Application of gas well production system analysis on down-hole throttling design of natural gas well

Chenshuang Lv [1, a], Lingfeng Li [1, b, *]

[1]Key Laboratory of Exploration Technologies for Oil and Gas Resources, Ministry of Education, Petroleum Engineering College of Yangtze University, Wuhan , 430100, China

[a]706749135@qq.com, [b]403089315@qq.com

* Corresponding Author

Abstract

Natural gas is a clean and efficient energy source. Natural gas has more advantages in reducing emissions and environmental protection than traditional fuels. Natural gas has the potential for large-scale development and is an important part of clean energy. Natural gas has a clean, efficient, safe, convenient transportation and so on. Natural gas well production system analysis (nodal analysis) is an important means for the overall optimization of natural gas well production system. It uses system engineering theory to deal with the flow process in the gas reservoir, vertical flowing process of gas wells and gas gathering system as a complete gas production system, and can carry out the overall optimization analysis. It can be used to design and evaluate the advantages and disadvantages of various parts of the natural gas well production system. In this paper, gas well production system analysis (nodal analysis) and software is applied to the natural gas well down-hole throttle design from the overall situation of the natural gas production system. And the natural gas well down-hole throttle design in the G production block of a natural gas field were simulated and optimized by gas well production system nodal analysis software(PIPESIM software). During the simulation process, the formation of hydrate formation was analyzed by various factors such as temperature, wellhead pressure, depth of inflow, and diameter of down-hole throttle, to select a reasonable down-hole throttle diameter and down-hole throttle depth into the well. The application of down-hole throttling has achieved good results, and down-hole throttling can effectively simplify the natural gas ground production system process, and improve the efficiency of natural gas production system.

Keywords

Natural gas; Production system analysis; PIPESIM software; Down-hole throttling; Application.

1. Introduction

As a clean and high-quality energy, natural gas has become the very important economic growth point in the 21st century energy strategy. Its status in the energy resources continues to be prominent. And natural gas wells and pipes will form dangerous hydrates in the process of production. Underground throttle technology can not only effectively control the formation of the hydrate of the wellbore and the ground pipeline, but also has the advantages of controlling the agitation of production layer, simplifying the ground gathering and transportation process, and greatly saving the cost. Installation of the throttle makes full use of ground temperature for heating after the throat of natural gas well, so the temperature of natural gas after throttle is higher than the temperature of hydrate formation. Natural gas well production system analysis (nodal analysis) is an important means for the overall optimization of natural gas well production system. It can be used to design and evaluate the advantages and disadvantages of various parts of the natural gas well production system. In this paper, the gas well production system node analysis and the software is applied to the natural gas well down-hole throttle design from the overall situation of the natural gas production system. And the natural gas wells down-hole throttle design in the G production block of a natural gas field, as an example, were simulated and optimized by natural gas well production system analysis software. During the simulation process, the formation of hydrate formation was analyzed by various factors such as temperature, wellhead pressure, depth and diameter of down-hole throttling, to select a reasonable throttle diameter, throttler depth into the well. The design of down-hole throttling achieves the goal of hydrate prevention and control. The down-hole throttling can reduce the pressure of wellhead and gathering pipeline, prevent the formation of hydrate, simplify the process of surface gathering and transportation.

2. Natural gas well production system analysis

Gas may flow through several components from the reservoir to the surface separator, as shown in Fig.1. From the point of pressure loss, the total pressure loss along the way from the reservoir to the surface separator includes several components of loss. For gas wells, The pressure loses flow through the porous medium, completion, tubing string, and flow line are regarded as 4 subsystems respectively[1-3]. The pressure system of the entire production consists of the four pressure subsystems above.

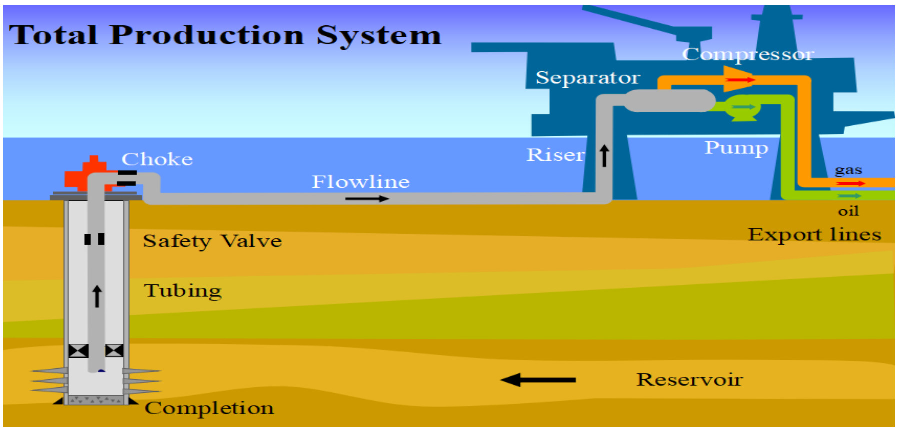

Figure 1. Producing system of natural gas well

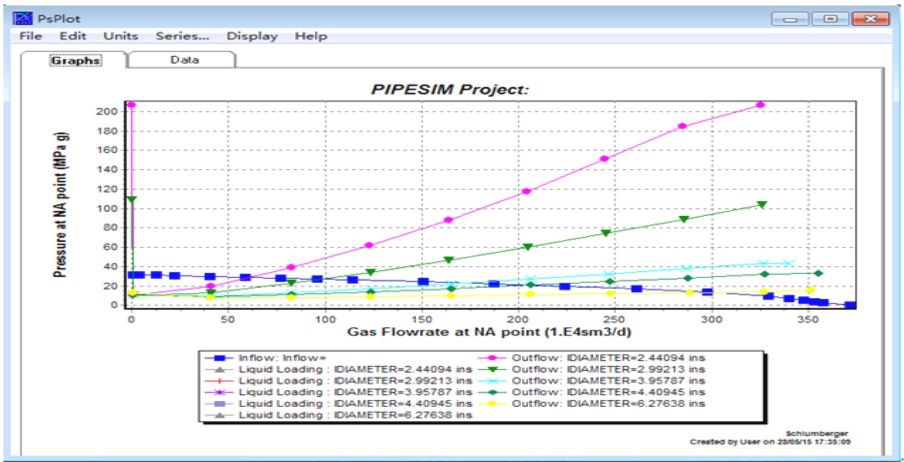

Figure 2. Drawing dynamic curve by using nodal analysis

Fig.2 is simulation of pressure of well dynamic curve and application to select a reasonable throttle diameter using nodal analysis. Fig.3 is hydrate formation temperature with different throttle diameters by using nodal analysis software(PISESIM software).

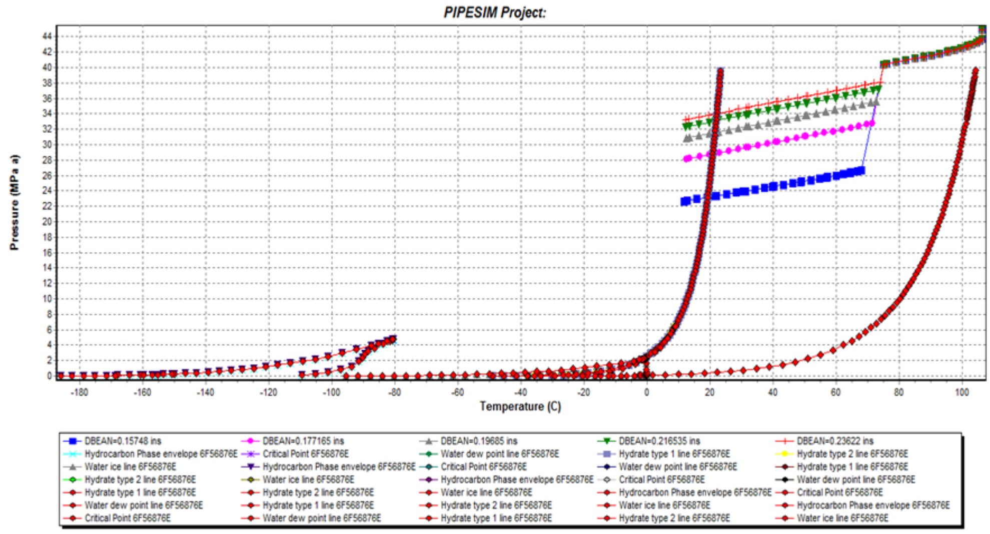

Figure 3. Hydrate formation temperature with different throttle diameters by using nodal analysis software

3. Natural gas hydrate formation analysis of gas well and design of down-hole throttling

3.1 Gas hydrate formation and control methods

Natural gas hydrate is a complex and extremely unstable compound, which consists of hydrocarbons and water. Its chemical formula is $CH_4 \cdot 7H_2O$, $C_2H_6 \cdot 8H_2O$, $C_3H_8 \cdot 18H_2O$, and is the white crystalline material, and similar to the ice or dense snow. As long as the conditions are met, it can be formed in the pores of the pipe, wellbore and porous media. Hydrate is very harmful, affecting the natural gas producing, gathering and processing of the normal operation. Over the years, hydrate has become the primary problem troubled in gas field for gas wells safety production. The formation of natural gas hydrate will increase the pressure drop of the pipeline, and even cause congestion in the throat and other parts of the pipeline, affecting the normal exploitation of natural gas wells. In natural gas storage and transportation process, hydrate formation will lead to valve block, which is a serious accident. Especially in the late stage of gas field development, it will form a large number of hydrates. Most of the gas fields have low temperatures in winter. At present, the clogging of hydrate in many gas wells is very serious, which directly affects the production of gas wells, and will cause a lot of waste of natural gas resources. Therefore, it is of great practical significance to effectively predict the generation conditions of natural gas hydrate and take reasonable measures to prevent. Down-hole throttling technology can not only effectively control the formation of the hydrate of the well and the ground pipeline, but also has the advantages of simplifying the ground gathering and transportation process, and greatly saving the production cost. By full use of the temperature of the underground layer, the temperature of natural gas after throttle may be higher than the temperature of hydrate to prevent hydrate, which is very favorable for gas well safety production.

3.2 Throttling mechanism and process parameter design

The principle of down-hole throttling technology is to move the ground gas nozzle into the upper tubing of the down-hole production layer, and use the formation temperature to compensate the temperature drop caused by throttling, so that the throttling, depressurization and expansion process of the natural gas occurs in the wellbore. The natural gas can still absorb the layer temperature after the throttling and cooling of the down-hole choke, and can reduce the gas pressure in the wellbore, and improve the wellhead temperature of the natural gas, and make the gas pipeline to run under lower pressure. In this way, the pressure and temperature conditions of hydrate formation can be broken, and the blockage of hydrate to oil pipe and gas pipeline can be effectively reduced or eliminated, and the purpose of preventing hydrate formation can be achieved.

The purpose of down-hole throttling is to prevent the formation of hydrate in wellbore and well station, and the temperature of gas flow must be higher than that of hydrate formation. Through the analysis of the temperature and pressure of the gas flow around the shaft and the well station, we know that the temperature after the down-hole throttling is determined by the depth of the throttle and the diameter of the choke. The design method of down-hole throttle technology parameters are mainly based on temperature distribution mathematical model. We established the wellbore pressure drop, hydrate formation conditions and a reasonable mathematical model to determine the diameter of nozzle.We can optimize the reasonable depth of down-hole throttle and can reasonably determine the specific parameters of choke diameter. The design steps are as follows [4-7]:

(1)According to the design yield and the wellhead pressure before throttling, the wellbore pressure and temperature distribution are predicted, and the curve of the relationship between the pressure and temperature and the well depth is established;

(2)According to the design yield and the wellhead pressure after throttling, the curve of the relationship between the wellbore pressure and temperature and the well depth under the condition of down-hole throttling is predicted;

(3)Taking the wellhead as the starting point and taking the appropriate well depth step, according to the pressure drop before and after throttling, the temperature drop at different points after throttling and the natural gas outlet temperature after throttling nozzle are predicted;

(4)The hydrate formation temperature after throttling nozzle is predicted according to the fluid composition and the pressure after throttling;

(5)According to the hydrate formation temperature, when the gas flow temperature after throttling is greater than the pressure of hydrate formation after throttling, that is the reasonable depth of the nozzle;

(6)According to the pressure before and after throttling and the airflow temperature before throttling and the designed gas well production, the choke diameter is chosen;

(7)According to the predicted choke diameter and down depth, the down-hole throttling parameters are determined.

4. Using nodal analysis and the nodal analysis software PIPESIM to predict hydrate formation of gas well

4.1 Nodal analysis software PIPESIM introduction

The Pipesim software developed by Schlumberger Corp is a design and analysis system for integrated simulation and optimization of reservoir, wellbore and ground pipe networks. The system can be based on different fluid production wells reservoir, wellbore, ground conditions, simulation analysis and optimization design to complete the single well analysis. Network also can be composed of a single well block simulation and analysis, to study effect of single well on the whole network from the macro, so as to put forward to well control measures.

4.2 Analysis of factors affecting hydrate formation[8-10]

The hydrate formation must have the following conditions: (1) with the presence of free water; (2) low temperature (usually less than 30 ℃), low temperature is an important condition for the formation of gas hydrate; (3) high pressure, high pressure is also an important condition for hydrate formation; (4) the gas molecules of appropriate size. In addition, there are some auxiliary factors that promote and accelerate the formation of hydrate. The gas liquid contact area is larger, and there are tiny hydrate crystals (seed crystals). Auxiliary conditions may include: the fluctuation of pressure in the flow process of gas, or the agitation produced by the pipeline or production equipment, the vortex produced by the sudden change of gas flow direction, the existence of acid gas and the induction of tiny hydrate crystal nucleus. The PIPESIM software is used to analyze the influence of common factors on hydrate formation from different production conditions.

4.2.1 Prediction of hydrate formation in well under different nozzle diameter of G gas field

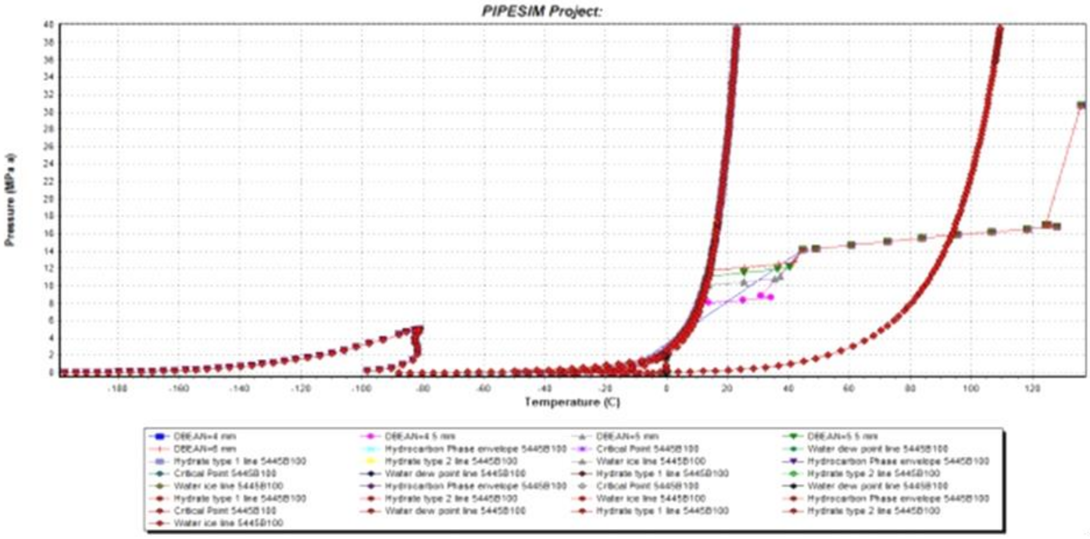

Figure 4. Prediction of hydrate formation in wellbore under different nozzle diameter

Considering the influence of different nozzle diameter changes on the hydrate formation in the gas well production of G gas field, the nozzle diameter is 4.0 mm, 4.5 mm, 5 mm, 5.5 mm and 6 mm respectively under the same formation pressure and yield, and the production conditions under different nozzle diameter are simulated. The simulation results are shown in Figure 4. From Figure 4, the smaller the diameter of the throttle, the greater the pressure drop in the throttling process, the lower the wellhead pressure, the lower the hydrate formation temperature, the more unfavorable to hydrate formation. The throttle pressure drop effect is most obvious between the nozzle diameter 4.0 mm and 4.5 mm. With the nozzle diameter increasing, the throttle pressure drop between the adjacent nozzle diameter decreases gradually.

4.2.2 Prediction of hydrate formation in wellbore under different formation pressures

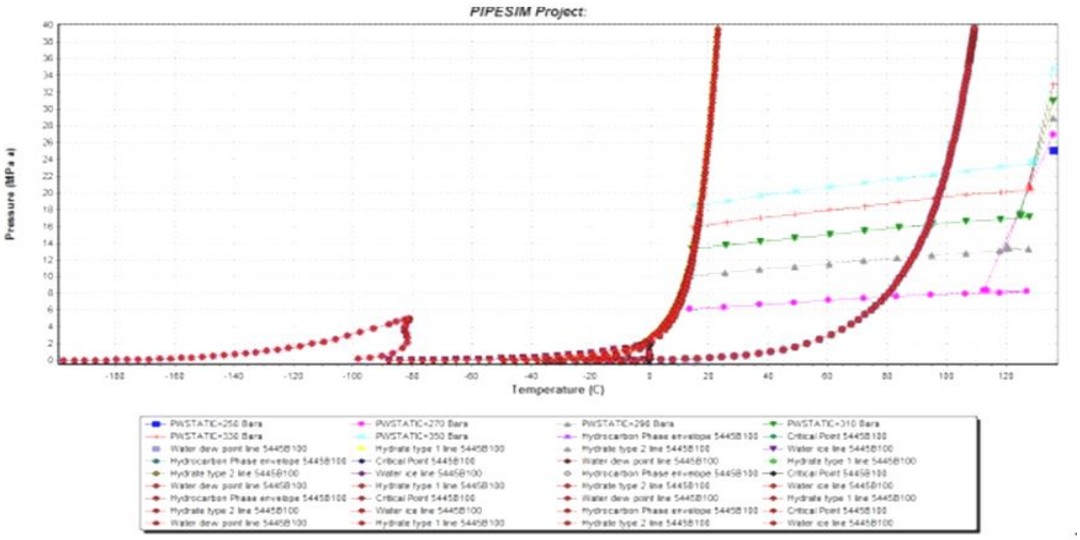

Figure 5. Prediction of hydrate formation in wellbore under different formation pressure conditions

Considering the influence of different formation pressure on hydrate formation in gas well production in G gas field, with the exploitation, the formation pressure gradually decreases, so it is necessary to simulate the production under different static pressure conditions. The 62 mm size tubing is selected to simulate the production conditions under different formation pressures, and the simulation results are shown in Figure 5.

It can be seen from Fig. 5 that the pressure of the bottom-hole to the wellhead decreases as the formation pressure decreases and the production is kept constant. The corresponding hydrate formation temperature decreases, below the wellhead temperature, and the hydrate formation is avoided.

4.2.3 Prediction of hydrate formation in wellbore under different tubing sizes

Considering the different changes of tubing size and its effects on wellbore hydrate formation in G gas field gas production, selecting different tubing diameter, respectively 62 mm, 68 mm, 76 mm, 98 mm, 102 mm, production of different diameter of the same formation pressure and gas production conditions were simulated, and the simulation results are shown in Figure 6.

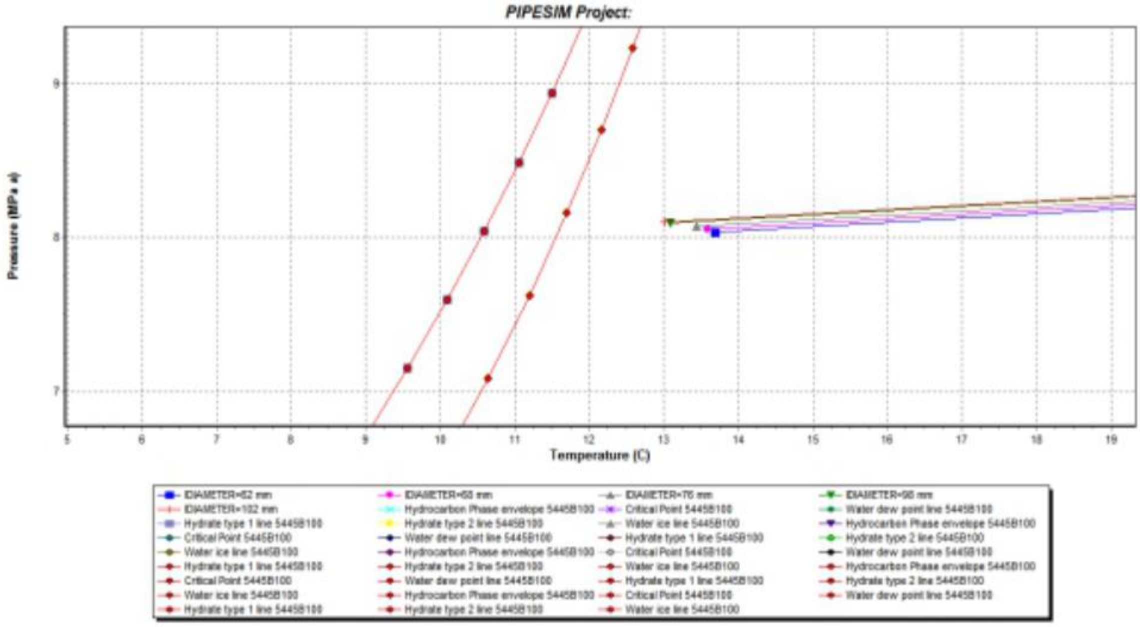

Figure 6. Prediction of hydrate formation in wellbore under different tubing size

4.2.4 Prediction of hydrate formation in wellbore under different gas production conditions

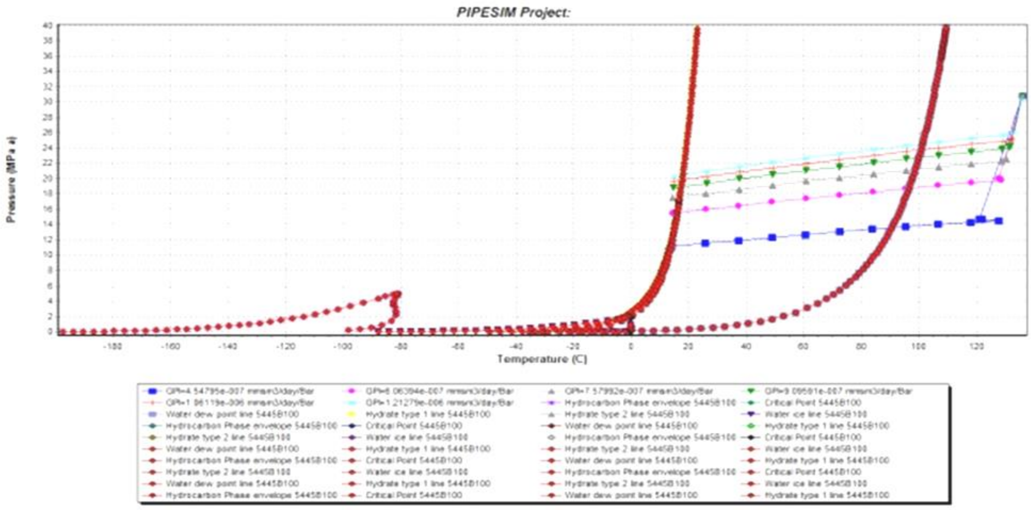

Figure 7. Prediction of hydrate formation in wellbore under different gas production conditions

It can be seen from Figure 7 that the change of gas production has little effect on the change of temperature and pressure in production, but the greater the gas production, the more conducive to hydrate formation.

5. Gas well down-hole throttling design by using nodal analysis software (PIPESIM)

5.1 PIPESIM simulation design basic data

In view of the fact that gas hydrate is easy to produce gas hydrate in G gas field, which seriously affects the safety and stable production of gas wells, taking a production well as an example, the applicability of down-hole throttling technology in the gas field is studied through the downhole throttling process design simulation test. The model built by PIPESIM software is as shown in Fig.8.

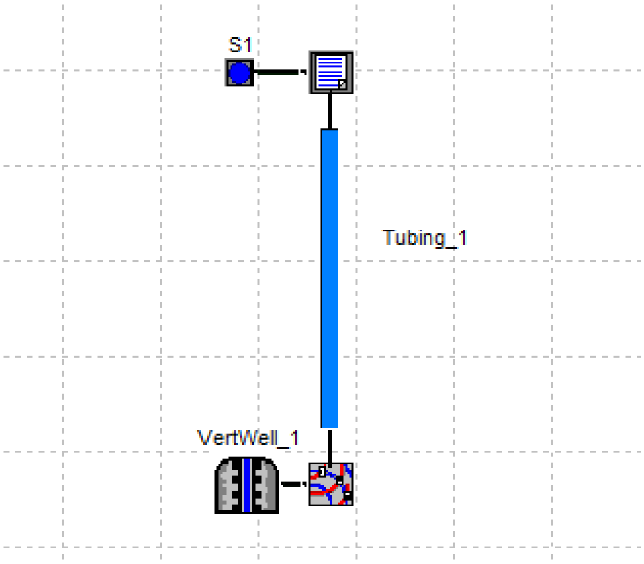

Figure 8. Simulation model setting diagram

5.2 Calculation results of non-throttle model

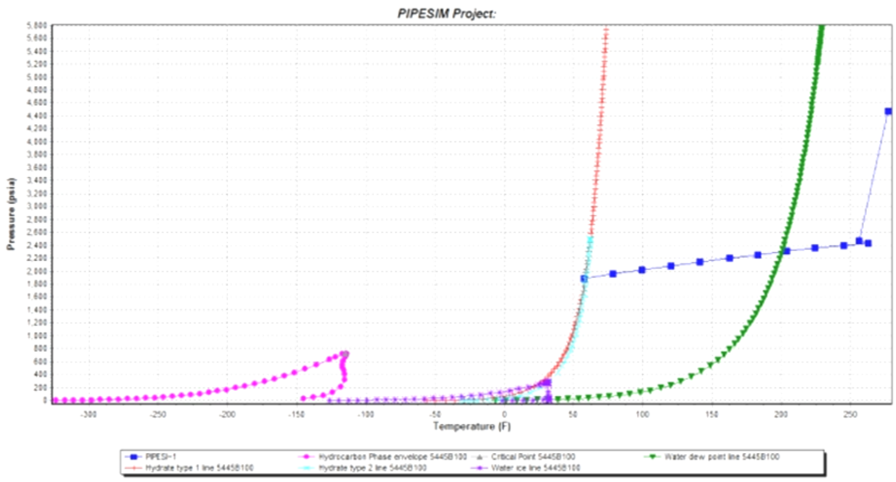

Figure 9. Pressure-temperature curve based on the phase diagram

The pressure and temperature curves based on phase diagrams are obtained when the software runs without throttling. It can be seen from the figure 9 that there is an intersection point between the system temperature pressure curve and the hydrate formation curve, indicating that hydrate formation may occur in the process of production. We can sort out the data of wellbore pressure and temperature and the data of hydrate formation temperature distribution without throttling, and obtain the data of wellbore pressure, temperature and hydrate formation temperature without throttling. We can get the distribution curve of pressure and temperature along well depth and hydrate formation temperature curve by the data collected and summarized, so we can know that hydrate can be formed in the wellbore near the wellhead, and down-hole throttling technology is needed to prevent hydrate.

5.3 Throttling model calculation results

After PIPESIM simulation, the wellhead oil pressure is 10.0 MPa. By the formation pressure given, we can determine the bottom hole flowing pressure according to the productivity equation and production requirements, and take the bottom hole as the solution node for analysis. According to the bottom hole flow pressure and the wellhead pressure and the production capacity, we can calculate the throttle orifice diameter by substituting different depths. When the temperature of nozzle and wellhead temperature are greater than the hydrate formation temperature of the corresponding point, the minimum downward entry depth is obtained. It can be seen that the temperature and the wellhead temperature are higher than the hydrate formation temperature when the nozzle is 4.5 mm at least the depth of 400 m. In engineering application, in order to get higher wellhead temperature and increase the temperature before throttling, it is possible to increase the down entry depth on the basis of determining the minimum down entry depth, and select the 4.5 mm nozzle choke at the depth of 800 m. Using PIPESIM software to simulate the throttling process, the following pressure and temperature can be obtained. It can be seen that after the downhole throttling, due to the heat transfer effect of the layer temperature on the fluid in the wellbore, the temperature rises and reaches the expected target.

It can be seen from Fig. 10 that the temperature and pressure curves of the system after the throttling have no intersection with the hydrate curve, and it is predicted that there is no hydrate formation, and the 4.5 mm nozzle restrictor is reached at 800 m to achieve the purpose of controlling the hydrate. It can be seen from the above, according to the gas production, the minimum inflow depth of throttle design is 800 m, and throttle diameter is 4.5 mm. In order to prevent the formation of hydrates, try to increase the temperature before throttling, the depth of inflow is increased appropriately on the basis of determining the minimum inflow depth, so that the air flow after the throttling is fully heated with the formation temperature. The final selection depth is set at 1200 m and the throttling diameter is 4.5 mm.

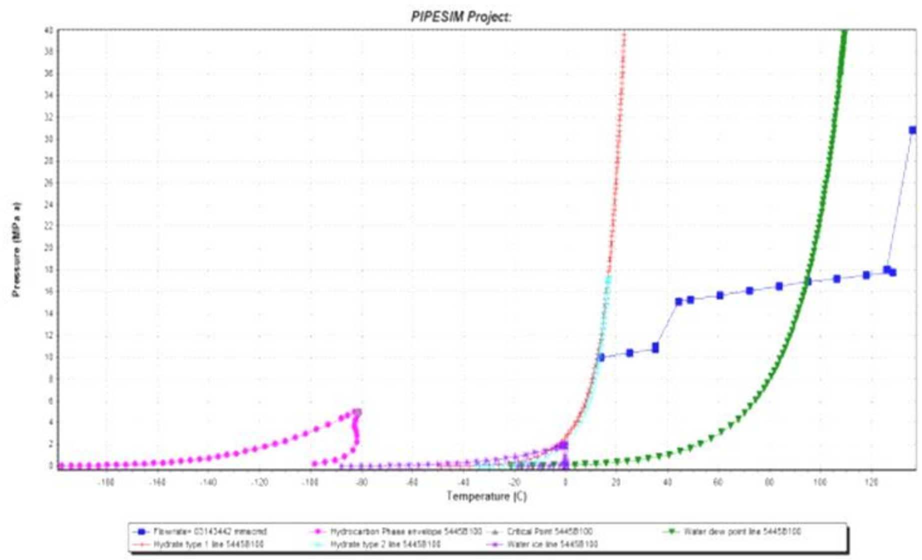

Figure 10. Pressure-temperature curve based on the phase diagram after throttling

6. Conclusion

Natural gas is a clean and efficient energy source. Natural gas has many advantages in reducing emissions and environmental protection. Natural gas has the potential for large-scale development and is an important part of clean energy. Natural gas has a clean, efficient, safe, convenient transportation and so on. Natural gas as a clean, high-quality energy, has become the most important economic growth point in the 21st century energy strategy. Downhole throttling is a strong method for the prevention and control of natural gas hydrate in natural gas gathering and production system,which avoids the large amount of capital investment and reduces the maintenance, and also has more advantages than other methods. However, the change of the pressure temperature in the gas well is a complex state. How to judge the applicability of the restrictor is our primary problem. Natural gas well production system analysis and the gas well production system nodal analysis software PIPESIM can simulate the various processes of gas well production with high precision, provide the pressure and temperature value and generate the phase diagram, which can let us have an intuitive judgment on the formation of hydrate. In this paper, the gas field of G gas field is used as an example to verify the applicability of PIPESIM software and to design a reasonable size, and to determine whether the design of the throttler is reasonable. By using in G gas field, it can reduce the pressure of gas wellhead and gathering and transportation pipeline, to control the formation of hydrate, to simplify the process of gathering and gathering ground, and to improve the efficiency of natural gas production system.

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