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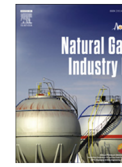

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Research article

Principles of and tips for nitrogen displacement in gas pipeline commissioning

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Abstract

Since the West-to-East Pipeline I was put into production, operators have made many attempts and accumulated valuable experiences in gas pipeline commissioning. However, there are still some problems. For example, the injected nitrogen quantity was determined only by experience rather than by quantitative calculation formula; there are some unnecessary steps in the nitrogen displacement process. Therefore, the authors summarized experiences from various scenarios at home and abroad over the past decade, and introduced some innovative practices in the preparation of pipeline commissioning schemes. Particularly, the calculation formula was first developed for the required nitrogen quantity in the commissioning process; the in-turn nitrogen displacement was replaced by the simultaneous way in the paralleling pipes at the stations; nitrogen displacement was abolished in vent and drainage lines; and several other tips were concluded for the nitrogen displacement process. Supported by scientific evidences, previous commissioning experiences and data, the above innovative practices help not only simplify the on-site operation on the premise of safe production but also shorten the nitrogen displacement time greatly, and save a large quantity of nitrogen gas, as a result, the economic benefit is significantly enhanced.

Keywords: Gas pipeline commissioning; Nitrogen displacement; Experience; Problem; Quantified nitrogen injection volume; Simplified operation; Innovation; Economic benefit

1. A brief introduction to gas pipeline commissioning process

Commissioning of gas pipelines involves complete displacement of air in the pipeline by natural gas before pressure is enhanced to the required level for trial operations of 72 h. Generally speaking, inert gas (usually nitrogen) shall be used to displace the air before displacement of nitrogen by natural gas [1—15]. To save the quantity of nitrogen used, nitrogen doesn't completely fill the entire pipeline, instead, it is only injected and preserved in the pipeline between the initial station and a pre-determined check point on the trunk line. When injected, natural gas in the pipeline will drive the nitrogen section to accomplish the displacement in the entire pipeline. In practice, displacement will be conducted simultaneously in trunk line and relevant stations. In other words, displacement in relevant stations will be completed when pure nitrogen section passes through intermediate stations. Since gas supplied from the upstream has high pressure, pressure regulating valves in the initial station should be used during commissioning to reduce the natural gas pressure. To avoid ice blockage in the pipeline after choking and depressurization, pressure reduction could be more than one stage. Glycol can also be injected in the upstream of these regulating valves to reduce the dew point of natural gas. Upon reaching the terminal station, natural gas will be pressurized in steps to the pre-required pressure level.

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2. Experiences on and simplified operations of gas pipeline commissioning

2.1. Calculation of injected nitrogen volume in gas pipelines and length of injected nitrogen in the trunk line

Injected nitrogen volume in gas pipelines refers to the volume of pure nitrogen (converted to the volume of pure nitrogen at zero gauge pressure and actual temperature) contained in the pipeline upon the completion of nitrogen-injection operation. Length of injected nitrogen in the trunk line refers to the length of trunk line corresponding to the volume of injected nitrogen at slightly positive pressure (at gauge reading of 0.02 MPa) and actual temperature.

In China, specific percentage of the total length of the pipeline is usually taken as the length of injected nitrogen for this gas transmission pipeline. This technique has two issues: ① during commissioning process, mixed gas plugs on both ends of nitrogen plug increase very slowly when reaching certain length, so the increase of injected nitrogen length in the trunk line is not in proportion with the total length of the trunk line. For example, the injected nitrogen length in the trunk line for a pipeline of 1000 km long is two times shorter than that for a pipeline of 500 km long with the same diameter; ② different number and type of intermediate stations require different length of injected nitrogen in trunk lines for gas pipelines with identical length and diameter.

Combining theoretical calculation and actual commissioning data, the authors advanced an equation to calculate the volume and the length of injected nitrogen in the trunk line during gas pipeline commissioning process in 2008.

Formula for calculation of injected nitrogen volume during gas pipeline commissioning is:

$$Q_{st} = (25000 + 50L_{total})S + 3V \tag{1}$$

Formula for calculation of injected nitrogen length in the trunk line is:

$$L_{ni} = \frac{Q_{st} - 1.2V_1}{1200S} \tag{2}$$

where, Q_{st} denotes the volume of injected nitrogen (the volume at zero gauge pressure and actual temperature) in the commissioning process, m^3; L_{ni} denotes the length of the trunk line corresponding to the volume of injected nitrogen at 0.02 Mpa gauge reading and actual temperature, km; L_{total} denotes the total length of the trunk line, km; S denotes the average sectional area of the trunk line, m^2; V denotes the total volume of all stations and pipelines other than those containing nitrogen, m^3; V_1 denotes the total volume of station pipelines containing nitrogen, m^3.

In the equations, "1.2" and "1200" are conversion factors related to 0.02 MPa gauge readings; "3" indicates that the volume of nitrogen deployed in stations shall be three times of the total volume in these stations during nitrogen displacement; "25000" and "50" are empirical coefficients determined through repeated tests.

Eqs (1) and (2) are suitable for the following conditions: ① the total trunk line length is from 200 km to 1500 km; ② in the case of simultaneous commissioning of the trunk line and branch lines, calculation results of the trunk line shall also include the volume of injected nitrogen required for independent commissioning of the branch lines; ③ all trunk lines have identical diameter; ④ if there are no intermediate stations or there are only pigging stations as the intermediate stations, 70%−80% of the calculation results shall be taken as the final results. A pigging station can be regarded as a valve chamber since trunk line gas flow can run through all major processes through suitable procedures.

To verify the applicability of Eqs (1) and (2), the length of injected nitrogen in the trunk line for gas pipelines in two different diameters and with trunk lines in five different lengths was calculated by using Eqs (1) and (2), the calculation results are listed in Tables 1 and 2.

Calculation results show that the ratio of the calculated length of injected nitrogen in the trunk lines to the total length of the trunk line is not a fixed percentage. Instead, the longer the trunk line is, the lower the ratio will be, which coincides well with the actual commissioning data.

It is worth noting that the calculation results of pipelines in different diameters in Tables 1 and 2 are slightly different from each other. According to operation experiences, such minor differences in the length of injected nitrogen have insignificant impact on pipeline commissioning.

To further verify the applicability of Eqs (1) and (2), the actual length of injected nitrogen in some gas pipelines put into production in the past 10 years was compared with the theoretical length of injected nitrogen (L) calculated by using Eqs (1) and (2), the results are listed in Table 3.

It can be seen from Table 3 that for several gas pipelines, the actual length of injected nitrogen in the trunk line is very

Table 1
Calculated length of injected nitrogen in the trunk line for the commissioning of Φ610 mm × 10 mm gas pipeline.

Total length of the trunk line/km	Length of injected nitrogen in the trunk line (at 0.02 MPa gauge reading, actual temperature)/km	Ratio of the length of injected nitrogen in the trunk line to the total length of the pipeline
500 (with 4 stations)	45.2	9.1%
750 (with 5 stations)	57.0	7.6%
1000 (with 7 stations)	70.2	7.0%
1250 (with 8 stations)	82.0	6.6%
1500 (with 10 stations)	95.1	6.4%

Note: The trunk line has an average wall thickness of 10 mm, average pipe volume in stations of approximately 150 m^3, and there is only one station, the initial station in the nitrogen section.