 of the Kharasaveyskoye field). The calculated parameters for these fields are taken for the same-age layers of the Kharasaveyskoye and Malyginskoye fields.

Thus, the gas reserves of the Rusanovskoye field are: in category C1 - 240.3 billion m3, in category C2 - 2217.1 billion m3. The main gas reserves are in the Aptian deposits.

Condensate reserves at the Rusanovskoye field are (geological/recoverable): category C1 – 4.8/2.4 million tons, category C2 – 37.0/18.5 million tons. All condensate reserves are in the Aptian deposits.

The gas resources of the Rusanovskoye field in the D1l category are 669.9 bcm.

Condensate resources for the Rusanovskoye field in the D1l category are (geological / recoverable) - 43.2 / 29.9 million tons.

2.2.2. Leningradskoye field

Based on the results of exploratory drilling at the Leningradskoye field, the productivity of the Albian-Cenomanian oil and gas complex and the Aptian subcomplex of the Neocomian-Aptian oil and gas complex was established. Based on the results of testing well No. 1 in the Albian-Cenomanian section, 4 gas deposits were identified - one massive type in reservoir C in the top of the Cenomanian deposits and three reservoir-type deposits in reservoirs AC1, AC2, AC3 in the deposits of the

Marresalinsky suite (Albian) and 1 gas condensate reservoir of the formation type in layer A1 in the top of the Aptian deposits (the top of the Tanopchinskaya suite).

Well No. 2 was not tested. In formations C and A, the well penetrated the gas-water part of deposits with a small amount of gas-saturated thicknesses, and in formations AC1, AC2, AC3, the well penetrated the fully water-saturated part of the section.

Based on the results of the conducted prospecting work, an operational calculation of gas and condensate reserves of reservoirs C, AC1, AC2, AC3, A1 was carried out. The reserves were assessed in C1 and C2 categories. Category C1 reserves were identified around well No. 2 within the drainage zone - within an area with a radius of 2 km. For the rest of the field, the reserves were categorized as C2.

Gas reserves amounted to:

- C1 category - 71.0 billion m3;
- C2 category – 980.6 bcm.

Condensate reserves were (geological/recoverable):

- for category C1 - 0.3/0.2 mln t;
- C2 category - 3.0/2.8 million tons.

The Institute of Geotechnologies, taking into account new structural constructions for basic reflectors, re-evaluated C2 reserves for layers C, AC1, AC2, AC3, A1 and estimated resources for layers not penetrated by drilling.

In the lower part of the section of the Tanopchinskaya suite (Apt-Barrem), which has not been explored by drilling, several more gas condensate deposits are expected to be discovered. Calculation of resources in this part of the section was performed for the conditional layer A8 in the base of the Aptian deposits (analogue of the layers TP13-14 of the Kharasaveyskoye, Malyginskoye fields) and for the conditional layer B1 in the Barremian deposits (analogue of the layers TP15-18 of the Kharasaveyskoye, Malyginskoye deposits). The calculated parameters for these fields are taken for the same-age layers of the Kharasaveyskoye and Malyginskoye fields.

The area of productivity of the predicted deposits is calculated on the basis of the available structural plans, taking into account the assumed fill factor of the trap.

For the A8 reservoir, the structural map of the A7 reservoir was taken as a calculation plan with the filling of the trap = 0.70. For reservoir V1, the structural map of OG “M” (K1 br) was adopted as a calculation plan, trap filling = 0.85.

Reservoir pressures and temperatures are calculated for the middle of the predicted gas deposits. The content of condensate is taken from the Kharasaveyskoye field.

Estimated parameters and results of estimation of hydrocarbon reserves of the Leningradskoye field for reservoirs with established and estimated productivity according to well logging are given in Table 5.7. Estimated parameters and results of estimation of hydrocarbon resources of the Leningradskoye field for strata not penetrated by drilling are given in Table 5.8.

Thus, the gas reserves of the Leningradskoye field are: in category C1 - 71.0 billion m3, in category C2 - 2364.2 billion m3. The main gas reserves are in the Aptian deposits.

Condensate reserves for the Leningradskoye field are (geological/recoverable): in category C1 - 0.3/0.2 million tons, in category C2 - 10.6/9.4 million tons. All condensate reserves are in Aptian deposits.

The gas resources of the Leningradskoye field in category C3 are 16.8 bcm.

The gas resources of the Leningradskoye field in the D1l category are 453.9 bcm.

Condensate resources for the Leningradskoye field in category C3 are (geological / recoverable) - 0.4 / 0.4 million tons.

Condensate resources for the Leningradskoye field in the D1l category are (geological / recoverable) - 8.4 / 7.7 million tons.

Other promising objects on the shelf of the Kara Sea may be a number of structures with large hydrocarbon resources that need to be prepared for putting into exploration drilling or start exploration drilling. These primarily include: Zapadno-Sharapovskaya - on the western Yamal shelf, Skuratovskaya and Nyarmeyskaya - east of the Rusanovskaya - Leningradskaya line.

The West Sharapovskaya structure tectonically belongs to the southern part of the Obruchev megaswell. The distance from the coast is 120 km, and the depth of the seabed within the structure is 75–175 m.

The Zapadno-Sharapovskaya structure was identified in 1974 by regional seismic surveys of the MOV TsL, carried out by KMAGE NPO Sevmorgeo (now OAO MAGE). In 1987 - 1988 the structure was studied by prospecting seismic surveys of the MOV CDP, carried out by the Sevmorneftegeofizika trust (now OAO Sevmorneftegeofizika).

Table 2.7 Summary table of estimated parameters and estimation of free gas and condensate reserves of the Leningradskoye field

Deposit age (reservoir type)	Reservoir, deposit, area	Stock category	Area of gas-saturated rocks, thousand m2	Weighted average gas-saturated thickness, m	Volume of gas-saturated rocks, thousand m3	Odds		Reservoir pressure		Reservoir pressure conversion factor into physical pressure, atm	Amendments		Initial balance gas reserves, bcm	Potential condensate content in formation gas, g/m3	Condensate recovery factor, units	Geological / recoverable condensate resources, mmt
						Open porosity, share of units.	Gas saturation, shares of units	Initial atm.	Final atm.		On the deviation of the properties of gases	For temperature				
Cenomanian	C	C1 gwz	52400	28,3	1482920	0,27	0,54	116,2		0,968	1,20	0,936	27,1	-	-	-
(G)		C2 gwz	1351990	28,3	38259024	0,27	0,54	116,2		0,968	1,20	0,936	698,7	-	-	-
Cenomanian Alb	AC1	C1 gz	12560	16,9	212264	0,27	0,63	165,2		0,968	1,16	0,904	6,3	-	-	-
(G)		C2 gz	280489	16,9	4740264	0,27	0,63	165,2		0,968	1,16	0,904	134,4	-	-	-
		gwz	577395	8,45	4878988	0,27	0,63	165,2		0,968	1,16	0,904	138,3	-	-	-
(G)	AC2	C1 gz + gwz	12560	36,3	455928	0,26	0,69	173,3		0,968	1,16	0,893	14,1	-	-	-
		C2 gz	121025	36,3	4393208	0,26	0,69	173,3		0,968	1,16	0,893	136,2	-	-	-
		gwz	563176	18,15	10221644	0,26	0,69	173,3		0,968	1,16	0,893	316,9	-	-	-

(G)	AC3	C1 gz + gwz	12 560	26,0	326560	0,26	0,65	179,5		0,968	1,16	0,883	10,0	-	-	-
		C2 gz	12 1025	26,0	3146650	0,26	0,65	179,5		0,968	1,16	0,883	94,7	-	-	-
		gwz	70 2676	13,0	9134788	0,26	0,65	179,5		0,968	1,16	0,883	247,8	-	-	-
	Total	C1											30,4			
	AC	C2											1109,4			
	Total	C1											57,5			
	Cenomanian Alb												1808,1			
Апт	A1	C1 gz + gwz	52000	8,3	431600	0,25	0,64	203,9		0,968	1,14	0,875	13,5	18,6	0,917	0,3/0,2
(GC)		C2 gz	888800	8,3	7377040	0,25	0,64	203,9		0,968	1,14	0,875	231,3			4,3/3,9
		gwz	224937	4,15	933489	0,25	0,64	203,9		0,968	1,14	0,875	29,3			0,6/0,5
(GC)	A4	C2 gwz	262326	9,4	2465864	0,18	0,60	232,6		0,968	1,14	0,857	58,3	18,6	0,917	1,1/1,0
(GC)	A5	C2 gz	74166	11,2	830659	0,17	0,60	247		0,968	1,14	0,837	19,3	18,6	0,917	0,4/0,3
		C2 gwz	604826	5,6	3387026	0,17	0,60	247		0,968	1,14	0,837	78,5			1,5/1,3
(GC)	A6	C2 gz	74166	17,0	1260822	0,18	0,60	280,2		0,968	1,14	0,825	34,6	18,6	0,917	0,7/0,6
		C2 gwz	439038	8,5	3731823	0,18	0,60	280,2		0,968	1,14	0,825	102,4			1,9/1,7
(GC)	A7	C2 gwz	66800	1,3	86840	0,18	0,60	284,5		0,968	1,14	0,821	2,4	18,6	0,914	0,1/0,1
	Total apt	C1 C2											13,5 556,1			0,3/0,2 10,6/9,4
	Total	C1											71,0			0,3/0,2
		C2											2364,2			10,6/9,4

Table 2.8 - Summary table of estimated parameters and estimation of free gas and condensate resources of the Leningradskoye field for domes and formations not explored by drilling

Deposit age (reservoir type)	Reservoir,deposit, area	Stock category	Area of gas-saturated rocks, thousand m2	Weighted average gas-saturated thickness, m	Volume of gas-saturated rocks, thousand m3	Odds		Reservoir pressure		Reservoir pressure conversion factor into physical pressure, atm.	Amendments		Initial balance gas reserves, bcm	Potential content of condensate in formation gas, g/m3	Condensate recovery factor, units	Geological / recoverable condensate resources, mmt
						Open porosity fraction units.	Gas saturation fraction units	Initial atm.	Final atm.		On the deviation of the properties of gases	For temperature				
Apt	A4	C3 east	54800	4,2	115080	0,18	0,60	239		0,968	1,14	0,849	2,8	18,6	0,917	
(GK)		C3 west	8800	2,1	18480	0,18	0,60	234,5		0,968	1,14	0,852	0,4			
		Total C3											3,2			0,1/0,1
	A5	C3 east	56800	4,2	238560	0,17	0,60	252,2		0,968	1,14	0,834	5,6	18,6	0,917	
		C3 west	9600	2,1	20160	0,17	0,60	248		0,968	1,14	0,837	0,5			
		Total C3											6,1			0,1/0,1
	A6	C3 east														
		Dome 1	17200	3,0	51600	0,18	0,60	285,7		0,968	1,14	0,821	1,4	18,6	0,917	

		Dome 2	25200	3,0	75600	0,18	0,60	285,7	1	0,968	1,14	0,821	2,1			
		C3 west	6800	1,5	10200	0,18	0,60	281,3	1	0,968	1,14	0,823	0,3			
		Total C3											3,8			0,1/0,1
	A7	C3 east	72400	1,7	123080	0,18	0,60	293	1	0,968	1,14	0,814	3,5	18,6	0,917	
		C3 west	12400	0,7	8680	0,17	0,60	288,7	1	0,968	1,14	0,818	0,2			
		Total C3											3,7			0,1/0,1
	A8	D1	664800	17,6	11700480	0,18	0,60	302	1	0,968	1,14	0,807	338,7	18,6	0,917	6,3/5,8
Total apt		C3											16,8			0,4/0,4
		D1											338,7			6,3/5,8
Barrem	B1	D1 center	240000	9,5	2280000	0,18	0,60	326,4	1	0,968	1,16	0,801	72,1	18,6	0,917	1,3/1,2
(GK)		D1 west	121000	9,5	1149500	0,18	0,60	330,0	1	0,968	1,16	0,803	36,8			0,7/0,6
		D1 East 1	15600	9,5	148200	0,18	0,60	331,0	1	0,968	1,16	0,803	4,8			0,1/0,1
		D1 east 2	5000	9,5	47500	0,18	0,60	331,1	1	0,968	1,16	0,803	1,5			
	Total D1												115,2			2,1/1,9
	Total	C3											16,8			0,4/0,4
		D1											453,9			8,4/7,7

Based on the results of detailed work performed by the Sevmorneftegeofizika trust in 1989, the structure was prepared for deep exploratory drilling along reflectors in the Cretaceous and Jurassic deposits along reflectors along the main horizons of the sedimentary cover: "B" (J3), "M" (K1br), "M" (K1a), "G" (K2 s), "C3" (K2 st). According to the Upper Jurassic deposits (OG "B"), the West Sharapovskaya structure is a structural nose, in general terms inheriting the structure of the basement. A small (5.8 x 1.1 km) low-amplitude (up to 10 m) anticlinal fold is outlined within its boundaries along the isohypse -2375 m, which is the Central dome of the West Sharapovskaya structure.

In the southern part, along the isohypse - 2310, an anticline fold is localized with dimensions of 23 x 5 km and an amplitude of up to 30 m, which is part of the single South Dome of the West Sharapovka uplift traced above along the section. According to the Lower Cretaceous sediments, the West Sharapovka uplift is a narrow submeridional brachyanticlinal fold, complicated by the South, Central, and Northwest domes. The main one in size is the Central dome, which is combined along the OG M / with the South dome. Based on the results of processing seismic survey materials by the specialists of JSC Sevmorneftegeofizika within the West Sharapovskaya area in the wave field in the interval of the section of the Cenomanian and Aptian deposits, anomalies of the “bright spot” type are distinguished, coinciding mainly with the arch part of the West Sharapovskaya structure, the anomaly “bright spot” is contoured in the interval of the section of the Cenomanian and Aptian deposits. The “bright spot” anomaly was also noted in the section interval of the Upper-Middle Jurassic deposits. These anomalies may indicate both the possible presence of hydrocarbons in sand formations and the lithological variability of the constituent rocks. The parameters of the West Sharapovskaya structure for the main seismic horizons are presented in Table 5.9.

The Nyarmeysko-Skuratovsky area is identified in the northeastern part of the West Yamal shelf (Figure 5.5). In tectonic terms, the site corresponds to the eastern part of the Rusanovsko-Skuratov arch and partially includes the southern part of the

Chekinskaya depression (the region of the Zapadno-Skuratovskaya structure). Within the area, in 1975, regional seismic surveys of the MOV TsL, carried out by KMAGE NPO Sevmorgeo (now JSC MAGE), delineated a group of Nyarmeysky and Skuratovsky uplifts.

Table 2.9 Parameters of the Zapadno-Sharapovskaya structure for basic OG

reflective horizon	Dimensions of the structure along the extremely closed isohypse, km x km	Amplitude, m	Structure area, km2 Counting contour, m	Brief description of the structure
C3(K2st)	77,0×26,5-575	215	1471,4-575	Brachianticline, tectonically disturbed
G(K2s)	71,8×15-22-715	215	1242,4-715	Brachianticline, tectonically disturbed.
M'(K1a)	57,0×9,4-1285	160	504-1285	Brachianticline (Central+South domes)
M(K1br)	31,9×5,1-1750	85	125,6-1750	Brachyanticlinal fold (Central dome)
	16,0x5,6-1725	45	85,3-1725	Brachyanticlinal fold (South Dome)
B(J3)	5,8×1,1-2375	10	5,7-2375	Anticlinal fold (Central dome)
	23,0×5,0-2310	30	107,2-2310	Brachyanticlinal fold (South Dome)

Within the limits of the Nyarmeysko-Skuratovskiy subsoil, according to the materials of the CDP seismic prospecting works carried out here, large anticlinal structures Nyarmeyskaya, Skuratovskaya and a number of small structures - Zapadno-Skuratovskaya, Zapadno-Nyarmeiskaya, Sportivnaya were identified. Sea depths within the local structures of the site are: Nyarmeyskaya 10–70 m, Skuratovskaya 20–

50 m, Zapadno-Skuratovskaya 50–90 m, Zapadno-Nyarmeiskaya 50–90 m, Sportivnaya 110–160 m. The size and amplitude of the structure up the section increase, reaching maximum values along the reflecting horizons "M'" (at the top of the Aptian) and "G" (at the top of the Cenomanian). Based on these deposits, the structure has an amplitude of 80 m and 60 m and a maximum area. The structure is complicated by several peaks (on the Aptian deposits - two, on the Cenomanian deposits - three).

In the lower sections of the section, in the Neocomian and Jurassic deposits, the structure has significantly smaller dimensions and an amplitude of up to 50 m. In the Barremian deposits, the structure is complicated by three peaks, and in the Jurassic deposits it has one peak.

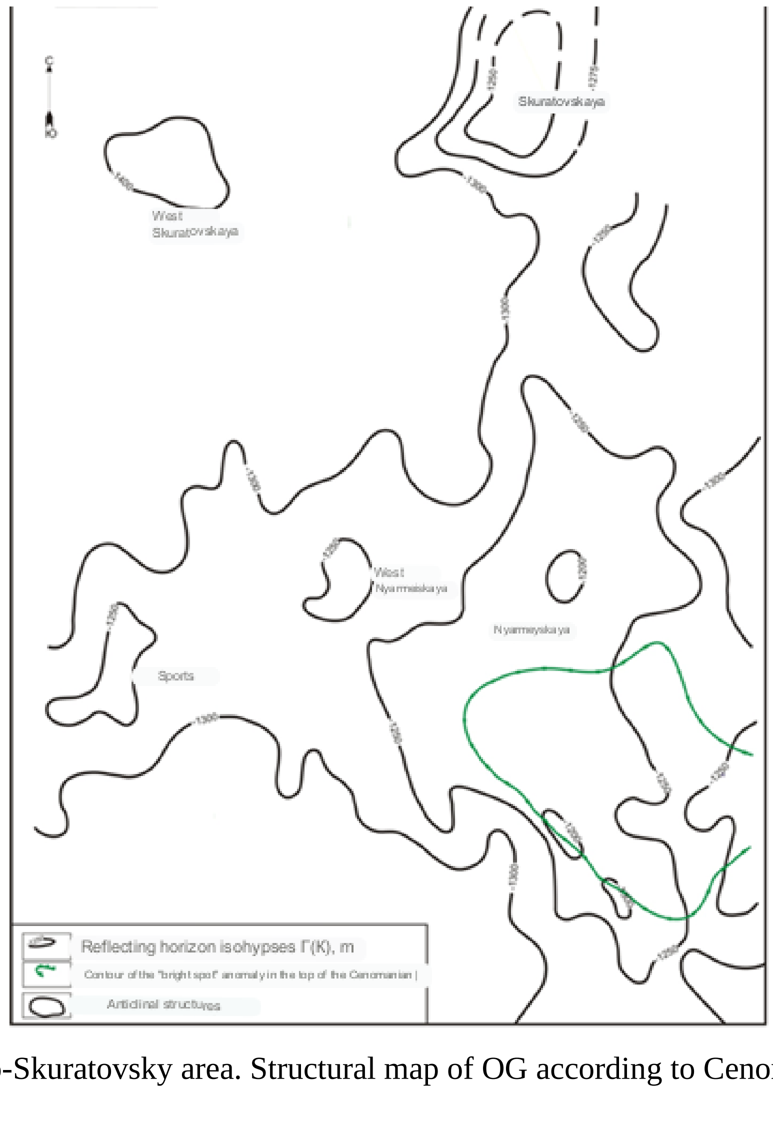


Figure 2.5 Nyarmeysko-Skuratovsky area. Structural map of OG according to Cenomanian G (K2S)

The Nyarmey structure is clearly expressed throughout the entire section of the sedimentary cover and is a brachianticline fold of a complex shape with a submeridional strike. The structure is located 40 km from the coast.

Based on the fact that the size and amplitude of the Nyarmei structure increased up the section, we can assume its most intensive growth in the Late Cretaceous and its consedimentary development. The presence in the section of the Nyarmey structure of a large number of intense reflections in the interval of the Aptian complex, according to the specialists of OAO Sevmorneftegeofizika, confirms the existence of layers with reservoir properties in the section, as well as interlayers of coal. The variability of the pattern of the seismic record, its zoning indicate the possible lithological variability of the rocks of the complex, which can lead to the formation of lithological hydrocarbon traps.

Significant attenuation of the intensity of reflections in the area of the crest of the Nyarmey structure at the level of OH "M'", by analogy with the Rusanovskoye field, may indicate the possibility of the presence of a hydrocarbon deposit in the top of the Aptian deposits. According to the results of seismic survey data processing by the specialists of OJSC “Sevmorneftegeofizika” in the section of the Nyarmey structure, the “bright spot” anomalies were identified on time sections at the level of the Aptian complex, in the Albian and in the Cenomanian deposits. Anomalies in the Aptian interval can be associated with both gas-saturated sandstones and coals.

Anomalies in the Albian and Cenomanian deposits are uniquely associated with gas deposits. The Skuratovskaya structure, located 60 km from the coast, is clearly delineated only in its western part. There is no network of prospecting seismic profiles in the northern and western parts of the area, and the closure of the structure is presumably planned. Nevertheless, the anticlinal inflection has a fairly clear expression throughout the section of the sedimentary cover and a significant amplitude.

The size and amplitude of the structure (within the assumed boundaries) increase up the section, reaching maximum values along the reflecting horizon "M/" (at the top of the Aptian). Based on the Aptian deposits, the Skuratovskaya structure is represented by two isolated domes, the northern one (dome 1, the main one in size) and the southern one (dome 2). According to the Cenomanian deposits, Barremian deposits and Jura deposits, only one dome is expressed - the northern one. The structure has the maximum amplitude along the Jurassic deposits (about 120 m). The minimum amplitude of the structure is based on the Cenomanian deposits (about 45 m).

2.3. Main technological indicators for development options for the Leningradskoye and Rusanovskoye fields in the Kara Sea

2.3.1. Justification of operational facilities

The substantiation of operational facilities was carried out taking into account the geological and operational characteristics of the identified and predicted deposits in the field section.

Productive formations of the Leningradskoye gas condensate field are united into five operational development objects.

Object I includes reservoir C. Gas reserves are estimated at 516.19 billion m3, the depth of the GWC position mark is 1165.2 m, and the average reservoir pressure is 116.2 atm.

Object II includes layers AC1, AC2, AC3. The total dry gas reserves for facility II are 797.11 bcm. The GWC position marks and the average value of the formation pressure of the deposits are respectively: for AS1 -1650 m and 165.2 atm., for AS2 -1703.1 m and 173.3 atm., for AS3 -1765.6 m 179.5 atm.

Object III includes layers A1, A4, A5. The total reserves of dry gas and condensate for facility III are 309.84 billion m3 and 5930 thousand tons, respectively. The marks of the GWC position and the average value of the formation pressure of the deposits are respectively: for A1 - 1968.9 m and 203.9 atm., for A4 - 2055 m and 232.6 atm., for A5 - 2185.6 m and 247.0 atm. .

Object IV includes layers A6, A7, A8. The total reserves of dry gas and condensate for facility IV are 267.15 billion m3 and 5,020 thousand tons, respectively. The GWC position marks and the average value of reservoir pressure of deposits are respectively: for A6 - 2305.6 m and 280.2 atm., for A7 - 2320 m and 284.5 atm., for A8 - 2370 m and 302 atm. Taking into account the small reserves of hydrocarbons and the geological and operational characteristics, the A7 reservoir is proposed not to be included in the development, the deposits of the A6 and A8 reservoirs are combined into one development object.

Object V includes layer B1. Gas and condensate reserves are equal

57.6 billion m3 and 1050 thousand tons, respectively. The depth of the GWC position mark is -2560.0 m, the average reservoir pressure is 330.0 atm.

Productive formations of the Rusanovskoye gas condensate field are united into four operational development objects.

Object I includes gas reservoirs C and AC1. The total dry gas reserves of the C and AC1 formations are 233.24 billion m3, respectively. The average formation pressure is assumed to be 128 atm. 150 atm. respectively.

Object II includes layers A1, A2, A3, A4, A5. The total gas and condensate reserves for facility II are 1,124.28 billion m3 and 22,380 thousand tons, respectively. The GWC position marks and the average value of reservoir pressure of deposits are respectively: for A1 - 2040 m and 206 atm., for A2 - 2080 m and 210 atm., for A3 - 2130 m and 217.2 atm. .5 atm., for A5 -2255 m and 247.8 atm.

Object III includes layers A6, A7, A8. The total reserves of gas and condensate for object III are 570.05 billion m3 and 11,420 thousand tons, respectively. The GWC position marks and the average formation pressure of the deposits are respectively: for A6 - 2390 m and 270 atm., for A7 - 2435 m and 279.4 atm., for A8 - 2440 m and 295 atm.

Object IV includes reservoir B1 and B2. The total gas and condensate reserves for facility IV are 181.1 billion m3 and 18,500 thousand tons, respectively. The GWC position marks and the average value of reservoir pressure of deposits are respectively: for B1 - 2600 m and 328.3 atm., for B2 - 2600 m and 344 atm.

2.3.2. Technological indicators of the development of the Leningradskoye and Rusanovskoye fields

Each of the facilities is supposed to be operated by a separate system of production wells. At the same time, it is assumed that part of the wells will be drilled not for all, but only for selective reservoirs related to one development object, and does not participate in the operation of other reservoirs. This decision depends on the geological features of the structure of the reservoirs, the gas-bearing area, the value of hydrocarbon reserves, and other factors.

The working flow rate was substantiated according to the test data of exploratory wells for the well stock designed for production development targets, tapped and tested in exploratory wells. For untested objects, the flow rate was selected by analogy, taking into account the predicted characteristics of the object and based on the analysis of well productivity at existing analogous fields.

To ensure the transport of products from wells to onshore production infrastructure, wells are subject to a minimum wellhead pressure limit of 30 atm. This solution allows minimizing the power consumption of the compressors while maintaining a high reserve recovery factor. In order to increase the recovery factor, it is allowed to selectively set increased wellhead pressures for development objects.

The annual gas extraction from the field is justified based on the condition of achieving a high coefficient of condensate and gas recovery (both for the field as a whole and for each object in particular) for the development period under consideration.

The maximum period for which the calculation of production indicators for the field as a whole was carried out is 50 years. In this case, uniform development of reserves of all operational facilities and an increase in the efficiency of technical and technological indicators are ensured. It should be taken into account that over the full life of the field, the true recovery factors will be higher.

The priority and timing of putting objects into development is justified by the expediency of the primary development of deposits with high initial reservoir pressure and the largest expected hydrocarbon reserves.

For the Leningradskoye field, the following sequence and terms of putting objects into development have been determined:

- 1st year - object II;
- 9th year - object I;
- 20th year - object IV;

- 21st year - object III;
- 27th year - object V.

For the Rusanovskoye field, the following sequence and terms of putting objects into development have been determined:

- 1st year - object II;
- 10th year - object III;
- 28th year - object IV;
- 30th year - object I.

The sequence of putting objects into operation, set in this way, ensures high stable technological indicators for the development of the entire field.

The calculation of the main technological indicators was performed for the scenario of independent development of the Leningradskoye and Rusanovskoye gas condensate fields (tables 2.10, figures 2.6.-2.11).

The planned volume of gas production for the Leningradskoye field of 44.0 billion m3 is achieved in the 11th year of the field's operation with a fund of 67 wells. The duration of the period of continuous production is 19 years. The average daily gas flow rate during the period of constant withdrawals is 1876 thousand m3/day.

For the Rusanovskoye field, the design gas production volume of 41.0 bcm is achieved in the 14th year of the field's operation with a pool of 75 wells. The duration of the period of continuous production is 20 years. The average daily gas flow rate during the period of continuous withdrawals is 1562 thousand m3/day.

The total fund of producing wells for the Leningradskoye and Rusanovskoye fields is 110 units. and 106 units. respectively.

For the calculation period (50 years) for the Leningradskoye and Rusanovskoye fields, the expected volume of cumulative gas and condensate production will be 1364.8 billion m3 (70.1% of the expected reserves) and 5014.7 thousand tons (41.8%) and 1476, 8 billion m3 of gas (70.0% of the expected reserves) and 24,057.1 thousand tons (80.4%), respectively.

The dynamics of well commissioning for the Leningradskoye and Rusanovskoye fields is presented in tables 2.1 and 2.13.

Table 2.10 - Leningradskoye field. Technological indicators of development

The years	Annual gas production, bcm	Annual gas withdrawal rate, %	Gas production since the start of development, bcm	Gas extraction, %	Active well stock	Average gas flow rate per well, thousand m3/day	Annual condensate production, thousand tons	Condensate withdrawal rate, %	Cumulative condensate production, thousand tons	Condensate withdrawal, %	Average flow rate of condensate, t/day
1	2	3	4	5	6	7	8	9	10	11	12
1	3,2	0,2	3,2	0,2	15	1829					
2	6,4	0,3	9,6	0,5	10	1829					
3	9,7	0,5	19,3	1,0	15	1838					

4	12,9	0,7	32,2	1,7	20	1843					
5	16,0	0,8	48,2	2,5	25	1829					
6	19,2	1,0	67,4	3,5	30	1829					
7	22,5	1,2	89,9	4,6	35	1837					
8	25,7	1,3	115,5	5,9	40	1834					
9	33,9	1,7	149,4	7,7	52	1863					
10	38,9	2,0	188,3	9,7	59	1884					
11	44,0	2,3	232,3	11,9	67	1876					

12	44,0	2,3	276,3	14,2	67	1876					
13	44,0	2,3	320,3	16,4	67	1876					
14	44,0	2,3	364,3	18,7	67	1876					
15	44,0	2,3	408,3	21,0	67	1876					
16	44,0	2,3	452,3	23,2	67	1876					
17	44,0	2,3	496,3	25,5	67	1876					
18	44,0	2,3	540,3	27,7	67	1876					
19	44,0	2,3	584,3	30,0	67	1876					

20	44,0	2,3	628,3	32,3	97	1771	46,3	0,4	46,3	0,4	33,1
21	44,0	2,3	672,4	34,5	98	1430	249,6	2,1	295,9	2,5	34,0
22	44,0	2,3	716,3	36,8	90	1396	255,5	2,1	551,3	4,6	31,7
23	44,0	2,3	760,3	39,0	92	1363	272,9	2,3	824,2	6,9	28,9
24	44,0	2,3	804,3	41,3	95	1324	282,1	2,4	1106,3	9,2	26,9

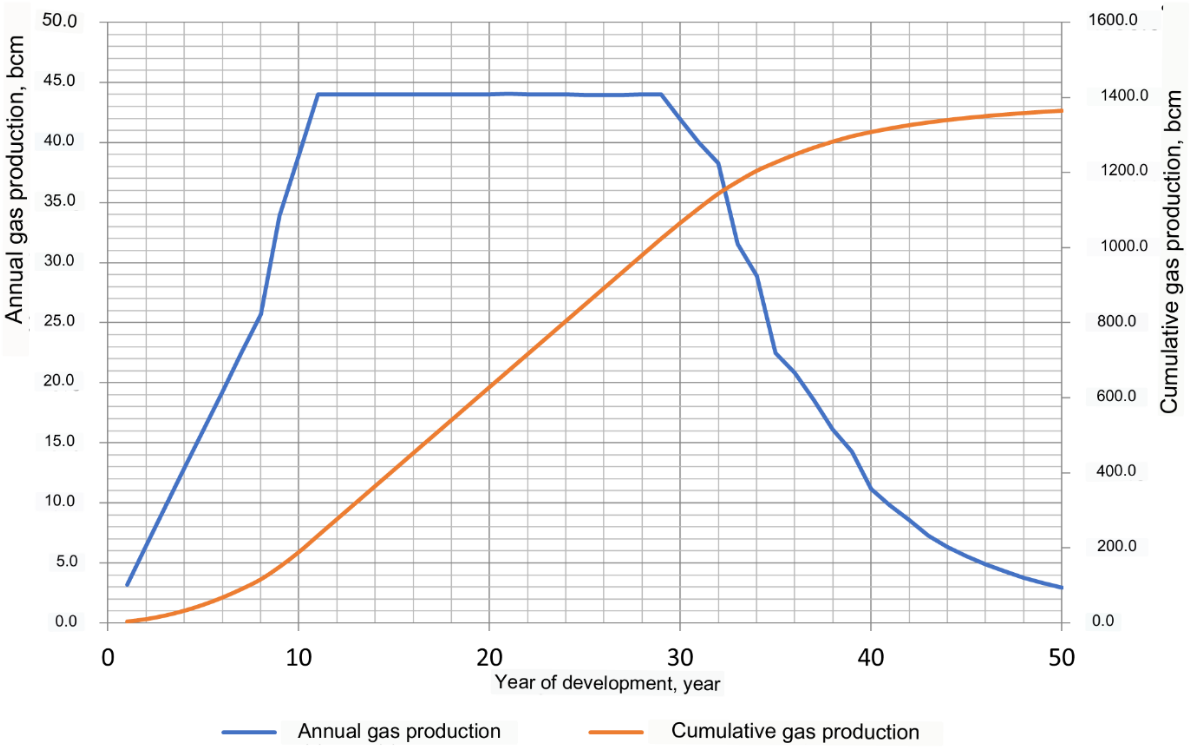


Figure 2.5 Change in annual and cumulative gas production of the Leningradskoye field

Figure 2.6 Change in annual and cumulative production of condensate from the Leningradskoye field

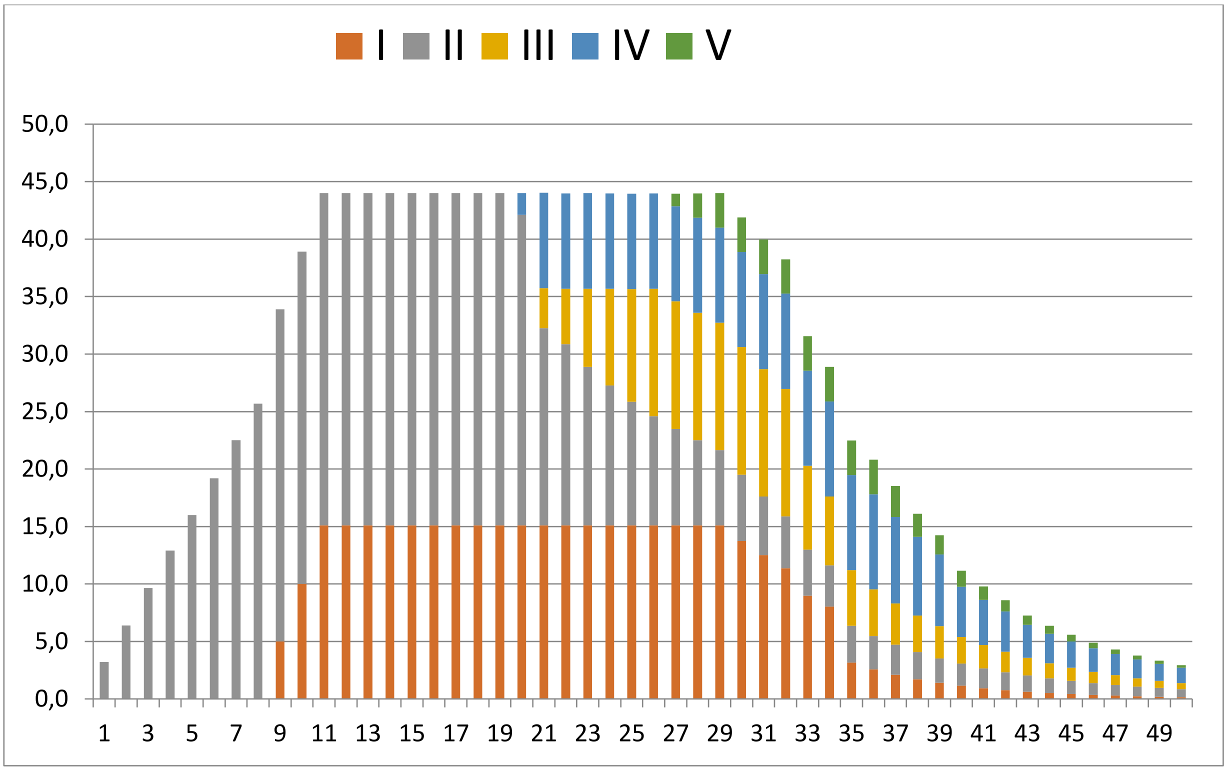


Figure 2.7 – Total gas production for all facilities of the Leningradskoye field

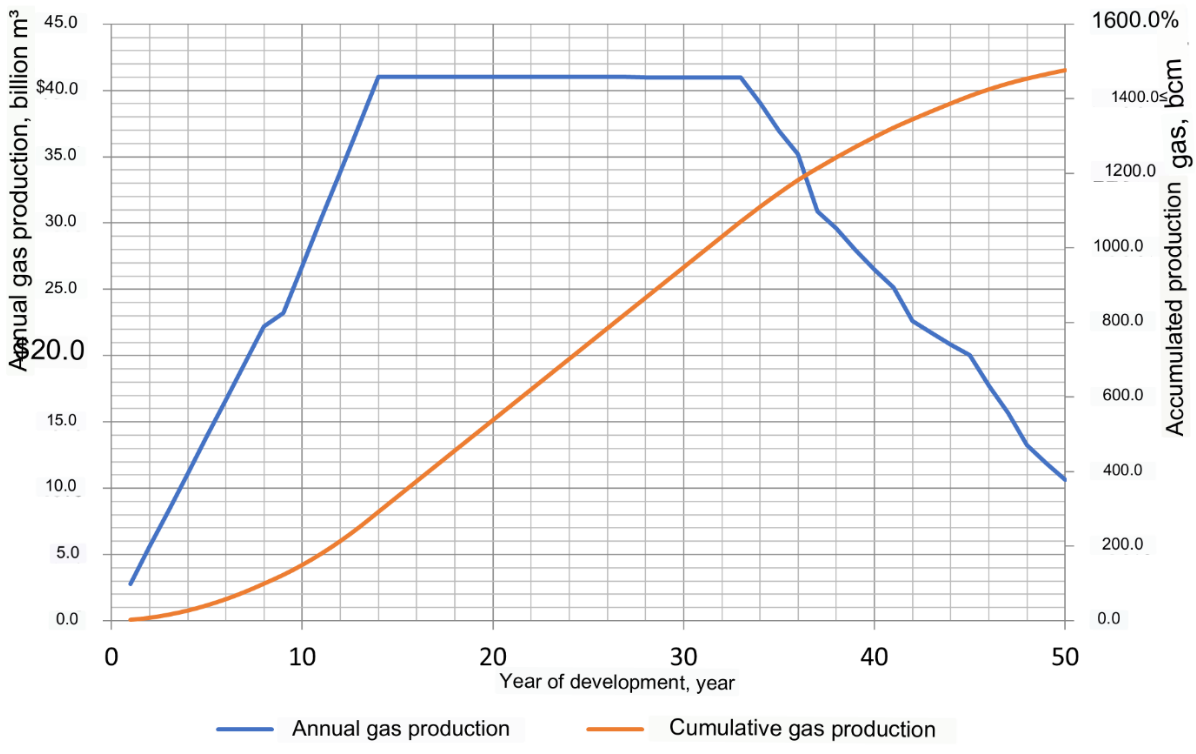


Figure 2.8 – Changes in the annual and cumulative gas production of the Rusanovskoye field

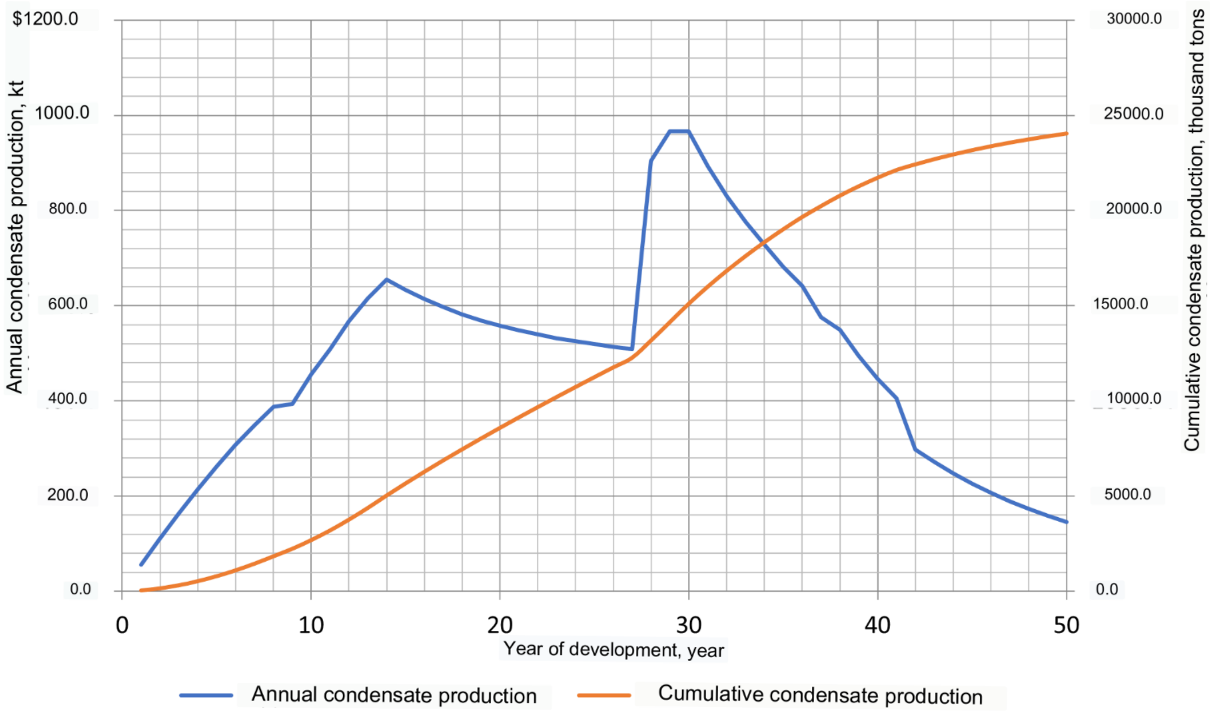


Figure 2.9—Change in annual and cumulative condensate production at the Rusanovskoye field

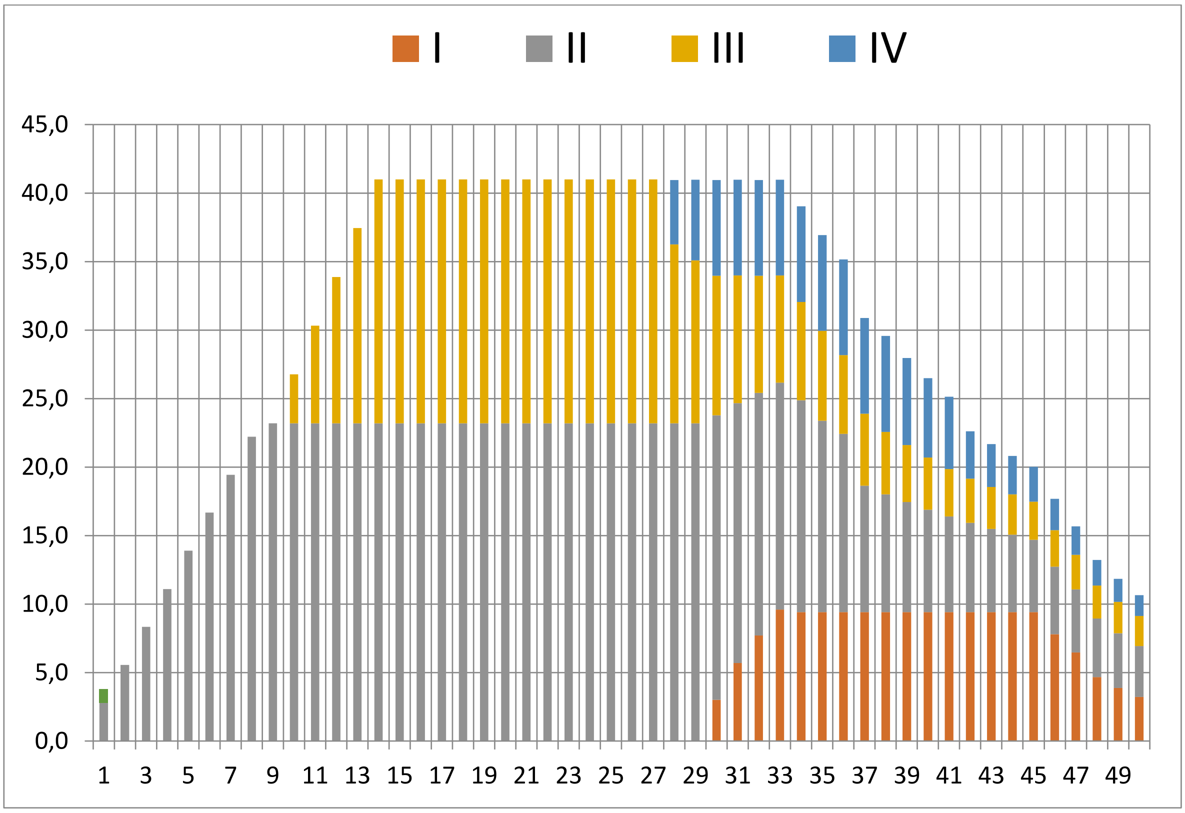


Figure 2.10 – Total gas production for all facilities of the Rusanovskoye field

Table 2.11 Dynamics of the well stock of the Leningradskoye field

The years	Well stock, units					
	Development object					Active well stock
	I	II	IIII	IV	V	
1		5				5
2		10				10
3		15				15
4		20				20
5		25				25
6		30				30
7		35				35
8		40				40
9	7	45				52
10	14	45				59
11	22	45				67
12	22	45				67
13	22	45				67
14	22	45				67
15	22	45				67
16	22	45				67
17	22	45				67
18	22	45				67
19	22	45				67
20	22	45		4		71
21	22	45	7	14		88
22	22	45	9	14		90
23	22	43	13	14		92
24	22	43	16	14		95

25	22	43	19	14		98
26	22	42	21	14		99
27	22	42	21	14	3	102
28	22	42	21	14	6	105
29	22	41	21	14	8	106
30	21	41	21	14	8	105
31	21	41	21	14	8	105
32	21	40	21	14	8	104
33	18	40	19	14	8	99
34	18	40	19	14	8	98
35	18	39	18	14	8	97
36	17	39	17	14	8	95
37	17	39	16	14	8	94
38	17	38	16	14	7	92
39	17	38	16	14	7	91
40	16	38	15	11	7	87
41	16	37	14	11	7	85

Table 2.12 Dynamics of the well stock of the Rusanovskoye field

The years	Well stock, units				
	Development object				Active well stock
	I	II	III	IV	
1		5			5
2		10			10
3		15			15
4		20			20
5		25			25
6		30			30
7		35			35
8		40			40
9		45			45
10		45	6		51
11		45	12		57
12		45	18		63
13		45	24		69
14		45	30		75
15		45	30		75
16		45	30		75
17		45	30		75
18		45	30		75
19		45	30		75
20		45	30		75
21		45	30		75
22		45	30		75
23		45	30		75
24		45	30		75
25		45	30		75
26		45	30		75
27		45	30		75
28		45	30	11	86
29		45	30	14	89
30	5	43	28	16	92
31	9	42	28	16	94
32	12	41	28	16	97
33	15	41	28	16	100
34	15	41	27	16	99
35	15	39	27	16	98
36	15	39	26	16	96

37	15	39	26	16	95
38	15	38	24	16	94
39	15	38	24	16	93
40	15	38	24	16	93
41	15	37	24	16	92
42	15	37	24	12	87
43	15	37	23	11	87
44	15	37	23	11	86
45	15	36	23	11	86
46	15	36	23	11	85
47	15	36	23	11	84
48	13	35	22	11	82
49	13	35	22	11	81
50	13	35	22	11	81

Operational facility I of the Leningradskoye field

The design level of production of 15.1 billion m3 is planned to be reached in the 11th year of the field development. Reserve recovery rate – 2.9% per year. The initial gas flow rate is 2041 thousand m3/day. The period of constant production lasts 19 years. Production well stock - 21 units.

It is planned to extract 72.3% of gas (373.1 billion m3) over the estimated period of field development (50 years). Wellhead pressure reaches the minimum allowable value of 30 atm. for the 29th year of field development. At the end of the calculation period, 8 wells are expected to be retired.

Operational facility II of the Leningradskoye field

The level of constant annual production of 28.9 billion m3 is reached in the 9th year of the field development. The recovery rate is 3.6% of the expected reserves. The initial gas flow rate is 1829 thousand m3/day. The period of constant production lasts 11 years. The fund of production wells is determined to be 45 units.

It is planned to extract 76.7% of gas (611.3 billion m3) over the 50-year period of field operation. Wellhead pressure will reach the minimum allowable value of 30 atm. in 19 years from the start of development. By the end of 1950, 10 wells are expected to be retired.

Operational facility III of the Leningradskoye field

The design level of gas production of 11.1 billion m3 is planned to be reached in the 26th year of the field development. The withdrawal rate corresponds to 5.1% of the reserves accepted for design. The initial gas flow rate is 1515 thousand m3/day. Production of gas condensate is projected at 166.8 thousand tons per year. The period of constant production lasts 7 years. The stock of producing wells is 21 units.

By the end of the 50th year since the beginning of the development of the field, it is planned to extract 71.9% of gas (156.6 billion m3) and 37.0% of condensate (2195 thousand tons). Wellhead pressure will reach the minimum allowable value of 30 atm. in the 34th year since the start of the field development. By the end of the 50th year of development of the field, 9 production wells are expected to be retired.

Operational facility IV of the Leningradskoye field

The design annual withdrawal of 8.3 billion m3 is planned to be achieved in the 21st year from the start of field development. The production rate is 3.1% of the withdrawal from the reserves. The initial gas flow rate is 1638 thousand m3/day. Production of gas condensate is projected at 185.4 thousand tons for the 22nd year of development. The fund of production wells is determined to be 14 units.

By the beginning of the period of declining production, it is planned to extract gas in the amount of 134.4 billion m3, which corresponds to 50.3% of the accepted reserves. The value of the average depression increases from 27.9 atm. up to 40.9 atm.

In the 50th year of the field development, it is planned to extract 68.5% of gas (182.9 billion m3) and 46.8% of condensate (2351.2 thousand tons). Wellhead pressure will reach the minimum allowable value of 30 atm. in 39 from the beginning of the development of the field. At the end of the estimated development period, 6 wells are expected to be retired.

Operational facility V of the Leningradskoye field

The design level of annual gas production from the facility of 3.0 billion m3 is planned to be reached in 29 from the start of field development. The withdrawal rate is assumed to be 5.2% of the reserves. The initial gas flow rate is 1048 thousand m3/day. Production of gas condensate is projected at 46.8 thousand tons per year. The continuous production period will last 8 years. Production well stock - 8 units.

It is planned to recover 79.0% of accepted gas reserves (45.5 billion m3) and 48.5% of condensate (509.3 thousand tons) during the estimated period of field operation. Wellhead pressure will reach the minimum allowable value of 40 atm. in the 38th year since the start of the development of the field. At the end of the calculation period, 2 wells are expected to be retired.

Development indicators by objects are given in tables 2.13-2.20.

Table 2.13 Leningradskoye field. Object I. Technological indicators of development

The years	Annual gas production, billion m3	Annual gas withdrawal rate, %	Gas production since the beginning of development, billion m3	Gas extraction, %	A
9	5,0	1,0	5,0	1,0	
10	10,0	1,9	15,0	2,9	
11	15,1	2,9	30,1	5,8	
12	15,1	2,9	45,2	8,8	
13	15,1	2,9	60,3	11,7	
14	15,1	2,9	75,4	14,6	
15	15,1	2,9	90,5	17,5	
16	15,1	2,9	105,6	20,5	
17	15,1	2,9	120,7	23,4	
18	15,1	2,9	135,8	26,3	
19	15,1	2,9	150,9	29,2	
20	15,1	2,9	166,0	32,2	
21	15,1	2,9	181,1	35,1	
22	15,1	2,9	196,2	38,0	
23	15,1	2,9	211,3	40,9	
24	15,1	2,9	226,4	43,9	
25	15,1	2,9	241,5	46,8	
26	15,1	2,9	256,6	49,7	
27	15,1	2,9	271,7	52,6	
28	15,1	2,9	286,8	55,6	
29	15,1	2,9	301,9	58,5	
30	13,7	2,7	315,6	61,1	
31	12,5	2,4	328,1	63,6	
32	11,4	2,2	339,5	65,8	
33	9,0	1,7	348,5	67,5	
34	8,0	1,6	356,5	69,1	

35	3,2	0,6	359,7	69,7
36	2,6	0,5	362,3	70,2
37	2,1	0,4	364,4	70,6
38	1,7	0,3	366,1	70,9
39	1,4	0,3	367,5	71,2
40	1,1	0,2	368,6	71,4
41	0,9	0,2	369,6	71,6
42	0,8	0,1	370,3	71,7
43	0,6	0,1	371,0	71,9
44	0,5	0,1	371,5	72,0
45	0,4	0,1	371,9	72,0
46	0,3	0,1	372,2	72,1
47	0,3	0,1	372,5	72,2
48	0,2	0,0	372,7	72,2
49	0,2	0,0	372,9	72,2
50	0,2	0,0	373,1	72,3

Table 2.14 Leningradskoye field. Object II. Technological indicators of development

The years	Annual gas production, billion m3	Annual gas withdrawal rate, %	Gas production since the beginning of development, billion m3	Gas extraction, %	A
1	3,2	0,4	3,2	0,4	
2	6,4	0,8	9,6	1,2	
3	9,7	1,2	19,3	2,4	
4	12,9	1,6	32,2	4,0	
5	16,0	2,0	48,2	6,0	
6	19,2	2,4	67,4	8,4	
7	22,5	2,8	89,9	11,3	
8	25,7	3,2	115,5	14,5	
9	28,9	3,6	144,4	18,1	
10	28,9	3,6	173,3	21,7	
11	28,9	3,6	202,2	25,4	

12	28,9	3,6	231,1	29,0	
13	28,9	3,6	260,0	32,6	
14	28,9	3,6	288,9	36,2	
15	28,9	3,6	317,8	39,9	
16	28,9	3,6	346,7	43,5	
17	28,9	3,6	375,6	47,1	
18	28,9	3,6	404,5	50,7	
19	28,9	3,6	433,4	54,4	
20	27,0	3,6	460,4	57,8	
21	17,1	3,4	477,6	59,9	
22	15,8	2,2	493,3	61,9	
23	13,8	2,0	507,1	63,6	
24	12,2	1,7	519,3	65,1	
25	10,8	1,5	530,1	66,5	
26	9,5	1,3	539,6	67,7	
27	8,4	1,2	547,9	68,7	
28	7,4	1,1	555,3	69,7	
29	6,5	0,9	561,9	70,5	
30	5,8	0,8	567,6	71,2	
31	5,1	0,7	572,7	71,9	
32	4,5	0,6	577,2	72,4	
33	4,0	0,6	581,2	72,9	
34	3,6	0,5	584,8	73,4	
35	3,2	0,4	588,0	73,8	
36	2,9	0,4	590,9	74,1	
37	2,6	0,4	593,5	74,5	
38	2,4	0,3	595,9	74,8	
39	2,1	0,3	598,0	75,0	

40	1,9	0,3	599,9	75,3	
41	1,7	0,2	601,6	75,5	
42	1,6	0,2	603,2	75,7	
43	1,4	0,2	604,6	75,9	
44	1,3	0,2	605,9	76,0	
45	1,2	0,2	607,0	76,2	
46	1,0	0,1	608,1	76,3	
47	0,9	0,1	609,0	76,4	
48	0,8	0,1	609,9	76,5	
49	0,8	0,1	610,6	76,6	
50	0,7	0,1	611,3	76,7	

Table 2.15 Leningradskoye field. Object III. Technological indicators of development

Table 2.16 Leningradskoye field. Object III. Condensate production indicators

The years	Annual condensate production, thousand tons	Condensate withdrawal rate, %	Cumulative condensate production, thousand tons	Condensate withdrawal, %	Average flow rate of condensate, t/day	GCF
21	64,2	1,1	64,2	1,1	26,2	18,3
22	85,2	1,4	149,4	2,5	27,1	17,8
23	116,2	2,0	265,6	4,5	25,5	17,1
24	137,6	2,3	403,2	6,8	24,6	16,4
25	153,6	2,6	556,8	9,4	23,1	15,7
26	166,8	2,8	723,6	12,2	22,7	15,0
27	161,2	2,7	884,8	14,9	21,9	14,5
28	156,7	2,6	1041,5	17,6	21,3	14,1
29	153,1	2,6	1194,6	20,1	20,8	13,8
30	150,1	2,5	1344,6	22,7	20,4	13,5
31	147,3	2,5	1491,9	25,2	20,0	13,3
32	144,5	2,4	1636,5	27,6	19,7	13,0
33	93,8	1,6	1730,2	29,2	14,2	12,8
34	75,9	1,3	1806,2	30,5	11,7	12,7
35	60,8	1,0	1867,0	31,5	9,4	12,5
36	50,3	0,8	1917,3	32,3	8,6	12,4
37	44,0	0,7	1961,3	33,1	7,7	12,3
38	38,5	0,6	1999,8	33,7	6,8	12,2
39	33,7	0,6	2033,4	34,3	6,1	12,0
40	27,8	0,5	2061,2	34,8	5,4	12,0

Table continuation 2.16

41	24,0	0,4	2085,2	35,2	4,7	11,9
42	20,8	0,4	2106,0	35,5	4,2	11,8
43	18,0	0,3	2123,9	35,8	3,7	11,7
44	15,4	0,3	2139,3	36,1	3,2	11,6
45	13,2	0,2	2152,5	36,3	2,8	11,6
46	11,3	0,2	2163,8	36,5	2,5	11,5
47	9,7	0,2	2173,5	36,7	2,2	11,5
48	8,3	0,1	2181,8	36,8	1,9	11,5
49	7,1	0,1	2188,9	36,9	1,7	11,4
50	6,1	0,1	2195,0	37,0	1,5	11,4

Table 2.17 - Leningradskoye field. Object IV. Technological indicators of developmen

Table 2.18 - Leningradskoye field. Object IV. Condensate production indicators

The years	Annual condensate production, thousand tons	Condensate withdrawal rate, %	Cumulative condensate production, thousand tons	Condensate withdrawal, %	Average flow rate of condensate, t/day	GCF
20	46,3	0,9	46,3	0,9	33,1	24,4
21	185,4	3,7	231,7	4,6	37,8	22,3
22	170,2	3,4	401,9	8,0	34,7	20,5
23	156,7	3,1	558,6	11,1	32,0	18,9
24	144,6	2,9	703,2	14,0	29,5	17,4
25	133,8	2,7	837,0	16,7	27,3	16,1
26	124,1	2,5	961,1	19,1	25,3	15,0
27	115,9	2,3	1077,0	21,5	23,7	14,0

28	108,8	2,2	1185,8	23,6	22,2	13,2
29	102,8	2,0	1288,5	25,7	21,0	12,4
30	97,6	1,9	1386,1	27,6	19,9	11,8
31	93,3	1,9	1479,4	29,5	19,0	11,3
32	89,6	1,8	1569,0	31,3	18,3	10,8
33	86,6	1,7	1655,7	33,0	17,7	10,5
34	84,2	1,7	1739,9	34,7	17,2	10,2
35	82,2	1,6	1822,1	36,3	16,8	9,9
36	80,6	1,6	1902,6	37,9	16,4	9,7
37	72,2	1,4	1974,8	39,3	14,7	9,6
38	64,8	1,3	2039,6	40,6	13,2	9,5
39	58,3	1,2	2097,9	41,8	11,9	9,4
40	40,4	0,8	2138,3	42,6	10,7	9,3
41	36,1	0,7	2174,4	43,3	9,7	9,2
42	32,2	0,6	2206,7	44,0	8,8	9,2
43	26,1	0,5	2232,8	44,5	7,9	9,1
44	23,2	0,5	2256,0	44,9	7,2	9,1
45	20,7	0,4	2276,7	45,4	6,5	9,0
46	18,5	0,4	2295,2	45,7	5,9	9,0
47	16,5	0,3	2311,7	46,0	5,3	8,9
48	14,7	0,3	2326,4	46,3	4,8	8,9
49	13,1	0,3	2339,5	46,6	4,4	8,9
50	11,7	0,2	2351,2	46,8	4,0	8,8

Table 2.19 Leningradskoye field. Object V. Technological indicators of development [2]

The years			Gas production since	Gas extraction, %	Active we

	Annual gas production, billion m3	Annual gas withdrawal rate, %	the beginning of development, billion m3		
27	1,1	1,9	1,1	1,9	3
28	2,1	3,6	3,2	5,6	6
29	3,0	5,2	6,2	10,8	8
30	3,0	5,2	9,2	16,0	8
31	3,0	5,2	12,2	21,2	8
32	3,0	5,2	15,2	26,4	8
33	3,0	5,2	18,2	31,6	8
34	3,0	5,2	21,2	36,8	8
35	3,0	5,2	24,2	42,0	8
36	3,0	5,2	27,2	47,2	8
37	2,7	4,7	29,9	51,9	8
38	2,0	3,5	31,9	55,4	7
39	1,7	2,9	33,6	58,4	7
40	1,4	2,4	35,0	60,8	7
41	1,2	2,0	36,2	62,8	7
42	1,0	1,7	37,2	64,5	7
43	0,8	1,4	38,0	66,0	7
44	0,7	1,2	38,7	67,1	7
45	0,6	1,0	39,2	68,1	7
46	0,5	0,8	39,7	68,9	7
47	0,4	0,7	40,1	69,6	7
48	0,3	0,6	40,4	70,2	7
49	0,3	0,5	40,7	70,7	7
50	0,2	0,4	40,9	71,1	6

Table 2.20 Leningradskoye field. Object V. Condensate production indicators

The years	Annual condensate production, thousand tons	Condensate withdrawal rate, %	Cumulative condensate production, thousand tons	Condensate withdrawal, %	Average flow rate of condensate, t/day	GCF
27	20,4	1,9	20,4	1,9	19,4	18,5
28	36,7	3,5	57,1	5,4	17,5	17,5
29	46,8	4,5	103,9	9,9	16,7	15,6
30	42,1	4,0	146,0	13,9	15,0	14,0
31	38,3	3,6	184,3	17,5	13,7	12,8
32	35,2	3,4	219,4	20,9	12,6	11,7
33	32,7	3,1	252,2	24,0	11,7	10,9
34	30,8	2,9	283,0	27,0	11,0	10,3
35	29,9	2,8	312,9	29,8	10,7	10,0
36	28,9	2,7	341,8	32,6	10,3	9,6
37	25,4	2,4	367,2	35,0	9,1	9,4
38	18,8	1,8	386,0	36,8	7,5	9,3
39	15,7	1,5	401,7	38,3	6,3	9,3
40	13,0	1,2	414,7	39,5	5,3	9,2
41	10,8	1,0	425,5	40,5	4,4	9,2
42	9,0	0,9	434,4	41,4	3,7	9,2
43	7,4	0,7	441,9	42,1	3,1	9,1
44	6,2	0,6	448,0	42,7	2,6	9,1
45	5,1	0,5	453,2	43,2	2,2	9,1
46	4,3	0,4	457,4	43,6	1,8	9,1
47	3,6	0,3	461,0	43,9	1,5	9,1
48	3,0	0,3	464,0	44,2	1,3	9,0
49	2,5	0,2	466,4	44,4	1,1	9,0

50	2,1	0,2	468,5	44,6	0,9	9,0

Operational facility I of the Rusanovskoye field

The design level of annual gas production from the facility of 9.4 billion m3 is planned to be reached in the 34th year from the start of field development. The recovery rate is assumed to be 4.0% of the deposit reserves. The initial gas flow rate is 1714 thousand m3/day. The continuous production period will last 12 years. Production well stock - 15 units.

By the end of the 50th year of development of the field, it is planned to extract 70.7% of the accepted gas reserves (164.8 billion m3). Wellhead pressure will reach the minimum allowable value of 30 atm. in 44 from the beginning of the development of the field. At the end of the calculation period, 2 wells are expected to be retired.

Operational facility II Rusanovskoye field

The level of constant annual production of 23.2 billion m3 is achieved in the 9th year of the field development. The recovery rate is 2.1% of the expected reserves. The initial gas flow rate is 1589 thousand m3/day. Production of gas condensate is projected at 394.0 thousand tons per year. The design gas extraction has been stable for 21 years. The fund of production wells is determined to be 45 units.

Over the 50-year period of operation of the facility, it is planned to extract 70.2% of gas (789.1 billion m3) and 50.3% of condensate (11262.6 thousand tons). Wellhead pressure will reach the minimum allowable value of 30 atm. in the 29th year since the beginning of development. By the end of 1950, 10 wells are expected to be retired.

Operational facility III of the Rusanovskoye field

The design production level of 17.8 billion m3 is planned to be reached in the 14th year of the field development. The rate of reserves withdrawal is 3.1% per year. The initial gas flow rate is 1695 thousand m3/day. Production of gas condensate is projected at 304.1 thousand tons per year. The period of constant production lasts 14 years. Production well stock - 30 units. It is planned to extract 72.0% of gas (410.4 billion m3) and 47.7% of condensate (5443.4 thousand tons) during the estimated period of field development. Wellhead pressure reaches the minimum allowable value of 30 atm. 26 years since the start of field development. At the end of the calculation period, 8 wells are expected to be retired.

Operational facility IV Rusanovskoye field

The design annual withdrawal of 7.0 billion m3 is planned to be achieved by the 30th year from the start of field development. The production rate is 3.9% of the withdrawal from the reserves. The initial gas flow rate is 1250 thousand m3/day. Production of gas condensate is projected at 588.6 thousand tons. The stock of producing wells is set at 16 units.

It is planned to extract 62.1% of gas (112.5 billion m3) and 39.7% of condensate (7351.2 thousand tons) during the estimated period of field development. Wellhead pressure will reach the minimum allowable value of 30 atm. in 42 from the beginning of the development of the field. At the end of the estimated development period, 5 wells are expected to be retired.

Development indicators are given in tables 2.22 - 2.28.

Table 2.21 Rusanovskoye field. Object I. Technological indicators of development

Table 2.22 Rusanovskoye field. Object II. Technological indicators of development [1]

Table 2.23 Rusanovskoye field. Object II. Condensate production indicators

Table 2.24 Rusanovskoye field. Object III. Technological indicators of development

Table 2.25 Rusanovskoye field. Object III (layers A6, A7, A8). Condensate production indicators

Table 2. 26 Rusanovskoye field. Object IV. Technological indicators of development

Table 2.27 - Rusanovskoye field. Object IV. Condensate production indicators

Generalized technical and technological indicators for the development of operational facilities of the Leningradskoye and Rusanovskoye fields are given in tables 2.28 - 2.29.

Table 2.29 Generalized technical and technological indicators for the development of production facilities of the Leningradskoye field

Parameter	Operational development facility					Total for objects I-V
	I	II	III	IV	V	
Year of commissioning of the first field development	9	1	21	20	27	-
Settlement period, years	41	50	29	30	23	50
Design level of gas production, billion m3	15,1	28,9	11,1	8,3	3,0	44
Well stock, units	22	45	21	14	8	110
CIG, d.u.	0,72	0,76	0,72	0,68	0,71	0,70
Cumulative gas production, billion m3	373,1	611,3	156,6	182,9	40,9	1364,8

Table 2.29 - Generalized technical and technological indicators for the development of operational facilities of the Rusanovskoye field

Parameter	Operational development facility				Total for objects I-V
	I	II	III	IV	
Year of commissioning of the first field development	30	1	10	28	-
Settlement period, years	21	50	41	23	50
Design level of gas production, billion m3	9,4	23,2	17,8	7,0	41,0
Well stock, units	15	45	30	16	106
CIG, d.u.	0,70	0,70	0,72	0,62	0,70
Cumulative gas production, billion m3	164,8	789,1	410,4	112,5	1476,8

With a total well stock of the Leningradskoye field in the amount of 106 units. object I accounts for 14.1% (15 units), object II - 42.4% (45 units), object III - 28.3% (30 units), object IV - 15.2% (16 units). With a total well stock of the Rusanovskoye field in the amount of 110 units. object I accounts for 20.0% (22 units), object II - 40.9% (45 units), object III - 19.0% (21 units), object IV - 12.7% (14 units), object V – 7.2% (8 units). The layouts of project wells in the gas-bearing area are shown in Figures 2.11-2.21.

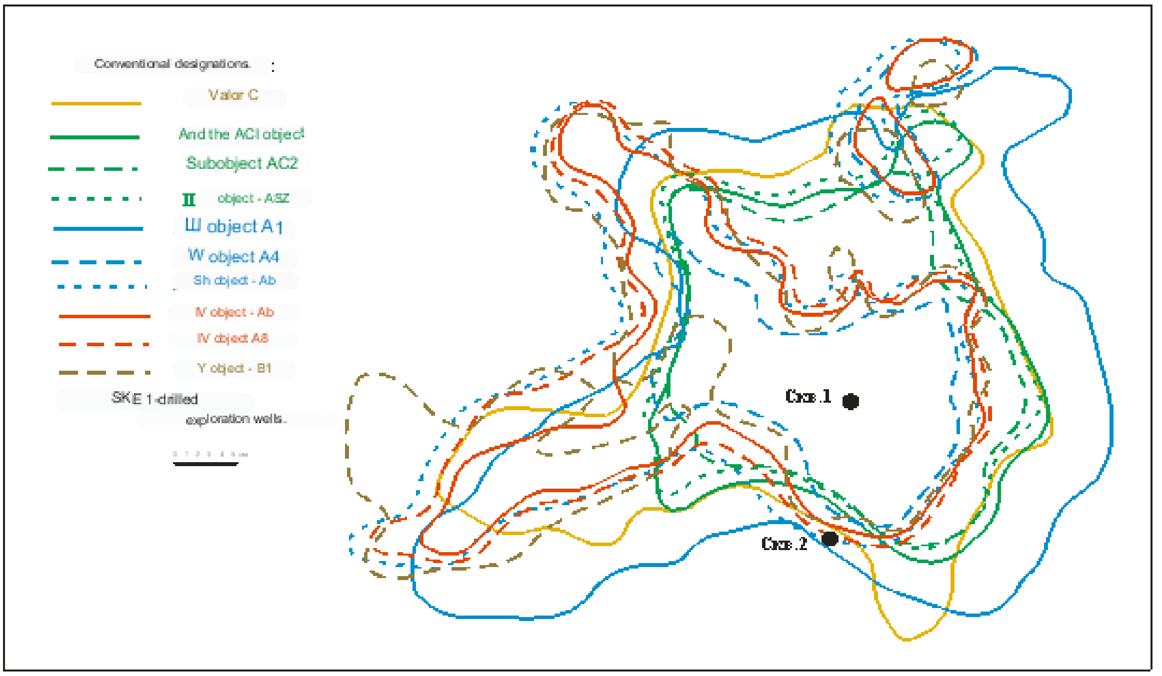


Figure 2.11 Scheme of location of wells of the Leningradskoye field

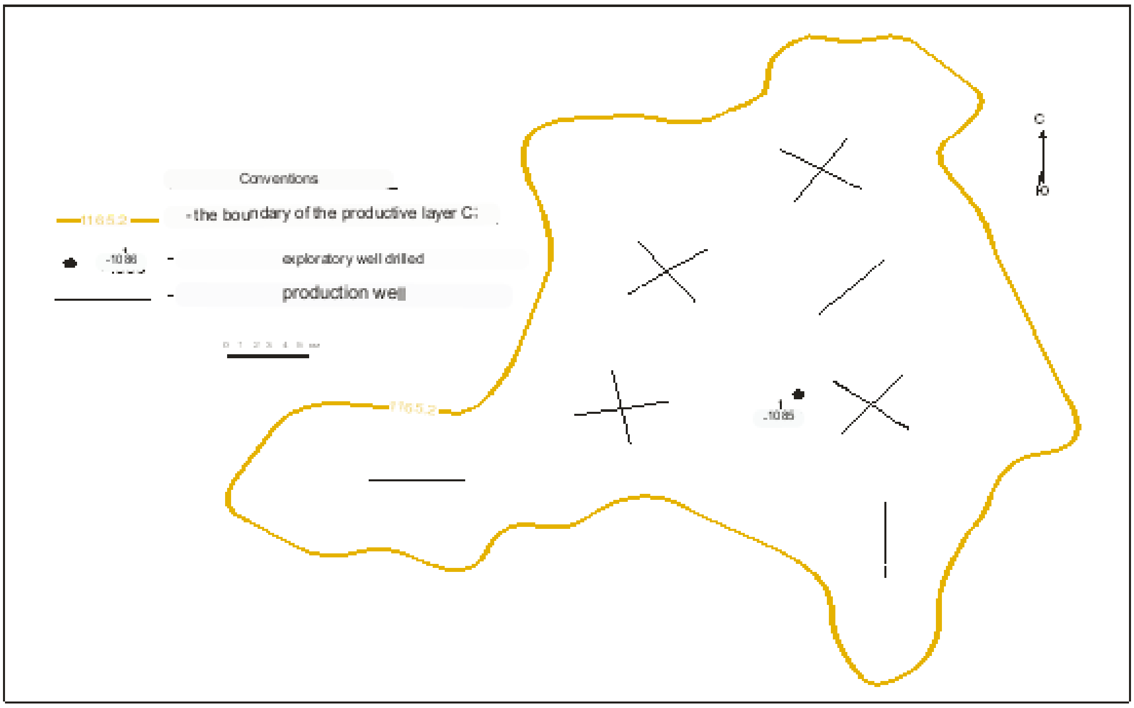


Figure 2.12 Scheme of location of wells of the Leningrad field(Object I)

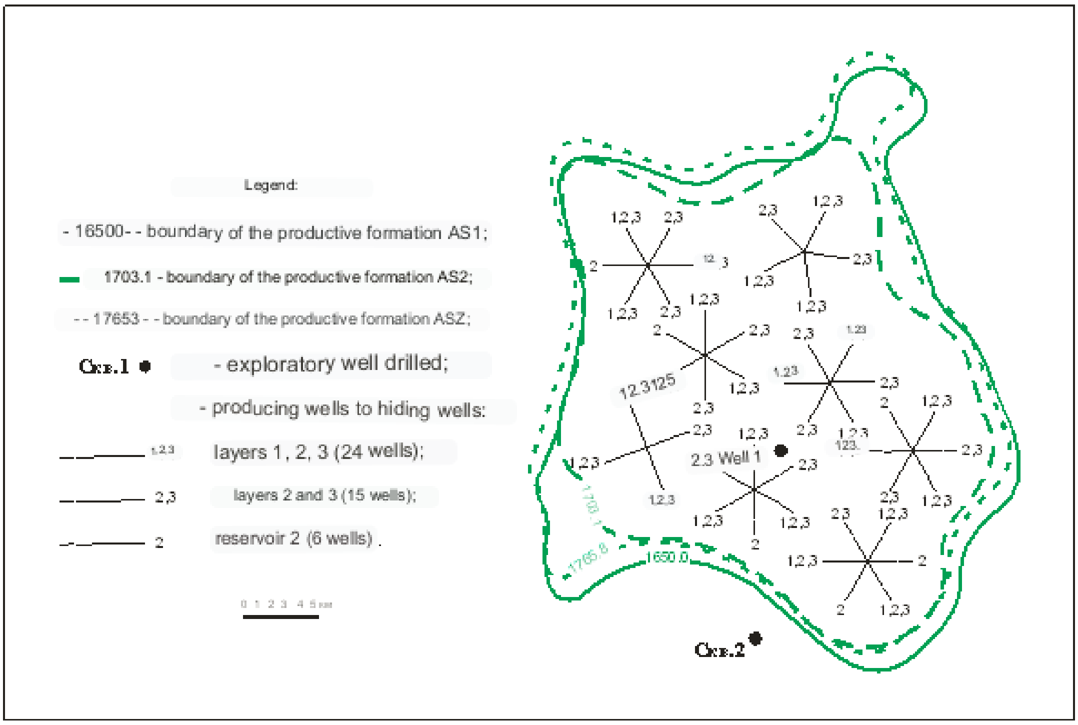


Figure 2.13 Scheme of location of wells of the Leningradskoye field(Object II)

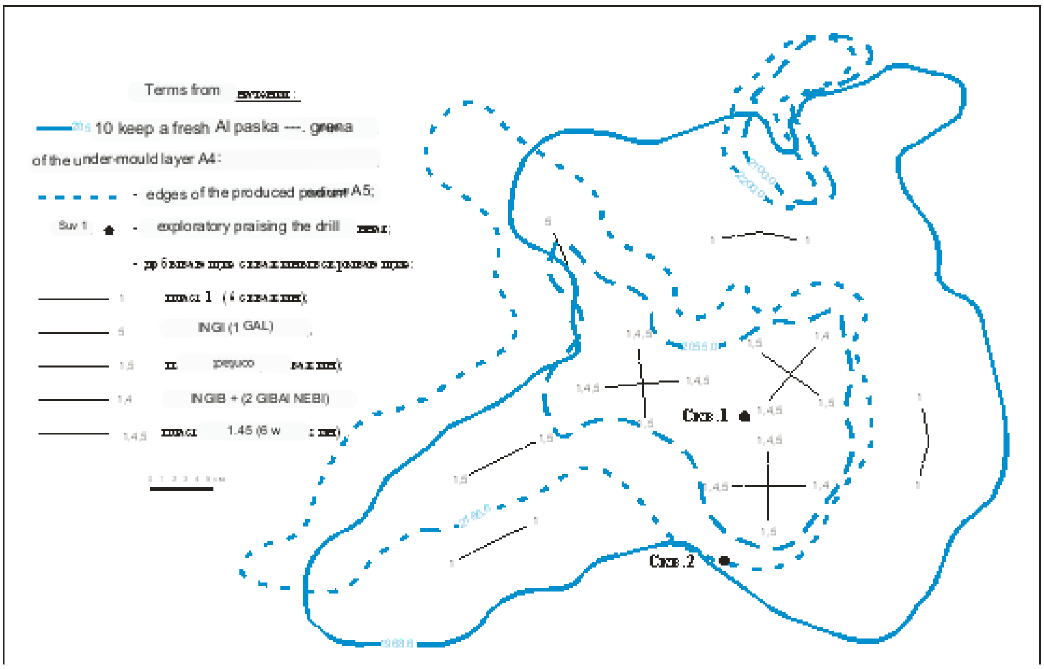


Figure 2.14 Scheme of location of wells of the Leningradskoye field(Object III)

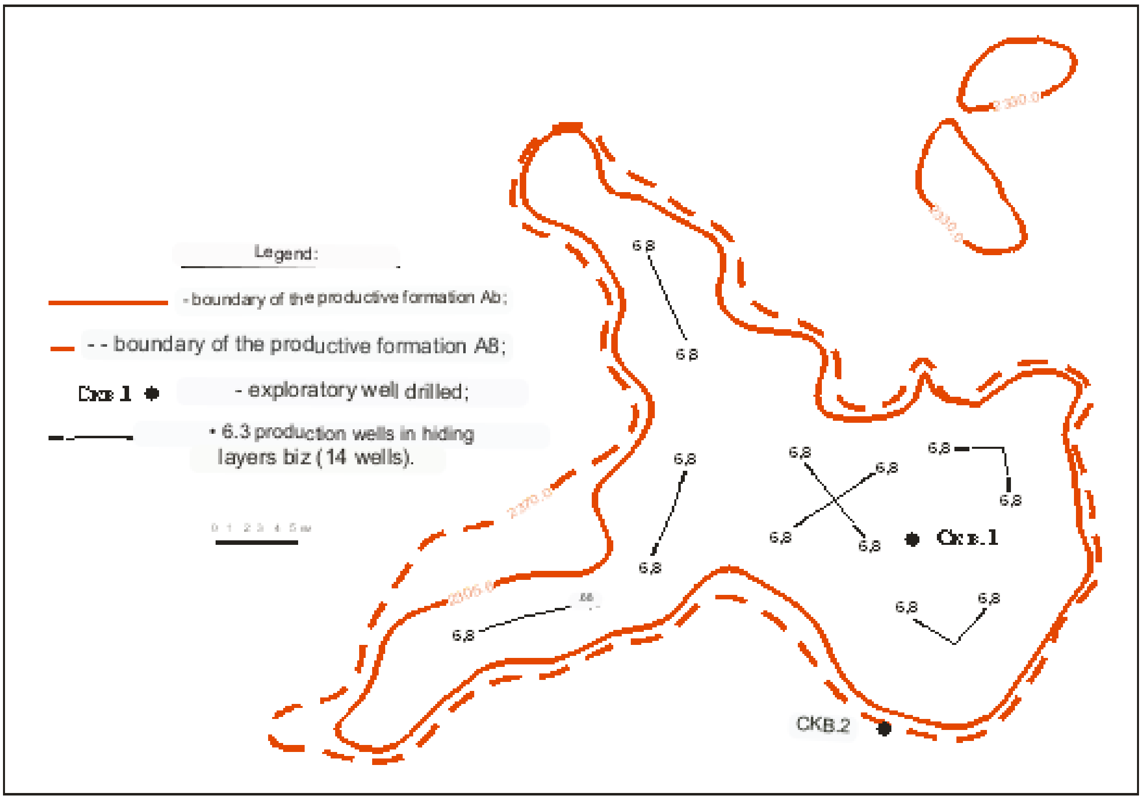


Figure 2.15 Scheme of location of wells of the Leningrad field (Object IV)

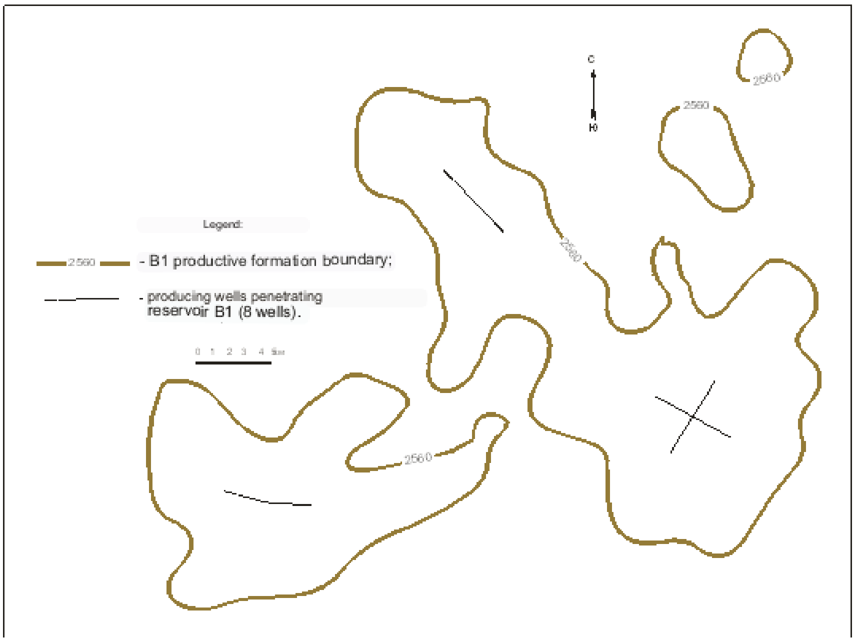


Figure 2.16 Scheme of location of wells of the Leningradskoye field (Object V)

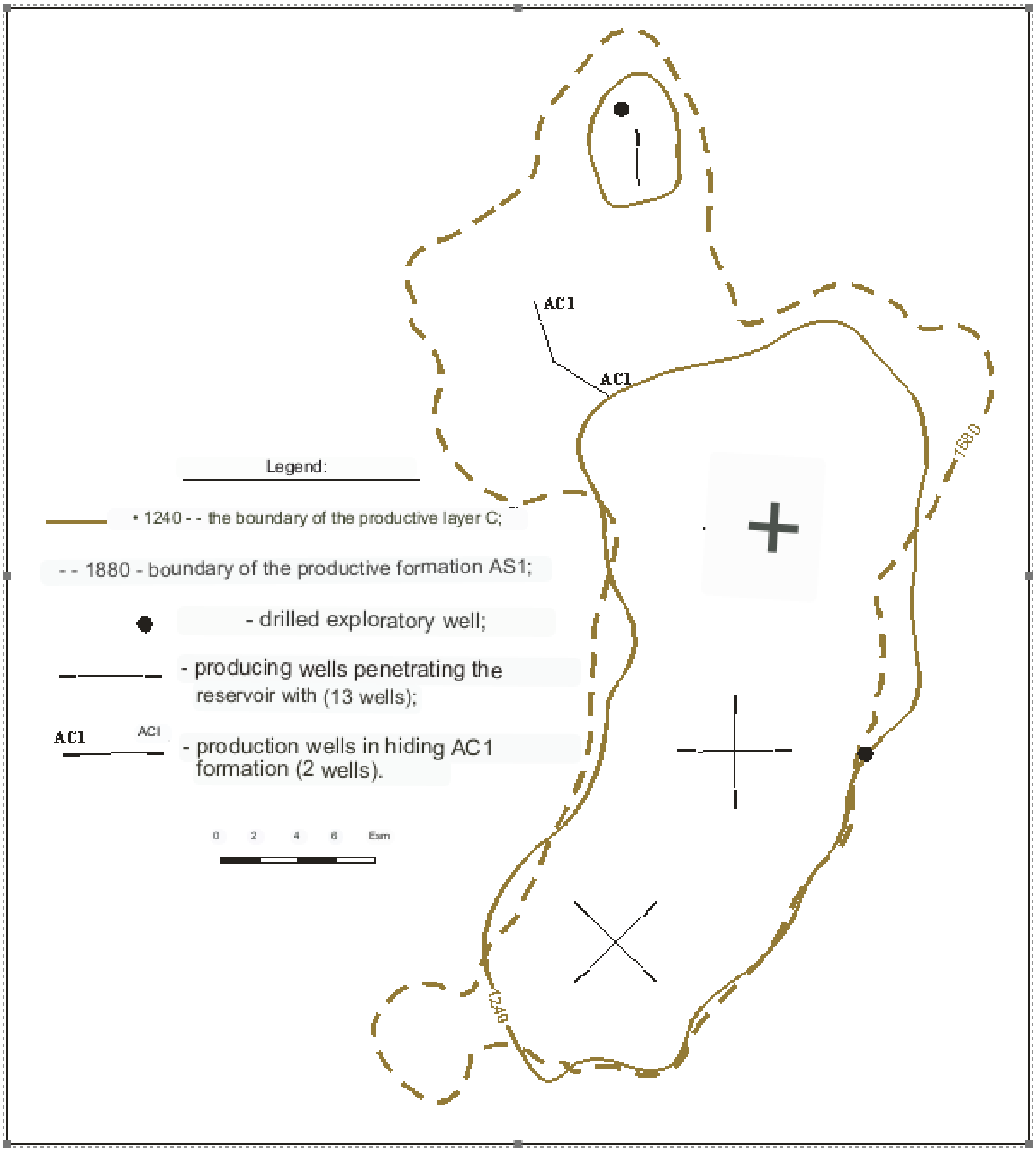


Figure 2.17 Scheme of the location of the wells of the Rusanovskoye field (Object I)

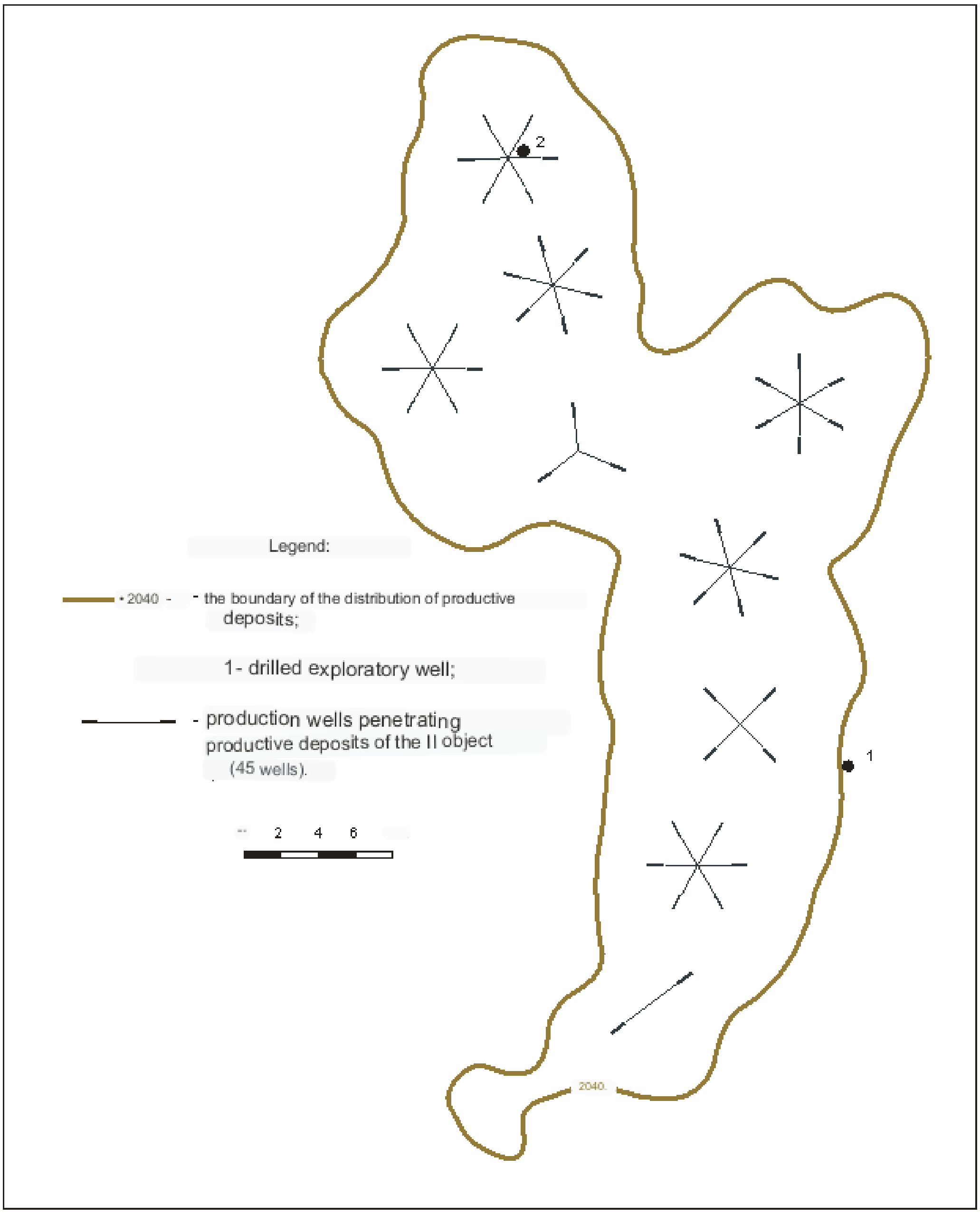


Figure 2.18 Scheme of the location of the wells of the Rusanovskoye field (Object II)

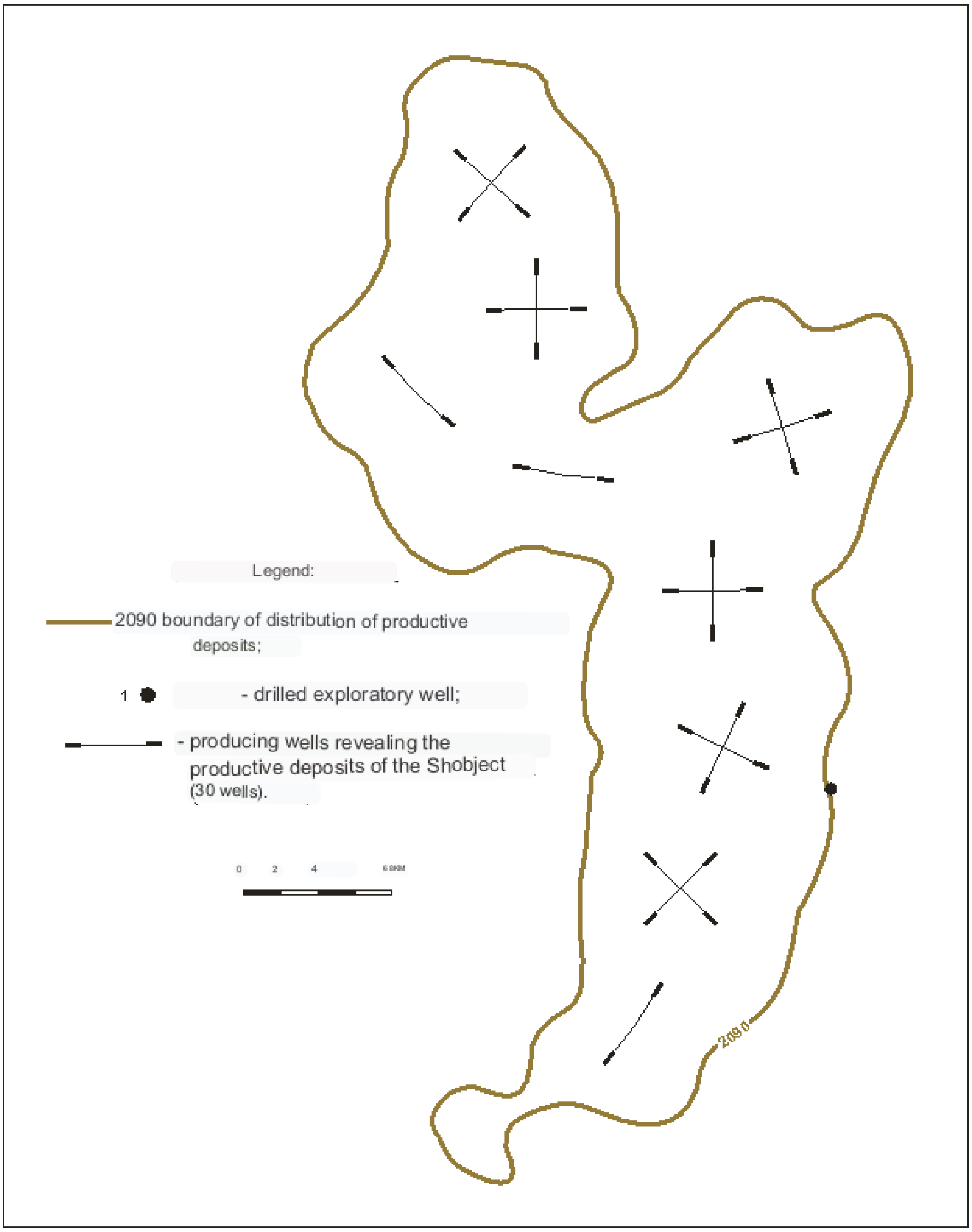


Figure 2.19 Scheme of the location of the wells of the Rusanovskoye field (Object III)

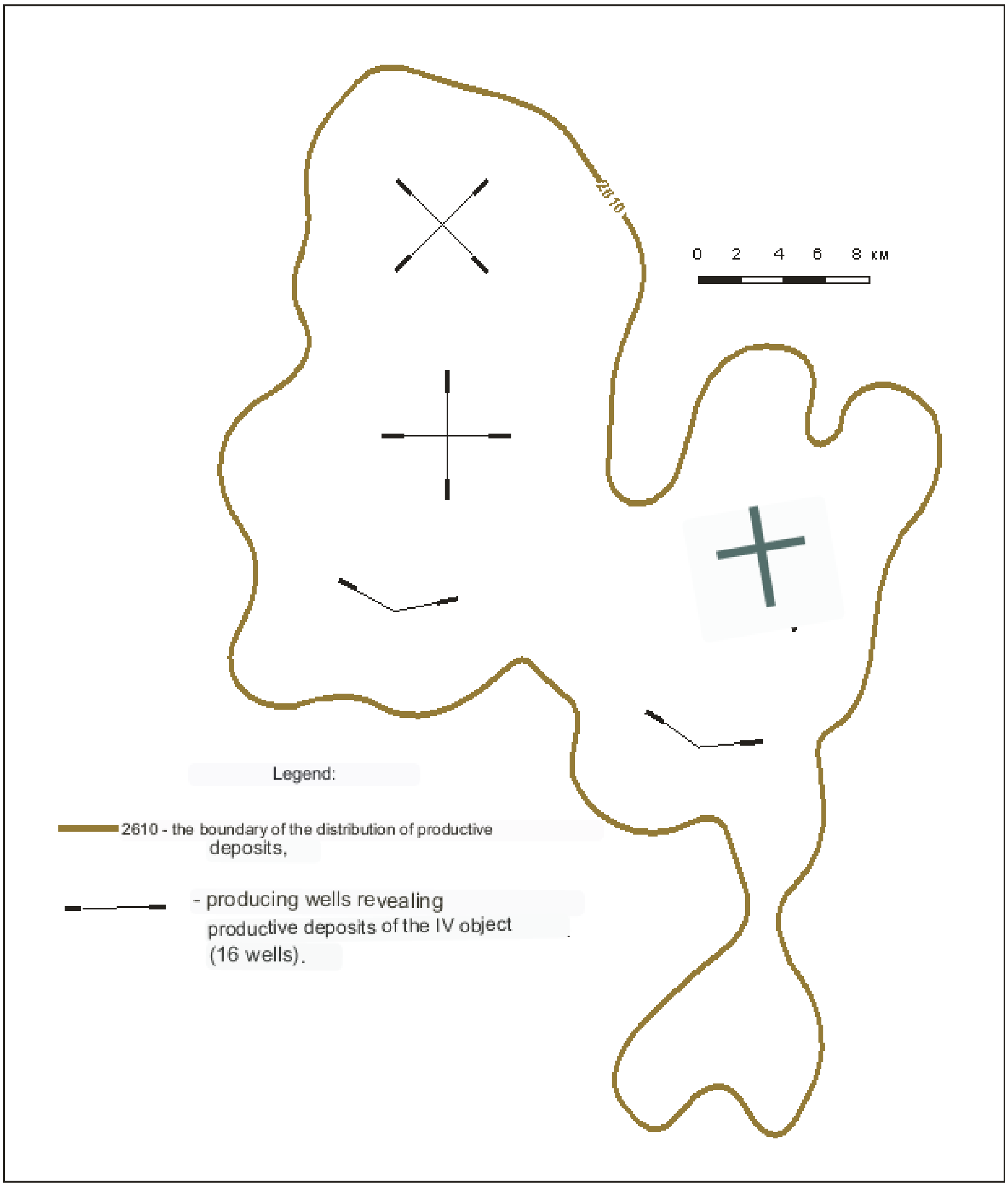


Figure 2.20 Scheme of location of wells of the Rusanovskoye field (Object IV)

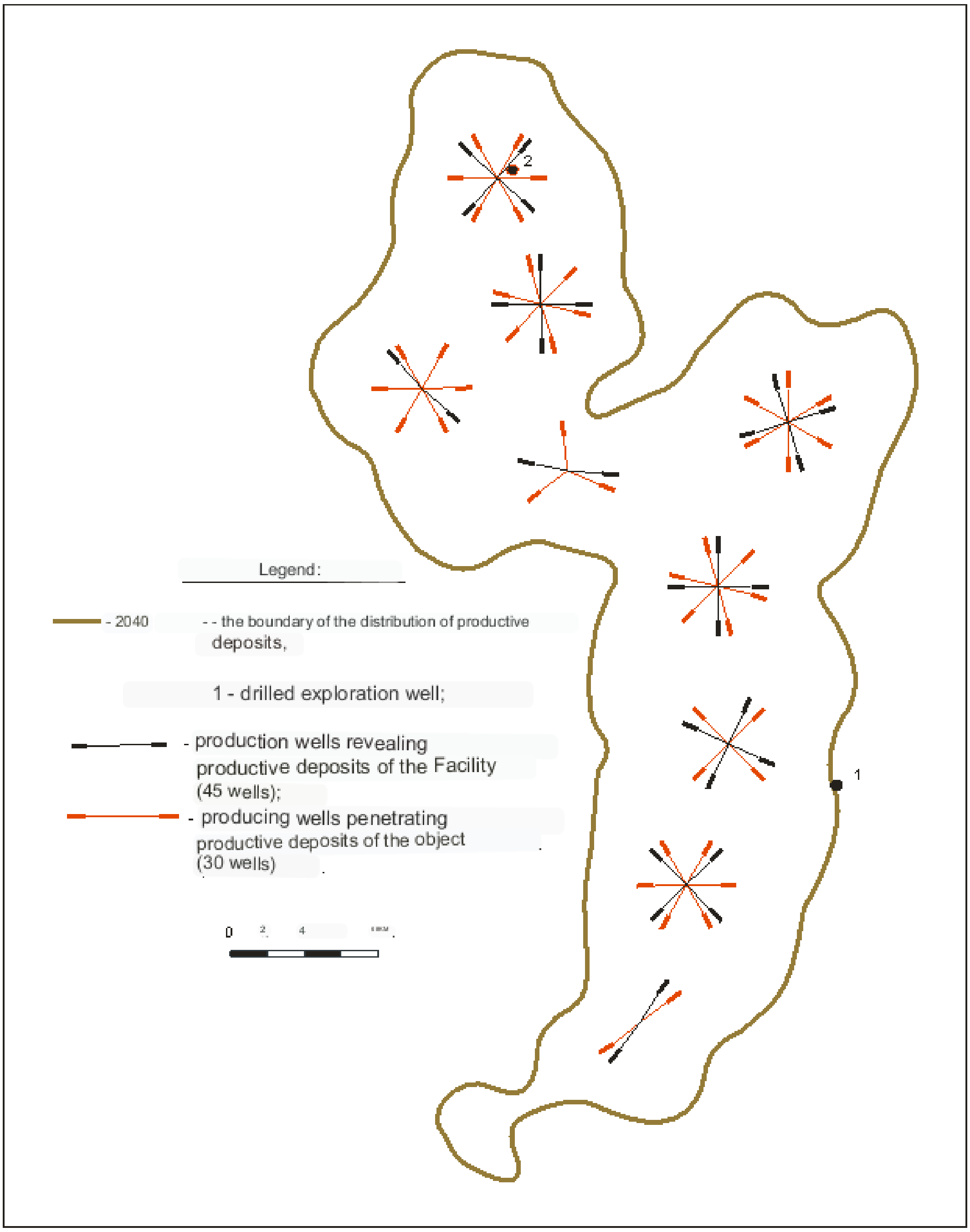


Figure 2.21 Scheme of location of wells of the Rusanovskoye field (Objects II and III)

3. SELECTION AND SUBSTANTIATION OF OPTIONS FOR THE DEVELOPMENT OF THE RUSANOVSKOYE AND LENINGRAD FIELDS WITH ACCOUNT OF THEIR TECHNICAL AVAILABILITY

3.1. Methodology for choosing a variant of the offshore field development concept.

It is known that the organization of work on the development and operation of offshore oil and gas fields depends on the availability of technical means, technologies and facilities that have been tested in domestic and foreign practice.

For the conceptual stage of project development, which is usually accompanied by a significant lack of geological and climatic information about the construction site, the most effective and objective form of choosing an acceptable design option for a field facility, taking into account the possible minimization of its cost, ensuring reliability and safety for the entire period of operation, is method of expert assessments.

The methodology for selecting options for the development of offshore oil and gas fields acceptable for further consideration can be divided into three stages:

1) Preparation and analysis of the initial natural-climatic, oceanographic and other conditions for the location and operation of field facilities;

2) Preparation and analysis of technological requirements affecting the design of commercial ice-resistant structures;

3) Formation of criteria for choosing an acceptable option.

All options considered must be comparable and meet the following conditions:

• meet the natural-climatic, oceanographic and other conditions of the field location area and all technological requirements for the operation of the facility being designed;

• calculations of external loads are carried out according to a single methodology;

• construction of a field facility provides for the use of Russian production facilities.

Criteria to evaluate and compare field facility design options include the following:

1. The technical level characterizing the experience of operating such structures.

2. Manufacturability, which characterizes the possibility of manufacturing platform structures at existing plants without significant reconstruction and the creation of additional or new infrastructure. This criterion can affect the construction time and, ultimately, the cost of the platform.

3. Efficiency of construction, taking into account the possibility of transporting the projected object and its installation at the point of operation using the available floating technical means and the possibility of cooperation of several plants in the manufacture of the structure, the ratio of the volume of construction and installation works (CW) onshore and at sea. Minimizing the amount of construction and installation work in open sea conditions is a positive factor in choosing an acceptable option. In world practice, there is a tendency to reduce the volume of installation of structural elements in the open sea.

4. Compliance with regulatory requirements, including estimated estimates of the values of horizontal and vertical movements, the provision of calculated indicators with regulatory requirements: strength, stability, etc.

5. Ensuring technical, fire and environmental safety.

6. Cost - is the most significant and weighty parameter, with favorable assessments of other criteria, since the capital intensity of offshore oil and gas fields development facilities significantly affects the profitability of field development.

When developing offshore fields and justifying the layout of production equipment, it is important to take into account the specific conditions of the region (for example, the Arctic) and identify the applicability of existing system solutions or identify gaps in the development / lack of technologies to provide design solutions. There are two types of gaps in the development of technologies:

• concepts that can be improved by new technologies, but proven technologies exist;

• concepts that are completely dependent on new technologies, as such technologies do not exist.

The level of technology readiness for use can be determined according to API RP17N [1] (Table 3.1).

Table 3.1 The level of technology readiness for use

Level	Development stage	Technology Description
TRL 0	Not a proven idea	Preliminary plan. Analysis or tests not performed
TRL 1	Analytically proven idea	Functionality is proven by calculation, reference to the general characteristics of existing technologies or tested on individual components/subsystems. This concept may not meet all requirements at this level, but demonstrates basic functionality and the potential to meet requirements when subjected to additional testing.
TRL 2	Physically Proven Concept	Conceptual solution or new characteristics of the solution, confirmed by the model or tests in the laboratory. The system reveals the ability to function in a "real" environment with imitation of key environmental parameters
TRL 3	Prototype test	Prototype built in real scale and tested to specification under limited operating conditions to demonstrate its functionality
TRL 4	Field trials	An experimental full-scale sample is created and tested according to the program for compliance with technical requirements under simulated or actual environmental conditions

Table continuation 3.1

TRL 5	Tests at the level of integration into the system	A full-scale prototype is created and integrated into the operational system with a full interface and testing for compliance with technical requirements
TRL 6	System installation	A full-scale prototype is built and integrated into the intended operational system with a full interface and performance testing in the intended natural environment and has successfully operated for > 10% of the intended life
TRL 7	Proven Technology	The production unit is integrated into the operational system and has successfully operated for > 10% of the expected life

As a rule, many oil and gas operators declare the readiness of new technology for implementation in the fields at the completion of the TRL 4 and TRL 5 development stages.

The problem of ensuring reliability is one of the most important in the development of offshore fields, since maintenance and (or) replacement of technological or other equipment at sea, as a rule, requires high costs.

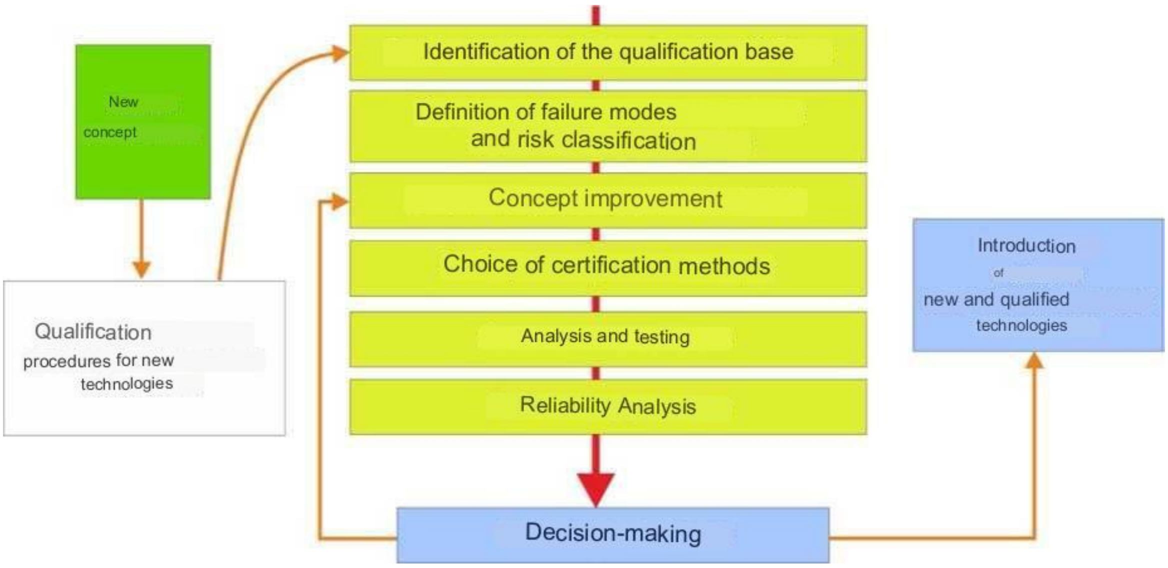


Figure 3.1 Decision-making algorithm for evaluating the reliability of offshore technologies

The reliability of new technologies can be assessed according to the scheme shown in Fig. 3.1, which is based on the methodology developed by the Norwegian Qualification Society DNV [2].

These criteria are transferred to the experts together with the designs of design options for subsequent evaluation and selection of the main option. Each criterion is evaluated by an expert on a 10-point system. Only highly qualified specialists are allowed to peer review. To reduce the subjectivity of experts' assessments, a weight coefficient from 1 to 5 is introduced for each criterion. After filling in the tables by experts, average assessments are displayed that determine the positions of the options under consideration. The final results of the evaluation of the criteria, taking into account the weighting coefficients (K), the number of criteria (n) and the number of experts (m), determine the ratings of design options (R), obtained from the expression:

$$R = \frac{\sum_{i=1}^{m} K_i E_i}{n}, \quad (3.1.1)$$

where: R - design option rating;

m - number of experts;

Ei - expert estimates;

Ki - weighting factor;

n is the number of criteria

3.2. Selection and justification of field development options

3.2.1. Selection and analysis of options for platform and underwater development of the Rusanovskoye and Leningradskoye fields

Of the stationary structures, ice-resistant platforms are the most widely used in the development of deposits on a freezing deep-water shelf [3].

Based on the development scheme for the development of the Rusanovskoye and Leningradskoye fields, the following options for ice-resistant stationary structures and their combinations (complexes) were considered:

• IRP - ice-resistant stationary platform. Platforms with a cone-shaped and prismatic support base were considered.

• IDC - an ice-resistant block-conductor with the functions of providing year-round drilling of wells using a mobile drilling complex (MDK) and placement of wellhead equipment above water.

• MIRP - a mobile ice-resistant drilling platform for drilling a cluster of production wells in a year-round mode in combination with an underwater production complex (UPC).

The analysis of all platform options was carried out taking into account the main natural and climatic features of the Arctic shelf:

• presence of silted soils with low bearing capac

• severe ice conditions.

• significant lithodynamic processes.

• short navigation period.

• significant remoteness of the production infrastructure from the platform construction site.

In accordance with these features, it is provided:

• appraisal of the applicability of gravity and piled foundations for the supporting base of platforms, artificial island structures and subsea production systems.

• removal of surface layers of weak soil and their replacement with soils with better strength characteristics.

• use of inclined structural elements and minimized dimensions of the supporting part hull in the area of ice impacts.

• partial deepening of the hull of the supporting part below the level of the bottom of the water area in order to protect the soils of the base of structures from erosion by the underwater current.

• determination of the weight and size characteristics of the supporting parts of platforms, taking into account the conditions of construction and operation, as well as the results of calculations of stability on the ground during operation and stability during offshore operations during towing and installation at the field.

At the ice-resistant fixed platform IRP (Fig. 3.2), the supporting part consists of a hull, a bearing deck, on which the VSP is located. The all-welded body of the platform has the shape of a truncated cone or a multifaceted pyramid.

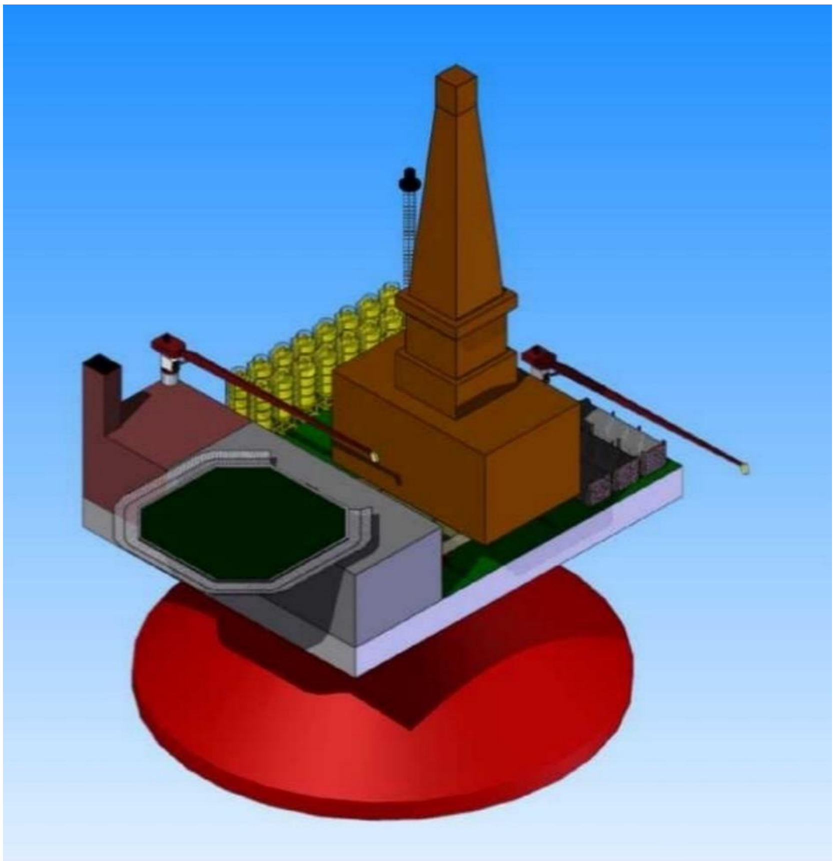


Figure 3.2 Axonometric image of the IRP

The overall dimensions of the supporting part are taken from the conditions of drilling up to 20 wells, placement of risers of underwater pipelines. On the upper deck of the platform there are: a living block with control posts, power and derrick winch blocks, a diverter, warehouses for pipes and bulk materials.

The drilling complex provides for the use of a drilling rig BU 5000/250 EK-BM (Ch). The operational complex is connected to work after drilling of the first production well and ensures the performance of standard operations: well flow rate measurement, control of X-mas tree and injection valves and downhole shutoff valves, transport of well production to the onshore gas treatment plant; development, purging and discharge of wells; well killing.

The residential block is designed to accommodate 90 people. and represents a multi-tiered structure with residential and amenity premises. To improve fire safety, the side of the reinforced concrete block facing the drilling equipment does not have portholes, and the sides with portholes are equipped with external decks with ladders to provide additional escape routes.

As a development of this concept, a two-block complex of ice-resistant platforms was considered, shown in fig. 3.3.

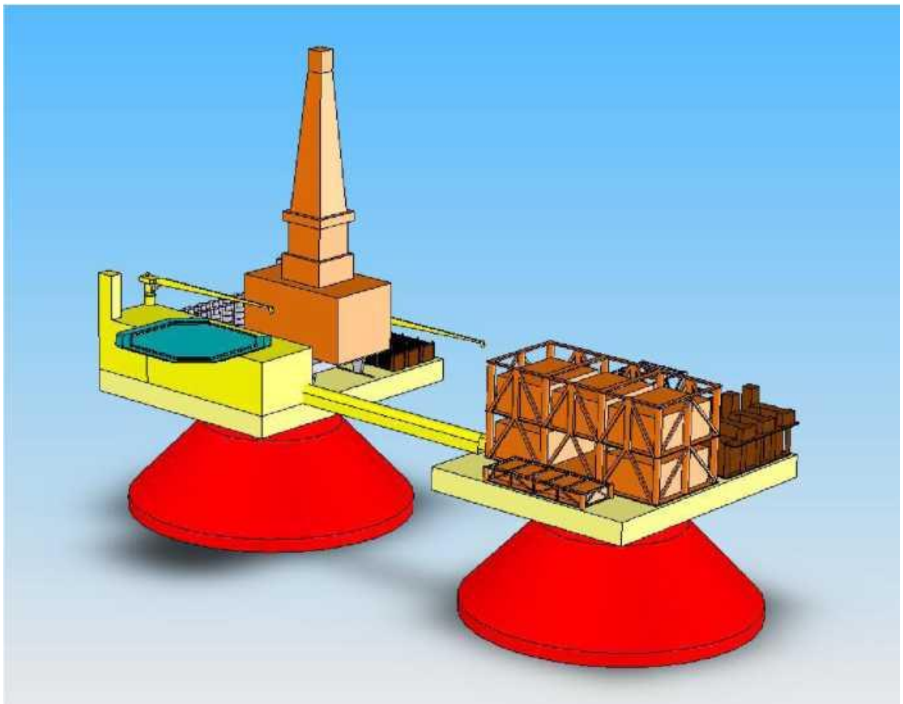


Figure 3.3 Axonometric image of the complex

The platforms of the complex are conditionally designated as IRP -BZh, that is, a platform for drilling with a residential block and IRP -K. The IRP -K platform is a technological platform with the function of gas preparation for transport and compression. IRP -K will be provided with electricity and housing from IRP -BZh, while the cables will be underwater, and a separately mounted bridge will serve for people to cross. Helicopter complex on IRP -K is not provided due to its presence on IRP -BZh. The topside houses equipment for partial preparation of gas for transport and its compression. According to rational field development options, IRP -K will be required 10-12 years after IRP -BZh is put into operation and gas production begins. This ensures the postponement of capital investments for the construction of IRP K.

An analysis of the technologies for construction, setting up a point and removing it from a point shows that the considered IRP can be manufactured at Russian shipbuilding plants. IRP has a draft of ~ 4 m and sufficient stability for towing by sea. It is also possible to tow from the construction plant on a transport barge with subsequent launching in the area of anchoring.

The technology of construction, installation at the point and removal from the IRP -K point is similar to the technology for IRP -BZh with the difference that after the installation of IRP -K, it will be necessary to install a bridge connecting IRP -K with IRP -BZh. The bridge ~70 m long and ~200 tons weight can be delivered on a barge and installed using a floating crane.

The IDC variant is a small-sized platform operating in an automatic unmanned mode, which serves as a support structure for drilling production wells through it with the help of a PBK and placing drilled wellheads on it.

The supporting part of the IDC is a steel spatial structure made in the form of a truncated polyhedral pyramid with inclined side faces. In accordance with the purpose of the IDC, the supporting part has the minimum required dimensions to accommodate the wellhead equipment of eight wells. Inside the body of the supporting part above sea level, a deck structure is provided, on which wellheads with equipment, manifolds, etc. are placed.

IDC can be made both with a carrier deck, on which a living block with a helipad is located, and without a deck and the indicated buildings. The choice of option depends on the operating conditions and the availability of the necessary floating facilities. We have considered the design of the IDC with a carrier deck, a living block and a helipad (Fig. 3.4).

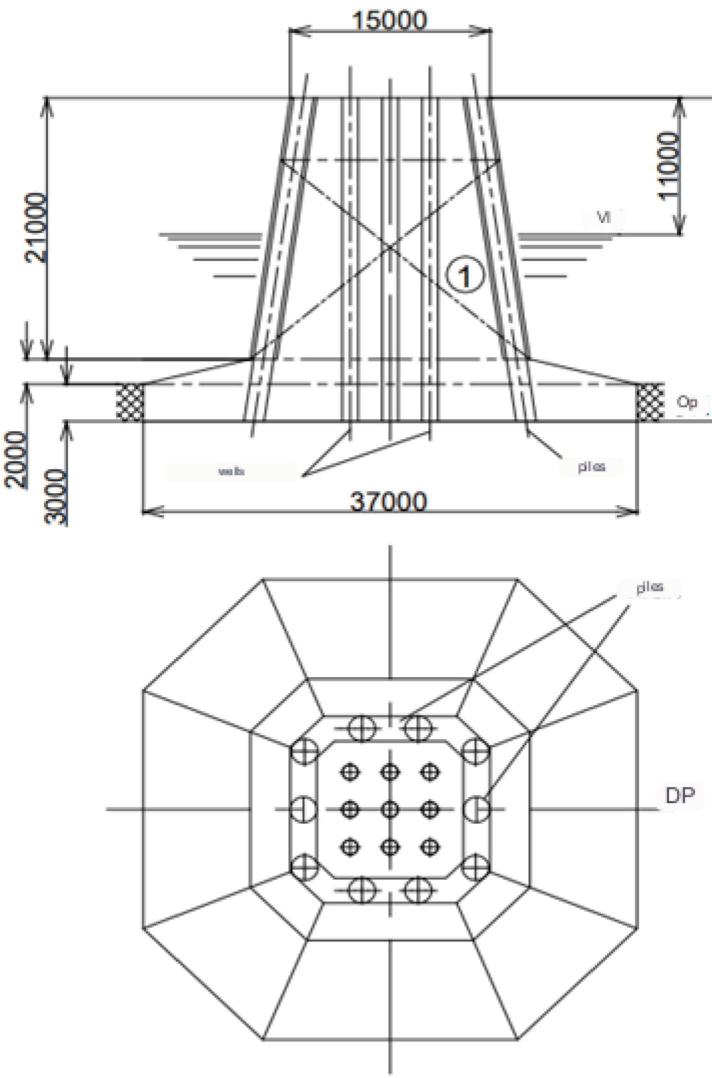


Figure 3.4 IDC General layout

There are three options for drilling wells using IDC:

• With the help of a mobile ice-resistant drilling platform (MIRP).

• With the help of a mobile drilling complex (PBK).

• With the help of a jack-up floating drilling rig (jack-up rig) during the navigation period.

In the first two cases, wells are drilled year-round. When using a jack-up rig, the main problem that hinders the use of technologies in a year-round mode is the timely delivery of goods to the jack-up rig during the ice period. Therefore, we are considering the possibility of using a mobile drilling complex (UDC) as a means of drilling wells with IDC. The general view of the UDC is shown in fig. 3.5.

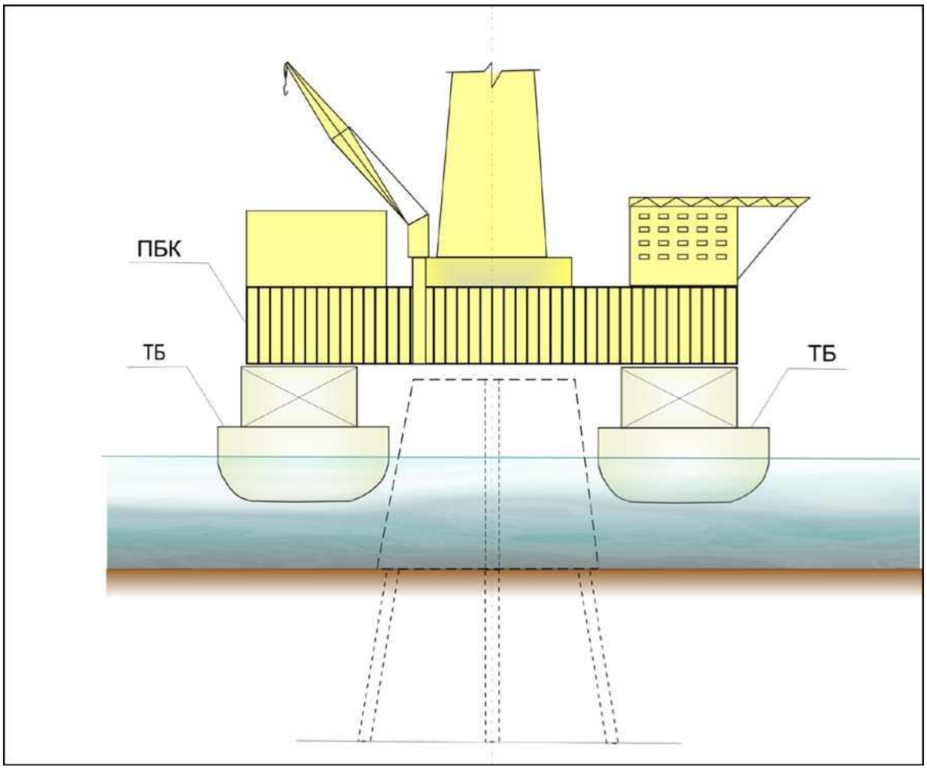


Figure 3.5 General view of a mobile drilling complex with transport barges (ПБК-UDC, ТБ-TB)

The UDC is a carrier deck with a complete set of drilling and auxiliary equipment (including accommodation module) installed, designed for drilling 8-10 production wells. UDC is installed temporarily on IDC for drilling wells. After completion of drilling operations, the UDC is dismantled and moved to another IDC Two transport barges are used for moving (transferring) the FCU from one LCU to another, as well as for installation and subsequent dismantling. The value of the transport draft of the UDC is assumed to be 3-4 m.

The "UPC-MIRP" complex is used for drilling underwater production wells and their subsequent operation with the help of an underwater production complex (UPC). The complex consists of 3 blocks: the hull structures of the MPC, the subsea foundation (PFO) and the mobile ice-resistant drilling platform (MIRP), which performs drilling.

In the water area, first, the PFD and the protective box of the MPC (without a cover) are installed, then the PFD is fixed with piles and protective backfilling is carried out. Installation on a prepared underwater base is carried out using a crane vessel, which is also planned to participate in driving piles for fixing platforms and other works.

After the installation of the PFD and the base plate of the MPC with protective walls, the MIRP is installed on the PFD, fixed on it, performs drilling, and upon completion of drilling, it unfastens, emerges and is diverted by tugs for further use at another point.

A variant of the three-dimensional model of the complex is shown in fig. 3.6, and the main stages of installation of the MPC in fig. 3.7.

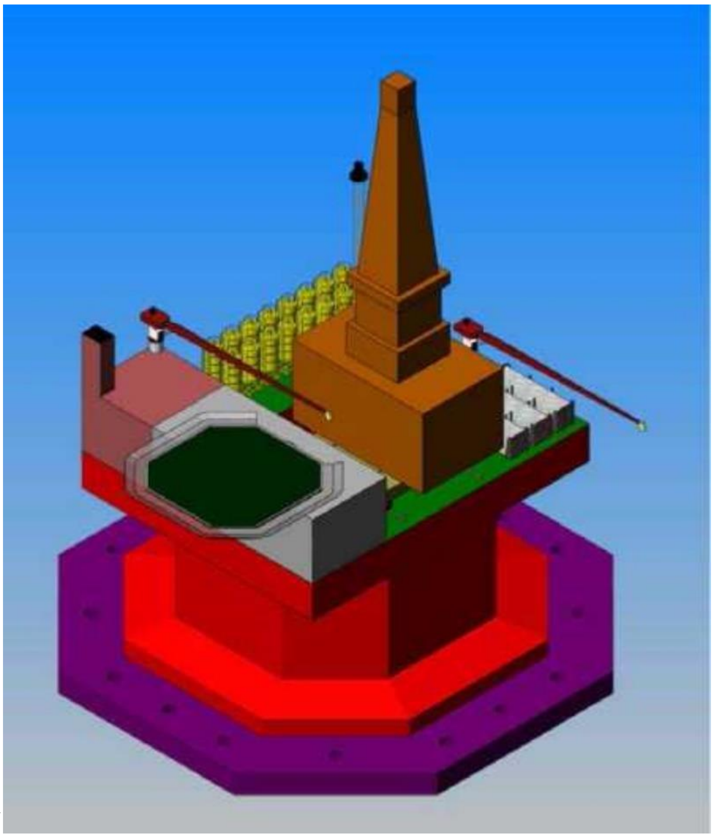


Figure 3.6 Complex "MIRP - UPC -UWF"

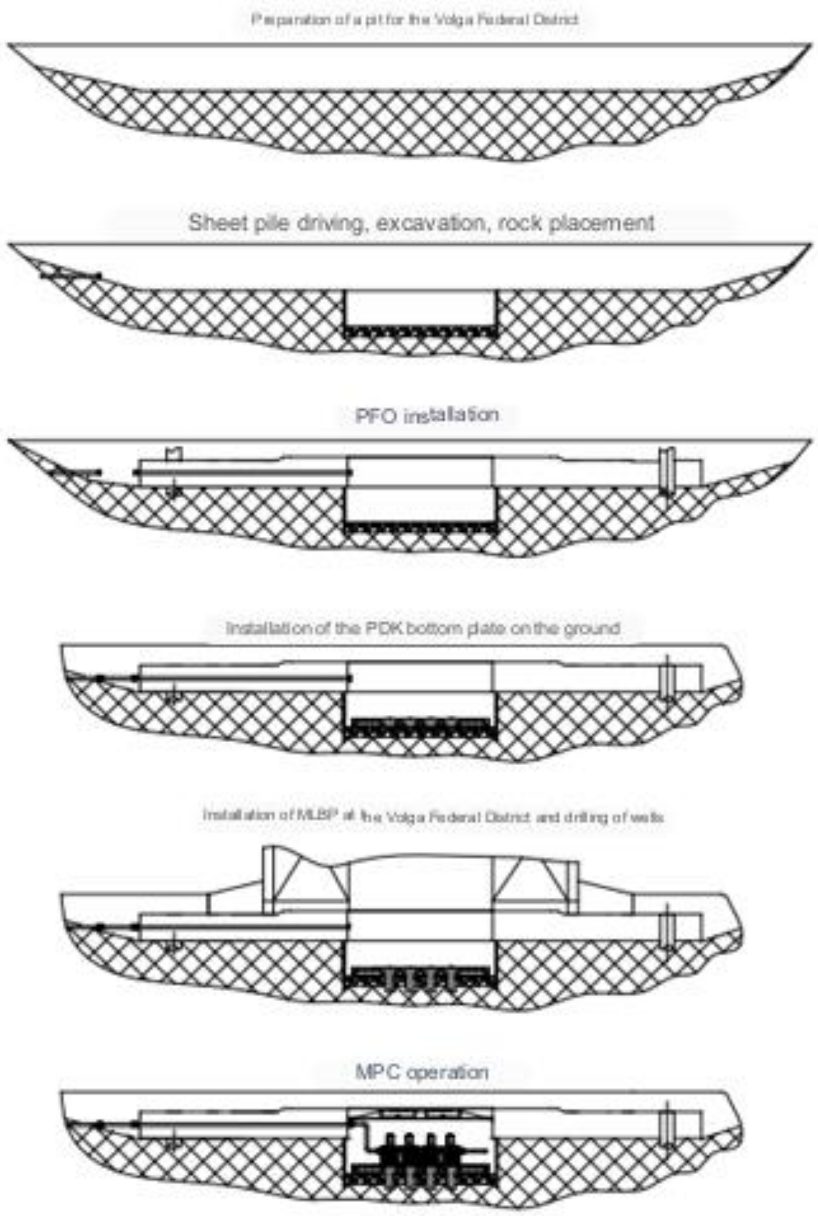


Figure 3.7 The main stages of the installation of UPC

The concept of a mobile ice-resistant drilling platform that provides drilling for MPC involves an ice-resistant hull on which the topsides are mounted. Drilling is carried out through a niche that runs along the entire height of the MIRP body. Underwater Christmas trees (FA) can be loaded through this niche. The topsides of the MIRP and the wells are arranged in such a way that the RC is as far as possible from the tower-winch block (VLB) and from the flare boom. The MIRP is equipped with a helipad that meets the requirements [4], as well as a special cradle for transferring people using a crane [5]. On the upper deck (VP) of the MIRP there is a drilling rig with moving devices, pipe storages, a residential block, a power block, and crane equipment.

Ballast tanks are located in the area of the waterline (WL) and below it in the ice-resistant hull of the MIRP. They allow you to immerse the MIRP to the depth of setting on the PFD and provide additional clamping weight.

Summary data on the considered alternative IRP options are presented in Table. 3.2 - 3.3 and options using underwater production systems - in Table. 3.4 - 3.5.

Table 3.2 Summary technical characteristics of the IRP options considered.

Parameter	Option 1		Option 2		Option 3
	IRP-BJ1	IRP -K1	IRP -BJ2	IRP -K2	IRP (monoblock)
Number of wells, pcs.	20	20	20	20	20
Ice-resistant hull weight, t	8330	7930	10800	10400	24000
Aircraft support deck weight, t	2000	2000	1230	-	-
Communication bridge, t	200		200		-
Mass of IRP metal structures, t	21760		23930		25000
Solid ballast (sand), t	-	-	4300	4300	20000
Empty displacement, t	14370	11900	20370	16670	49220

Table continuation 3.2

Empty draft, m	4,4	3,9	4,0	3,2	5,4
Water ballast, t	33870	33870	42940	30200	73690
Minimum clamping force to the ground, t	5780	5470	7360	3610	14240
Ice-resistant hull shape	cone	cone	prism	prism	caisson
Tilt of the ice-resistant hull relative to the vertical, degrees	45	45	0	0	13
Dimensions of the ice-resistant base LxBxT, m	B65x26	B65x26	73x73x26	73x73x26	102x102x26
Dimensions including BC LxBxT, m	82x82x96	65x65x44	102x89x92	73x73x39	127x109x91
Number of piles, pcs.	20	20	20	20	35
Diameter x Thickness of a pile, (mm)	1800x50	1800x50	2400x50	2400x50	2400x50
Pile length, m	70	70	50	50	50
Pile inclination relative to the vertical	1:7	1:7	-	-	-

Table continuation 3.2

Elevation of the pile above the level of the bottom soil	23	23	flush	flush	flush
Metal consumption of piles, t	6040		5760		5040
i	1. Installation of an ice-resistant base 2. Mounting the aircraft using submersible pontoons		1. IRP installation without helipad 2. Installation of a helipad by a floating crane		Installation and fixing of the entire IRP
Pit volume, m	64230	64230	83940	83940	136850
Backfill volume, m	40280	40280	45930	45930	103000
Relative reliability and testing of technical solutions	0,8		0,9		1
Possibility of phased financing	+		+		-

Table 3.3 Summary economic indicators of IRP options

Parameter, dimension	Option 1		Option 2		Option 3
	IRP-БЖ1	IRP -К1	IRP - БЖ2	IRP -К2	IRP monoblock)
Mass of IRP metal structures, t	21760		23930		25000
Metal consumption of piles, t	6040		5760		5040
IRP construction cost, million rubles	4950	4560	5690	4760	10920
IRP design cost, million rubles	800	640	800	670	1200
The cost of piles, million rubles	332	332	316	316	554
The cost of marine operations projects, mln.r.	50	50	50	50	50
The cost of the communication bridge, million rubles	0	60	0	60	0
The cost of diving operations, million rubles	0,46	0,46	0,6	0,6	0,98
IRP towing cost, million rubles	22,66	22,66	34,6	34,6	45,32
The cost of towing piles, million rubles	17,76	17,76	17,76	17,76	35,52

Table continuation 3.3

The cost of towing the bridge, million rubles	0	1,94	0	1,94	0
Excavation cost, million rubles	88,63	88,63	115,83	115,83	188,85
The cost of sand and gravel mixture, mln.r.	7,97	7,97	10,56	10,56	22,73
The cost of backfilling the sand and gravel mixture, mln.r.	12,91	12,91	17,1	17,1	36,81
The cost of crushed stone, million rubles	14,57	14,57	18,05	18,05	19
The cost of crushed stone dumping, mln.r.	20,89	20,89	25,88	25,88	27,24
The cost of the stone, million rubles	8,01	8,01	11,19	11,19	32,82
The cost of filling the stone, mln.r.	90	90	12,57	12,57	36,84
Total cost of earthworks, million rubles	10,5	10,5	15,4	12,4	22,8
The cost of installing IRP at a point, mln.r.	25,62	25,62	19,06	19,06	36,32
The cost of piling, million rubles	144,15	144,15	96,1	96,1	168,18
The cost of cementing piles, million rubles	31,72	31,72	21,93	21,93	23,79

Table continuation 3.3

The cost of completion at the point, mln.r.	1	1	1	1	0
The cost of demobilization of leased boats, million rubles	10	10	14	14	20
The total cost of work on IRP, mln.r.	6638,85	6150,79	7287,63	6286,57	13441,2
The total cost of the option, million rubles	12790		13574		13441

From Table. 3.3 it follows that the IRP -BZh1 + IRP -K1 variant (with a cone-shaped hull) wins somewhat economically. At the same time, the adopted technical solutions regarding the installation of topsides have not been sufficiently tested in practice. From the point of view of reliability, simplicity and approbation of technical solutions, the option using a monoblock IRP is preferable.

Table 3.4 Summary technical characteristics of the considered options using mining complexes

Parameter	Objects when using IDC		Objects when using MPC			
	IDC	UDC		UPC	MIRP	PFO
Number of wells, pcs.	8	8		8	8	-
Ice-resistant hull weight, t	3000				7800	
Aircraft support deck weight, t	-	1500			1230	
Mass of metal structures, t	PBK и PPE	2500		350	10030	3000

Table continuation 3.4

Solid ballast (sand), t	2000					
Empty displacement, t	5000	4350		-	12900	
Empty draft, m	5,0	1,8		-	4,4	
Water ballast, t	4820	-		-	-	-
Minimum clamping force to the ground, t	1515				7400	3000
Ice-resistant hull shape	pyramidal	-		-	prism	-
Tilt of the ice-resistant hull relative to the vertical, degrees	1:7	-		-	-	-
Dimensions of the ice-resistant base LxBxT, m	37x37x26					
Aircraft support deck dimensions LxBxT, m	-	60x40x7			64x64x2	
Number of piles, pcs..	10	-		-	-	20
Diameter x Thickness of a pile, (mm)	1800x50*	-		-	-	2400x50
Pile length, m	70	-		-	-	50
Pile inclination relative to the vertical	1:7	-		-	-	-
Elevation of the pile above the level of the bottom soil	23	-		-	-	flush
Metal consumption of piles, t	1510	-		-	-	2880
Pit volume, m^3	36080	-		-	-	141220

Table continuation 3.4

Filling volume, m^3	39560	-		-	-	68170
Relative reliability and testing of technical solutions	Setting up the deck with the aircraft on an ice-resistant base from 2 pontoons, between which the deck is located, is carried out for the first time		The use of a mobile drilling rig and a PFO is offered for the first time			

Table 3.5 Summary economic indicators of alternative options for mining complexes

Parameter, million rubles	Objects when using UDC			Objects when using MPC		
	UDC	PBK		UPC	MIRP	PFO
Total mass of metal structures, t	9550			13380		
Metal consumption of piles, t	1510	-		-	-	2880
The cost of the object, million rubles	940	1090		150	4380	940
The cost of piles, million rubles	166	-		-	-	317
Cost of offshore operations projects, million rubles	20	10		5	10	20

Table continuation 3.5

The cost of preliminary diving operations, mln.r.	0,26					0,86
Towing cost, million rubles	5,66	24,67		1,94	34,60	23,07
The cost of towing piles, million rubles	8,88	-		-	-	17,76
Excavation cost, million rubles	49,80	-		-	-	194,88
The cost of sand and gravel mixture, mln.r.	3,64	-		-	-	15,55
The cost of backfilling the sand and gravel mixture, mln.r.	5,89	-		-	-	25,18
The cost of crushed stone, million rubles	4,03	-		-	-	23,32
The cost of crushed stone dumping, mln.r.	5,78	-		-	-	33,44
The cost of the stone, million rubles	3,99	-		-	-	9,69
The cost of filling the stone, mln.r.	4,47	-		-	-	10,88
The cost of installing IRP at a point, mln.r.	131,07	-		-	-	37,20
The cost of piling, million rubles	72,07	-		-	-	96,10
The cost of cementing piles, million rubles	15,86	-		-	-	21,93

Table continuation 3.5

The cost of completion at the point, mln.r.	0,50	-		0,50	-	-
The cost of demobilization of leased boats, million rubles	3,00	5,00		3,00	14,00	5,00
The total cost of work on IRP, mln.r.	1440,9	1129,67		60,44	4438,6	1791,86
The total cost of the option, million rubles	3979,31			6390,9		

From Table. 3.5 it follows that the option of the mining complex using MPC is much more expensive than the option using IDC.

3.2.2. Recommended options for platform development of the Rusanovskoye and Leningradskoye fields

In accordance with the results of the analysis according to the methodology described in Section 3.1 and the recommended technological option for the development of the Rusanovskoye and Leningradskoye fields with two well clusters, two alternative options are recommended as the main platform for drilling 20 wells:

a) monoblock IRP and its two-block structural modification with a residential block located separately from the main production platform, connected by a communication bridge;

b) IDC is proposed for drilling two pads out of 8 wells.

For drilling wells at all IDC s, it is recommended to use a mobile ice-resistant drilling platform (MIRP), designed for year-round drilling of production wells.

The two-block platform consists of two separate blocks: IRP "B" and IRP "Zh", interconnected by a bridge with a span of 50-70 m. The general view of the two-block platform is shown in Fig. 3.8.

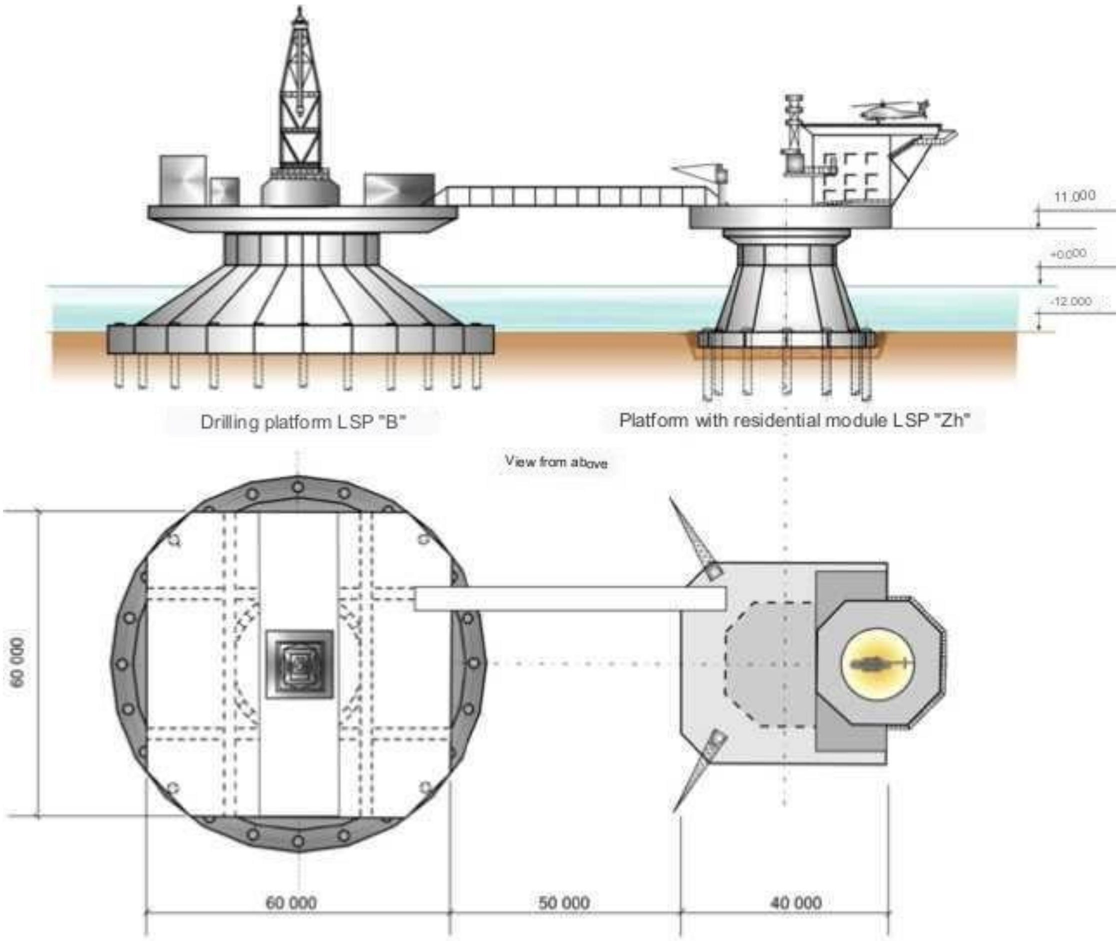


Figure 3.8 Two-block platform IRP "B" + IRP "Zh"

In comparison with monoblock structures, a two-block design has the following advantages: increased safety of the location of the residential module away from high-risk areas; conditions for the construction of a platform, consisting of two separate blocks, having relatively smaller weight and size characteristics than one larger monoblock structure, are facilitated.

At the same time, in terms of metal consumption and cost, the two-block platform, although slightly, is inferior to the monoblock platform.

The design of the supporting part is offered in two versions, differing in the design of the foundation part. Option 1 provides for the use of inclined piles passing tent-like through the entire height inside the body of the supporting part.

Option 2 provides for the use of vertical piles located under water along the perimeter of the developed foundation part of the structure. In both versions, the stability of the platform is ensured by driving piles d = 1800x50 mm, in the amount of 20-24 pieces.

Two variants of IDC are offered, differing in the design of the pile foundation. In one case, inclined piles are used, in the second, vertical ones. In both cases, the stability of the IDC is ensured by driving piles d = 1800x50 mm, in the amount of 12 pieces and driving depth of 50-70 m.

The design of the IRP "Zh" differs from the IDC in the presence of a carrier deck on which the residential module is located, and the absence of tubular guides for drilling wells. The body of the supporting part of the IRP "Zh" and the design of the pile foundation are similar to the IDC.

MIRP is necessary for drilling production wells in a year-round continuous mode when using IDC or MPC. In non-freezing water areas, where there are no problems associated with ice, conventional jack-up drilling rigs (jack-up drilling rigs) with an overboard console with a drilling rig are used for similar purposes.

Drilling wells using a jack-up rig and IDC is possible, but only during the navigation period. With this approach, the drilling of a cluster of 8 wells will last 4 years at the rate of two wells in one season. With the use of MIRP, a cluster of 8 wells with underwater or above-water wellheads is expected to be drilled within 1 year. But there are no active MIRP in the world.

An insufficiently studied problem is also the applicability of MPC in the hydrological and engineering-geological conditions of the Kara Sea.

CONCLUSION

In this paper, 14 different platforms were considered, which are operated on the shelves of both Arctic and non-Arctic seas. And this showed that with all the huge amount of explored hydrocarbon reserves on the shelf, we do not have much experience in the development and development of such oil and gas fields on the shelf of the Arctic seas.

Comparison of the results of the analysis and classifications of platforms, as well as the method of enlarged calculation, made it possible to select the most effective design of the supporting block of the oil and gas production platform for the conditions of the Rusanovskoye and Leningradskoye fields. And this, in turn, made it possible to create a methodology for selecting an effective platform design for the development of offshore fields in the Arctic seas.

On the basis of the studies carried out, rational schemes for platform development of deposits were determined and two alternative options were recommended for implementation:

- monoblock IRP and
- its two-block structural modification with a living block located separately from the production platform, connected by a communication bridge.

Such a scheme, despite a slightly higher cost, provides increased security for the location of the residential module.

For the recommended options for the development of the Rusanovskoye and Leningradskoye fields, when drilling two remote pads from 8 wells, it is proposed to use an ice-resistant block conductor.

The technical solutions for the design of the MPC, intended for the implementation of schemes of arrangement using underwater technologies, as well as issues of reliability, maintenance and repair of underwater equipment, are considered.

The inaccessibility of wells is the most significant disadvantage of using underwater construction methods. The use of MPC in the conditions of the Arctic shelf is possible, but is associated with a high risk of operation. An alternative technical means of the MPC is an ice-resistant block-conductor capable of functioning like a MPC in an unmanned automatic mode. Therefore, the decision to apply one or another method must be made on the basis of a comparative assessment of their technical and economic characteristics.

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