INTERPRETATION OF CONTINUOUS MEASUREMENT OF STEAM AND WATER FLOW RATES AT A PRODUCTION WELL 2H-21, HATCHOBARU GEOTHERMAL FIELD, JAPAN

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SUMMARY - The continuous measurement of steam and water flow rates at a production Well 2H-21, at Hatchobaru geothermal field, Japan with a newly developed measurement system to evaluate and understand unsteady state behaviors of well characteristics is carried out. The measurement apparatus consists of pressure sensors, water level sensor and a PC to store the measured data. The data are recorded every second for the pressures at upstream of the orifices, the pressure drops at the orifices, the pressures at the separators, and the water level at weir box. The atmospheric pressure is also measured daily. The degree of valve opening is changed three times during the measurement and the duration of respective wellhead valve operation for controlling flow rate affect the flow to stabilize in wellbore. Quick valve operation causes longer period of stabilization and produces impulse response of flow rate soon after the valve operation stopped. The fluid flow requires shorter time to stabilize for closing valve operation compared with that for opening valve operation. After changing the wellhead pressure, the steam flow rate stabilizes quickly while the water flow rate shows a gradual change.

1 INRODUCTION

As a part of a geothermal reservoir management, a regular measurement of wellbore performances such as pressure, mass flow rate and enthalpy at the wellhead during the production stage is required to evaluate the well productivity. This is because as a production stage of the field begins the well performances reflect wellbore and reservoir conditions such as declines of reservoir pressure and temperature and scaling in the wellbore.

There are two methods for measuring steam and water flow rates; (a) lip pressure method and (b) the orifice and weir method. In the lip pressure method, the fluid is discharged from the well directly to the atmosphere. The lip pressure is then measured at the extreme end of the discharge pipe using a liquid-filled gauge to damp out pressure fluctuations (Grant et al., 1982). In the latter method, the orifice is used for steam flow rate discharged from the separator and the weir for the water flow rate leaving from the separator (Lindeburg, 1992). The wellhead pressure is usually measured using a bourdon gauge. In order to avoid any thermal and chemical contaminations on surface soil and vegetations near wellbore by discharging fluids to the atmosphere, the latter method is preferable for flow measurement.

One of the problems found in the mass flow rate and wellhead pressure measurements is whether and when the well discharge reaches to stable conditions after operating the wellhead valve. When the wellhead pressure is changed, the steam and water flow rates would also change, then stabilize as the time elapsed. In practical conditions, the time required for the flow rates to stabilize is determined according to the operator experiences. Therefore, a continuous measurement of steam and water flow rates is necessary to understand transient discharge behaviors in detail. Field measurement with a newly developed equipment was conducted for the production Well 2H-21, at Hatchobaru geothermal field, Japan.

2 LOCATION MAP OF WELL 2H-21

Figure 1 shows the location map of the Hatchobaru geothermal field and wells. Well 2H-21 is located at the Hatchobaru geothermal field situated 1100 m above sea level in the central part of Kyushu. The power station of 2x55 MW installed capacity is now in operation. The well has a maximum static temperature of 252°C at a depth of about 2100 m and has a total length of 2500 m (Fujikawa and Ikegami, 1992). Basic design of the Hatchobaru power station is of the use of double flash system with steam-hot water mixture transport pipeline for both units. The advantage of using this system is that the generating output can be increased by about 20%. There were 20 production wells to provide the steam and 13 wells for reinjection when the measurement was conducted.

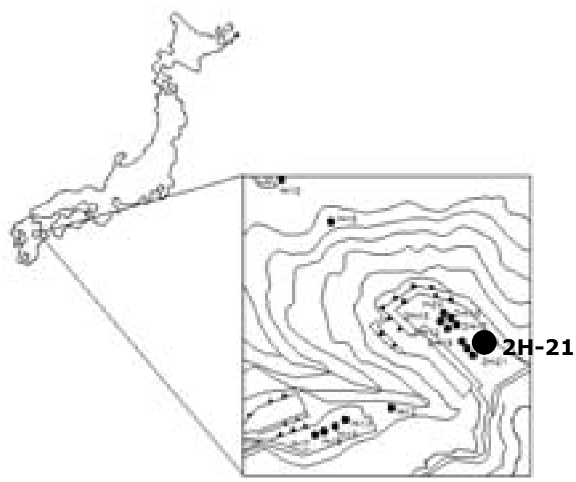

Figure 1: Location map of Well 2H-21

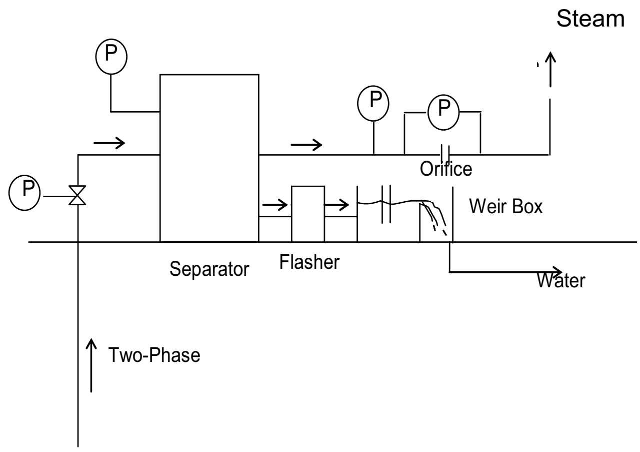

Figure 2: Schematic diagram of apparatus

3 SETUP OF APPARATUS AND MEASUREMENT PROCEDURE

Setup of apparatus

In the measurement, the flow rates of the production Well 2H-21 are measured when production wells discharge to atmosphere through separators. The measurement apparatus consists of pressure sensors, water level sensor, and a computer as shown in Fig. 2.

Measurement procedure

The separator pressure, the upstream pressure at the orifice, the pressure difference at the orifice and water level at the weir box are measured every second. The measured data are then used to calculate steam and water flow rates. The procedure for measurements, apparatus, and the results of measurements are discussed in detail in the later sections.

The mixture of steam and hot water from the production well is separated through twin separators. The separated hot water is discharged through a weir box while steam flows through two discharge pipes (Pipe 1 and 2). As there are two sets of separator for the well, pressure measurements at separator and orifice are conducted at respective system. A contracted weir box built by the separator is used for measuring hot water flow rate. The data collected during this measurement is the hot water level in the weir box. The steam flow rate is measured using orifice flow meters that are installed at each discharge pipe. The pressure of the separators and that of upstream of the orifice and the pressure at the orifice are measured with pressure transducer. All measured pressures are recorded every second and stored in the computer through AD converter.

4 ANALYSIS OF MEASURED DATA

Measurement of pressures

Based on the experiences, the well is left to discharge in the full open from the previous day and the valve opening is controlled twice on the same day, in the morning and in the afternoon. The main valve is throttled such that the wellhead pressures increase from 1.4 MPa to 1.7 MPa in the morning and left as it is until the afternoon. Then the valve is controlled back to full open.

Figures 3 (a) to (c) show the examples of the measured pressure at the upstream of orifice 1, measured differential pressure at the orifice 2, and the measured pressure at the separators with time.

After leaving the well in full open on the previous day, the valve is partly closed in a period of 14 minutes from 9:10 to 9:24. All curves in the figures indicate that the pressures decrease. There are two steps how the pressure decrease can be observed. This may suggest that the operators do not make a smooth operation in controlling the valve. The well then is kept flowing without any valve operations until 11:48. The pressures remain relatively constant in this period. Further valve closing operation for a period of 5 minutes from 11:48 to 11:53 results in a sharp decrease in measured pressures. The first and the second closing valve operations cause the pressure decrease of about 4.4 kPa and 12.2 kPa, respectively for upstream pressure of the orifice 1 as shown in Fig. 2 (a). This corresponds to the pressure decrease rates of 0.31 kPa/min and 2.44 kPa/min, respectively.

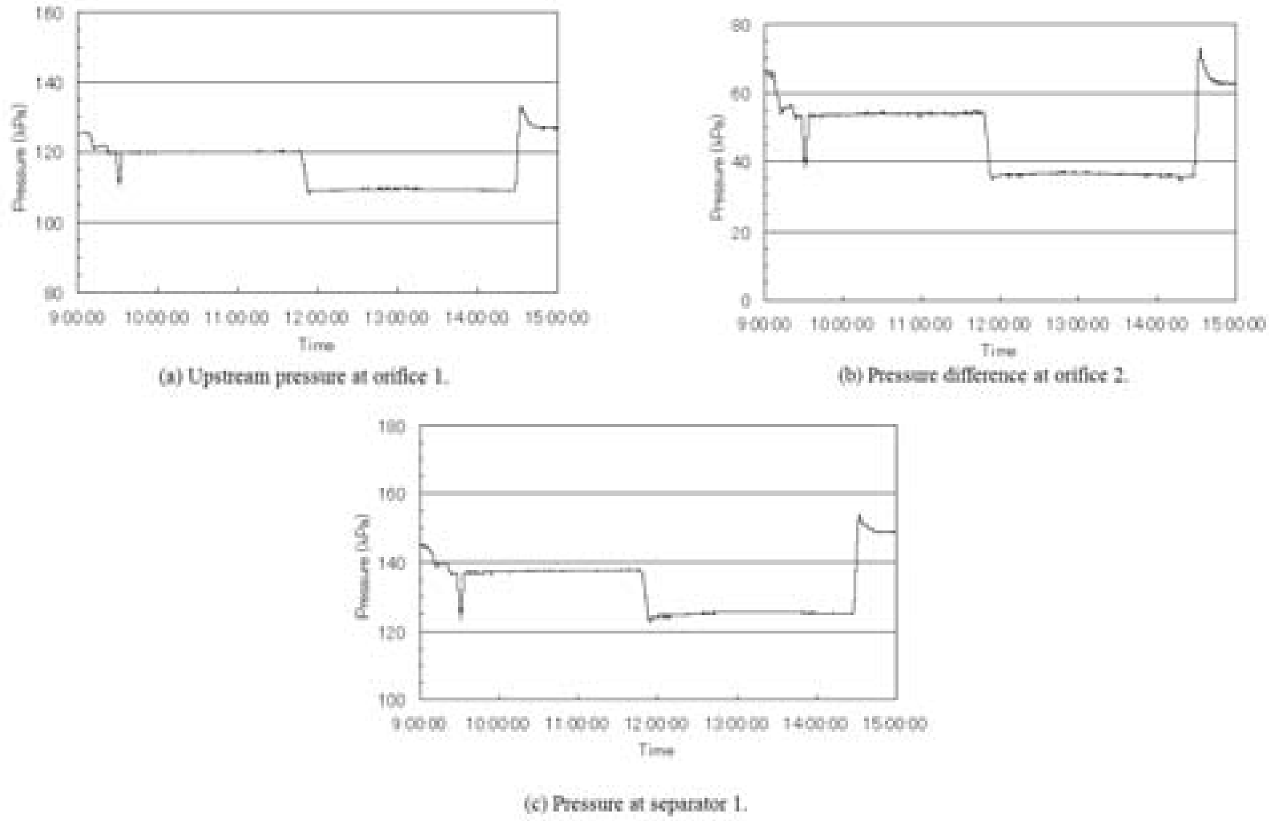

Figure 3: Samples of measured pressures

The differential pressure measured at the orifice 2 is shown in Fig. 3 (b). It can be seen that the differential pressure decrease rates are of 12 kPa/min and 20 kPa/min. While, the pressure decrease rates at the separator 1 are calculated to be 8 kPa/min and 16 kPa/min as shown in Fig. 3 (c). The differences in decrease rate of pressures imply that the second valve operation at about 11:50 is made faster than that of the first one. This quick valve operation results in a fast drop in pressure followed by a recovery of the pressure in a pulse manner.

From 11:53 to 14:28 the pressures show relatively constant values until they suddenly increase to the maximum values due to quick valve opening in a period of 12 minutes from 14:28 to 14:40. During this period, the increase rates in pressures during valve operation for the upstream pressure of the orifice 1, the pressure difference rate in the orifice 2 and separator 1 are 2.04, 3.00 and 2.50 kPa/min, respectively. However, these increase values are small compared with the decrease rate during the first and the second closing operations of valves. After reaching the maximum values, all curves decrease quickly soon after the opening valve operation finished. Then, they decrease gradually and seem to reach stable conditions as time elapsed. From this discussion it can be concluded that the closing valve operation tends to lead faster stabilization in the measured pressure than the opening operation. This is one of the reasons why the measurement of wellhead pressures and mass flow rates to obtain a deliverability curve should be conducted from the full open condition of the valve. When the well reaches stabilization after the valve operation, then the next wellhead pressure and mass flow rate measurements can be carried out.

Measurement of water level in weir box

Figure 4 shows the result of water level measurements both with the ruler for the period from 9:00 to 15:00 and with the water level sensor from 13:05 to 15:00. Because the fluctuation of the measured water level (dotted line) with the sensor is large, the value obtained by applying the moving average method with time interval of 100 s is used and indicated by solid line. However, a relatively good agreement is obtained between values obtained with the two methods.

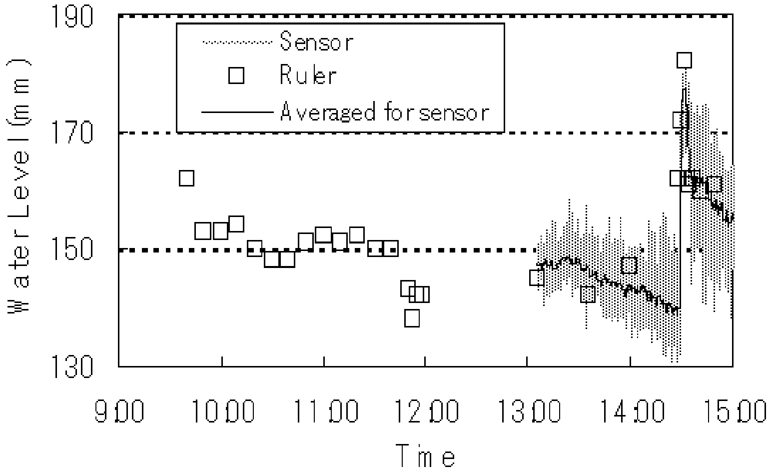

Figure 4: Measured water level vs time

5 RESULTS OF FLOW RATE CALCULATION

Steam flow rates at respective discharge pipe are calculated and summarized to introduce steam flow rate of the well. The thermodynamic properties of the fluid are calculated using the package program PROPATH. Steam flow rates are calculated for the period from 9:40 to 15:00 where the measurement in the very early period is excluded because of malfunction of power supply. Next, water flow rates are calculated using two different measurements: water level measured with a ruler from 9:40 to 13:00, then calculated water level using the data of water level sensor from 13:00 until the end of the measurement. The measured water level with the ruler and the sensor is shown in Fig. 4. The atmospheric pressure is 90.4 kPa. The wellhead pressure is measured using Bourdon gauge that is already installed at the wellhead. By using measured values above and the standard equations, the mass flow rates of hot water and steam at the separator, then at the wellhead are calculated. The results are shown in Fig. 5.

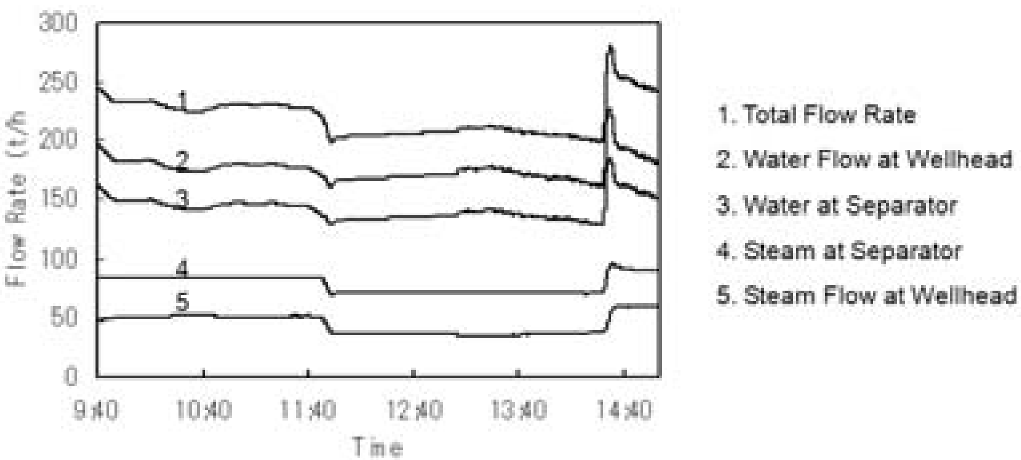

Figure 5: Measured mass flow rates

6 CONCLUSIONS

1. The fluid flow requires shorter time to stabilize for closing valve operation compared with that for opening valve operation.
2. The duration of valve operation affects the flow stabilization in wellbore. Quick valve operation causes longer period of stabilization and produces impulse response soon after the valve operation stopped.
3. Well characteristics measurement should be made in a manner of flow rate decrease to minimize stabilization time.
4. Steam flow rate stabilizes more quickly than water flow after valve operation ceased.

7 REFERENCES

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