TESTING OF STEAM-WATER WELLS

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1 ABSTRACT

The paper considers the method for measuring discharhe parameters of steam water wells. It is pointed out that the methods of the tests are different depending on the stage of the well development. Three different stages have been identified resulting from different tasks of the well tests: short-term test, long-term test and production well test. Based on the results of complex studies including expriments in laboratory the authors propose methods appropriate for each stage: the orifice method for short-term test, the James method for long-term test and orifice method for production well test.

1. INTRODUCTION

At present there are many different methods of measuring the discharge parameters of steam-water wells. However, when it comes to practice, there happen some difficulties of choosing rational method of measuring and its implementation. Differences of stages of development of wells as differences of the goals of the well tests account for different requirements.
Hence it is important to choose the right method which would suit the stage and meet the goals of the well tests.
In the course of the last 10 years the scientific staff of "Kamchatskenergo" actively developed new methods and elaborated the old ones for measuring the discharge parameters of steam-water mixture. The investigations were based on laboratory studies in the experimental plant that enabled one to conduct tests in the wide range of mixture parameters typical of geothermal deposits. We have studied more than 10 different methods and their versions and it has been established that not all of the methods are suitable in practice. The present paper considers only those methods which turned out to be more reliable. The well tests are based on the accepted in Russia stages of tests: short-term test (experimental), long-term test (experimental and experimental-exploitational) and production well test.

2. EXPERIMENTAL PLANT

Laboratory studies were conducted in the experimental plant created for investigation of the steam-water flow (Figure 1). Steam (temperature about 250°C, pressure about 10 bar and flow-rate 0-8 kg/s) and water (temperature about 80°C, pressure about 14 bar and flow-rate 0-30 kg/s) after measurements of flow-rate and enthalpy of single-phase flows are transported in the mixer. Flow-rate and enthalpy of mixture are calculated on base of single-phase measurements. Steam-water mixture is transported in the experimental area. Experimental area consists of three pipelines with 0.1, 0.2 and 0.3 m in diameter. Pipelines have horizontal, sloping and vertical parts. Also pipelines have special parts for testing of various experimental equipment (orifices, nozzles, separators etc.)

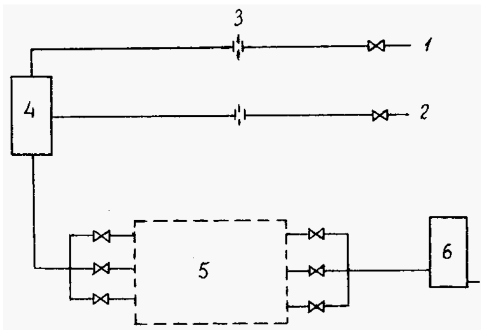

Figure 1. Scheme of experimental plant. 1 - steam pipeline, 2 - water pipeline, **3 -** orifice meter, 4 - mixer, **5 -** experimental area, **6 -** silencer.

3. SHORT-TERM TEST

This test is made on termination of well drilling and has the aim of preliminary estimate of discharge parameters.
Usually the plot of production is defined which shows the dependence between discharge and pressure at the head of the well. Depending on the results of this test we decide about further utilization of the well and choose equipment for more detailed measurements. The basic requirement to the well test methods at this stage is the simplicity of its realization in practice.
The quality of the steam-water well is described principally by discharge of the steam phase. According to the experimental data this parameter has important relationship with critical discharge pressure. Hence the task of the short-term test in some cases can be solved by simple measurement of the critical discharge pressure and of the using of the well-known James formula (James,1984):

$$Q = 46300\, d^2 \frac{P_c^{0.96}}{i^{1.102}} \qquad (1)$$

where Q - mass flow-rate of mixture (kg/s), d - pipe diameter (m), P_c - critical discharge pressure (Pa), i - specific stagnation enthalpy (J/kg).
Substituting to (1) the value of enthalpy determined through measurements of deep temperatures, or introduced by similarity with earlier studied wells, or some other way we can draw out mixture flow-rate. Recalculation of the steam phase flow-rate based on the parameters of the steam-water mixture gives, as a rule, close to reality result even when parameters of the mixture

were determined with considerable error.
However, this approach is not efficient when we have problems with estimation of the values of enthalpy. Some problems arise also from the necessity of meeting the conditions of critical discharge (critical discharge pressure must exceed ambient pressure by more than 0.3 bar) which makes this test impossible for low pressures at the well head.
Simple in practice and reliable in terms of accuracy of determination of discharge is the method of orifice (Figure 2). This method is based on the measurements of pressure variation on the orifice ΔP_0, pressure in the positive chamber P and dynamic pressure of the running on the orifice flow ΔP_1 (Shulyupin,1994). The last parameter is obtained in practice as pressure variation between positive chamber and a point located at some distance up the flow.

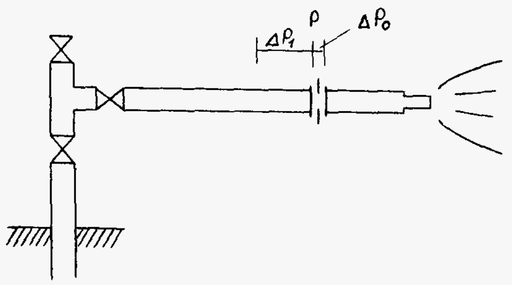

Figure 2. Wellhead equipment for orifice method.

Theoretical studies have shown that the ratio of the dynamic pressure to the pressure variation on the orifice can be found using the relationship

$$\Delta P_1 / \Delta P_0 = kA^2 f(x) \qquad (2)$$

where k - equipment coefficient, A - expansion coefficient, f(x) - generalized function of mass discharge steam fraction **x.**
The coefficient k depends on the orifice module (ratio of the orifice area to the section area of pipeline) and the dynamic pressure measurement technique; it does not depend on the parameters of the medium being measured and, consequently, may be easily found experimentally. The expansion coefficient is determined by the formula

$$A = 1-(0.36-0.31m^2)\Delta P_0 / P \qquad (3)$$

where m - orifice module.
Two series of experiments were conducted using orifices with modules m=0.485 and m=0.615 to determine **f(x).** Expression (2) was used to make generalizations (Figure 3). The experimental data agree well with the formula

$$f(x) = x^{-0.8} \qquad (4)$$

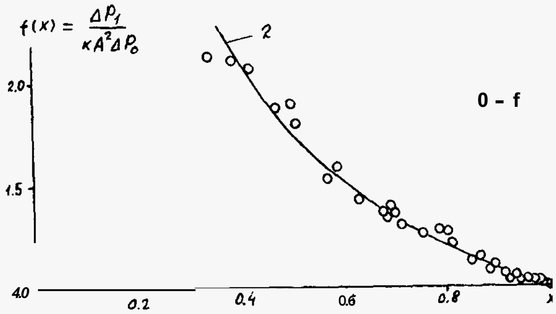

Figure 3. The function f(x). 1 - experimental points, 2 - calculation using formula (4).

Using expressions (2) and (4) we obtain the following formula for the steam fraction as a function of measured parameters

$$x = (kA^2 \Delta P_0 / \Delta P_1)^{4.25} \qquad (5)$$

Having the value of the mass discharge steam fraction after ΔP_0 and P it is not difficult to determine the flow-rate of the steam phase as well as the flow-rate of the mixture.
Enthalpy of the slowed down in front of the orifice mixture flow can be defined by:

$$i = xi'' + (1-x)i' \qquad (6)$$

where i" and i' - specific saturation enthalpy of steam and water (J/kg).
Based on the experimental data this method is characterized by the mean square deviation of determination of the mixture flow-rate and enthalpy as 3.7 % and 3.0 %, respectively and steam phase flow-rate as 1.4 X.

4. LONG-TERM TEST

These tests are made to determine the resource of the deposit. These methods of measuring discharge parameters must meet the following requirements: simplicity of implementation, high precision, environmental concern.
Widely-known James method fits the desribed requirements (James,1970). It is based on measurement of critical discharge pressure and water discharge at the outlet of the silencer. The main advantage of this method is localization of the discharge of the disposed water which decreased negative influence on the environment and utilization of efficient silencer which significantly decrease the noise (in principle, this method was developed taking into consideration the existing by that time technology of decreasing the noise). Another important advantage is that this method allows one to run the test continuously or by steps which simplifies the technique of calculation of the resource. This method has small influence on the errors on initially measured parameters on the determination of the mixture parameters (Shulyupin and Alekseev,1993).Major errors are connected with the measurement of critical discharge pressure which is pulsating in the course of the test. Besides, it has been established that formula (1) on which the whole method is based corresponds to experimental data only when the mixture flows out from long pipes. Formula (1) has inaccurate correlation with the enthalpy for short pipes (Figure 4).

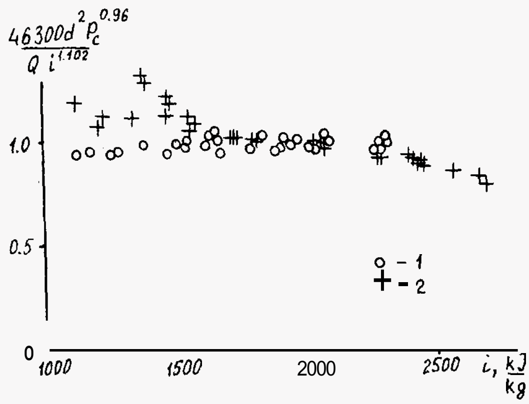

Figure 4. Generalizations of experimental data using of formula (1). 1 - long pipe, d=0.05 m , l/d=80; 2 - short pipe (cylindrical nozzle) d=0.1 m, D = 0.3 m, l/d=1.

Application of James' method at the Mutnovsky geothermal field proved that it is necessary to use special narrowing devices to create critical flow (Shulyupin and Alekseev,1993). Namely, cylindrical nozzles were used with sharp entering brim and with the length equalling to 3 diameters. In this case, if you want to calculate the parameters of the mixture it is worthwile to use the following ratio instead of formula (1):

$$Q = Bd^2 \frac{P_c}{i} \qquad (7)$$

where $B \approx 6000$.

Coefficient B depends on the nozzle diameter d, pipeline diameter D and method of the determination of average critical discharge pressure which is pulsating. Generalization of one experimental serie for the nozzle with d=0.1 m, D = 0.3 m and l/d = 3 are shown in Figure 5. Average value B is 6000. However, average value B is changed from 5900 to E400 for other experimental series that is connected with the difference of the determination of average critical discharge pressure.

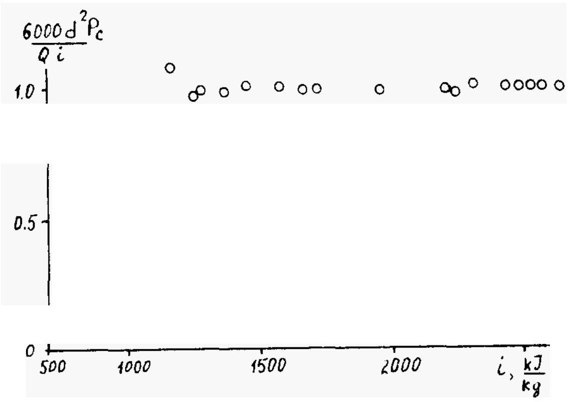

Figure 5. Generalization of experimental data using of formula (7).

Using of (4) simplifies calculation and increases the accuracy of determination of mixture flow-rate and enthalpy with the application of nozzle. In general based on the experimental data James-method is characterized by the mean square deviation of determination of the mixture parameters as 4%.

5. PRODUCTION WELL TESTS

Measurements of discharge parameters of the production wells are made with the aim of controlling development of the deposit as well as necessity of more precise recalculation of the resourses of deposit. The principal requirements to the well tests at this stage include: high precision, convenience of application of measuring devices, minimum influence of the test upon operation of the station and environmental concerns.

In case separation equipment is installed at the mouth of the well the problem id easily solved by the well-known method of individual measurements of discharge-thermal phase parameters (Narasimhan and Viterspoon,1979). There are different versions of this method and, as a rule, all of them meet the requirements described.

In case of transportation of steam-water mixture it is recommended to use the method of orifice described earlier. To avoid deposition of salts which influences the precision of measurements the orifice should be installed at the bypass. Using of orifice method is proposed in design of Mutnovsky geothermal power station.

6. CONCLUSION

Therefore, it is necessary to have clear idea of the task of the test before running any well test. Depending on the goals we chose duration of the test as the method of measuring of discharge parameters- The set of methods described in this paper enables one to envelope all stages of the well tests.

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8 REFERENCES

James,R.(1970). Factors controlling borehole performance. Geothermics, Vol.2, pp.1502-1515.

James,R.(1984). Successful prediction of Mokai 5 discharge. Geothermal Energy, Vol.12(12), pp.7-9.

Narasimhan,I.N. and Viterspoon,P.A.(1979). Geothermal well testing. J.of Hydrology, Vol.43(1/4), pp.537-553.

Shulyupin,A.N. and Alekseev,V.I.(1993). Determination of the flow rate and enthalpy of steam-water mixture discharged from geothermal wells during geothermal experiments and production tests. Volcanol. and Seismol.,Vol.14,(5-6), pp.558-569.

Shulyupin,A.N.(1994). Measurement of flowrate and enthalpy in steam-water wells with diaphragms on operating geothermal power stations. Thermal Engineering, Vol.41(2), pp.104-106.