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Procedia Structural Integrity 20 (2019) 242–247

Structural Integrity Procedia

www.elsevier.com/locate/procedia

1st International Conference on Integrity and Lifetime in Extreme Environment (ILEE-2019)

Influence of natural climatic conditions on the spatial position of the underwater gas pipelines on the Lena floodplain

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Abstract

Interaction with complex geotechnical and operational conditions is one of the main factors for the efficiency of trunk gas pipelines, in particular, transitions across the water bodies of Yakutia. The underwater crossing of the trunk gas pipeline across the river Lena was laid in an open-cut way by underwater trenching. This method involves excavation of significant volumes of soil and depends on the climatic conditions. Additional materials are required for ballasting the pipeline and this leads to higher construction costs. The article presents the data of the planned-high-altitude position of the I and II lines of the underwater crossing of the main gas pipeline across the Lena River from the time of their laying. The results of field surveys show that the underwater crossing of the main gas pipeline runs almost parallel to the surface relief and shows the influence of hydromorphological processes on the erosion dynamics of the siphons. During operation, the phenomenon of pipeline erosion in the trench and its sags occurs. The erosion of the soil can change the planned-high-altitude position of the pipeline and create additional stresses in it. The uneven distribution of the planned-high-altitude positions of the I-st and II-nd lines of the main gas pipeline in floodplains from the left bank of the river has been established, which is associated with heaving irregularities, processes of soil thawing and freezing, as well as gas pipeline subsidence and ascent due to inhomogeneous soil composition, distribution of moisture, density, freezing conditions along the pipeline route through the river Lena.

Peer-review under responsibility of the ILEE-2019 organizers

Keywords: Underwater crossing, pipeline, high-rise planning position, pipeline depth, erosion of the soil.

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2452-3216
Peer-review under responsibility of the ILEE-2019 organizers
10.1016/j.prostr.2019.12.146

1. Introduction

The underwater crossing of the trunk gas pipeline (TGPL) for gasification of the regions on the eastern side of the river Lena of the Republic of Sakha (Yakutia) is an extension of the trunk gas pipeline of Hatassy GDS-2 (project 0371.00.03.MG.000.000.000.PZO). The main line of the underwater crossing constructed in 2003 and the reserve line constructed in April 2009 are laid across the lands of the Hatassky production-agricultural cooperative, the water resource of the river Lena, Pavlovsk village, and Pavlovsky production-agricultural cooperative.

The starting point of the main line of the gas pipeline is PK 1 + 00 (10.5 km) of DN 500 trunk gas pipeline of Hatassy GDS-2. The terminal point is the junction point on the right bank of the Lena River at Pavlovsk and thread extent – 16.96 km.

According to the work by Sapsay et al. (2017) based on the analysis of the underwater crossings laid by the trench method of construction, the deviations of the pipeline from the planned-high-altitude position (PHAP), such as not full penetration, denudation and sagging, are about 30% in the channel part and 45% in the flood plain section of the water body.

On the basis of synthesis of design data features of washout of the first string of TGPL through the Lena River taking into account hydromorphological factors are considered below.

From the left-hand coast the route TGPL through the Lena River crosses Tabaginskaya to a channel, several lakes, streamlets and lake hollows. On the island "Uluu of an arya" does turn on 68 ° to the main bed and further goes straight, crossing a bed, islands Bergehe of Yec, Manastyyr, Haptagaysky to a channel to the village of Pavlovsk.

An unnamed island opposite the Tabaginsky Cape splits the main river bed into two branches in the direction of the right bank. One of them is the Haptagaj channel, which has a rather strong current and a large amount of water flow discharge during the period of spring floods and summer-autumn floods. Hatassy-Pavlovsk TGPL crosses these two channels, the depth of which increases annually. Consequently, the erosion of the bottom and shore slopes of the islands in these channels increases by Ammosov et al. (2019). Unfavorable conditions are being created for the underwater crossing of the main gas pipeline due to the reorganization of the Lena River riverbed by Chalov et al. (2016)

In our opinion, these hydromorphological processes have a significant impact on the operational reliability of the underwater gas pipeline across the river Lena. This is confirmed by the fact that on August 5, 2013, a gas leak was detected in the non-navigable section of one of the channels mentioned above during the scheduled tests on strength and water tightness of the reserve line of the underwater trunk gas pipeline across the Lena. Here, the first line is marked as reserve line. The gas pipeline in PK97 area was destroyed by the pipe welded joint.

2. Research materials and methods

In accordance with the methodology for conducting an inspection of the planned-high-altitude position of the gas pipeline, measuring of the line-I of the underwater gas pipeline was conducted on the floodplain section and on Uluu Aryy island in the area of Hatassy village, which is located on the left bank of the river Lena, 15 km southward from Yakutsk, 4 km long and on the right bank, on Byldjahyktaah island 2.5 km long. According to the data obtained, the average depth of the underwater gas pipeline at the site of Uluu Aryy island is 2 m, and it is 2.5 m at the Byldjahyktaah island. The smallest depth is 0.9 m from the land surface at a distance of 2489,91 m from the Hatasskaya channel. Moreover, particularly dangerous denuded sections of the underwater gas pipeline were detected at distances of 1592.28 m and 2798.56 m.

On the right bank at the intersection of the channels, the pipe lines 0.30 m above the land surface and that constitutes danger during spring erosion of the channel bottom.

Owing to the weak water-saturated soils in the section of the underwater gas pipeline, located at a distance of 1,592.28 m from the Hatasskaya channel, a 2.3-meter-long gas pipeline was denuded (Fig 1). The lower part of the pipe lies at the bottom of the stream creating an artificial dam. In this case, one side of the pipeline lies on the water level, the other is 15 cm above the water level.

At this section, bending of the gas pipeline along the longitudinal axis is observed as a result of sagging and seasonal “loosening” (pipe blowing) of the gas pipeline (Fig. 2).

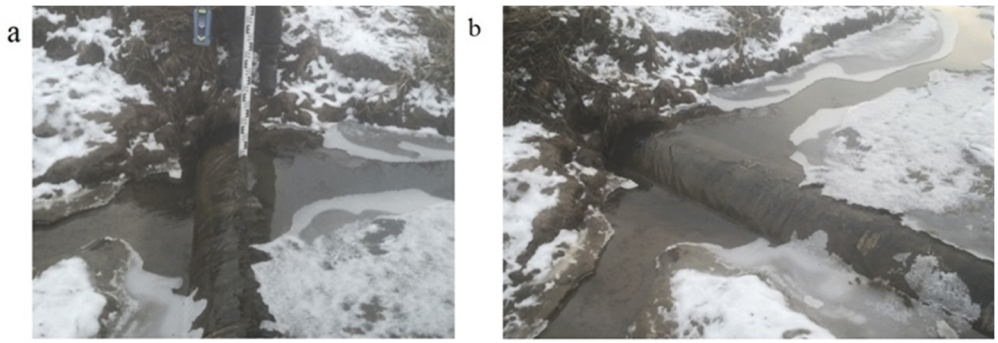

Fig 1. Pipeline denudation.

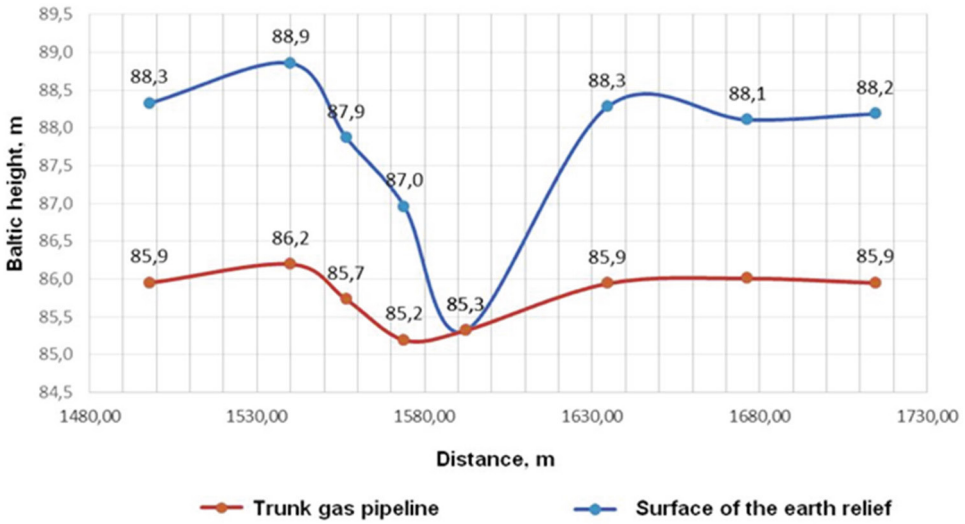

Fig. 2. Section of the line-I of the underwater crossing of TGPL on Uluu Aryy island of Hatassy village (1592.28 m).

At a distance of 3555 m from the Hatasskaya channel, there is a section of the gas pipeline with a length of 30 m sagging under the water (Fig 3). The outer generating line of the pipeline from the surface of the water is 0.2 m. During the autumn inspection after the freeze-up period, the pipeline in this area is under the ice.

The planned-high-altitude position of the pipeline is demonstrated in Figure 4. The present graph shows that the gas pipeline also has a deflection due to sagging and seasonal swelling at the shore slopes of the channel.

Measuring of the line-II of the underwater gas pipeline was accomplished as well on the floodplain section of Uluu Aryy island in the area of Hatassy village located on the left bank of the river Lena, 15 km southwards from Yakutsk and 4 km long and on the right bank, on Byldjahyktaah island, which is 2.5 km long.

The average depth of the underwater crossing of TGPL in the area of Uluu Aryy island is 1.73 m. The deepest depth is 3.73 m from the surface at the intersection of the channel at a distance of 2911 m from the point of reference. Measuring was conducted regarding the defining point according to the methodology.

In the area of Byldjahyktaah island, the smallest depth of underwater gas pipeline laying is 0.9 m from the surface level of the earth relief at a distance of 2489.91 m from the Hatasskaya channel. On the right bank, a section of the thermokarst was formed in dangerous proximity to the gas pipeline. Its further development may well encompass a section of the gas pipeline route and cause a decrease in the operational reliability of the line-II of the underwater crossing of Hatassy-Pavlovsk TGPL across the river Lena.

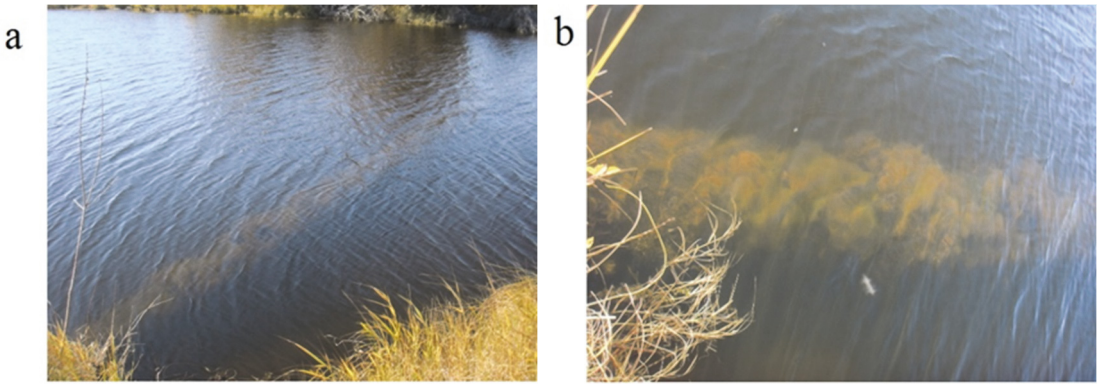

Fig 3. Sagging section of the gas pipeline.

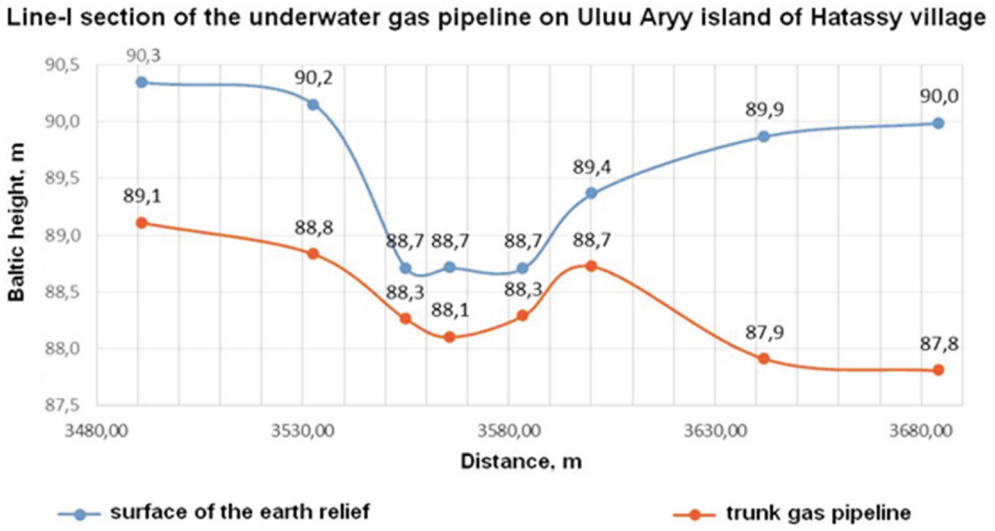

Fig 4. Line-I section of the underwater gas pipeline on Uluu Aryy island of Hatassy village.

The results of the field surveys of the line-II reveal that the pipe of the underwater gas pipeline runs almost parallel with the surface relief of the area. On the islands from the right bank of the river, there are no wide elevation differences, deep gullies and channels.

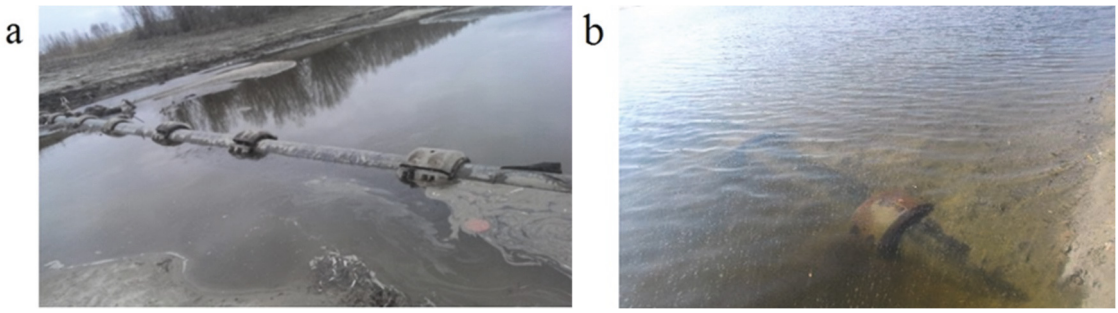

Fig 5. The position of the gas pipeline on the Hatasskaya channel in April 2015: a) line-I; b) line-II.

In August 2014, denuded and sagging sections of the two gas lines had been formed during the operation of the inverted siphons from the time they were laid (Fig 5). Fig 5,a demonstrates that the denuded and sagging section of the line-I lies slightly higher than the section of the line-II. Moreover, part of the denuded and sagging section of the line-II lay under the water at the minimum depth (Fig 5, b). At the time of the inspection of the underwater crossing of TGPL, the width of the Hatasskaya channel was ~60 m. In that area, the visible part of the denuded and sagging sections of the pipeline route reached ~30 m. It should also be noted that in the section of the pipeline route adjacent to the left bank the siphons of the lines I and II were elevated in comparison with their location in distant areas (Fig 5, a).

After repair operations and excavation works by JSC Sakhatransneftegaz from 2015 to 2019, continuous monitoring of the underwater crossing of TGPL is still conducted in the floodplain of the river Lena.

3. Discussion and results

The instrumental examination of the states of the two lines of the underwater gas pipeline on the floodplain areas of the pipeline route revealed the most dangerous, constantly developing deflections and subsidence of the gas pipeline, which occurred due to frost heaving and thermal subsidence on the thermokarst section, as well as hydrological and hydromorphological processes.

The uneven distribution of the planned-high-altitude positions of the I-st and II-nd lines of the underwater gas pipeline has been detected on floodplains from the left bank side of the river, which is most likely due to uneven heaving, ground thawing and freezing processes, as well as pipeline sinking and floating-up, owing to heterogeneity of soil composition, moisture distribution, density, freezing conditions, etc. along the underwater crossing of TGPL route across the river Lena.

Permyakov et al. (2013) show that in winter period at a temperature of the transported gas approximately equal to minus 12.5°C, water begins to freeze around the gas pipeline and the pipeline gradually covers with ice forming an ice “shell” up to 3-5 cm thick at the end of April.

During the spring ice drift, ice jams occur on the river Lena and its major tributaries. The ice gorging is accompanied by flooding of lower areas of the river valley. For example, in May 2010, a powerful ice jam was formed at the Tabaga-Yakutsk site in the area of the underwater crossing of Hatassy-Pavlovsk TGPL located ~9.0 km from Tabaga, and the long-standing water level at Tabaga gauging station was exceeded by 1,11 m what is pointed by Kusatov et al. (2012).

There are several modern developments on ice gorging carried out by Takakura et al. (2017) and Burrell et al. (2015), that describing its nature, physical-mechanical, hydrological and hydromorphological basis.

4. Conclusion

The formation of denuded and elevated sections 2,800 m far from the left bank in autumn period, the water freezing from the surface at a lower level of the low water during the winter months, as well as the gradual icing of the gas pipeline, contributing to its further elevation, lead to complete freezing of the gas pipeline and its jamming in ice due to gradual increase of the ice thickness.

Besides, there is a propensity for the main river bed to move to the left bank eroding the island shores and the main shore depending on the seasonal change of the water level. During the spring ice drift, spring and summer-autumn floods, the intensity of erosion of the river bottom and the main coast at Pavlovsk village arises where the underwater crossing of trunk gas pipeline is located.

Soil erosion can change the planned-high-altitude position of the pipeline and create additional tubular stress. Protection of the underwater crossings from changes in their planned-high-altitude position is a difficult task, while projects on maintenance and repair during the pipeline operation in most cases imply only localized protection for denuded and sagging sites.

After repair works, the length of areas with deviations from the planned-high-altitude position is often increased compared with the results of previous inspections, or deviations occur where there were none. These questions demand expanded monitoring researches in months of a freezing and the fullest thawing of a soil.

Acknowledgements

This research has been supported by The Ministry of Science and Education of Russian Federation (Project III.28.1.1).

References

Sapsai, A.N., Sharafutdinov, Z.Z., Shatalov, D.A., Vafin, D.R., 2017. The choice of the construction method for the underwater crossings of trunk pipelines. Oil industry 11, 143-148.

Ammosov, A.P., Shpakova, R.N., Kustov, K.I., Kornilov, 3.G., 2019. Change of water levels and water surface slopes in case of congestion on the Lena river. News of Irkutsk state University, Earth Science series 28. 3-20.

Chalov, R.S., Zavadskij, A.S., Ruleva, S.N., Kirik, O.M., Prokop'ev, V.P., Androsov, I.M., Saharov, A.I., 2016. Morphology, deformation, temporary changes in the Lena river bed and their effect on the economic infrastructure in the area of Yakutsk. Geomorfologiya 3, 22-35.

Permyakov, P.P., Ammosov, A.P., Popov, G.G., 2013. Influence of a cryolithozone in the basis of the underwater crossing of the gas pipeline across the Lena River. Gas industry 2. 59-61.

Kusatov, K.I., Ammosov, A.P., Kornilova, Z.G., Shpakova, R.N., 2012. Antropogenic faktor of ice jamming and spring breakup flooding on the Lena River. Russian Meteorology and Hydrology 37(6), 392-396.

Takakura, H., Yoshikawa, Y., Watanabe, M., Sakai, T., Hiyama, T.. 2017. Ice Movement in the Lena River and Effects of Spring Flooding on Human Society: An Interpretation of Local Sources Integrated with Satellite Imagery in a Multidisciplinary Approach. Global Warming and Human - Nature Dimension in Northern Eurasia, Global Environmental Studies. Springer, Singapore.

Burrell, B.C. Huokuna, M., Beltaos, S., Kovachis, N., Turcotte, B., Jasek, M., 2015. Flood Hazard and Risk Delineation of Ice-Related Floods: Present Status and Outlook. CGU HS Committee on River Ice Processes and the Environment, 18th Workshop on the Hydraulics of Ice Covered Rivers Quebec City, QC, Canada.