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Natural Gas Transmission Pipeline Temperature Drop Calculation

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Abstract

The numerical computation of natural gas pipeline temperature drop will provide the reference data for the design of gas pipeline, the judgement of hydrate formation, the normal production and operation. On the basis of Suhuofu formula, considering the effect of the Joule-Thomson, according to the natural gas flowing through a pipe heat conduction basic theory, combined with engineering thermodynamics, heat transfer and fluid mechanics knowledge, establishing gas transmission pipeline temperature drop model, adopt iterative method, the natural gas temperature along the pipe is calculated, comparing some kind of factors such as gas composition, the pipeline operational factor, the heat preservation situation, and analysis how the factors influent the temperature drop, providing the theory basis for how to reduce the temperature drop in the gas line, the heating power and the heating furnace heating temperature calculation, and energy conservation and optimization.

Key words: Natural gas; Temperature drop calculation; Gas line

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INTRODUCTION

In the process of natural gas transmission pipeline, the pipeline may generate hydrate with the decrease of temperature. This caused the pipeline section becomes smaller and volumetric efficiency becomes lower. The method of dehydration, heating or heat transfer sporting usually is used to transport the natural gas. Numerical calculation of gas pipeline temperature drop be used to judge whether the design of gas transmission pipeline hydrate and ensure the production operation to provide reference data[1]. This paper starts from the basic theory of heat conduction. According to the basic theory of thermal gas flow in pipeline, this paper combined with engineering thermodynamics heat transfer, fluid mechanics. Considering the various influence factors of natural gas components, pipeline design parameters ,thermal insulation and buried on the natural gas pipeline temperature drop[2]. The forward and reverse calculation of pipeline temperature drop is calculated, the temperature drop curve is draw. The calculation formula for natural gas pipeline along the temperature drop was come out. Effects of various factors on the temperature drop, gas composition, operating parameters, pipe insulation was contrasted to provide a way to reduce natural gas pipeline temperature drop[3].

1. PHYSICAL MODEL

The buried line contains enormous advantages, such as little limiting factors about terrain and surface features, shortening transportation range, safety seal, free of bad weather and long-term stable operation. So it gets common application in the petroleum pipeline engineering. Figure 1 is diagrammatic drawing about buried Natural gas pipeline.

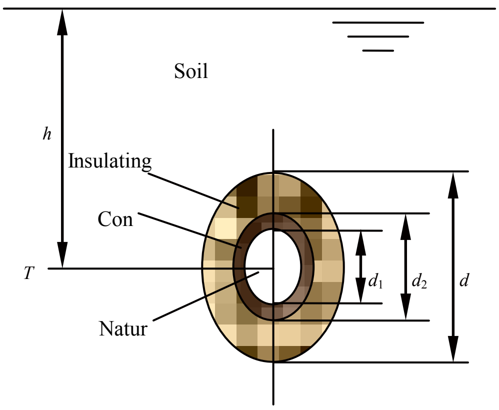

Figure 1
Schematic Diagram of Buried Gas Pipeline

2. THE PHYSICAL PARAMETERS OF NATURAL GAS

Natural gas in the pipeline have been formed through mixtures of Various single component gases which could not chemically react. Mean parameter are obtained by The properties of single component gases according to the mixing rule[4]. It mainly embodied in molecular weight, average density, virtual critical parameter, correlation parameter of natural gas. The main parameters in the process of calculation have heat absorption capacity, viscosity and coefficient of heat conductivity.

2.1 The Heat Absorption Capacity

By thermodynamics, the formula which calculate heat absorption capacity of is:

$$C_P - C_V = \frac{T}{\rho^2}\frac{\left(\frac{\partial P}{\partial T}\right)_\rho^2}{\left(\frac{\partial P}{\partial \rho}\right)_T} \quad (1)$$

Above formula: C_P is mass heat capacity at constant pressure, kJ/(kmol·K); C_V is mass heat capacity at constant volume, kJ/(kmol·K); T is temperature of The actual gas, K; ρ is density of The actual gas, kg/m^3; P is presure of The actual gas, Pa.

2.2 Viscosity

The viscosity of one component gas depends on the temperature and pressure, but component of gas also is an important factor to decide viscosity of gas mixture[5]. The viscosity of gas mixture rises with temperature increasing. The approximate formula that the temperature effect on gas dynamic viscosity is:

$$\mu_T = \mu_0 \frac{273+C}{T+C}\left(\frac{T}{273}\right)^{1.5} \quad (2)$$

Above formula：μ_T is gas dynamic viscosity when temperature is T, Pa·s; μ_0 is gas dynamic viscosity when temperature is 273 K, Pa·s; C is dimensionless number associated with the kind of gas. When absolute atmosphere is one,the illustrates dimensionless number of several hydrocarbons are as Table 1.

Table 1
The Illustrates Dimensionless Number of Several Hydrocarbons *C*

Name	C	Temperature/℃	Name	C	Temperature/℃
Methane	164	20~250	Pentane	383	122~300
Ethane	252	20~250	Ethylene	225	20~250
Propane	278	20~250	Propylene	321	20~120
Butane	377	20~120	Butene	329	20~120
Isobutane	368	20~120			

2.3 The Heat Conduction Coefficient

The heat conduction coefficient of gas hydrocarbon rises with temperature or pressure increasing. It could determine heat conduction coefficient though chart and calculation method[6].

2.3.1 The Effect of Temperature on Heat Conduction Coefficient

$$\lambda = \lambda_0 \frac{273+C}{T+C}\left(\frac{T}{273}\right)^2 \quad (3)$$

Above formula：λ is actual gas heat conduction coefficient, W/(m·K); λ_0 is gas heat conduction coefficient when temperature is 273 K, W/(m·K); C is dimensionless number associated with the kind of gas.

2.3.2 The Effect of Pressure on Gas Heat Conduction Coefficient

The heat conduction coefficient of one component gas is calculated according to the reduced density ρ_r when the pressure is high.

$\rho_r < 0.5$

$$(\lambda - \lambda_0)\Gamma Z_c^5 = (2.69654\times10^{-4})(e^{0.535\rho_r} - 1) \quad (4)$$

$0.5 < \rho_r < 2.0$

$$(\lambda - \lambda_0)\Gamma Z_c^5 = (2.51972\times10^{-4})(e^{0.67\rho_r} - 1.069) \quad (5)$$

$2.0 < \rho_r < 2.8$

$$(\lambda - \lambda_0)\Gamma Z_c^5 = (5.74673\times10^{-5})(e^{1.155\rho_r} + 2.016) \quad (6)$$

Above formula：ρ_r is gas compared density; λ_0 is low-pressure gas heat conduction coefficient, W/(m·K); Z_c is critical compression.

3. HYDRAULIC CALCULATION OF NATURAL GAS IN PIPELINE

3.1 Flow of Gas

Pipeline gas flow rate is calculated as:

$$u_s = 2.3\times10^{-5}\times\frac{QZT}{Pd_1^2} \quad (7)$$

Q is the beginning of the pipeline gas flow rate, m^3/s; Z stands for compression factor.

3.2 Gas Pressure

Assume the length of a section of gas pipeline as L. Assume x. X represents any point on the pipe from the B to A, the gas pressure of the pipeline is：

$$P_x = \sqrt{P_Q^{\,2} - \left(P_Q^{\,2} - P_Z^{\,2}\right)\frac{x}{L}} \qquad (8)$$

In the formula, p_Q describes the calculation of the starting pressure of the gas pipeline or the stop pressure upstream of the compressor station, MPa; P_z stands for the calculation of the ending pressure of the gas pipeline or the outbound pressure downstream of the compressor station for the gas pipeline, MPa[7-9].

4. PIPELINE GAS THERMODYNAMIC CALCULATION

4.1 Overall Heat Transfer Coefficient

Heat transfer process of buried pipeline consists of three parts: (a) the exothermic from gas to pipe wall; N layer heat transfer; (b) pipe wall insulation, N layer heat transfer and so forth; (c) heat transfer from pipe wall to the surrounding soil. Overall heat transfer coefficient is calculated as：

$$\frac{1}{Kd} = \frac{1}{\alpha_1 d_1} + \frac{1}{2\lambda_g}\ln\frac{d_2}{d_1} + \frac{1}{2\lambda_b}\ln\frac{d_3}{d_2} + \frac{1}{\alpha_2 d_3} \qquad (9)$$

In the formula, α_1 stands for the exothermic coefficient from gas to the inner pipe wall, $W/(m^2{\cdot}K)$; α_2 is described as the exothermic coefficient for the pipe wall to the surrounding medium heat transfer coefficient, $W/(m^2{\cdot}K)$; λ_g is the thermal conductivity of the pipe wall, W/(m·K); λ_b is the thermal conductivity of insulation, W/(m·K).

4.2 The Reduction Formula of Temperature

The Pipe wall reduction formula is calculated as：

$$T = T_0 + \left(T_Q - T_0\right)e^{-ax} - D_i\frac{P_Q - P_Z}{aL}\left(1 - e^{-ax}\right) \qquad (10)$$

In the formula, p_Q stands for the starting pipeline pressure, Pa; p_Z is the ending pipeline pressure, Pa; L is the pipe length, m; T is the gas temperature, K or ℃; T_0 is the ground temperature of burial deep pipeline in the, K or ℃; D_i joules - Thomson coefficient, ℃/MPa .

5. EXAMPLES OF CALCULATION AND ANALYSIS

5.1 Pipeline Design Parameters

Take from XUSHEN sixth gas gathering station to the song-associated gas pipeline for example, the design parameters are: Diameter φ 219 mm × 7 mm, the length is 12 km; Pipes are made of 20# steel, natural gas is the transmission medium, starting temperature is 60 ℃, starting pressure is 10 MPa, the ending pressure is 3 MPa, the designed capacity is 80 × 104 m^3/d; insulation materials adopt superfine wool carpets with the thermal conductivity of 0.035 W/(m·K), insulation thickness is 15 mm.

5.2 The Conditions of Laying Pipelines

Laying conditions: The depth of the center of the pipe is 1 m, the soil thermal conductivity is 1.5 W/(m·K), the air temperature is -20 ℃ (worst condition). The percentage of each component of the natural gas are in Table 2.

Table 2
The Percentage of Each Component of the Natural Gas

CH_4	C_2H_6	C_3H_8	n-C_4H_{10}	i-C_4H_{10}	CO_2	N_2
92.302	1.511	0.129	0.033	0.011	3.333	2.61

5.3 Fitting the Relationship Between Temperature and Distance

Considering the impact of throttling, the gas temperature of pipeline would below the underground temperature of the burial depths. When the temperature drop to the lowest point, soil transfer heat to the pipe, so that the temperature of the ending pipe would rise slowly. Fitting the relationship between temperature and distance are shown in Figure 2.

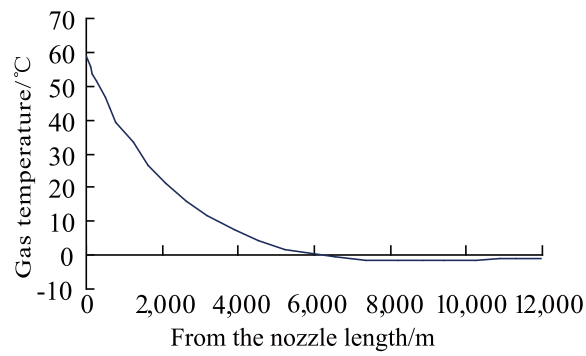

Figure 2
The Dropping Curves of the Pressure of Gas Pipeline

5.4 Comparing the Impact of Various Parameters on the Dropping of the Temperature.

In order to analyze the impact of various factors, enlarging or narrowing some of the Setting value[10]. Set the length of the Pipe is 15,000 m, other parameters are the same as the parameters from Xushen sixth gas gathering station to the song -associated gas pipeline. The consulting results of the impact of Pipeline are shown in Figures 3-13.

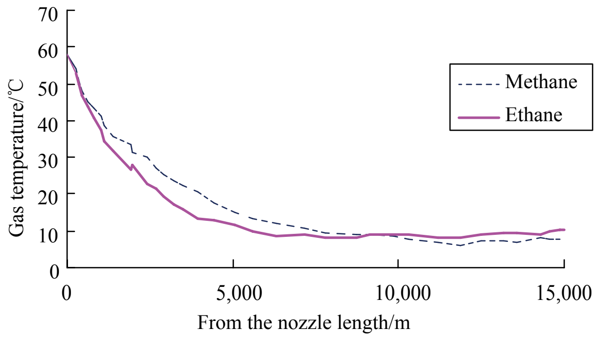

Figure 3
The Impact of the Content of Methane and Ethane on the Dropping of the Temperature

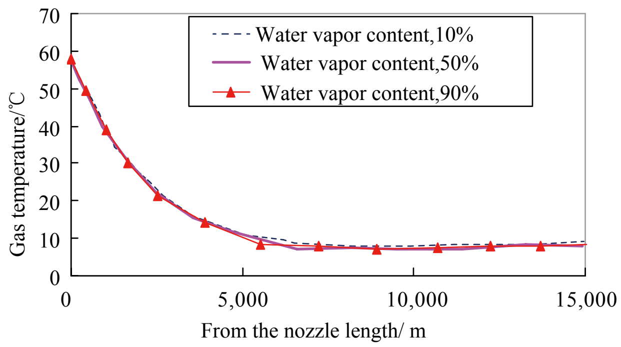

Figure 4
The Dropping of Temperature of Different Content of Water Vapor Along the Pipe

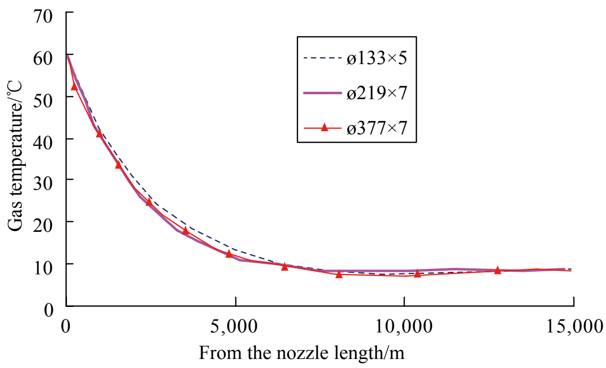

Figure 5
The Dropping of Temperature of Different Diameter Along the Pipe

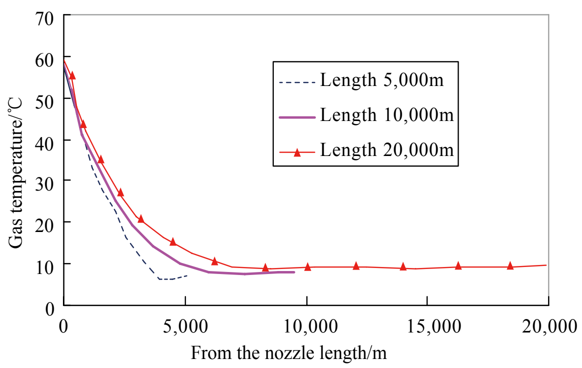

Figure 6
The Dropping of Temperature of Different Length Along the Pipe

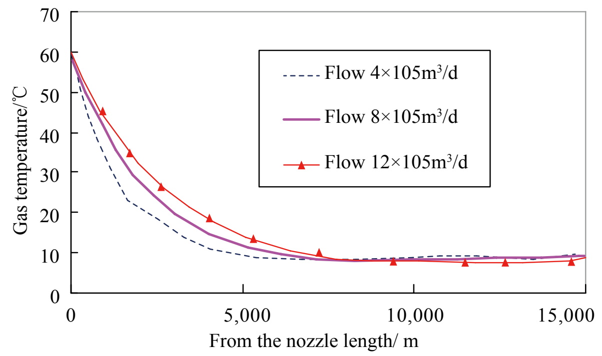

Figure 7
The Dropping of Temperature of Different Flow Along the Pipe

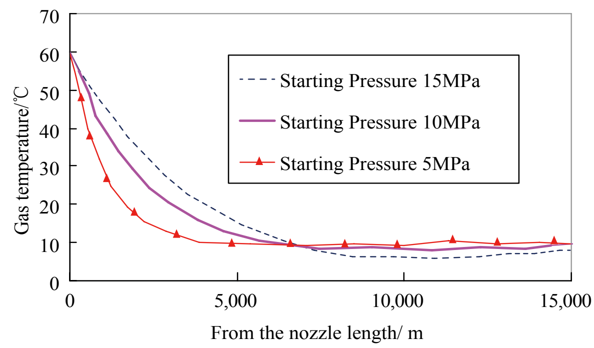

Figure 8
The Dropping of Temperature of Different Starting Pressure Along the Pipe

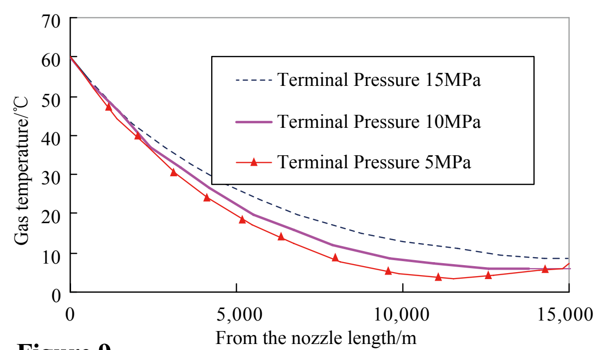

Figure 9
The Dropping of Temperature of Different Ending Pressure Along the Pipe

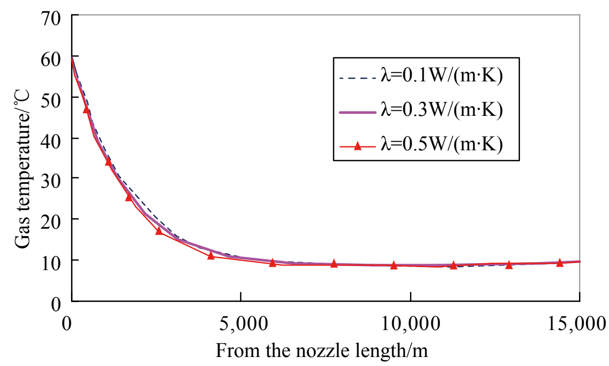

Figure 10
The Dropping of Temperature of Different Thermal Conductivity of the Insulation Layer Along the Pipe

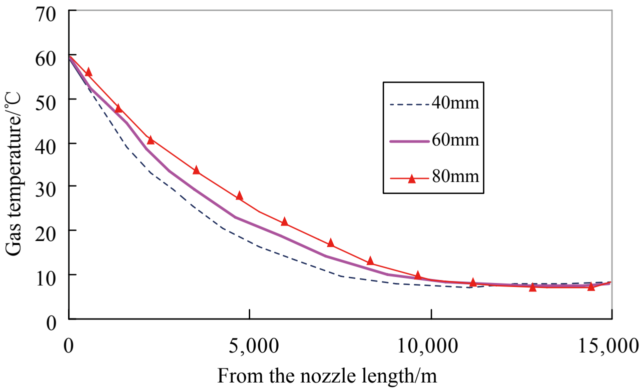

Figure 11
The Dropping of Temperature of Different Thickness of Thermal Conductivity Along the Pipe

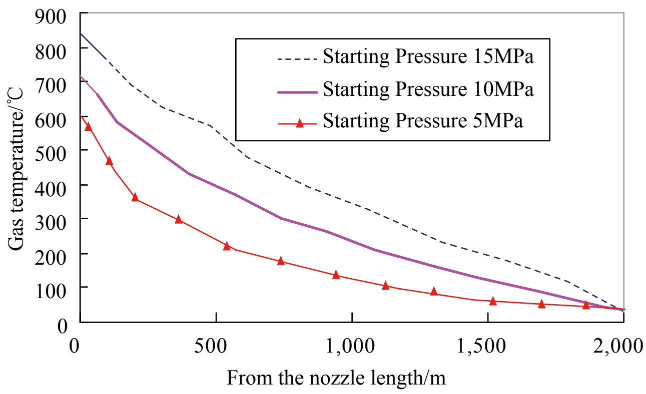

Figure 12
The Dropping of Temperature of Different Starting Pressure Along the Pipe

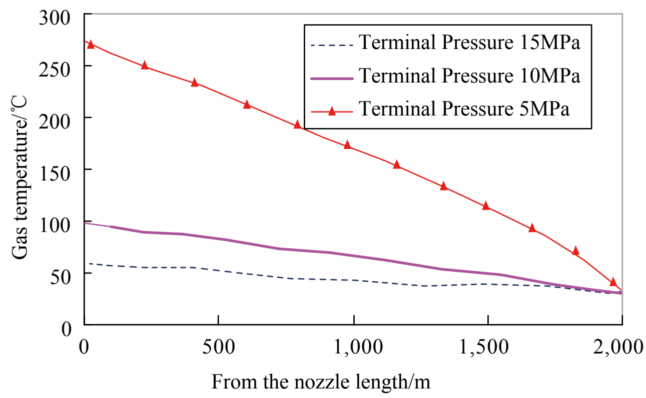

Figure 13
The Dropping of Temperature of Different Ending Pressure Along the Pipe

CONCLUSION

(a) Gas composition, the length, the task flow start and end pressure and the thickness of the insulation layer have a great influence on the temperature drop. Water vapor content, diameter and thermal conductivity of the insulation layer have little influence on the temperature drop.

(b) For the long distance gas pipeline, the temperature drop in the pipeline near the beginning is the most obvious. Because of the influence of throttling effect, the minimum temperature of natural gas will be lower than the temperature. After the gas heat transfer, the temperature of natural gas increased slightly.

(c) Starting and end point of the pressure and tube length effect of low temperature. The greater the differential pressure of starting and end point is and the smaller the length is, throttling effect is significant and the lowest temperature of natural gas is lower.

(d) When the length of the pipeline is longer, the diameter have no effect on the diameter.

REFERENCES

[1] Yao, L., Zhang, L. N., & Zhao, Y. (2004). Present situation and development trend of the natural gas storage and transportation technology. *Natural Gas Economy*, (5), 63-66.

[2] Shen, W. D., Jiang, Z. M., & Dong, J. D. (2001). *Engineering thermodynamics* (3rd ed.). Beijing, China: Higher Education Press.

[3] Wang, S. L., Zhao, Z. Y., & Wang, S. H. (1999). Temperature drop calculation method of oil gas gathering and transportation pipelines. *Oilfield Surface Engineering*, *18*(2), 22-25.

[4] Yang, S. M. (2006). *Heat transfer* (4th ed.) (pp.4-6). Beijing, China: Higher Education Press.

[5] Tao, W. S. (2000). *Recent progress in computational heat transfer* (pp.1-16, 33-37). Beijing, China: Science Press.

[6] Liu, J. L., Liu, J., & Ren, H. (2010). Discussion on natural gas hydrate sampling height. *Oil Field Equipment*, *39*(10), 12-15.

[7] Li, W. C., Wang, F. J., Li, Y. M., & Hong, H. Y. (2006). The analysis and evaluation of the total heat transfer coefficient of long distance pipeline. *Oilfield Surface Engineering*, *25*(10), 20-21.

[8] Li, C. J. (2000). *Pipeline transportation of natural gas* (pp.86-94). Beijing, China: Petroleum Industry Press.

[9] Liu, D. S., Gong, J., & Wu, H. H. (2010). The experimental research progress of the 3rd phase flow. *Oil Field Machinery and Oil Gas Water Level Tube*, *39*(4), 9-16.

[10] Li, J., Wang, P., & Wang, H. X. (2009). Drop law. *Journal of Higher School of Petrochemical Pipeline Temperature Exposed*, *22*(1), 73-75.

