The Second International Conference on Oil and Gas Distribution in the Former Soviet Union, Pipeline Transmission Systems

Conference Documentation

9th - 10th March 1994
Hotel InterContinental, Vienna

WESTERN AND FORMER SOVIET UNION (FSU) PIPELINE CODE COMPARISONS WITH EXAMPLES FROM PROJECTS IN THE FORMER SOVIET UNION

H.D. Evans, Boris Taksa, Alexander Aynbinder, and Patrick Dalton
Gulf Interstate Engineering, Houston, Texas

The opening of the oil and gas industries of the countries in the former Soviet Union (FSU) to foreign investment offers great opportunities and challenges for Western companies. To take advantage of these opportunities and successfully meet the challenges, Western companies must know as much as possible about the design approach and philosophy of their FSU joint venture partners.

A Western company participating in a joint venture for a pipeline project must consider many code-related topics, including the accuracy of the translation (interpretation), how the project will be reviewed, and how the project fits into the existing overall system.

As a first step in the pursuit of understanding, Gulf Interstate Engineering (GIE) has translated the two most important FSU codes concerning transmission pipelines: SNIPs 2.05.06-85, "Design of Transmission Pipelines," and III-42-80, "Work Execution and Acceptance for Transmission Pipelines." These codes, along with their addenda (especially concerning hydrotesting), are still being used by the FSU design institutes. GIE is documenting a comparison of these codes with corresponding U.S. codes; ASME B31.4, "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols," and B31.8, "Gas Transmission and Distribution Piping Systems." In presenting these comparisons, whenever possible, a comparison to actual projects is used.

We conclude that thorough knowledge of both partners' codes is necessary for the successful design of a pipeline within a joint venture framework. More important than actual differences in the codes, is the realization that these differences exist. A thorough knowledge of these differences will aid any joint venture through the approval processes typical of a pipeline project.

BACKGROUND

In GIE's experience with FSU based projects, we have found that translations by professional translators often miss the technical nuances associated with specialized terminology, especially that used in the pipeline industry. Therefore, it is possible to have a translation and still not understand or use it. Also, a translation by itself is of little help without some kind of comparison. Therefore, GIE translated these codes "in-house" using GIE's staff of FSU engineers. One engineer authored the stress analysis section of SNIP 2.05.06-85. Others used the codes extensively while working at various institutes dealing with the FSU's Ministries of Oil, Gas, and Oil and Gas Construction.

GIE's experience has proved the importance of understanding the approach and philosophy of the FSU technical institutes reviewing feasibility studies and design documents.

Often joint ventures design to satisfy the more stringent criteria of the two partners' requirements (i.e., codes or company-specific requirements). In all cases, the project must obtain approval of the FSU ministries involved, which means the design or study is subject to technical review. To meet the needs of these technical reviews and possibly speed up negotiations, Western companies need to know how pipeline design was done in the FSU up to its recent opening to foreign capital.

Another reason the work was performed was the clear understanding that successful execution of rehabilitation projects depends on comprehending how previous designs were arrived at.

STYLE AND APPROACH

The structures of the U.S. and FSU codes present an interesting example of a difference between the two code systems. ASME B31.4 and B31.8 have provisions for the design, installation, testing, and operation of pipelines. Conversely, the SNIP (the English pronunciation of the Russian acronym for *Construction Standards and Regulations*) system has a single document for oil and gas transmission pipeline design, a separate document covering pipeline construction (including installation and hydrotesting), and still other documents for operating these lines (*not* SNIPs). As in the U.S. system, the FSU codes reference several other codes, including SNIPs, GOSTs (state standards and specifications), ONTPs (state standards governing technological [process] designs), and VSNs (interministerial construction codes).

U.S. codes use general phrases such as "done with sound engineering practice" or "it is the operating company's responsibility to. . . ." ASME B31.4 and B31.8 state in their scopes that they are not design handbooks and often are supplemented by client requirements. The FSU codes go into greater detail, often dictating how something must be done or which equation must be used (e.g., SNIP 2.05.06-85 contains 68 equations, more than three times the number in ASME B31.4 or B31.8). The SNIP system resembles a step-by-step guide of how design and construction must be performed, including the sequences of job performance, distances from various objects, and slopes of trench walls.

This division of the design and construction codes resulted in a less obvious but more tangible result; often the pipeline was not constructed as designed. There was less on-site supervision of the construction process than is typical for a western pipeline project.

Examples used in comparisons concentrate on three recent GIE projects. First is the North-Gubkinskiy crude oil line in western Siberia; this is a 52.5-kilometer, 10.75-inch pipeline. Second is the Yamal-Center project, consisting of 416 kilometers of gas pipeline and three compressor stations located in the Arctic on the Yamal peninsula. Finally, the third project is the proposed Denisovskaya Gas Trunkline project, a 550-kilometer pipeline to be located in the Timan-Pechoria Basin of northern Russia.

DESIGN FACTORS AND COEFFICIENTS

The most common initial question asked by an engineer designing to both code systems is which code yields a thicker, more conservative wall thickness. Unfortunately, no simple answer exists. The wall thickness is largely a function of the respective design factors. The number of location-based design factors is comparable: ASME B31.4 has one, B31.8 five, and SNIP 2.05.06-85 three. In addition, the FSU code uses five principal coefficients for pipeline calculations. The structural analysis chapter has more than 20 coefficients. Consequently, preliminary design cannot be as simplistic as the following: "The FSU design factor is 0.75 and the U.S. 0.72. Therefore, I can design it to the U.S. code, and it will automatically be more conservative (i.e., thicker walled)." This often is not so. Awareness of the similarities and differences in the two codes' specific provisions is important.

Table 1 compares the location-based design factors for the three codes.

For oil pipelines, ASME B31.4 has the single design factor 0.72. SNIP 2.05.06-85 has three design factors: 0.6, 0.75, and 0.90.

Because SNIP 2.05.06-85 is applicable for oil and gas, comparisons are also valid for ASME B31.8. For example, the primary FSU design factor for compressor station piping is 0.6, while the U.S. design factor is typically 0.5. Again, wall thickness calculations must be made under both codes, considering specific environments that influence the other coefficients involved.

MATERIALS

Another difference is how both code systems indirectly use different definitions for the specified minimum yield strength (SMYS) of the pipe steel. ASME B31.4 does not explicitly define SMYS; it references codes for acceptable materials. The most common code for pipe is API SPEC 5L, "Specification for Line Pipe," which defines SMYS as the stress producing 0.5-percent total elongation. SNIP 2.05.06-85 also does not explicitly define SMYS, instead referencing GOSTs. The FSU convention defines SMYS as 0.2-percent residual elongation. The difference may be slight, but it affects calculations. Design engineers should be aware of the different approaches.

There are also differences in the levels at which steels are mill hydrostatically tested. API SPEC 5L requires a varying percentage of SMYS (60 to 90 percent), although many companies request a higher mill pressure. Russian steels are generally tested at a mill hydrostatic pressure that produces a hoop stress of 95 percent of the SMYS (when using the pipe wall's minimum thickness) according to SNIP 2.05.06-85.

FSU engineers are accustomed to selecting pipe wall thicknesses based on the pipe steel's specified minimum ultimate strength (SMUS), while U.S. codes require use of the SMYS. Because of this philosophy, the FSU steel manufacturing method evolved somewhat differently than the U.S. method. A comparison of pipe steel strengths in the two countries' specifications for line pipe shows that pipe steels with similar SMYS values have quite different ultimate strengths. Russian steels are specified to have higher SMUS values.

DIFFERENCES

One difference between the two code systems is that ASME B31.4 and B31.8 are typically used (often with further design requirements stipulated by the client) for all transmission pipelines (even those crossing cities), while SNIP 2.05.06-85 does not apply to pipelines running through populated areas.

Another is the conceptual layout of a project. When an FSU engineer begins designing a pipeline, the SNIP codes organize the project more than U.S. codes. It begins by classifying the entire pipeline depending on pressure or diameter. The classification dictates the separation distances for the pipeline from various objects. SNIP then categorizes various sections of these pipelines based on their location, and the design factor changes based on these categories for oil and gas pipelines.

An additional cost introduced by SNIP results from the FSU requirement (SNIP 2.05.06-85, subsection 6.17) for a second "reserve" line at major river crossings. In practice this cost is often absorbed in the West because often a second line is constructed for logistic, economic, and/or environmental reasons.

Another philosophical difference between the two codes is how they determine the circumferential stress due to internal pressure. In ASME B31.4, the hoop stress is calculated using the pipe's outside diameter ($S_{hoop} = PD/2t$). In SNIP 2.05.06-85, it is calculated using the inside diameter ($S_{hoop} = P(D-2t)/2t$).

Following are detailed examples of how the wall thickness differs for the two sets of codes using specific project parameters.

The equations used by the two different code systems to determine the wall thickness of pipelines are shown in Table 2.

The first example concerns a pipeline designated to carry oil. The wall thickness for an X65 steel pipeline with a 32-inch outside diameter, calculated according to ASME B31.4, is 0.496 inch. If calculated to SNIP 2.05.06-85, the wall thickness varies. The wall thickness of most of the pipeline is nearly the same (i.e., 0.500 inch); the thickness for those sections changing category, (e.g., swamps, river crossings, or road crossings) increases to 0.596 inch, and pump station pipelines would have 0.738-inch wall pipe.

The second example concerns a pipeline designated to carry gas. The wall thickness for an X65 steel pipeline with a 42-inch outside diameter, calculated according to ASME B31.8 using a design factor of 0.72, is 0.656 inch. If calculated to SNIP 2.05.06-85, the wall thickness varies. The wall thickness of most of the pipeline is comparable at 0.688 inch; however, the thickness for those sections changing category, (e.g., swamps, river crossings, or road crossings) increases to 0.844 inch, and at a compressor station - 1.031-inch.

The final major difference is the stress criterion. The FSU code uses von Mises' theory and values for an "effective-elastic modulus" and "effective-Poisson's coefficient" that are solutions to equations considering the nonlinear segment of the stress elongation curve for steels around the yield point.[1] For example, a constant modulus of elasticity are usually used in the U.S. codes, while the SNIP value for the nonlinear effective-elastic modulus when the stress reaches the maximum allowable level is 15 to 20 percent less. In the U.S. code, ν is assumed constant (in ASME B31.4, $\nu = 0.3$), while the FSU value for the nonlinear effective-Poisson coefficient is 15 to 30 percent greater when the stress values reach the maximum allowable level.

In summary, the wall thickness depends on a variety of environment-specific factors, including location. Because of the large number of coefficients used by FSU engineers in their calculations, there are instances where either code system may require a more conservative wall thickness. Thus, it is necessary to design using both codes and compare results to determine the more conservative wall thickness.

PROJECT EXAMPLES

North-Gubkinskiy Crude Oil Line

In 1993, GIE completed the design, procurement, and construction phase of one of the first field development projects in western Siberia. This work was performed for the joint venture company Geoilbent, which involves a U.S. oil and gas company (Benton Oil & Gas) and two Russian firms (Purnefty Gas and Purnefty Gas Geologia).

In Geoilbent's North-Gubkinskiy project, the main 52.5-kilometer pipeline meets the ASME B31.4 wall thickness requirement. However, the proposed pump station and the river crossing conform to SNIP 2.05.06-85 requirements. The design factor for a pump station would change to 0.6 in the FSU code and remain at 0.72 according to ASME B31.4. Another example is the Purpe River crossing, where the FSU code requires a change in the design factor and the U.S. code does not. Thus, at the Purpe River, the wall thickness was increased from 0.219-inch to 0.279-inch. At the pump station, the wall thickness is 0.365-inches.

North-Gubkinskiy taught us other more practical lessons as well. The North-Gubkinskiy project demonstrated the need to teach FSU contractors how to bid. They are generally familiar with scheduling but not in tracking their real costs, which makes bidding for work a new concept for most contractors. Most are also unfamiliar with profit, and other free-market concepts such as supply and demand.

Another practical learning experience involves logistic concerns. For a country that has many miles of pipelines such as Russia is expected to have a presence of pipelining technology. GIE found that it is best to plan to supply the spare parts and the infrastructure; this part of the system has essentially broken down. This also affected other project areas performed under Western and FSU codes, particularly welding qualification. However, when workers were supplied with adequate tools, they qualified under the Western standard most often used in conjunction with ASME B31.4: API STD-1104, "Welding of Pipelines and Related Facilities."

Yamal-Center Project and Denisovskaya 550-kilometer Gas Trunkline

In 1993, GIE completed a feasibility study for the northernmost section of the proposed Yamal-Center pipeline system. The feasibility study include the northernmost 416 kilometers of 56" pipeline along with three compressor stations and a gas chilling station. The feasibility study was performed in accordance with ASME B31.8.

GIE has also recently performed an optimization study for a proposed 550-kilometer pipeline in the Timan-Pechoria Basin of northern Russia. The pipeline originates in the Arctic and traverses permafrost, discontinuous permafrost, and temperate soils. During this study, a number of Russian concepts were examined, including if the system were designed to SNIP 2.05.06-85 or Russian-specification steel were used.

A common feature of these projects is their origination on permafrost. Yamal-Center offered unique challenges because the gas must stay below freezing for the first 390 kilometers of the proposed pipeline system. The Denisovskaya system must remain below freezing for the first 170 kilometers. These prerequisites require special engineering solutions. Following is a more detailed discussion of the Denisovskaya gas trunkline.

The results of GIE's optimization were that a SNIP design would be marginally more costly. This is not a blanket statement that can be used when comparing the two code systems. Rather, because of the unique considerations of this pipeline, this system is more expensive than the ASME B31.8 design. Specifically, three areas had increased costs: wall thickness, river crossings, and buoyancy control.

Cost increases for this project due to SNIP 2.05.06-85 are detailed below.

Steel Costs

The first additional cost results from increased wall thickness requirements required by SNIP 2.05.06-85, which causes an increase in the quantity of steel. These are at places where the FSU "design" factor changes because of "category" location.

For this project, approximately 12.5 percent of the route becomes Category II (i.e., thicker walled). This primarily includes swamps, but also involves the three major river crossings, and roads and railroads crossings (current and proposed). This increase in wall thickness is mandated by SNIP 2.05.06-85 and is independent of a proposal to increase the wall thickness to mitigate potential frost heave or thaw settlement. The estimated material cost for this increase in the amount of steel is $5.4 million U.S. dollars.

Crossings Costs

The second additional cost is due to the FSU requirement (SNIP 2.05.06-85, subsection 6.17) for a second reserve line at major river crossings. This requires approximately three extra 42-inch crossings adding a total of eight extra kilometers. The increased cost includes the extra construction cost, steel, and all necessary testing, and is estimated at $6.4 million U.S. dollars.

Concrete Coating Costs

The final additional cost considered was the increased cost of concrete coating for buoyancy control. The FSU code requires an additional coefficient (a load safety factor ($n=0.95$)) be applied to potentially buoyant sections along the pipeline, which results in increase concrete thicknesses. This requirement is found in SNIP 2.05.06-85 subsection 8.30. Because of the large quantity of concrete coating (335 kilometers), this increased cost becomes very significant ($6.7 million U.S.).

For the preliminary design and cost estimate phase of the proposed project, these three costs represent most of the expected cost increases. During the detailed design phase, there will be other more minor cost items (e.g., the design of tees is different under the two code systems).

CONCLUSIONS

We have presented pipeline issues that must be addressed when considering a joint venture between FSU and Western firms. This discussion familiarized engineers with the variations in pipeline design approaches; it does not provide an all-inclusive list of the issues that must be considered. GIE has used these ideas with other concepts involving various concerns to successfully advance one of the first pipeline joint ventures involving U.S. and FSU firms to the production phase. Through further inquiry, study, and attempts at mutual understanding, future joint ventures in the FSU can be implemented with fewer delays resulting from differences in pipeline design philosophy.

We have observed that when calculating the wall thickness of the main line-pipe for oil lines, the wall thicknesses are very comparable. It is the larger number of changes in location category that SNIP requires that causes most differences, usually at a nominal additional cost.

For gas lines, because of the large number of class locations in ASME B31.8 as well as in SNIP there are more likely to be confusing sections. During detailed design, these areas probably must be examined on a case-by-case basis.

We believe that U.S. oil and gas companies with accurate translations and comparisons will better understand the impact of pipeline issues arising during negotiations with FSU entities for joint field development. These companies can assess the cost and schedule effects of various trade-offs in the negotiating process. Design engineers evaluating existing facilities in the FSU will better understand the issues and regulations faced by the original designers. These translations will aid in understanding why current conditions exist and the effects of modifications required by proposed new facilities on existing pipelines.

To get the approval of the FSU ministries and design institutes involved, the pipeline system will most likely undergo dual design, i.e., it will be designed to both code systems, and the more conservative design for the particular section is adopted. This could result in a system where the mainline is designed according to ASME B31.4 or B31.8; swamps, rivers, and road and railroad crossings according to SNIP 2.05.06-85; and the compressor or heating stations to SNIP. By designing the system in such a way, the system will be the safest under an "international" consensus.

REFERENCES

1. Aynbinder, A., Powers, J.T., and Dalton, P., "An Engineering Method that Considers Nonlinear Mechanical Properties of Pipe Materials in Pipeline Stress Analysis," in review for publication.