WAVEGUIDE ULTRASONIC LIQUID LEVEL TRANSDUCER FOR POWER-GENERATING EQUIPMENT

Dountzev, Andrei

Niznzy Novgorod State Technical University, Russia
E-mail: melnikov@nntu.sci-nnov.ru

Fleischer, Sebastian
HS Zittau/ Gorlitz IPM, Germany
E-mail: S.fleischer@hs-zigr.de

1 INTRODUCTION

One of the most important operational parameters in power-generating equipment is the level of coolant (mass and physical). The level measurement is a part of system of operative control for equipment. The most well-known types of level measurement and in particular the float level, capacity inductometric, piezometric, radioisotope and optical gauges are exposed to the action of corrosion and thermic destruction. The thickening of the gauges to protect against high pressure damage and radiation cause problems when using the above mentioned types. That is why these types of level measurement are not used in practice.

In modern practice control of the level of two-phase coolant in the steam generator are carried out by using hydrostatic level measurement. The hydrostatic level gauges contain the sensor for measuring differential pressure and are placed in regions having normal conditions and have long joint tubes. Such a disposition of the gauges guarantees its furnace life and its reliability. However, using long connecting tubes significantly reduces the quick response of the gauge, causing errors of measurement and reduced safety of the unit. The progressive level gauges for steam generators, in our opinion, are acoustic level gauges based on the waveguide transducer. The reasons of such a conclusion are:

- the sensor is produced from austenite steel and does not contain insulators or other elements made from nonmetallic materials;
- the sensor is thickened by using welding or solder;
- high temperature, pressure and irradiation do not have a significant effect on convection of ultrasound in the waveguide;
- the waveguide lines can be crooked;
- the acoustic transformer is placed in normal conditions.

2 PHYSICAL BASIS

The basic principle of ultrasonic coolant level transducers is a local acoustic sounding method [1]. This method is based on indication of the gaseous phase in control point, between the end of two waveguides (so-called sensing elements). When in control point the liquid phase, ultrasound is gone from radiator to receiver, when gas-ultrasound is no gone. The radiation of acoustic waves occurs only in the liquid because the gas phase has low wave impedance. It is possible to calculate the local volumetric steam fraction by relating the total time of steam detection to the measuring period:

$$\varphi = \sum\tau_i / T$$

where τ_i is the time of steam detection during an individual big bubble contact (contact time).

The statistical distribution of contact time can be transformed into a big bubble size distribution (length of steam cork), when the velocity of the bubbles is known. The several control points are located on line, one after another. In this case it is possible to measure the velocity for big single bubble (spreading time between two points) and height of foam of boiling water. The minimum size of a bubble mast be greater then the distance between the end of two waveguides.

The transducer operates as follows (Fig. 1,2). Acoustic impulses, created by the first converter, spread along the communication waveguide to the first sensing element and are radiated in the water. Then the acoustic impulses are received by the second sensing element and are reflected to the second converter. The indication of steam phase in the control point is carried out by discriminating the pulses received.

3 DESIGN AND EXPERIMENTAL TESTING OF AN ACOUSTIC TRANSDUCER

For the realization of the described acoustic methods the waveguide ultrasonic transducer was produced by NNTU N. Novgorod with the participation of IPM Zittau (Fig. 3,4). The basic elements of the transducer are pairs of parallel waveguides with diameter of 0,8 mm, the top ends of them are connected to conic concentrators, and the bottom ends, put into the coolant are form the control volume. The waveguide communication lines are placed inside a two protective tubes, each has a diameter 10 mm. The minimum length of waveguide is 255 mm, maximal length of waveguide is 850 mm. The transducer was made of chromium- nickel steel. The converters are made of crystal-ceramic. The radiators are connected to the output cascades of generator. The receiver are connected to input cascades of amplifiers. Operating frequency of transducer is 500 kHz, impulse frequency is 200 Hz . The working parameters are : pressure up to 16 MPa; temperature up to 400 ^{o}C. The amplifiers of the transducer can operate in an environmental temperature of up to 100 ^{0}C. The maximal length of waveguide can be up to 5 m. The seven control volumes are located on line one after another.

The personal computer acts as a signal acquisition unit. The primary probe signal is displayed graphically. The computer program allows the setting of the working parameters, such as period of measuring, position of strobe, amplitude of signal, it is possible to store and to accumulate results as digital files for the next processing of experimental data.

Experimental tests of transducer and measurement methods were carried out at the test facility of IPM Zittau. The transducer was installed in the vertical gauging tube with the diameter of 45 mm and length of 1m.

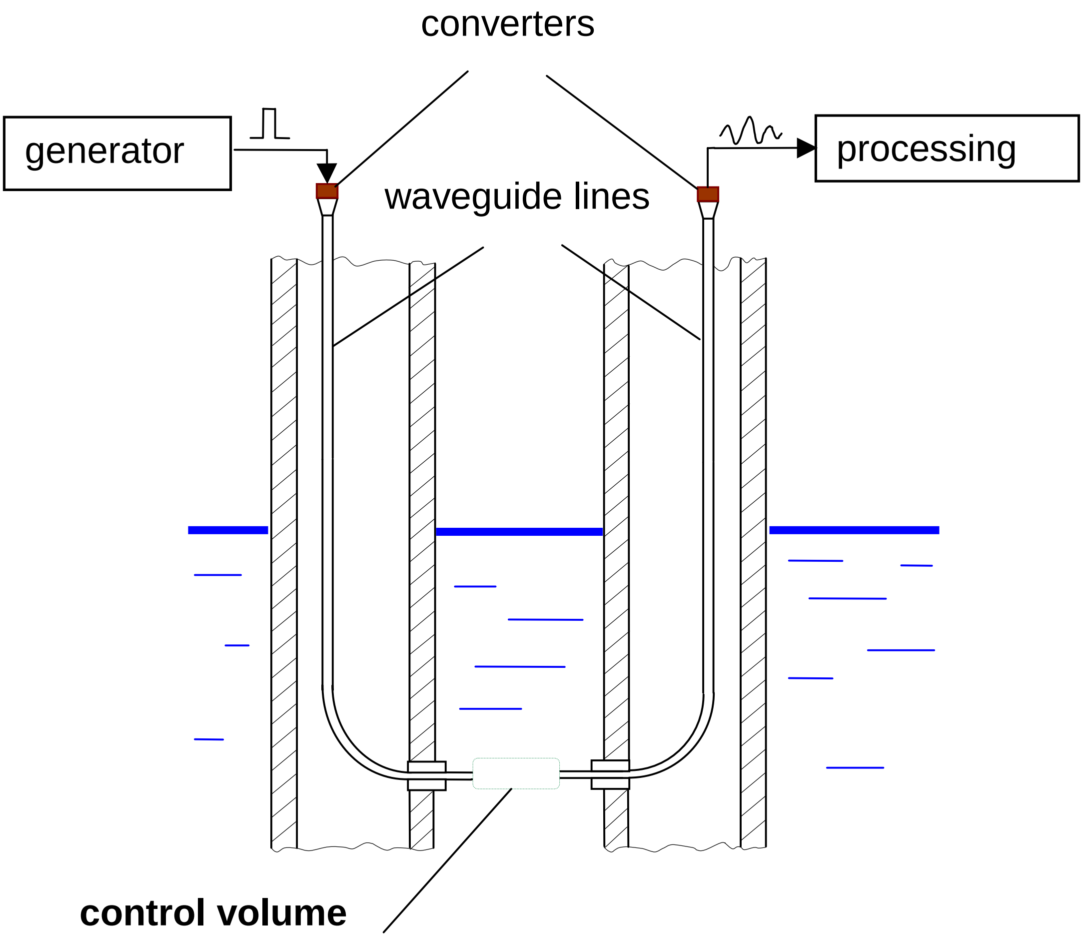

Fig. 1 Diagram of operation of the transducer

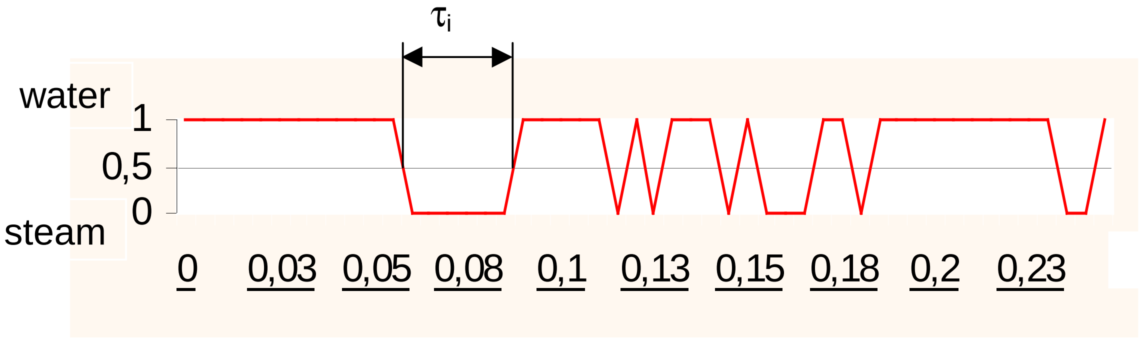

Fig. 2 Typical output signal

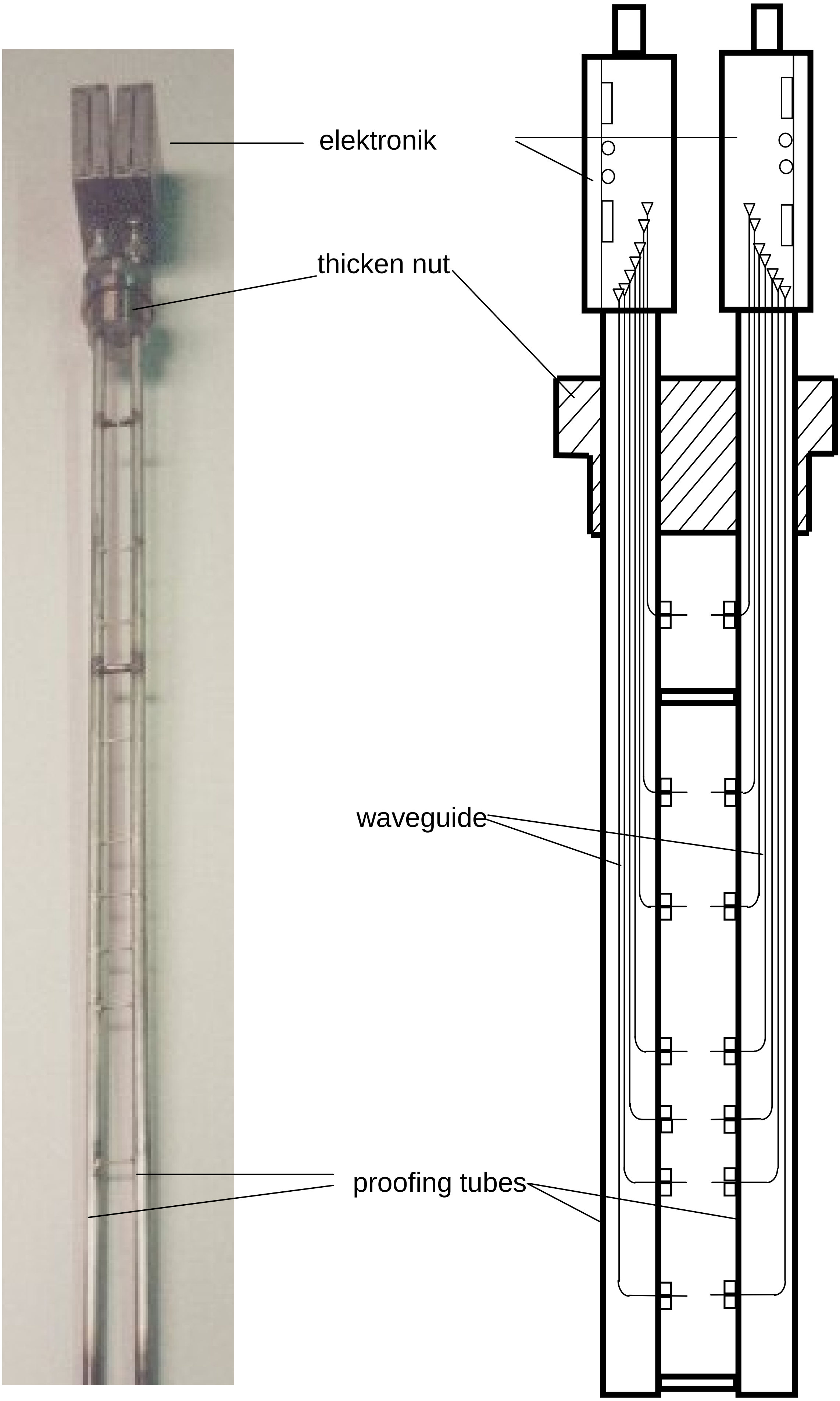

Fig.3 Design of the waveguide ultrasonic transducer

Fig. 4 The control volumes

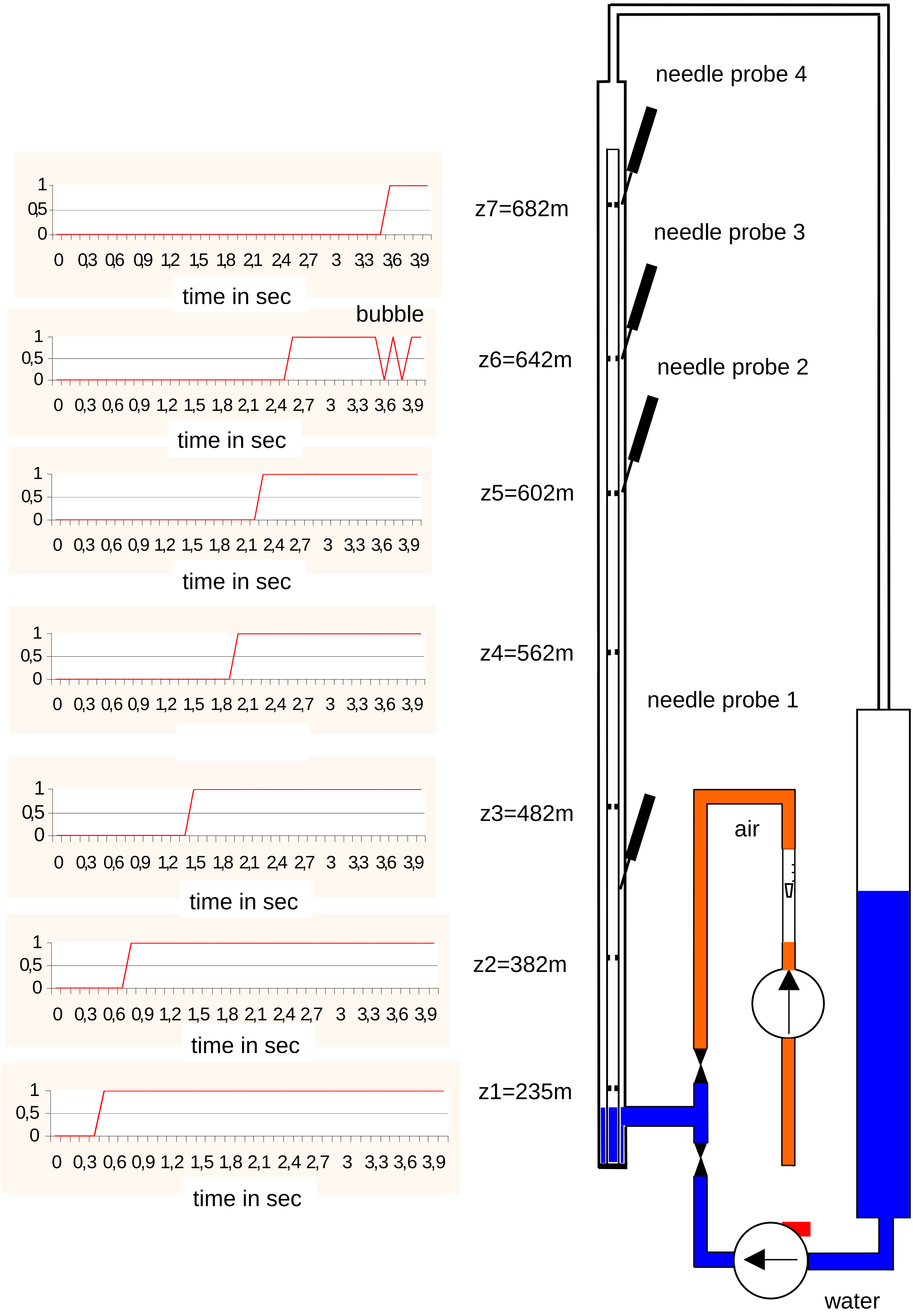

Fig. 5 Test facility and transducer signals for a fill-in experiment

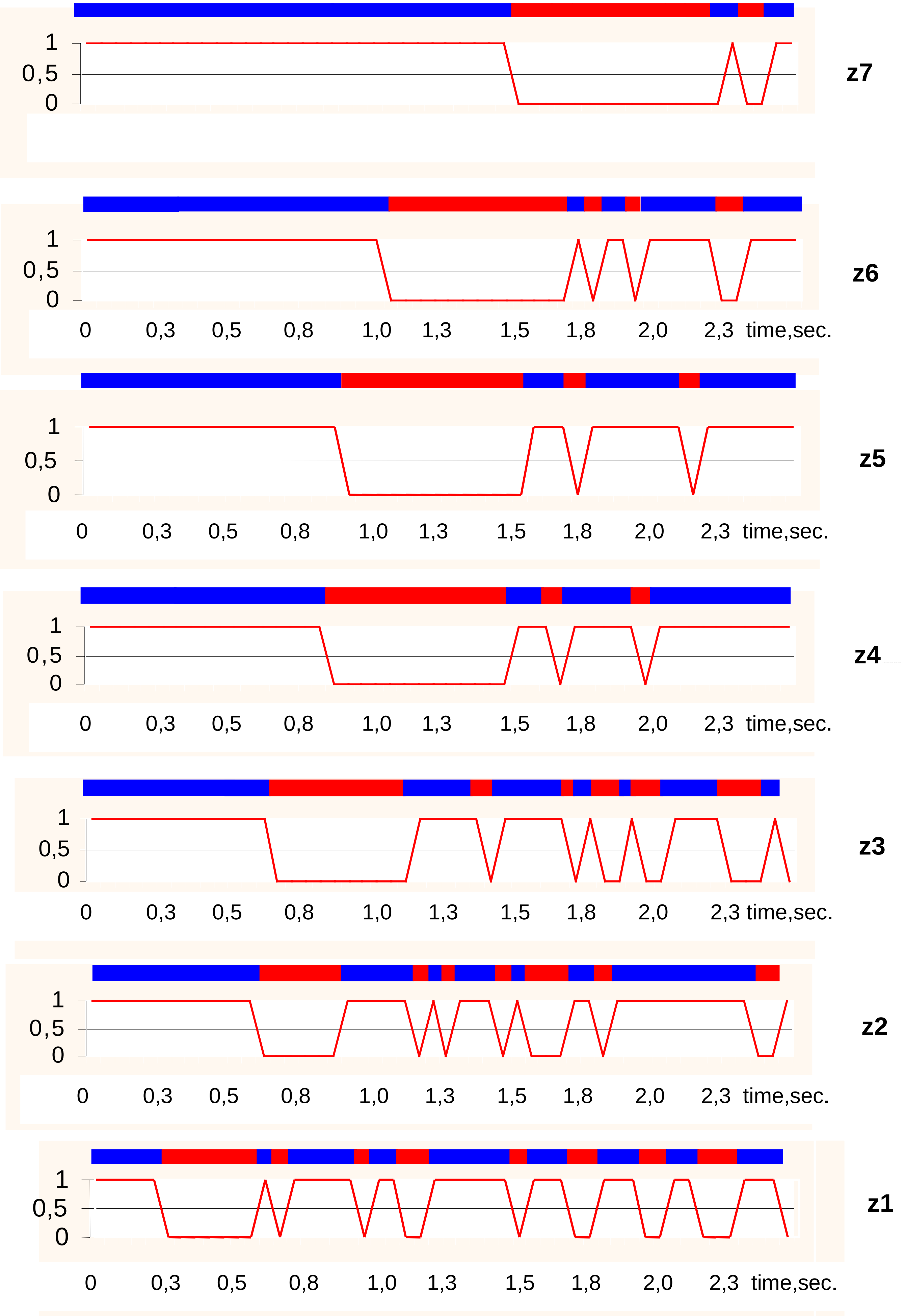

Fig. 6 Output signals for rising of the big bubble

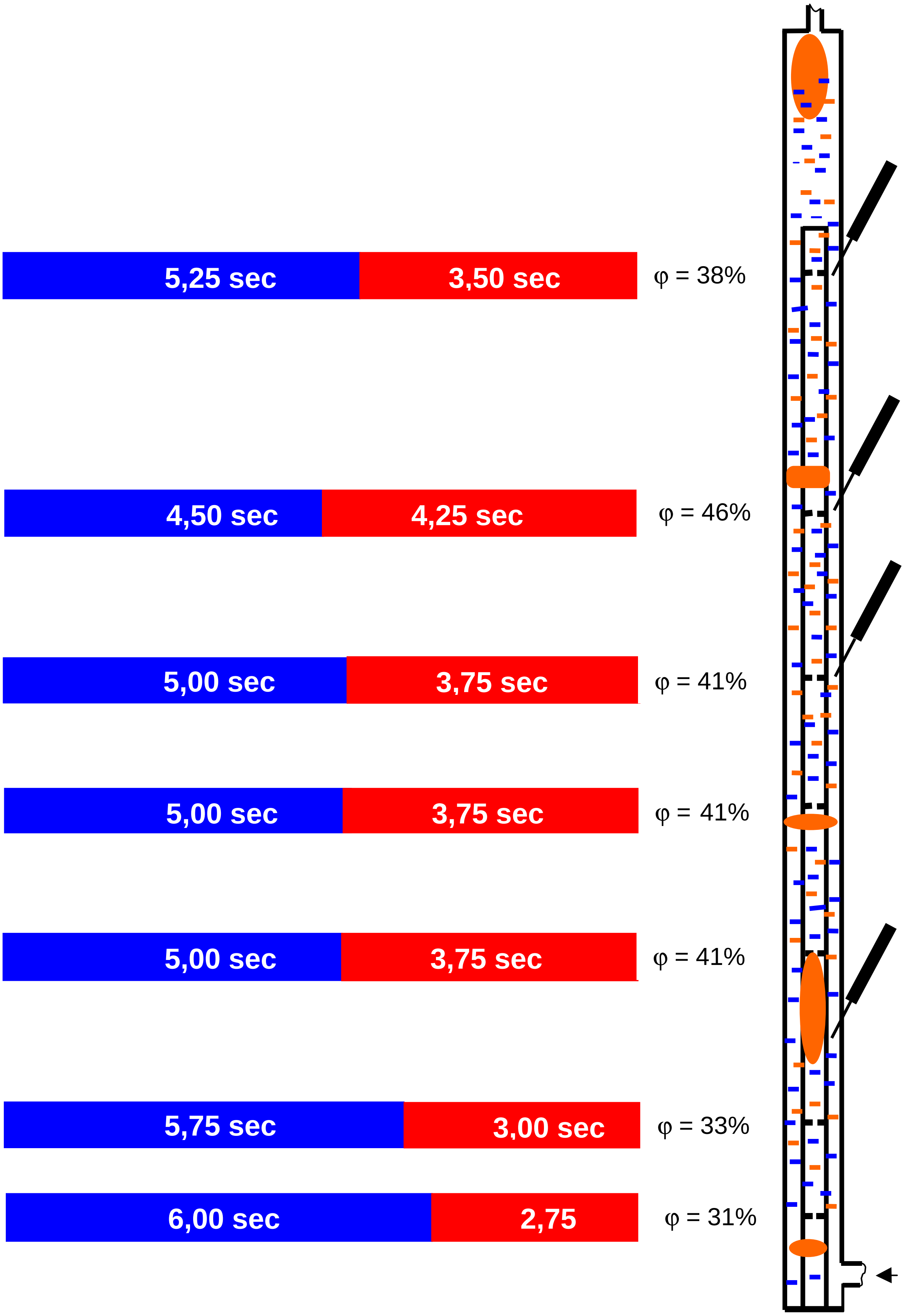

Fig.7 Distribution of gas content at the measuring tube

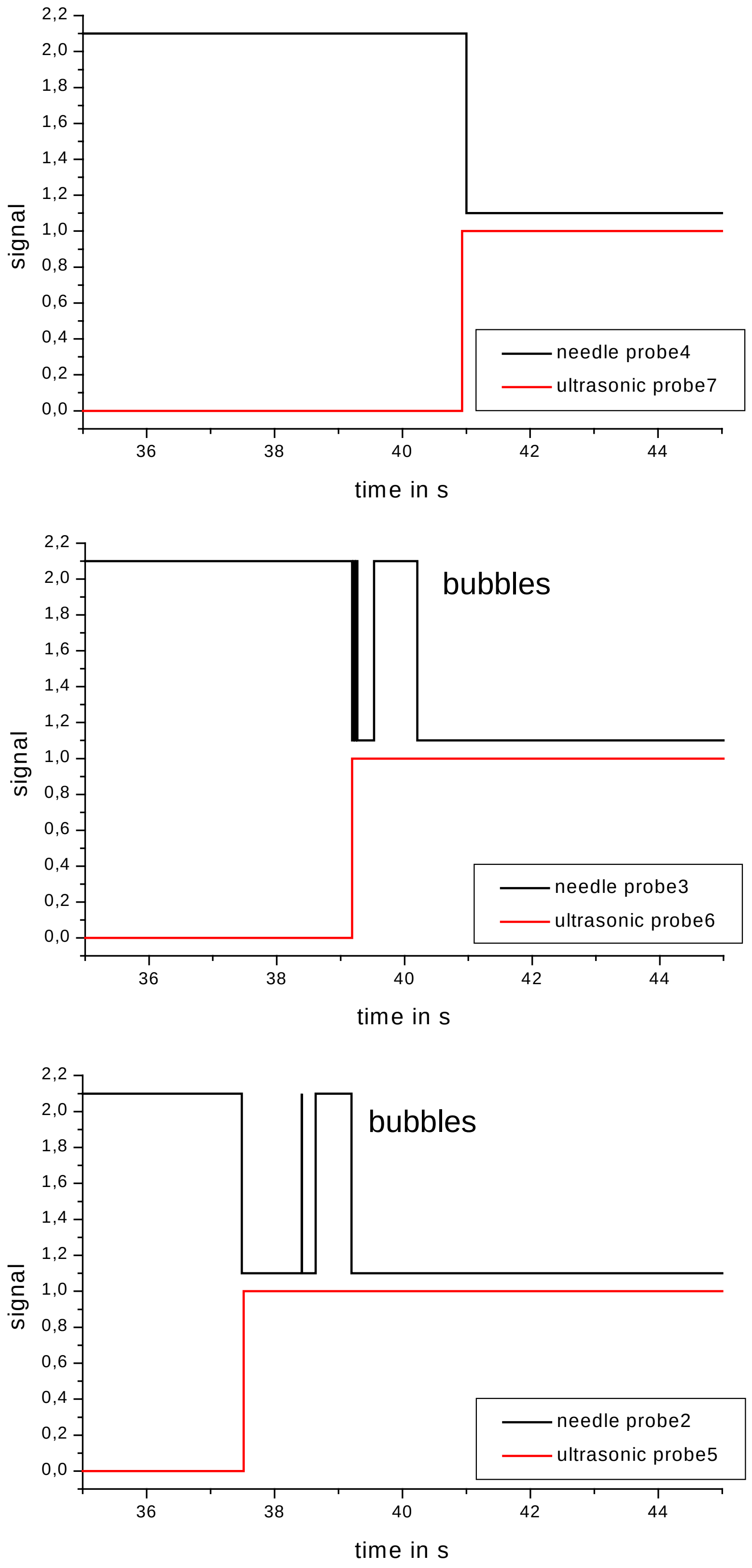

Fig.8 Output signals of ultrasonic transducer and needle probes for a fill-in experiment.

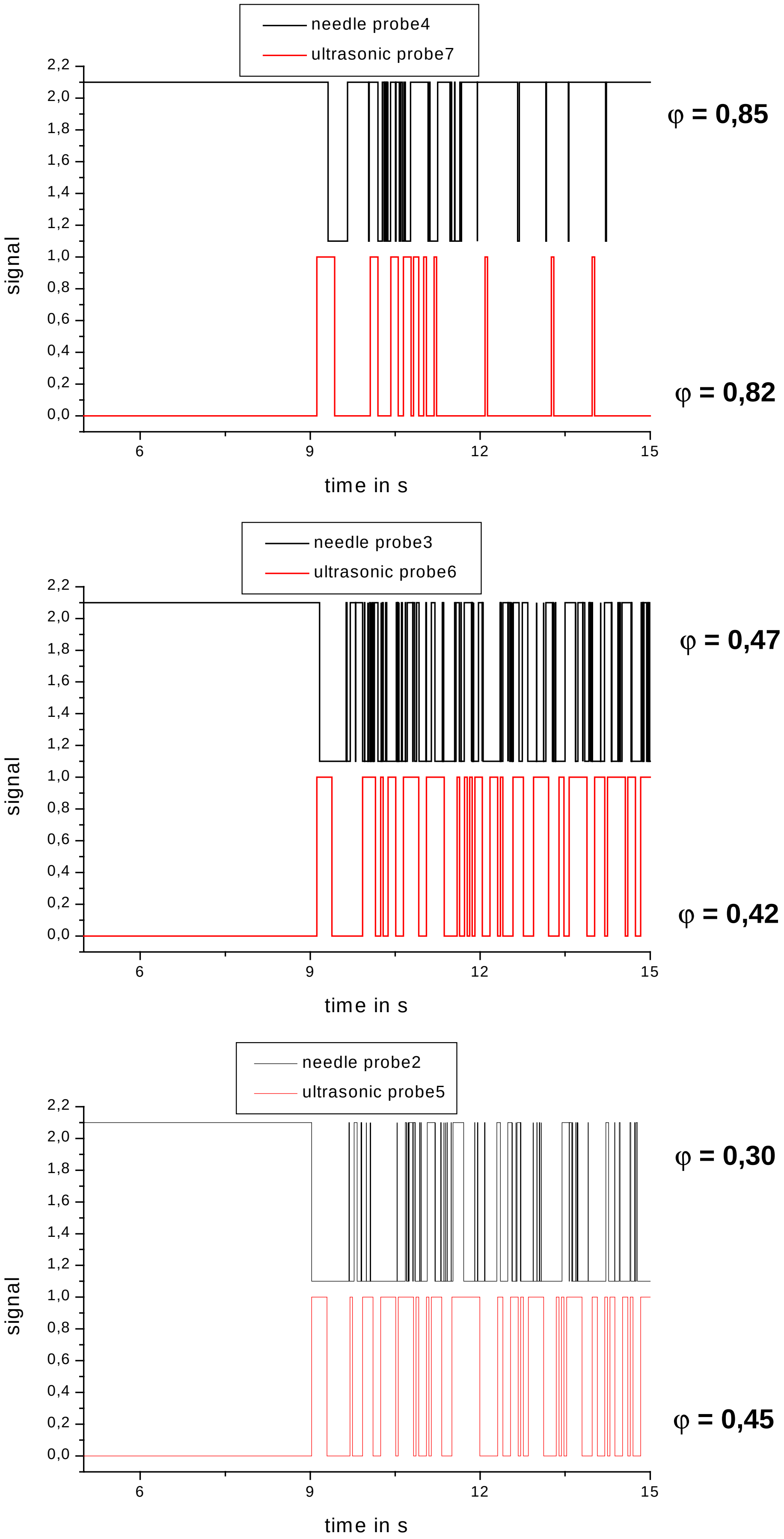

Fig.9 Output signals of ultrasonic transducer and needle probes for a pressure decreasing experiment

Control measurements were carried out by using a bubbling device simulating a two-phase flow under normal condition. The processing models of leveling change (Fig. 5) and different regimes of two-phase flow (Fig.6) were made. For big gas contents and mixture level is possible to determining the distribution of gas content at the measuring tube (Fig. 7). The results of comparative experiments with needle shaped conductivity probes are represented on Fig. 8 and Fig. 9. Some difference between signals are caused by difference position of sensors and hydrodynamic phenomenon’s.

4 CONCLUSIONS

The new waveguide ultrasonic transducer has successfully been used for liquid level measurement at two-phase flow experiments. The application of the acoustic waveguide provides high stability and reliability for the transducer, as the acoustic converter is placed outside the high-temperature zone and is not subjected to extreme effects.

REFERENCE

1. Melnikov V.I., Usinin G.B. Acoustic methods of diagnostics of two-phase coolants in NPP. Moscow. Energoatomizdat,1987.

2. Isakovish I.P. Common acoustics. Moscow. Science. 1973.