Features of the transport system of the Republic of Sakha (Yakutia) and the substantiation of the need for searching of ways to increase the reliability of coal supply

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Abstract. The article describes the transport corridors of coal delivery to remote hard-to-reach consumers of the Republic of Sakha (Yakutia). A brief description of the waterways and the timing of their operation are given. The conditions of functioning of winter roads are reflected. The main risks of coal delivery are described. The article describes the whole cycle of finding coal in the open air from the moment of production to the final consumption in boiler houses. The results of experimental analysis and modeling of oxidation state during delivery are presented. The economic inexpediency of forming long-term coal reserves is explained, while maintaining the traditional technology of transportation and storage. The economic difficulties of the organization of coal supply have been singled out. As a result of the analysis of the current state of coal supply, key points of improving the coal supply system of the Republic of Sakha (Yakutia) are highlighted.

1 Introduction

Reliability of fuel supply is a steady receipt of quality fuel in the required volume. Regions of the North have serious natural unevenness of processes of supply and consumption of fuel [1]. The peculiarity of the transport systems of the North-East of Russia is a large number of remote hard-to-reach fuel consumers.

Difficult consumers do not have year-round service routes with fuel supply centers. Their transport corridors strongly depend on natural and climatic conditions. Remoteness is a factor complicating the delivery of goods. Thus, a remote, inaccessible consumer is a consumer who has unserved seasonal long distance communication routes. All 268 settlements and industrial facilities in the Arctic and northern regions of the Republic of Sakha (Yakutia) belong to such consumers.

Difficult access is the main cause of high risks of supply disruption. Here are some examples:

• Strong shallows on the river Yana in the navigation period of 2009 made it difficult to deliver fuel to the Verkhoyansk district. It was planned 50 thousand tons of coal for the heating season of 2010. In fact, about 16 thousand tons were delivered. The reason for this

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was the change in the wintering place of dry cargo barges. Part of the fuel was delivered by winter roads. Additional costs amounted to about 70 million rubles, without taking into account the rise of coal prices [2].

In 2015, since the beginning of the winter, warm weather has set in the Abyisky district and in the village of Abyj coal reserves were not sufficient until the opening of the winter road and a new supply of fuel. The boiler house that consumes 10 tons of coal per day worked with a total reserve of 35 tons for about 2 weeks. To support the supply of heat, a combined furnace was used: coal with wood. The shortage of coal reserves arose due to the overrun of coal in connection with the joining to the village heating of new houses that were recently commissioned. At that time in the village lived 500 people [3–6].

Due to a coal deficit in the village of Abyj, a tragic event occurred. On December 2, 2015, three "Ural-583100" vehicles belonging to the Abyisk branch of the State Unitary Enterprise "Housing and communal services of the RS (Y)" (SUE "HCS RS (Y)"), left Belaya Gora settlement for delivery of coal. The total weight of each vehicle was 15 tons. All three cars fell through the ice 30 km from the village of Belaya Gora during the passage of the ice crossing of the river Indigirka. One of the drivers died, two were taken to the hospital with hypothermia. The investigators determined that at the time of the incident the maximum permissible mass of vehicles should not be more than 10 tons [7, 8].

In February 2017, difficulties arose in the preparation of winter roads to settlements: Andryushkino (Nizhnekolymsky District – fig.1), Aleko-Kuel, Ebah and Berezovka (Srednekolymsky ulus[1]), Deputatsky, Saylyk, Tumat, Yukagir, Kazachye (Ust-Yansky ulus), Honuu (Momsky ulus) due to abnormal precipitation. The estimated cost of additional funds for the delivery of fuel was about 500 million rubles only to the objects of SUE "HCS RS (Y)" [9].

Fig.1 The winter road. Nizhnekolymsky District, 2017.

After in February 2017 managed to establish transport communication with remote settlements, another problem arose – ensuring the traffic intensity. The heavy financial condition of the largest life-sustaining enterprise in Yakutia – SUE "HCS RS (Y)" – did not allow making contracts with a sufficient number of carriers on time.

[1] Ulus – national district

2 Characteristics and features of the transport system

Fig. 2 shows the main transport corridors for the delivery of coal to remote hard-to-reach consumers in the Republic of Sakha (Yakutia). The entire planned volume of coal is delivered to intermediate (depot) warehouses along these corridors. Then it is transported to final consumers along winter roads of municipal importance. Coal is delivered to intermediate warehouses by water in normal mode. With disruption of navigation, the lack of coal is imported along the winter roads. The navigation period for the delivery of goods along the Yana and Indigirka rivers lasts from the end of May to the middle of September, only 3.5 months. There are different length breaks in the movement of vessels in different areas. They are caused by natural and climatic factors: storm conditions, low water level, unfavorable situation on river bars (winds, storms). The non-constancy of the conditions for navigation causes a non-uniform flow of cargo, which also complicates its processing at the transshipment points. The emergence of queues at such points is not a rare phenomenon.

Fig.2 The main transport corridors (waterways and winter roads of regional importance) supply of remote hard-to-reach consumers of the Republic of Sakha (Yakutia).

The Extent and function periods (for 2016) of waterways are shown in Fig. 3.

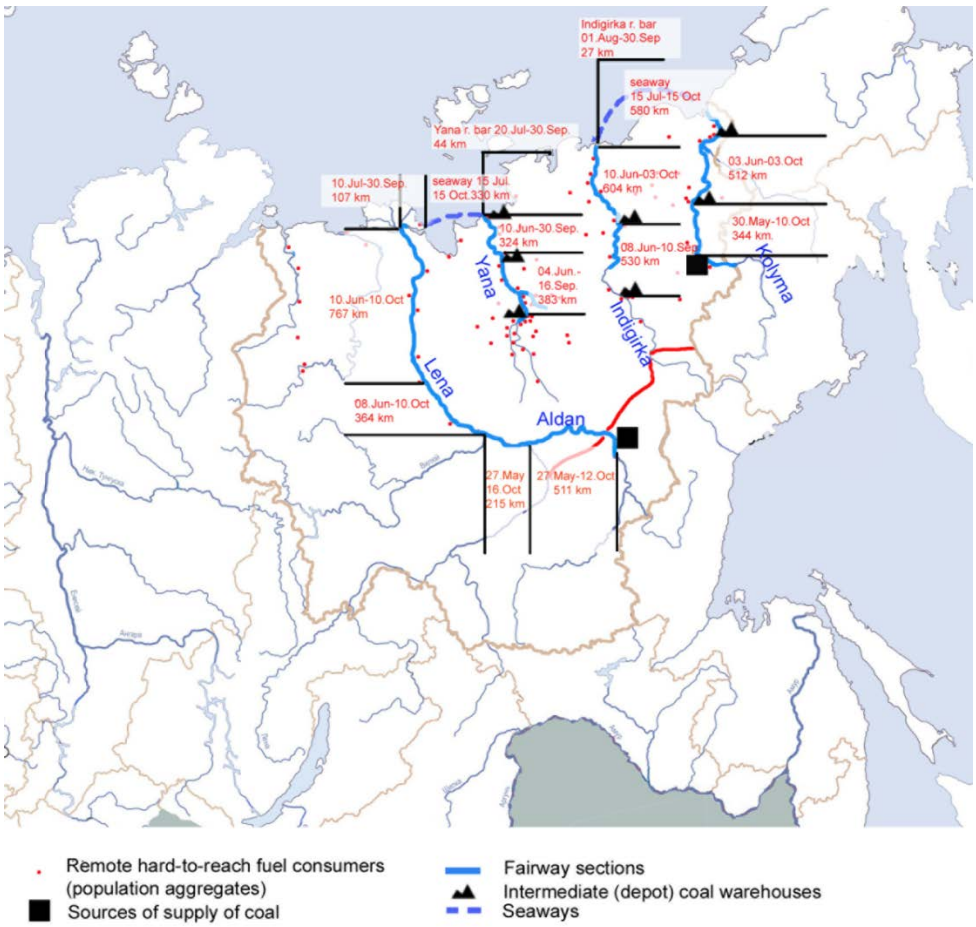

Fig.3 The Extent and function periods (for 2016) of waterways for coal delivery to a remote hard-to-reach consumer of the Republic of Sakha (Yakutia).

Hard-to-reach consumers do not have year-round road communication also with intermediate warehouses. From intermediate warehouses, coal is delivered to them on municipal winter roads – roads laid along frozen ground and ice after their hardening. Winter roads open near the end of the calendar year and function for no more than 4 months (end of December – mid-April), for vehicles weighing more than 20 tons – not more than three months (mid-January to mid-April). During the period of their operation, the payload increases gradually. The period of maximum load capacity is much shorter than the total period of validity. The permissible maximum mass of vehicles on ice areas is only 30 tons. During this time, the entire amount of fuel that is consumed before the opening of the next winter road must be delivered. The timing of the opening and closing of the winter roads is very sensitive to weather conditions. Exceeding the average temperature of the winter months and/or a high level of precipitation (snow) slows down the process of freezing of soils and ice. It postpones the opening of roads. Stability of functioning also depends on the appearance of ice on ice crossings and areas laid along rivers, as well as from the occurrence of snowstorms. The movement along the winter road is suspended until the detour is broken through if there is ice. With strong snowstorms, the road closes until it stops. Then the road is rebuilt again. Relatively rare, the reason for stopping the action of

winter roads is the abnormally high level of snow cover (winter 2016–2017 Kolyma-Indigirskaya group of uluses). It requires the transfer of heavy road equipment from other districts. A long recovery period is required.

There are 3 winter roads of regional importance (Fig. 2): “Yana”, “Indigir”, “Arctic” to meet the needs of the Yana’s and Kolyma-Indigir’s groups uluses. Their total length is more than 6.1 thousand km, including ice - more than 2.8 thousand km.

Reservation of fuel is the main tool for ensuring the reliability of fuel supply. It is necessary to reserve risks of delivery by water transport in intermediate storage depots and reserve risks associated with the functioning of winter roads near heat supply sources (boilers). The length of coal supply for remote, hard-to-reach consumers ranges from 10 months to 1.5 years, and the period from production to direct combustion can be more than 2 years (Fig. 4a). According to the traditional scheme of open transportation and storage, coal undergoes several cycles of freezing and thawing, ultraviolet and precipitation. It accelerates oxidation and loss of consumer properties. The period of storage of coal from the moment of extraction can reach 3.5 years in the formation of reserve coal reserves (Fig. 4b). This period is observed both when reserving shipping, and when reserving winter roads or their combination. Exceeding the specified deadlines for the majority of consumers served by a two-stage scheme (“river-winter road”), possibly when the supplier sells stagnant coal. It should be noted that in the conditions of the republic, a three-stage scheme ("river-river-winter road") of fuel supply is also possible, under which all these conditions are extended for 1 year. Thus, the maximum shelf life of coal from production to consumption can reach 4.5 years under certain conditions.

Difficult access and remoteness cause high losses and a decrease in the quality of coal during transportation. The loss of energy value of raw coal grade D under normal conditions of delivery, according to the author's estimates, is 18–20% [10, 11].

Losses are formed from physical losses, quality degradation due to oxidation and increased humidity during combustion. Physical losses are due to:

- spillages during transportation and loading operations
- grinding the fraction during transportation and blowing wind
- unavoidable remains on ships.
- the need to form cushions in warehouses with a ground base.

Humidification of coal is a cyclic process. The cycle of increasing the humidity of the coal coincides with the heating period. This is due to a decrease in moisture evaporation as the temperature decreases.

In Fig. 5, the results of an experimental assessment of the total mass of moisture in the ash sampled basis of ordinary coal in the warehouse of the Deputatski Heat and Power Plant. Observations were conducted from September 10, 2011 to August 24, 2012. The solid line corresponds to the approximation of the experimental data. The dashed line is the result of modeling. A straight line shows the level of the deal at the time of the purchase of coal in the mine stock.

When organizing reserve stocks in open stacks, according to the empirical model developed at the Institute (in part, the model is described in [13], an article with a detailed description of the model is aimed at publication in the journal «Izvestiya RAN, Energetika»), only a reduction in the heating value of more than 40%. Accordingly, with the cost of delivery of coal 15–18 thousand rubles for a ton reserve storage with open storage becomes unacceptable, both economically and technically, due to a significant deviation of the quality of coal from the fuel parameters of boilers. An example of modeling the dynamics of changes in the lower heat of combustion of ordinary coal with the existing transportation and storage technologies is shown in Fig. 6.

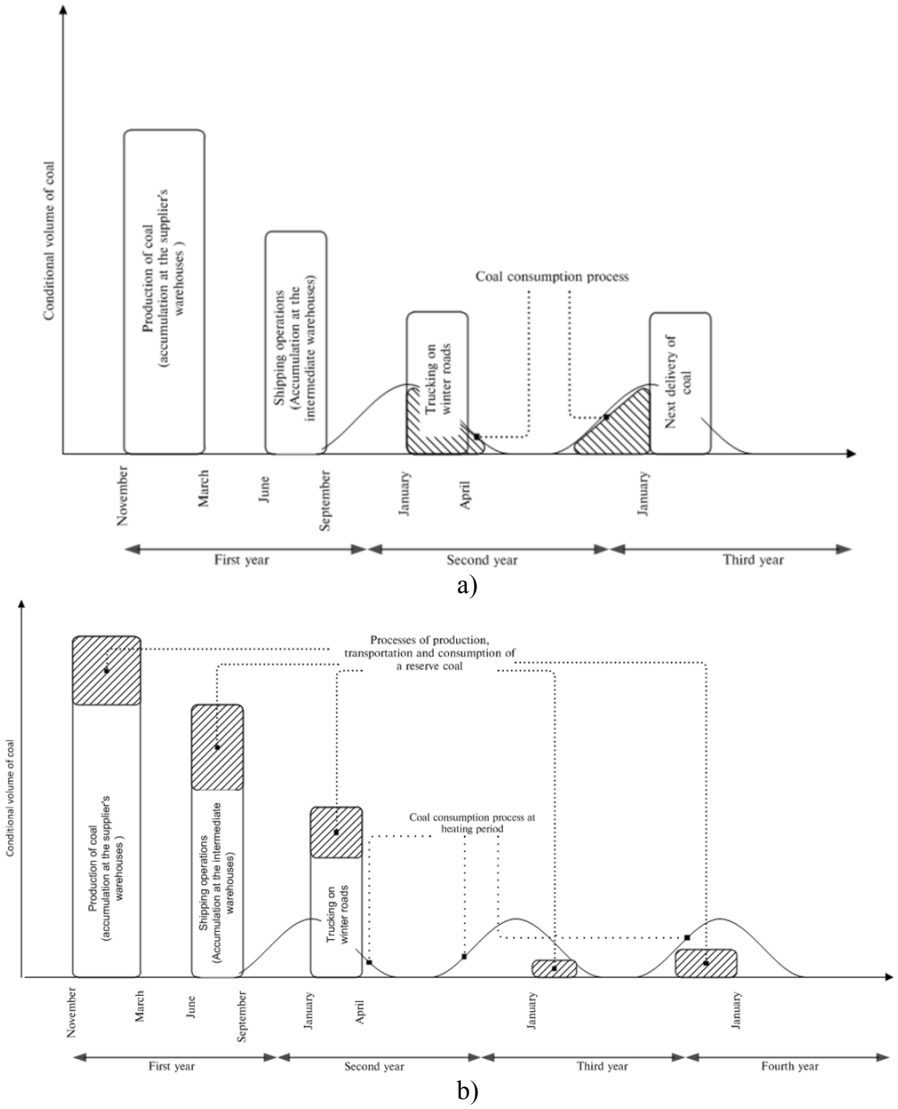

Fig. 4. Duration of storage of the main volume of coal from the beginning of accumulation in the supplier's warehouse to the final consumption (a), (b) – the same in the formation of reserve stocks.

There are serious economic factors in the organization of fuel delivery. They strongly influence the reliability of deliveries:

• Long-term cash gap in the budgets of energy supplying organizations. It is necessary to pay for the purchase and transportation of total volume of fuel for the next heating period before the end of the current heating period. The fuel component in the cost of heat for consumers exceeds 60%. The cost of delivery is 2–3 times higher than the purchase price of coal. To cover the cash gap requires attracting large loans commensurate with the volume of current assets of enterprises.

• High depreciation of port infrastructure and fleet on the rivers Yana, Indigirka and Kolyma.

• Lack of a system for accurately recording the volume of coal transported in bulk because of the high cost of organizing such a system.

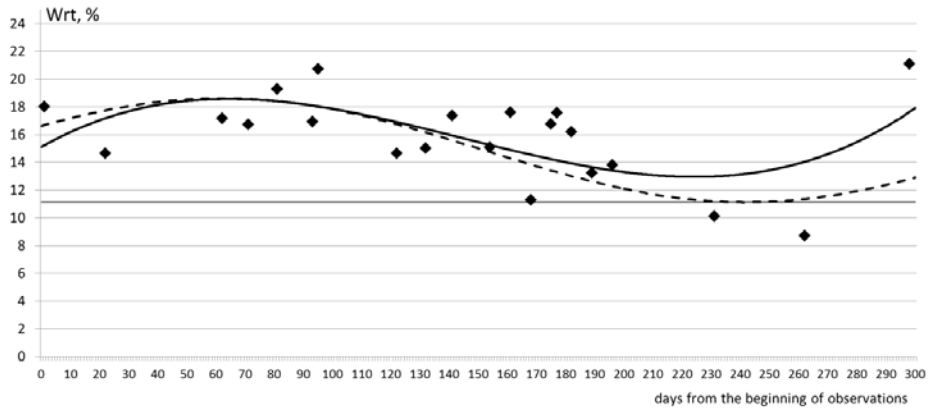

Fig.5 Change in the mass fraction of total moisture in the ash sampled basis of ordinary coal from the Jabariki-Khai coal field at the expense depot of the Deputatski Heat and Power Plant.

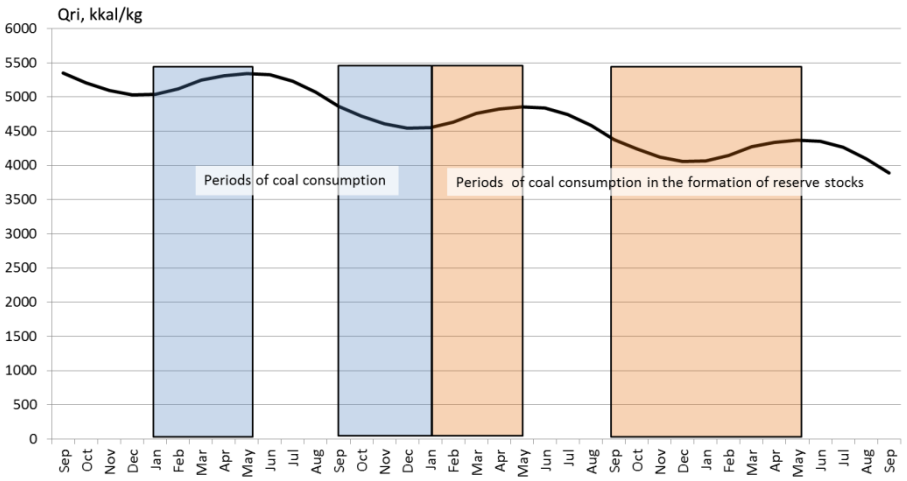

Fig.6 An example of modeling the dynamics of net calorific value changes of ordinary coal with existing transportation and storage technologies

3 Implications

The current state of reliability of coal supply systems for remote hard-to-reach consumers of the Republic of Sakha (Yakutia) is critical. It requires constant monitoring from outside (special commissions of the Chairman of the Government of the Republic of Sakha (Yakutia)) and the reservation of significant budgetary funds to prevent possible emergency situations and eliminate the consequences of their occurrence. This condition is deteriorating every year due to the lack of technological development in thermal generation systems. The main reason is that modern technologies for automation of boiler equipment place high demands on the quality of coal. The existing coal supply system cannot provide these requirements.

Increasing the reliability of coal supply to remote, hard-to-reach consumers requires the use of mechanisms for reserving risks of a different nature and methods and models for calculating volumes and optimizing the location of reserves. The solution of these tasks is

impossible without improving the coal supply system to a state that meets the following requirements:

- Ensuring the stability of coal quality during storage up to 4–5 years;
- Substantial reduction or total elimination of quantitative losses during transportation;
- ensuring high quality grade coal availability;
- Existence of an accurate system of accounting for movable and deposited coal throughout the transport scheme.

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