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Monitoring and Alarming System for Hydrate in Gas Wells

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Abstract

When the wellhead temperature for gas wells is low, freezing accident in wellbore could happen because of hydrate generation. Through designing the monitoring and alarming system, the freezing accident can be avoided. The pressure and temperature distribution along wellbore is computed through multi-phase flowing theory, based on the data acquired from the wellhead. Comparing to the hydrate P-T Graph by the picture interpreting means, the results can judge the situation of the hydrate and show the depth range with the hydrate in gas wells, so that the system can monitor and alarm hydrate. The system contains three main functions: calculating the pressure and temperature in wellbore during production or well shutting; forecasting the hydrate generation; design of the alarming and prevention. The software made up by these methods can realize the aim to real-time monitor and alarm hydrate. Finally, the software of the system is shown with the suggestion to avoid hydrate during gas well testing and production.

Key words: Gas well; Hydrate; Monitoring; Well head freezing

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INTRODUCTION

Natural gas usually accompanies water when we produce it. When the water in the wellbore has reached saturation, continuous high pressure will throughout the borehole because of low-density mixing fluid. The production is very different if well bore temperature is low, that is because generated natural gas hydrate crystal can gather in tubing wall or flow regulator and then freeze up[1]. Most of all frequent change of working system during backpressure test and fuzzy understanding the about production state of gas well made the potential threats of hydrate formation in well bigger. So monitoring manufacturing parameters of wellhead in real time is very important as well as resulting from physical property parameters of multiphase flow in wellbore. Ultimately form theoretical method of gas well hydrate real-time warning for devoid freeze-up happens which is because of careless operation.

Gas well hydrates monitoring and alarming system is a kind of real-time dynamic monitoring. The monitoring point located between wellhead and separator, which is 10 meters away from well head. It collects pressure, temperature and flow rate in real time when the natural gas passes the point. With monitoring system, an alarm can sound to reminder operators to prepare for prevention if the data reach the alarm threshold.

The monitoring and early warning system calculate pressure and temperature distribution along the wellbore based on gas reservoir parameters, wellbore parameters, thermodynamic parameters and manufacturing parameters, then get the natural gas hydrate p-t with different components through graphical method, then estimate whether the wellbore can produce a hydrate, if the answer is yes, the system will warning and prevent it.

We design three computation modules: wellbore parameter calculation, hydrate generation forecasting and early warning based on the operation principle of the monitoring system.

1. WELLBORE PARAMETER

We divide working status of the well into well startup and well shut-in based on approximation of wellhead temperature, pressure and flow which is got 10 meters away from the wellhead. The wellbore parameter calculation is different in different production status.

1.1 Well Startup

When the gas flows upwards the wellbore from the down hole, heat transfer to all-around formation will happen through heat conduction, convection and radiation because of the temperature difference between the gas and formation around the wellbore. As shown in Figure 1[2], the heat transfer mediums are tubing, annulus, casing, cement sheath and stratum.

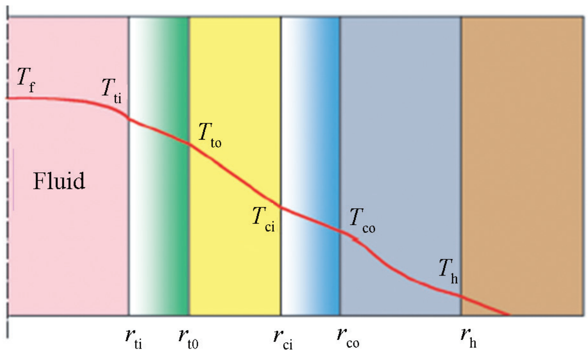

Figure 1
Tubing Annulus Casing

We can get the wellbore temperature distribution formula according to Shui&Beggs wellbore temperature computing method[3]

$$T_f(z) = T_{wf} - g_T z + g_T A - g_T A e^{-z/A}. \quad (1)$$

$T_f(z)$ is the temperature at any point in wellbore, K; T_{wf} is the bottom hole temperature (approximately gas reservoir temperature), K; g_T is geothermal gradient, K/m; Z is the well depth, m; A is the relaxation distance, it is concerned with output, fluid density, diameter of oil tube and geothermal gradient, m.

Getting different point temperature based on temperature model and finally get the wellbore pressure distribution, which is calculated by the way of Beggs&Brill, the steps are listed below: Take the wellhead pressure as initial pressure, design iteration well section depth, estimate target segment pressure and judge flow pattern, then calculate parameters associated with fluid and pressure gradient, so we can get the theoretical calculation of target segment pressure. At this time, comparing it with estimated pressure before, the calculated value is correct if it is within the limit of error. Then take the calculated value as initial pressure for the next segment calculation to do iteration until get pressure distribution of the whole well.

When calculating wellbore parameters in monitoring system, the wellhead temperature and pressure in real-time we used is not consistent with monitoring point data in reality, that is because there is some difference between wellhead and monitoring point, pressure loss and heat loss of surface pipeline has a little to do with flow and surface temperature. The monitored temperature is largely deviated from wellhead temperature especially when the surface temperature is too low. So it is necessary to correct the wellhead parameters. The formula of calculating pressure and temperature is below[4].

$$p_1 = \sqrt{p_2^2 + \left(\frac{Q}{11522 E d^{2.53}}\right)^{1/0.51} ZTL\gamma_g^{0.961}}, \quad (2)$$

$$T_1 = \frac{T_2 - T_0}{e^{-aL}} + T_0. \quad (3)$$

In formulas, P_1 is calculated wellhead pressure, MPa; P_2 is monitoring point's pressure MPa; L is the distance from the monitoring point to the wellhead, m; T is monitoring point's temperature, K; d is the diameter of surface oil pipeline, cm; E is efficiency coefficient; T_1 is calculated wellhead temperature, K; T_2 is monitoring point's temperature, K; T_0 is surface temperature, K; $a=KL\pi d/mC_p$, m is mass flow rate, kg/d, K is the over thermal conduction of surface pipeline, W/(m·k).

1.2 Well Shut-In

The fluid in wellbore will dissipate heat to the stratum after the well is shut up. If off-time is infinitely long, the wellbore temperature will tend to formation temperature. The formula of temperature in wellbore is below[5-6]:

$$T_f = (T_{f0} - T_{ei}) e^{-a\Delta t} + T_e. \quad (4)$$

In the formula, T_{fo} is initial temperature, K; T_f is target temperature, k; Δt is closed-in time, s; T_{ei} is initial formation temperature, k; T_e is target formation temperature, k; H is well depth, m; Z is target segment depth, m; $a = \frac{2\pi K_e}{m(1+C_p)}$, K_e is wellbore thermal conductivity, W/(m·k); m is gaseous mass of Z segment, g; C_p is specific heat capacity of gas at constant pressure, J/(g·K). Each parameter is shown in the Figure 2.

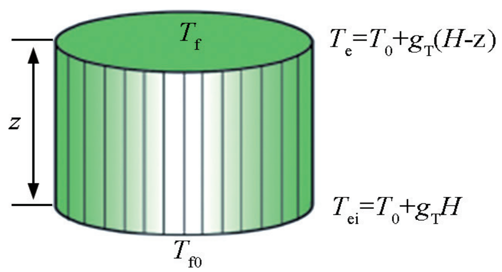

Figure 2
Meters of Stage in Gas Well

Geothermal gradient should be calculated according to the following formulas

$$H < Zo, Te = \frac{T_{oe} - T_o}{H_c} H + T_o \ , \quad (5)$$

$$H \geq Zo, Te = T_{oe} + G_T(H - Zo)\ . \quad (6)$$

In the formulas, H is the gas reservoir depth, m; T_e is formation temperature, ℃; T_{oe} is the boundary temperature of constant zone, ℃; Z_0 is the boundary depth of constant zone, m; T_0 is the ground average temperature, ℃, it could be got by the method of interpolation between maximum temperature and minimum temperature that day.

If the wellhead temperature can be monitored in real-time, then the bottom hole temperature can be calculated by that and finally get the temperature distribution of whole well.

The pressure distribution along the well is related to fluid density during shut-in period of a gas well, the calculation formulas is below [2]

$$P_{ws} = P_{wh} e^s\ , \quad (7)$$

$$s = \frac{28.97\gamma_g g H}{R\bar{T}\bar{Z}} = \frac{28.97\gamma_g \times 9.81\mathrm{H}}{8.315 \times 10^{-3}\bar{T}\bar{Z}} = \frac{0.03415\gamma_g H}{\bar{T}\bar{Z}}\ . \quad (8)$$

In the formulas, P_{ws}, P_{wh} are bottom hole static pressure and static wellhead pressure of gas well, MPa; H is the depth from wellhead to the middle of gas reservoir, m; T is the average temperature of static gas column in wellbore, $T=(T_{ws}+T_{wh})/2$, k; Z is average deviation factor of gas column in wellbore

We can apply the method of piecewise iteration for a more-accurate wellbore pressure. Setting length from wellhead to the bottom can get pressure distribution of whole well.

2. FORECASTING METHOD OF HYDRATE FORMATION

After we got wellbore temperature and pressure, combine it with the predicted temperature-pressure map of hydrate formation with different components of natural gas, then judge generating condition of hydrate for early warning.

Graphical method experience formula method[7-10], phase equilibrium calculation and statistical thermodynamics can be used for forecasting pressure and temperature of hydrate formation. The graphical method can get pressure-temperature graph of hydrate formation by query the plate; Lev Ponomarev experience formula method organized a large number of experimented data to obtain natural gas hydrate formation conditional equation with different density; phase equilibrium calculation introduce phase equilibrium constant to evaluate the condition of natural gas hydrate formation, but it is not accurate enough when non hydrocarbon component is high or it is high pressure gas; statistical thermodynamics derived statistical thermodynamic algorithm of forecasting natural gas hydrate formation, this method has a high computing precision which is also very complex with so many parameters.

Since many thermodynamic parameters are difficult to obtain accurately during the test of gas well, statistical thermodynamic is not suitable for the forecasting. Phase equilibrium calculation is also inappropriate because there are so many high-pressure gas wells[11]. Graphical method and experience formula method are suitable for forecasting hydrate formation; graphical method is selected in this study as shown in Figure 3[12].

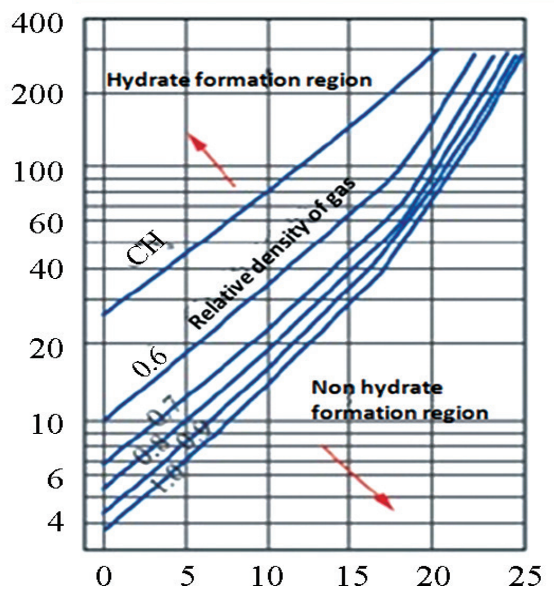

Figure 3
***P-T* Curve of Natural Gas**

It can be seen from Figure 3 that hydrate formation is easier with smaller relative density of natural gas. When temperature reach 30℃, no hydrate generate no matter what its pressure is.

With the help of wellbore pressure distribution from real-time monitoring and calculation, we can get the corresponding temperature of hydrate formation at this pressure by graphical method. Comparing it with wellbore temperature which is got from monitoring and calculation, draw judgment on whether it is possible to produce a hydrate and realize the forecasting, provide well section scope where hydrate formation could happen in order to take countermeasures.

3. MONITORING AND EARLY WARNING SYSTEM

The warning setting should in accordance with different situations because the calculated temperature and pressure reached the condition of hydrate formation does not mean it is certain to generate a hydrate.

During the generation process of natural gas hydrate by natural gas generation mechanism[13-16], at fist, unite cell format in initial condition, then cells gather and generate crystal as state maintained or further deepening. Crystals can suspend in air-water mixture at the moment and aggregate to generate ice with an increasing number of crystals. To some extent, the ice in wellbore may not always cause ice block problem, but ice in pipeline, elbow and valve will lowering temperature, then the wellbore and wellhead may be blocking as conditions worse further. So, reach the condition of hydrate formation does not always produce ice, while reach the condition of hydrate formation is necessary to form ice.

As a result of analysis, the set-up of alarming threshold should prevent both make unvalued and hysteresis. In order to define alarming threshold flexibly, the threshold can change a little according to calculate temperature of hydrate formation. The alarming threshold should raise some degree when the surface temperature is too low while the threshold should be eased if the surface temperature is high.

The monitoring system suggests some countermeasure when it is begin to alarming. Prevent set-up has the character of timeliness. It has many options like wellhead heating, enlarging flow, tubing heating, inject inhibitor, down whole throttle, and inject hot water or steam and so on.

We design and complete the synthetic system based on theories and methods above, which has functions of real-time monitoring, analytical calculation, sensitivity analysis, monitoring wells management, generate monitoring report and print.

We can see from the result of DXA1426 well in Junggar basin, the error is less than 5% according to the contrast of wellbore pressure and temperature distribution in real-time and theoretical result.

CONCLUSION AND SUGGESTIONS

(a) Real-time monitoring provides warning function for gas well testing and processing, focus attention on prevent hydrate formation.

(b) In consideration of monitoring and early warning system, we should pay particular attention to four aspects of work. First, monitoring and early warning in real-time with gas well hydrate dynamic monitoring and warning software when testing, get the work of dynamic monitoring and warning done while early warning and early preventing. Second, a series of work should be optimize: traffic control when well is startup, the time to shut in well, speed level, surface pipeline heating, and preventive action, emergency processing and so on, in order to avoid icing accident by misconduct. Third, winter is the high-incidence season of hydrate formation, within 200m to near-wellbore need the most important protection. We should pay attention to high-incidence season and high-incidence interval. Forth, emphasize preventive interval can use the method of direct heating, set an injection valve on the upper of wellbore can be adopted to inject inhibitor.

REFERENCES

[1] Li, D. Q., Ai, M. Y., & Wang, Y. B. (2012). Hydrate accident and prevention in Sebei-Xining-Lanzhou gas pipeline. *Oil & Gas Storage and Transportation, 31*(4), 267-269.

[2] Li, S. L. (2008). *Gas engineering* (pp.127-131). Beijing: Petroleum Industry Press.

[3] Zhang, Q. (2000). *The principle and design of oil production engineering* (pp.50-53). Dongying, China: China University of Petroleum Press.

[4] Yan, L., Zhu, T., & Wu, J. Z. (2003). Analysis of heat transfer in gas pipe and a software design of its temperature field. *Energy Sawing Technology, 21*(5), 5-7.

[5] Yan, Z. H. Liu, Y. J., & Tang, S. L. (2010). Calculation of shut-in wellbore temperature and pressure for offshore condensate gas well. *Gas Engineering, 30*(9), 36-40.

[6] Lai, F. P., Li, Z. P., & Qu, J. L. (2010). Forecasting method for wellbore pressure in high-pressure gas well by considering temperature changes. *Xinjiang Petroleum Geology, 3*(6), 641-643.

[7] Yu, H. M., Zuo, J. L., & Zhang, Q. (2010). Prediction of formation conditions for gas well hydrate. *Natural Gas Geoscience, 21*(3), 522-527.

[8] Liu, Y., Lu, Y., & Yi, X. Y. (2008). Gas hydrate factors. *Lithologic Reservoirs, 22*(3), 124-127.

[9] Wu, Z. L. (2008). Prediction of gas hydrate formation conditions in wellbore. *Petroleum Geology Experiment, 30*(3), 316-321.

[10] Li, H. F., Wang, Q., & Feng, X. (2011). Research on flow velocity and pressure distribution of horizontal well considering wellbore pressure drops. *Fault-Block Oil & Gas Field*, *18*(3), 366-368.

[11] Zhang, Z. Y., Tong, L., & Pan, Y. (2013). Prediction of gas hydrate in pipeline. *Contemporary Chemical Industry, 42*(4), 425-427.

[12] Yang, S. L., & Wei, J. Z. (2004). *Reservoir physics* (p.46). Beijing: Petroleum Industry Press.

[13] Liu, S. X., Guo, P., & Tang, L. P. (2005). Experiment research of generation system of gas hydrate in gas fields. *Natural Gas Industry, 25*(1), 97-100.

[14] Deng, K., Li, Y. C., & Li, Q. S. (2006). The generation of natural gas hydrates: Contributing factors and sensitivity analysis. *Drilling Fluid and Completion Fluid, 23*(6), 64-69.

[15] Liu, C. W., Li, M. Z., Wang, W. Y., Li, D., & Gao, Y. H. (2012). Formation mechanism of gas hydrate slug in gas pipelines. *Acta Petrolei Sinica, 33*(1), 150-156.

[16] Pi, Y. H., Liao, K. X., & Ouyang, S. (2012). Prediction model for natural gas hydrate formation conditions and applicability evaluation. *Natural Gas and Oil, 30*(6), 16-18.

