Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Methods of Production and Possibilities of Determining Hydraulic Properties of Gas Saturated Water

Sava Djuric and Slobodan Vidovic

SCG, 2100 Novi Sad, Narodnog fronta 12

djuric.s@mail.nis-naftagas.co.yu

vidovic.s@mail.nis-naftagas.co.yu

Keywords: Thermomineral water, gas saturation, bubble point, pump installation depth

ABSTRACT

It is not possible to produce thermal water in the Pannonian Basin without encountering the problem of the water saturated with all types of gases.

The gases can indicate the water layer depth, and they can show traces of oil hydrocarbonate and other substance saturation.

So far there has not appeared a study that would give an in depth and comprehensive view of the characteristics and use of the gas saturated water.

Almost all the known literature dealing with this subject usually contains only theoretical and/or experimental results on particular gas solubility in hydrothermal water.

To produce gas saturated water and particularly to solve many practical hydraulic problems, it would be of key interest to conduct a wide range of exploration and to apply the experience to test the results.

The main objective of the following paper is to serve as a pretext for a basic view on the problems that occur in producing gas saturated hydrothermal water.

1. INTRODUCTION

NIS-Naftagas is a part of the state-owned National Petroleum Industry of Serbia and deals with exploration and production of oil, natural gas, ground water and geothermal energy. Ground water and geothermal energy are explored and produced in the Province of Vojvodina, in the northern part of Serbia.

In Vojvodina 73 hydrothermal wells have been drilled, with a total depth of 62,847 m. 23 systems for thermomineral water use have been built, partly for energy and partly for balneotherapeutic and recreation needs (Fig. 1).

2. PROPERTIES OF GEOTHERMAL RESERVOIRS

The average depth of geothermal wells in Vojvodina is 860 m, which is considered to be relatively shallow for the Panonian basin conditions. However, drilling to greater depths often has been limited by the presence of highly mineralized waters, inadequate for use and especially difficult for disposal after being used.

Optimal wells' natural flow ranges between 10 l/s - 15 l/s, and the waters' temperature between 45°C and 65°C. Geothermal gradients in Vojvodina are between 4.5°C/100 m - 7.5°C/100 m.

All ground waters in Vojvodina from depths greater than 400 m - 500 m, with few exceptions, can be characterized as thermomineral, since the content of soluble minerals is more than 1 g/l, and their temperatures exceed 20°C.

In practice, thermomineral waters of the type HCO_3-Na and total mineralization up t6o 6.4 g/l are used for both energy and non-energy needs.

Gases dissolved in water are also present in thermomineral waters. The most common is methane (over 94% of total gas content in water), which can be found in quantities ranging between 0.5 to 1.5 m^3/m^3 of water. Other gases (CO_2, H_2S, N_2) can be found only in traces or not at all.

In the waters of Vojvodina some undesired content can be found, and the most common is phenol, but rarely in large quantities.

3. THERMOMINERAL WATER – GAS SYSTEMS

It is not possible to produce thermomineral waters in the Panonian basin without encountering the problem of their gas saturation.

Energy potential loss occurs during the distribution process of geothermal fluid from the reservoir to the consumer. The highest loss in the total available energy of about 70-80% occurs in the wellbore. Irreversible energy loss can be related primarily to pressure drop, but during the flow of geothermal fluid its temperature also decreases, so that it is lower at the wellhead than at the bottomhole.

Note that any change in temperature is closely and functionally related to pressure changes; and any change in these two basic values has effect on the changes in physical and thermodynamic properties of geothermal fluid. Gas would not separate from water until the system pressure levels with saturation pressure; until that moment we are dealing with single-phase flow. In other words, when saturation pressure exceeds the system pressure, gas is separated from water and the two-phase flow of water-gas mix occurs.

3.1 Two-phase flow

A single phase distribution is established, depending on water and gas flow quantity and velocity, giving the flow specific regime definition. There are several classifications of flow regimes or structures, but a basic one divides them into following flows:

- bubble
- slug
- transient

- annular-mist

Each of the regimes can occur independently or consecutively. The most common flow structure at the bottomhole is bubble flow followed by other structures (as functions of both pressure and temperature drops).

3.1.1 Bubble flow

Continual liquid phase contains dispersed gas bubbles, which size and number can change in a wide range of values, but the main characteristic is low gas content. Liquid and gas phase flow velocity ranges between 0.3-0.6 m/s. If the bubbles flow in the direction of liquid, then we have bubble flow regime, and when the flow is turbulent, then the term foam structure is used.

3.1.2 Slug flow

The increase of gas phase volume leads to the bubbles clustering and growing; under certain conditions these clusters can fill up part of the pipe’s volume. The phase flows are not continual, so that slugs of dispersed water can occur in gas and slugs of dispersed gas can occur in water; then the phases flow alternately. Liquid and gas phase flow velocity ranges between 2-2.5 m/s.

3.1.3 Transient flow

A further increase in gas phase volume results in forming stable slugs (big gas bubbles); with further increase both in quantity and flow velocity, the slugs deform thus creating transient flow structure, owing to their instability and turbulence. This specific flow structure has not been sufficiently reported yet – there is not enough data on its occurrence, characteristics and duration – that slug structure models can be applied for practical use.

3.1.4 Annular-mist flow

Annular-mist flow structure occurs when gas fills the mid part of the pipe, owing to its further volume increase, while the liquid flows by the pipe walls creating annulus. The gas phase velocity exceeds the liquid velocity. With further gas phase volume increase the liquid will completely disperse in gas, thus creating a misty flow structure.

4. DETERMINATION OF GAS BUBBLE POINT

The most common process of single- to two-phase flow change occurs in vertical pipe – the tubing. When the reservoir pressure is sufficient to override the well fluid and different barriers, the well flows naturally. However, when the hydrodynamic pressure is insufficient, or when natural flowing yields undesired water production, then sucker rod pumps must be operated. To achieve effective pump performance, it must be installed into the interval with single-phase flow, under the gas bubble point in hydrodynamic conditions, to avoid any damaging effect of free gas on the pump. It is therefore very important to know the depth of gas bubble point in the well. The depth can be determined by using several different methods, such as:

4.1 Measuring Resistivity

This method uses the fact that thermal water has low resistivity, compared to gas in gas phase. All the gas is solved in water below the gas bubble point and does not have any effect on the water resistivity value. Above this point, gas bubbles occurrence results in resistivity increase. Further increase of gas volume leads to resistivity increase until the electric circuit is cut. Thus resistivity depending on depth can be charted and the depth of bubble point determined. This method is simple, continual, low cost and easily applied in any conditions.

4.2 Rheometry

This method uses fluid velocity at different depths. Velocity is measured with measuring propeller, which rotation depends on the fluid velocity. While rotating, the measuring propeller generates electric impulses, and the number of impulses per time unit determines the flow velocity. Two-phase flow velocity differs from single-phase. A depth and velocity chart can be used to determine the bubble point depth.

4.3 Manometer

This method uses measuring hydrodynamic pressure at certain well depths, as well as measuring pressure both at the downhole and the wellhead. Based on these data the bottomhole pressure gradient can be determined. This gradient is constant in the liquid phase, and variable in the two-phase mixture

5. SUCKER ROD PUMP IN SINGLE-PHASE FLOW

At the pump’s entrance point the water migrates and its velocity depends on the flow and cross section of the pump intake. At that point its pressure is also below the interpipe area pressure at the same depth. Since the pump should be operated in single-phase conditions, it has to be located below the gas bubble point to produce the value of H_d. H_d value is calculated from the relation:

$$H_d = \frac{Q^2}{2gA^2} \tag{1}$$

where: Q = flow, A = cross section of intake and g = gravity velocity

To maintain secure performance of the pump the minimum depth for its installation is determined based on the depth of gas bubble point reduced by the value of H_d.

6. CONCLUSION

Production of thermomineral water saturated with gas is often performed by the use of sucker rod pump; its effective work is achieved by the pump installation below the gas bubble point, i.e. in single-phase flow conditions. However, insufficient experimental data does not allow derivation of a reliable mathematical model for the most adequate pump installation depth.

Measuring should include determination of the gas bubble point in different wells, for different physical and chemical water properties, and different gas factors. The depth of gas bubble point should be determined in stable well conditions, as well as in production conditions at different flows. A change of mixture density with depth is also notable, which is a function of pressure change and gas water solubility.

Another value important for this test is the acceptable gas content in mixture at which the pump operates normally. This issue requires experience and a number of measurements to define what is considered acceptable. It includes the knowledge of pump operation at different depths above the gas bubble point. The results could later prove very useful in geothermal wells production where the bubble point depth is too great for the pump to be installed.

REFERENCES

Solesa, M., Djajic, N., Paradjanin, Lj.: Production and Use of Geothermal Energy, Faculty of Mining and Geology, Belgrade, 1995

Dr Aksin, V., Milosavljevic, S., Vidovic, S., Tonic, S.: Exploration and Use of Geothermal Energy Resources in Serbia, Serbian Academy of Science and Arts, Energy Committee, Geothermal Energy Subcommittee, Novi Sad/Beograd, (1998)

Basic, Dj., Vidovic, S., Stevanov, M.: Analysis of Hydraulic Characteristics of Water-Gas Hydrothermal Systems, Faculty of Technical Sciences, Novi Sad, Naftagas, 1988

Documentation of NIS-Naftagas, 1949-2004

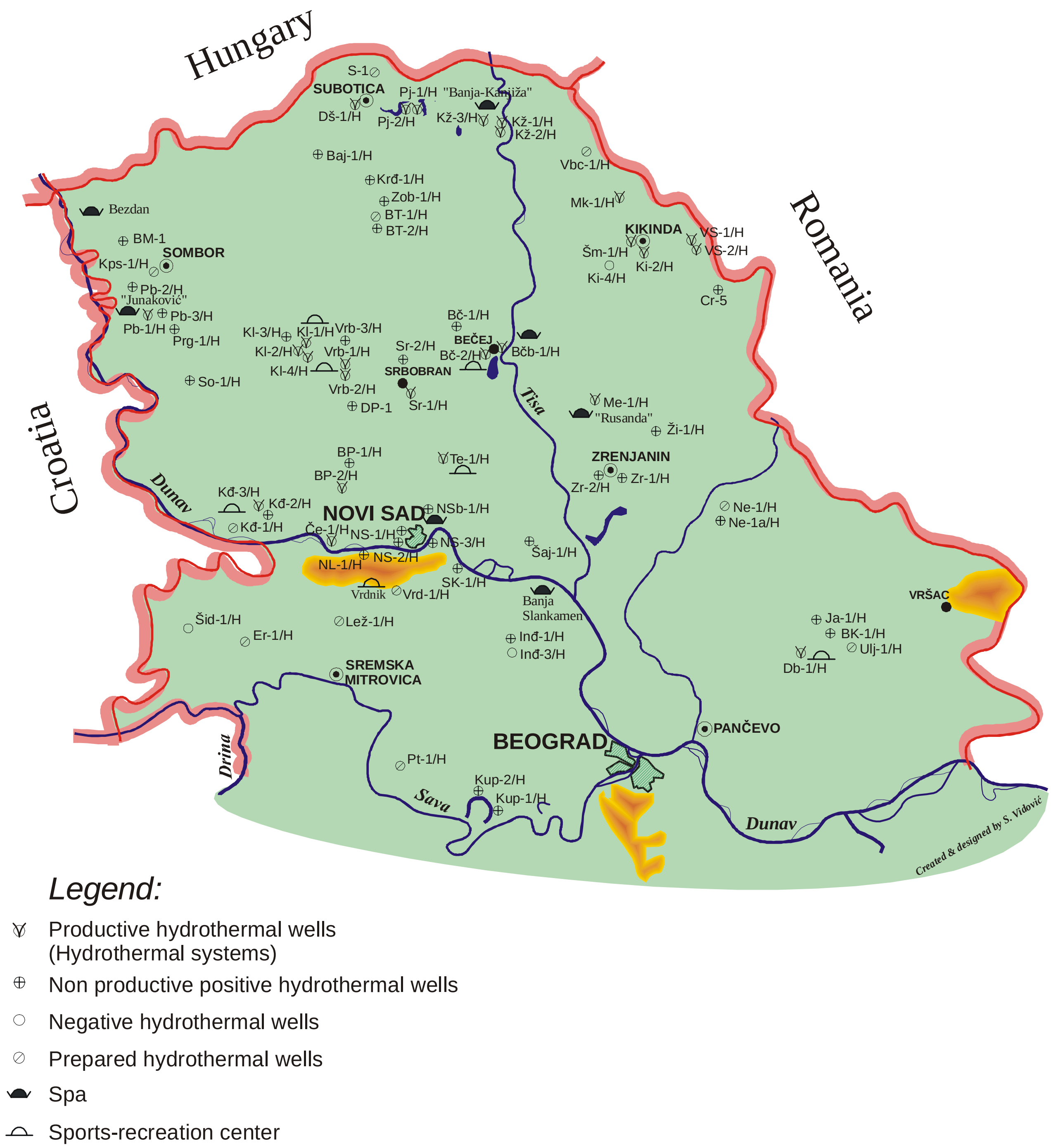

Figure 1: Hydrothermal objects in Vojvodina