Flomeko 2000 - IMEKO TC9 Conference
Salvador, Bahia, BRAZIL
4-8 June, 2000

DEMONSTRATION TEST ON AND EVALUATION OF AN ULTRASONIC FLOW METER IN A HIGH-PRESSURE GAS PIPELINE

M. Watanabe, H. Okamoto
Engineering Department
Torishima Technical Center
Osaka Gas Co., Ltd.
Osaka, Japan

Abstract: Osaka Gas conducted a demonstration test on an ultrasonic flow meter in a high-pressure gas pipeline. In this paper we report on the result of that test.
Keywords: High-pressure gas pipeline, Ultrasonic flow meter, Leakage detection

1 INTRODUCTION

Osaka Gas supplies natural gas to about 6.2 million customers in the six prefectures in the Kansai region. Its total pipeline length is longer than 52,000 km. High-pressure gas trunk lines extend about 500 km, which account for approximately 1% of the total gas pipeline length. While the volume of gas sales is approximately 6.6 billion m^3 per year at present, demand for natural gas is expected to increase in the future. To meet this demand, Osaka Gas plans to expand its high-pressure gas pipeline networks and improve its facilities.

Under these circumstances, custody transfer and gas measuring technology are very important for high-pressure gas pipelines. Ultrasonic flow meter is one of the most recent type of high-technology meter, which features no moving parts and does no impart a pressure loss across the meter. In addition, having excellent features such as high accuracy, great rangeability, and capability of by-directional measurement, the ultrasonic flow meter is considered most suitable to high-pressure gas pipelines.

Osaka Gas conducted an empirical test, in which ultrasonic flow meters were installed in a 4-MPa gas pipeline. They were operated to establish whether they could be introduced into high-pressure gas pipelines. We examined the ultrasonic flow meter in terms of ease of installation and operation, maintenance procedures, and cost in gas pipeline application. In addition, to make use of flow measurement data, we compared flow rate measurements with a result of unsteady state analysis of high-pressure gas and evaluated leakage detection capability.

2 DEMONSTRATION TEST

We conducted a demonstration test between the Harima Onaka station and the Seishin station (distance: approx. 22 km) in Osaka Gas's Kinki Trunkline-No. 2 West Line (pressure: 4 MPa; size: 600 A). Single-path reflective ultrasonic flow meters and pressure gauges were installed at these stations, serving to measure flow rates and pressure changes. At the same time, leakage was simulated by controlling the gas flow from a high-pressure governor to a medium-pressure pipeline at an intermediate station (the Uozumi station).

2.1 Flow Meters Tested

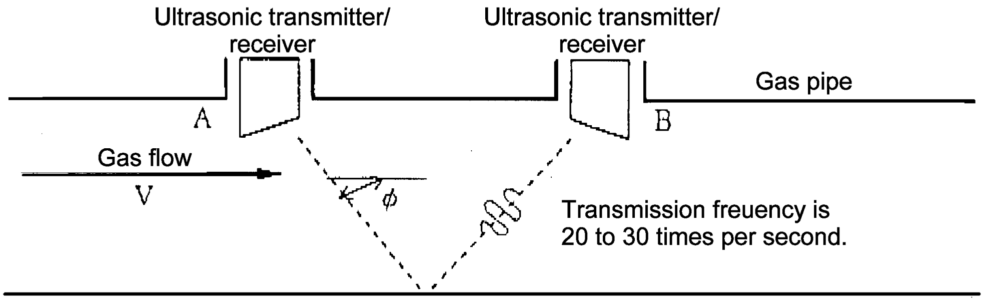
The table below shows specifications of the ultrasonic flow meters used in the demonstration test.

Table 1. Specifications of Tested Flow Meters

Item	Specification
Type	Single-path reflective type (GasSonic)
Manufacturer	Instromet
Pressure resistance	13 MPa (130 kg/cm^2)
Airtightness	9 MPa (90 kg/cm^2)
Connecting flange	2B ANSI600#
Accuracy	Within ±1.0%
Repeatability	Within ±0.5%

2.2 Features of the Ultrasonic Flow Meter and Its Measuring Principle

The ultrasonic flow meter has the following excellent features as a high-pressure flow meter.
① High accuracy
② Virtually no pressure loss
③ Full bore (Allows a pig to be passed through the pipeline.)
④ Maintenance work possible under live conditions
⑤ Measurement in a range of small Reynolds' numbers (wide rangeability)
⑥ Measurement in two directions
Measuring principle of the ultrasonic flow meter: the flow rate in a pipe is determined by measuring the average flow velocity in the path of an ultrasonic beam.



Transmission time: $t_{AB} = L / (C + V\cos f)$ .... (1)
: $t_{BA} = L / (C - V\cos f)$ .... (2)

By eliminating C in equations (1) and (2) and rearranging the equations, we obtain,

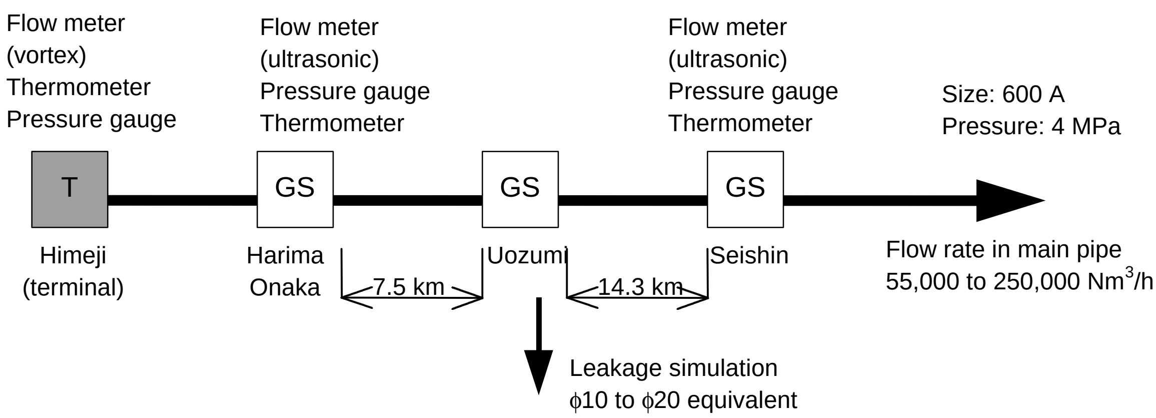
Flow velocity : $$V = \frac{L}{2 \cdot \cos f}\left(\frac{1}{t_{AB}} - \frac{1}{t_{BA}}\right)$$

Flow rate : Q = k • V • D

L : path length
k : constant
D : cross-sectional area of pipe
C : sound velocity
V : flow velocity

2.3 Overview of the Demonstration Test

2.3.1 Pipeline Used for the Demonstration Test



2.3.2 Test Conditions

Test conditions were established in the following cases to test the ultrasonic flow meter in the widest range possible from a practical standpoint. We decided the amount of simulated leakage on the assumption that the defect is equivalent to a hole 10 to 20 mm in diameter.

Table 2. Test Conditions

Case	Flow rate in main pipe (10,000 Nm^3/h)	Amount of simulated leakage (Nm^3/h)	Operating condition
1 - 4	10 - 17	1,500 3,000	Steady state and unsteady state
5 - 9	5.7 - 8.6	1,500 1,800	Steady state and unsteady state
10 - 12	5.7 - 7.2	3,000	Steady state and unsteady state
13 - 14	5.5 - 8.9	6,000	Steady state

2.3.3 Test Procedures

① Valves were operated to form the pipeline system shown in 2.3.1, so as to prevent a diversion of flow or reverse flow in the main pipeline.
② Changes in the flow rate of natural gas sent out from the Himeji manufacturing plant were monitored on a 24 hour basis. Measurement began when prescribed conditions were established.
③ Under each set of test conditions a high-pressure governor installed at the Uozumi station was operated to divert gas to the medium-pressure side to realize a certain amount of simulated leakage.
We conducted the test in all 14 cases by repeating the procedures described above.

3 TEST RESULTS AND EVALUATION

3.1 Evaluation of Field Performance

3.1.1 Evaluation of Work under High-pressure, Live, and No-blow Conditions

We installed and then removed the flow meter under high-pressure, live, and no-blow conditions and tested airtightness and required time. Installation conditions of the ultrasonic flow meter are shown in Figure 1. We obtained the following test results.
① Airtightness
No leakage or other faulty conditions occurred during live installation, measurement, or removal.
② Required time for installation
The required time was about one hour in total, of which it took 30 minutes for installation (to attach flanges, insert sensors, etc.) and an additional 30 minutes for adjustment (to monitor input and output waveforms on an oscilloscope, effective hit ratio, etc.).

Figure 1. Installation conditions of the ultrasonic flow meter

3.1.2 Operation Checking of the Measuring System

We checked operations of the measuring system, including impact of noise and transmission and reception of ultrasound. We obtained the following results.

① Impact of noise

Noise in pipe did not affect measurements, with the effective hit ratio being 95% to 100% (no problem occurs in terms of measurement if the effective hit ratio is at least 50% or 60%). (See Figure 2.)

② Transmission and reception of ultrasound

No faulty conditions were detected regarding sound velocity or waveforms.

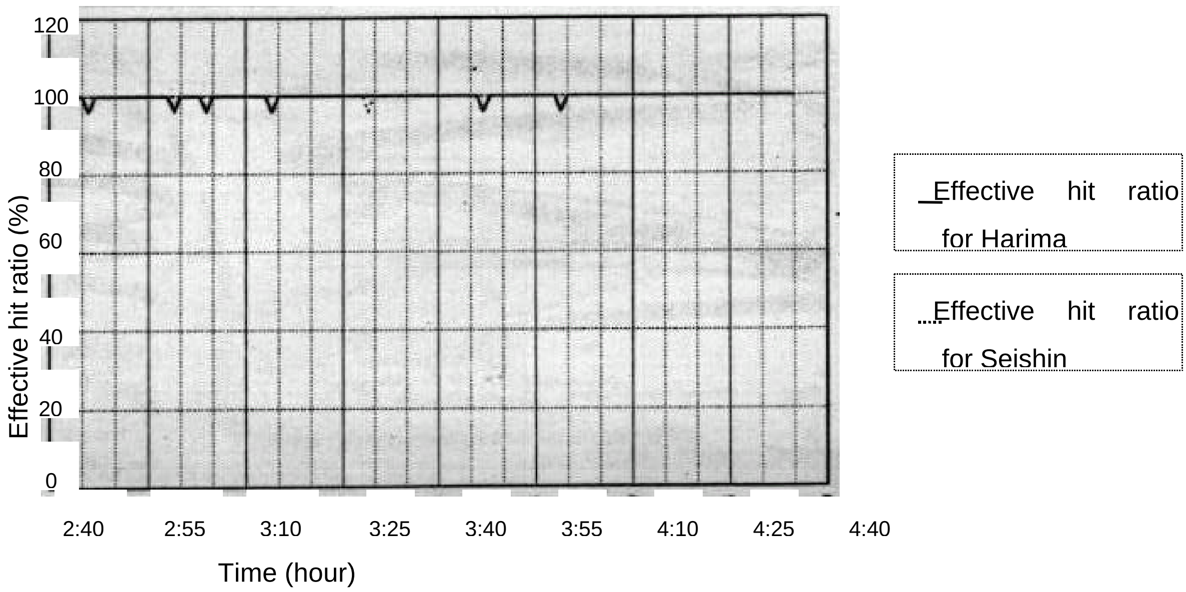


Figure 2. Effective Hit Ratio (case No. 14)

3.2 Evaluation Based on Flow Rate Measurements

3.2.1 Comparison between Unsteady Analysis Results of High-pressure Gas and Flow Rate Measurements

We compared unsteady analysis results of high-pressure gas in real time with flow rates measured by the ultrasonic meter to verify the discharge coefficient used for the analysis.

① Comparison between the discharge coefficient used in AGA equations to calculate high-pressure flow rate and that determined by flow rate measurements

Figure 3 compares discharge coefficients used in the AGA equations to calculate high-pressure flow rate and that determined by flow rate measurements in the range of Reynolds numbers adopted in the demonstration test. The discharge coefficient based on flow rate measurements becomes smaller than that of AGA with increasing Reynolds numbers. This indicates that the actual friction factor of high-pressure trunklines is greater than the friction factor used for calculation.

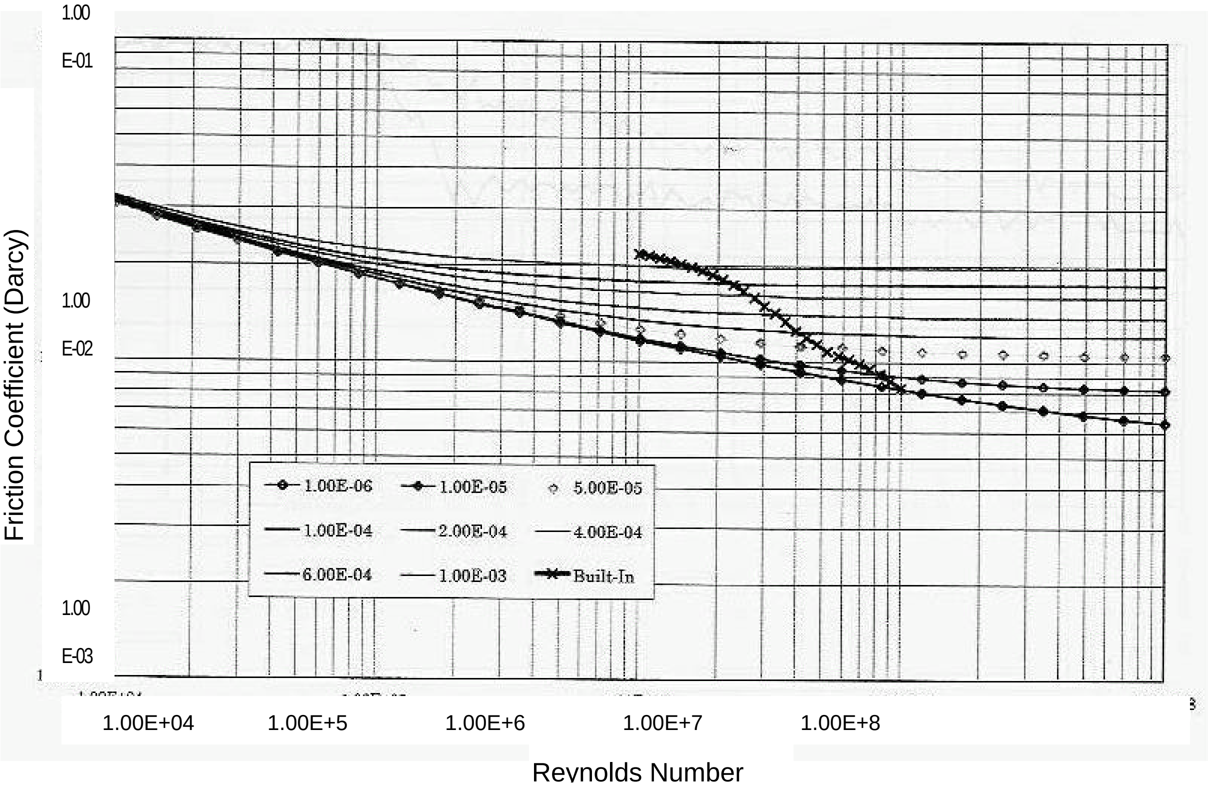


Figure 3. Comparison of the Discharge Coefficient Used by AGA with That Determined by Experiment, against Reynolds Numbers

Comparison of flow rate calculations with flow rates measured at tested stations

Figure 4 compares flow rates measured at the Harima Onaka and Seishin governor stations in real time with flow rate calculations based on AGA equations. Flow rate calculations are greater than flow rate measurements under both steady and unsteady states.

③ Comparison between flow rate measurements and corrected flow rate calculations in line with flow rate measurements

In Figure 5, flow rates measured at the two governor stations are compared in real time with flow rate calculations using the friction factor determined from measurements. Those calculations reproduce flow rate measurements with high precision whether under steady or unsteady state.

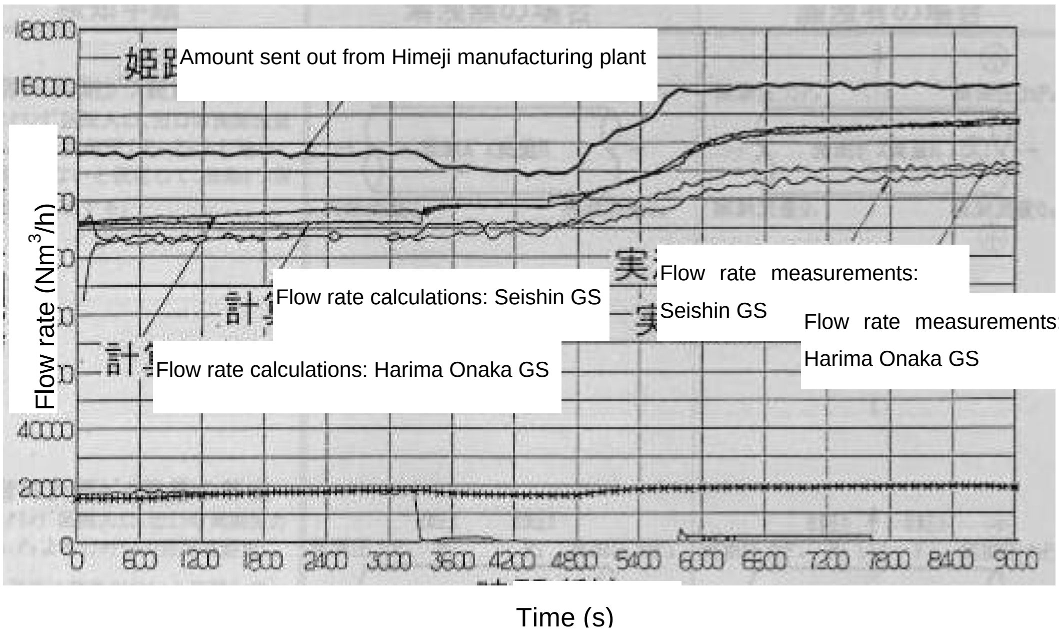


Figure 4. Comparison between Flow Rate Analysis and Flow Rate Measurements (Case No. 2) (Friction factors indicated in AGA are used.)

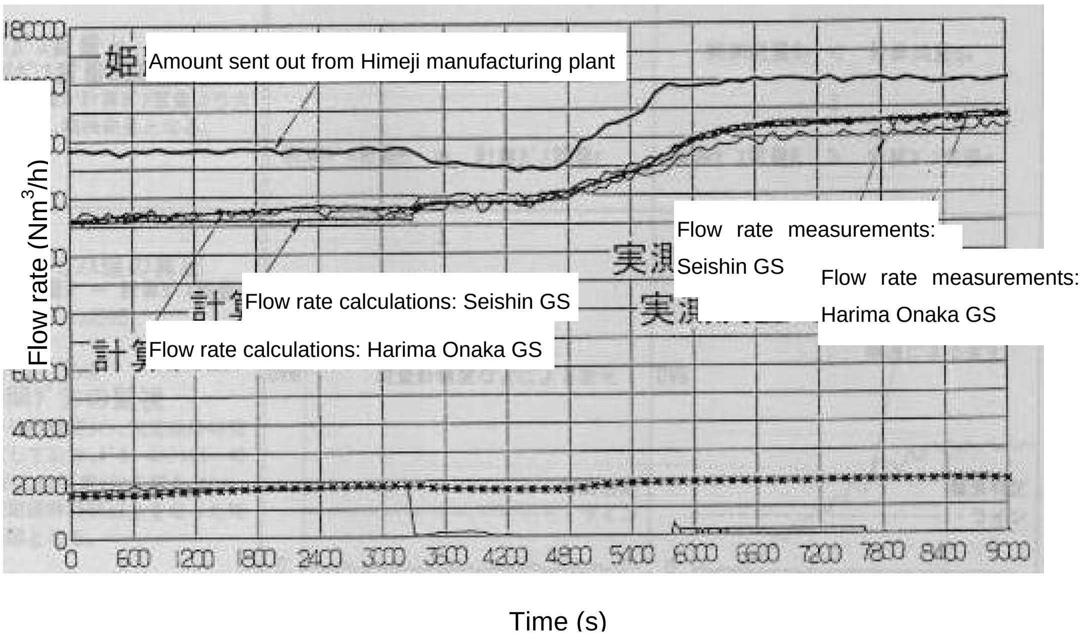


Figure 5. Comparison between Flow Rate Analysis and Flow Rate Measurements (Case No. 2) (Friction factors determined from measurements are used.)

3.2.2 Leakage Detection by Leakage Simulation

We evaluated performances such as leakage detection, time required for leakage detection, and leakage location by varying the amount of simulated leakage at the intermediate station (Uozumi governor station).

① An overview of the leakage detection technique

The flow-rate method for leakage detection is a method in which leakage within a pipeline section is monitored constantly by measuring flow rates and pressures at both ends of that section. Our system consists of two steps. Probable leakage is detected in the first step (leakage detection step). In the second step (leakage confirmation step), the probable leakage is reviewed to establish whether it is an actual leak or not, to prevent false detection. The leakage detection step compares the measured mass of the gas in the section with the calculated mass of gas. A gas leak is detected if the measured mass of gas is greater than the calculated mass of gas. The corrected discharge coefficient noted in the previous section is of course used in the calculation as the discharge coefficient for non-steady state analysis. Leakage is confirmed in the second step when the difference between the measured and the calculated mass of gas (differential volume balance: DVB) exceeds both a preset threshold value and retention time for leakage detection. A model of this system is shown in Figure 6.

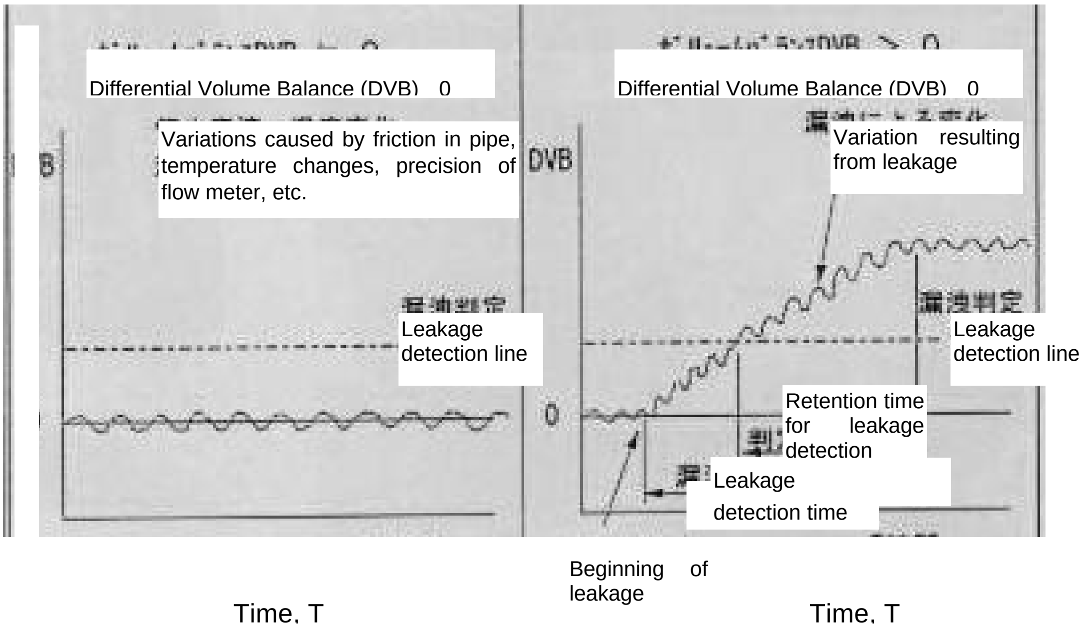


Figure 6. A model of the leakage detection system

② Evaluation of the performance of the leakage detection system

Figure 7 shows an example of leakage detection. We examined each (steady and unsteady state) test case and found that the detection system can detect in about 10 minutes when a leakage equivalent to 10 mm in diameter (1,500 to 2,000 Nm^3/h) occurs either in steady or unsteady state operation. The system is also capable of estimating leakage location with precision in a range of ±2 ±3 km.

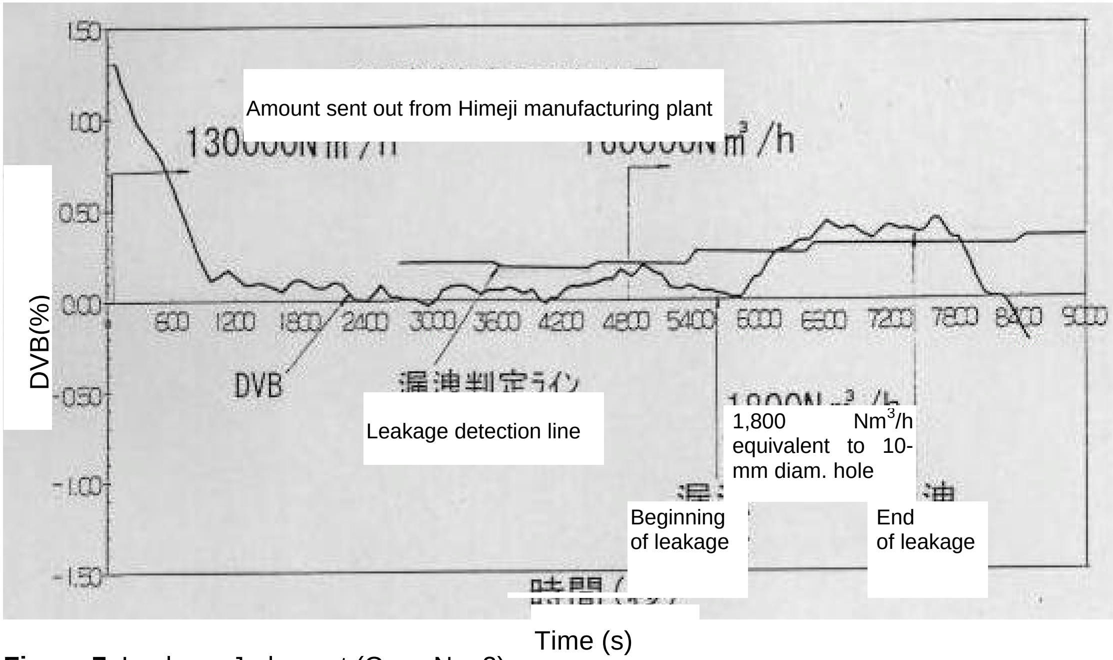


Figure 7. Leakage Judgment (Case No. 2)

4 CONCLUSION

The ultrasonic flow meter can be installed successfully and it can function efficiently in a high-pressure pipeline in the field.

The ultrasonic flow meter operates with sufficient precision if a certain straight length of pipeline is provided. It can be installed and maintained with superb ease. The meter is suited to high-pressure, high-capacity pipeline for flow control and metering for commercial purposes.

With flow rate measurements, we have verified the discharge coefficient used in unsteady state analysis of high-pressure pipelines.

We have found that ultrasonic flow meters installed at a distance in a suitable section are useful for leakage detection.

5 FUTURE DIRECTIONS

We have verified an ultrasonic flow meter for its basic performance and suitability to actual pipelines in the field. We intend to study its application to branches in planned high-pressure pipelines.

AUTHORS: M. Watanabe, H .Okamoto, Engineering Department Torishima Technical Center Osaka Gas Co., Ltd. 11-61, Torishima 5-Chome Konohana-Ku, Osaka, 554-0051, Japan, phone xx81-6-6465-2002. E-mail:masaki-watanabe@osakagas.co.jp, hideki-okamoto@osakagas.co.jp