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A Method for Measuring Fluid Pressure Using Magnetic Tape

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ABSTRACT

This paper has described a new method for measuring fluid pressure by using a magnetic tape. The fundamental ideas of this method are as follows; the magnetic tape is magnetized by a magnetic field and the magnetization quantity of the tape is related to the strength of the magnetic field. Therefore, when the diaphragm made of the magnetic tape is placed in a magnetic field and is deflected by a pressure, the magnetization quantity of the magnetic tape is changed according to the deflection. This means the magnetization quanlity of the tape relates to the pressure value. Therefore, the pressure value is obtainable by reading the magnetization quantity. A pressure transducer is made for trial by applying this principle. Measurements of fluid pressure around a circular cylinder were carried out by using the pressure transducer. The experimental results showed that the present method was useful for measuring fluid pressure. As an application of this method, a measurement of pressure distribution on the surface of a plate placed perpendicularly to a jet was performed successfully.

1. Introduction

Pressur measurements are very important in the study on fluid dynamics. At present, many kinds of pressure transducers, such as the manometer, the strain gauge, the semiconductor transducer, the quartz transducer and so on, have been used according to the purpose of various kinds of pressure measurement.

From the point of response time, the manometer is suitable for the measurement of a constant pressure value. On the other hand, the strain gauge, the semiconductor transducer, the quartz transducer, etc. are widely used by bonding to diaphragms and these pressure sensors are suitable for the measurement of changeful pressure values.

In this paper, a new method to measure fluid pressure by using a magnetic tape has been described. The present pressure teansducer by this method belongs to the diaphragm-type pressure tranducers. Therefore, this method is suitable for the measurement of changeful pressure values. Besides, judging from the measuring principle, the method is considered to be useful for several purposes, such as the measurement of pressure distribution around models, the measurement of pressure around rotors, etc. As for the application of the method, this paper concerns the pressure distribution measurement.

2. Measuring Principle and Desigh of Pressure Transducer

In this experiment, as the magnetic sensor, an usual magnetic recording head which is used as a cassette tape recorder on the market is utilized. It is generally known that the magnetic field around the magnetic recording

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head decreases rapidly with the distance from the head.[1] When a magnetic tape is placed in a magnetic field, the tape is magnetized. The magnetization quantity is related to the magnetic field strength at the place. In a constant magnetic field, if the position of the magnetic tape changes, the magnetization quantity of the tape also changes. This means that the displacement of the tape can be obtained by measuring the magnetization quantity and that the magnetic tape can be utilized as a diaphragm type pressure sensor.

By utilizing these ideas, the author has designed a new diaphragm type pressure transducer using a magnetic tape as shown in Fig.1. The pressure chamber partioned by the diaphragm is lead to the test chamber. The magnetic tape is attached to the diaphragm. A suitable gap length between the diaphragm and the magnetic recording head which is put to a micro-meter, is made. The gap length is adjusted by the micro-meter so as to obtain the most suitable magnetization quantity of the tape which is magnetized when the tape is deflected. In this experiment, the relation between the length and the magnetization quantity is preliminary investigated,

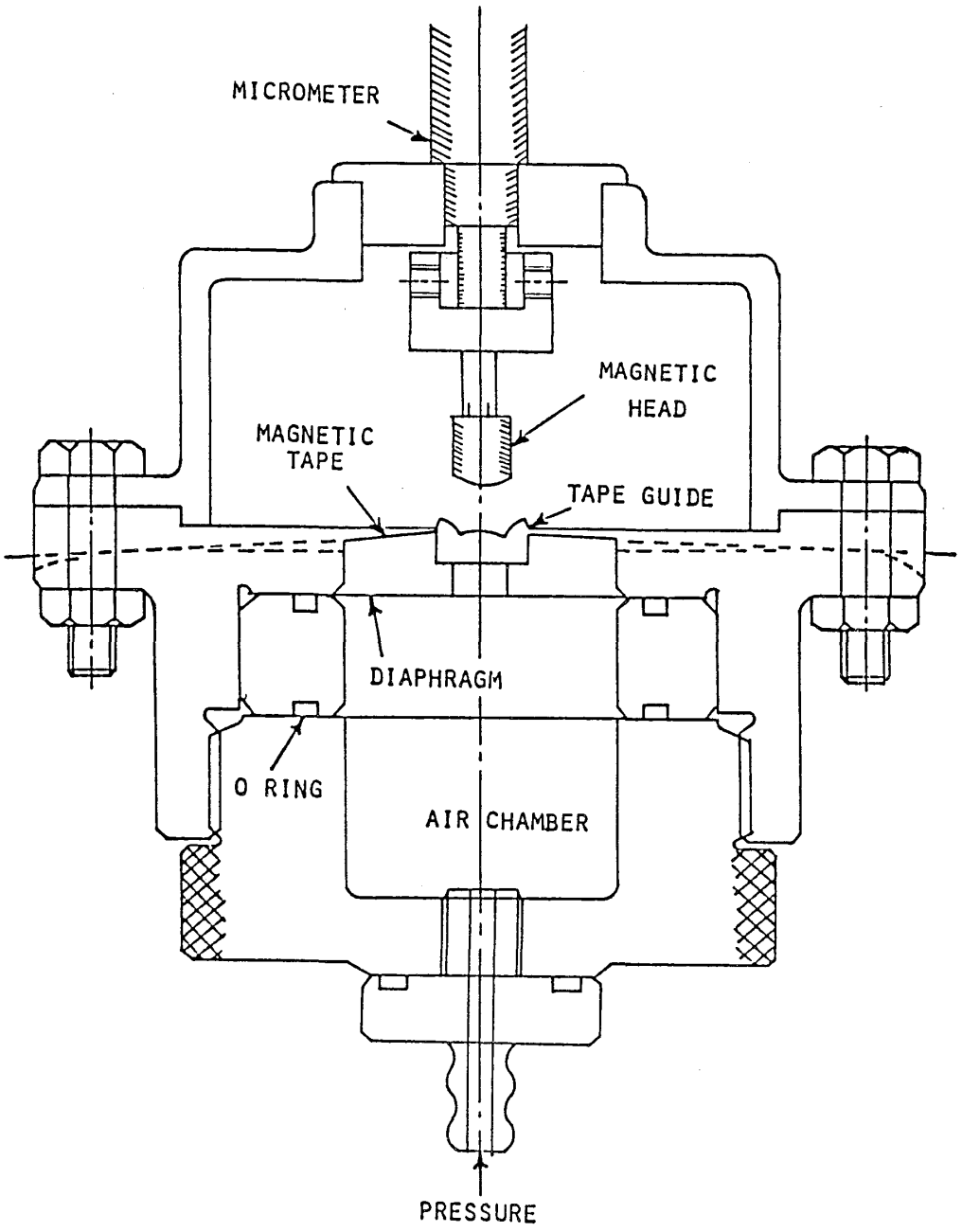

Fig.1. Pressure transducer

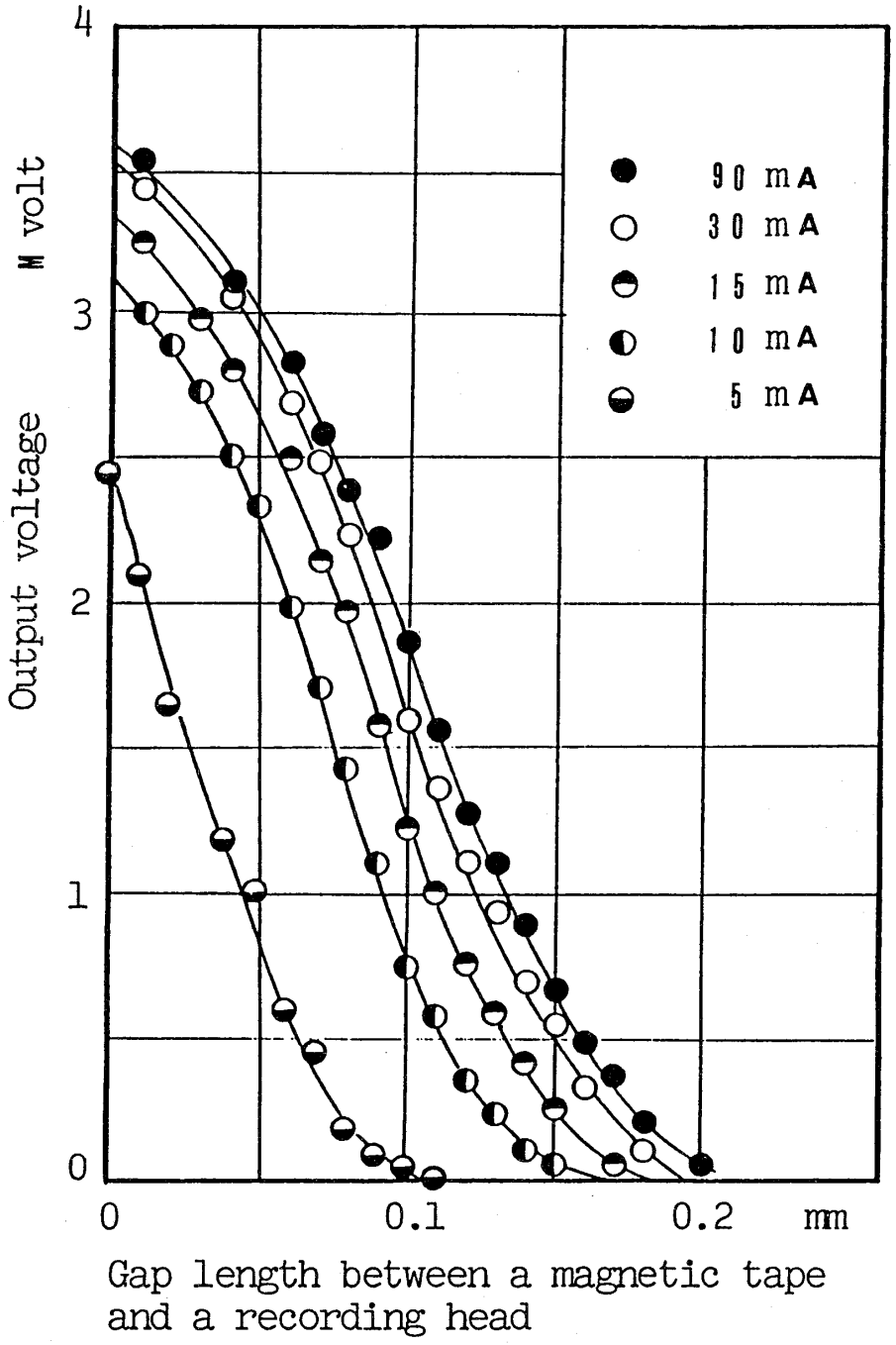

Fig.2. Relation between gap length and output

and the result is shown in Fig.2.

When a suitable voltage is applied to the both ends of the coil in the magnetic head to flow a suitable electric current in the coil while the measuring pressure is applied to the pressure chamber, the magnetic tape is magnetized accdording to the gap length between the magnetic tape and the magnetic head, namely the pressure value. The pressure value is obtainable by using the calibration curve prepared preliminary as shown in Fig.3. The magnetization quantity is obtained by using a magnetic recording head, and the vertical value in Fig.3 shows the output voltage of the magnetic reading head.

The relation between the gap length and the magnetization quantity, which is shown in Fig.2, will be further explained. The suitable initial gap length is also related to the electric current in the coil of the magnetic head. Therefore, the relation between the gap length and the magnetization quantity is investigated and is shown in

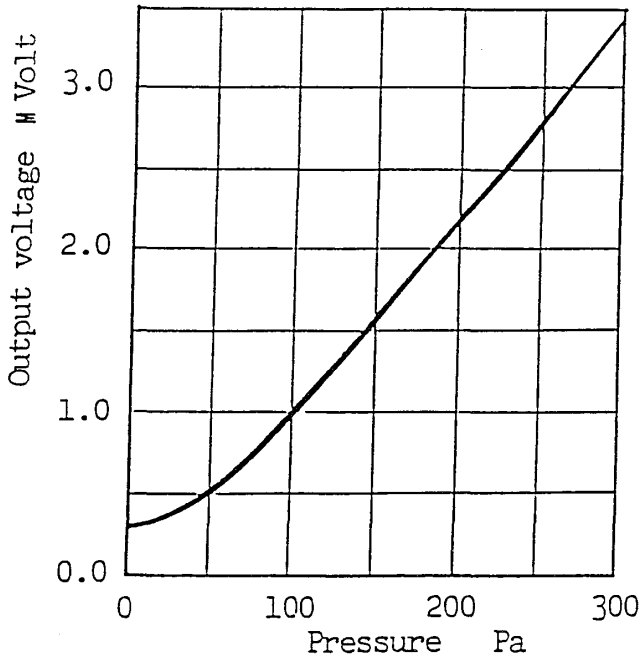

Fig.3. Calibration curve

Fig.2. The vertical value in Fig.2 shows the output voltage of the magnetic reading head which uses in order to read the magnetization quantity of the tape. When we design the prseeure transducer, the followings must be considered.

(1) When the output voltage is small(namely, the regions of the downward of the curves), it becomes difficult to read the voltage value accurately.

(2) When the output voltage is large(namely, the regions of the upwards of the curves), the magnetization quantity and the output voltage changes very little even if the gap length changes because of the large magnetic field. Consequently, the accurate measurement becomes difficult.

(3) When the gap length is too large(namely, the regions of the right of the curves), it becomes necessary to flow a large amount of electric current. In this case, there is a possibility of heating the coil in the magnetic recording head.

(4) When the gap length is too small(namely, the regions of the left of the curves), the linearity becomes worth and the measuring field becomes narrow.

From these, in this experiment, the electric current in the coil of the magnetic head is decided to be 15 mA, and the initial gap length between the magnetic tape and the magnetic head is decided to be 0.15mm.

As described in the experimental principle, the present pressure transducer is a diaphragm type one. Therefore, when we use such kind of pressure transducer, the following characteristics, such as the senstivity, the pressure range, the accuracy etc. have to be considered.

As for the sensitivity of the pressure transducer, the output voltage v.s. the distance of the deflection of the diaphragm was 0.2 mvolt/10^{-3}mm as shown in Fig.2, in the case that the electric current in the coil was 15 mA. From this it is considered that the sensitivity of the magnetic tape is large enough for reading the output voltage. Therefore, the magnetic tape is usable as the sensitive pressure sensor.

Concerning the pressure range of the pressure transducer, diaphragm type transducers are usable for from low pressure to high pressure by selecting the suitable valuse of the thickness, diameter, modulus of elasticity, etc. of the diaphragm.

As for the accuracy of the pressure transducer, it is considered that the pressure transducer using the magnetic tape is considerably accurate, as will be shown in the experimental results indicated in Fig.4.

3. Experiments

First, the relation between the pressure and the magnetization quantity are investigated by using the pressure transducer shown in the Fig.2 in order to make the calibration curve. The diaphragm used in this experiment is made of metal. The thickness and the diameter of the diaphragm are 0.1 mm and 50 mm, respectively. The pressure values applied to the diaphragm are varied from 0 Pa to 300 Pa and we read the output voltages by reproducing the magnetic tape by using a reading head at the various pressure value. The calibration curve is shown in Fig.3.

To verify the usefulness of the present pressure transducer, the pressure around a circular cylinder is measured. In this case, the dynamic pressure of the freestream is 250 Pa and the diameter of the model is 4

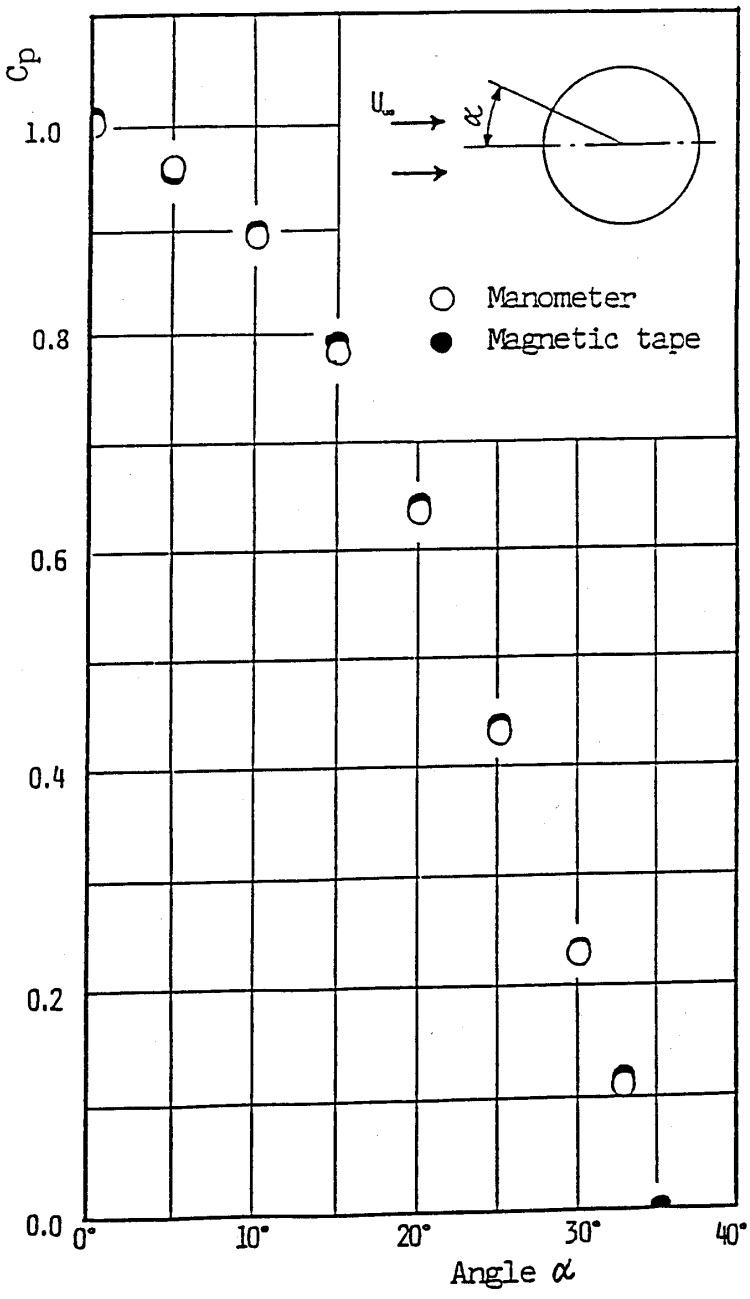

Fig.4. Pressure values atroud a cylinder

cm. The experrimental result is shown in Fig.4. For a comparison, the pressure measurement using U-tube manometers are also carried out under the same conditions and the result is shown in the same figure. Fig.4 shows that both of the results agree quite well with each other. From these experiments, it is confirmed that the present prseeure transducer using magnetic tape is usable tor measuring surface pressure values.

One great merit of this method is that it can be applied to pressure transducers for pressure distribution measurements. In the following studies, the pressure transducer for pressure distribution measurements is developed by using the fundamental idea described above. In this case, a lead wire is used instead of the magnetic recording head, and the magnetic tape itself is used as a diaphragm. The arrangement of the lead wire and the magnetic tape is show in Fig.5 and Fig.6 to explain the fundamental principle of the pressure

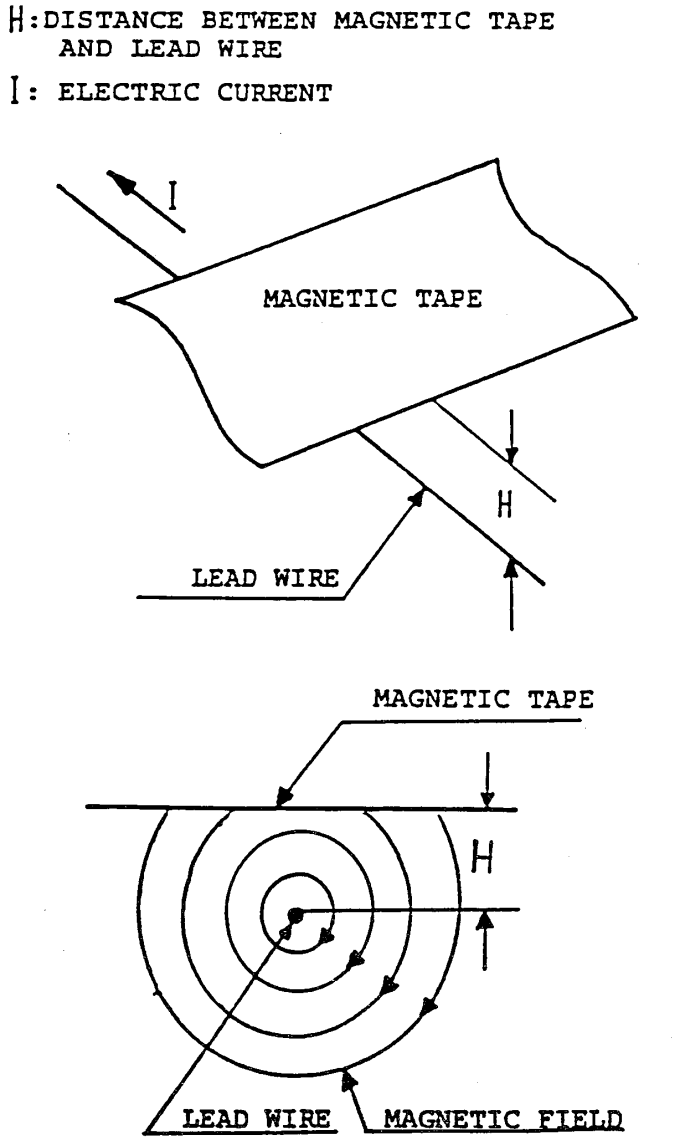

Fig.5. Illustration of measuring principle

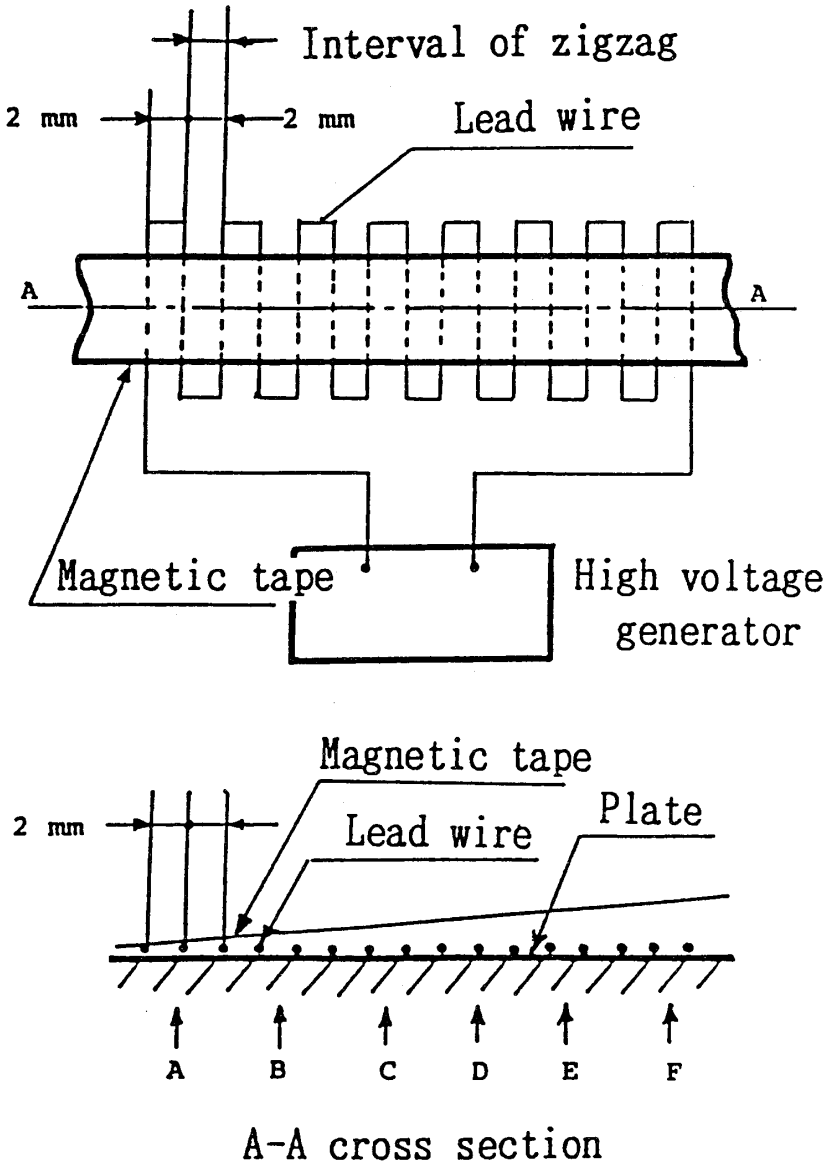

Fig.6. Arrangement of lead wire and magnetic tape

transducer. The tape is magnetized by the magnetic field generated around the wire by an electric current. The magnetization quantity on the tape varies according to the distance between the wire and the tape since the magnetic field strength is related to the distance from the wire. The diaphragm made of the magnetic tape subjected to fluid pressure is deflected in the magnetic field according to the pressure strength, and the magnetization quantity on the tape will relate to the pressure strength. Therefore, it becomes possible to measure the pressure values by reading the magnetization quantity. Figure 7 is the electric circuit to flow a large amount of electric current in the lead wire. Figure 8 is the experimental result in a case of Fig.6.

The fundamental idea described above is applied to the design of pressure transducer for pressure distribution measurements on the surface of models. In order to obtain pressure distributions by a single experimental procedure, a zigzag shaped lead wire is adopted for making such pressure transducer imstead of the magnetic recording head. And a sheet of magnetic tape is arranged so as to cross the magnetic fields generated around the zigzagged wire at a large number of positions as shown in Fig.9. In this experiment, eight holes are made in the thin plate along its center and each hole works as a pressure transducer. Hence, the pressure values at

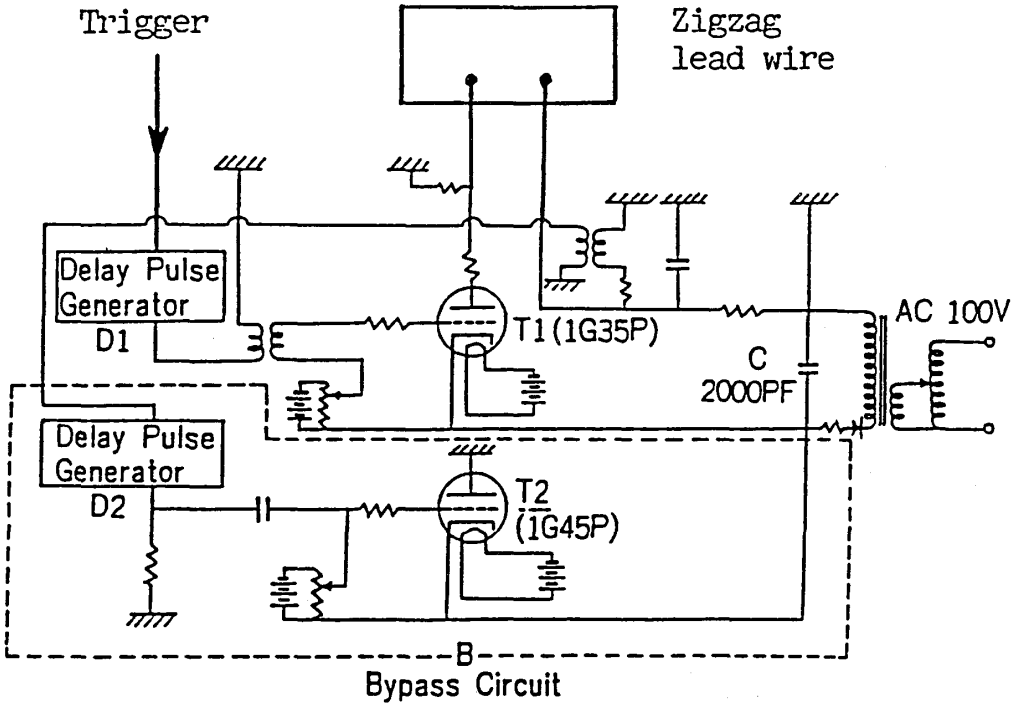

Fig.7. Electric circuit

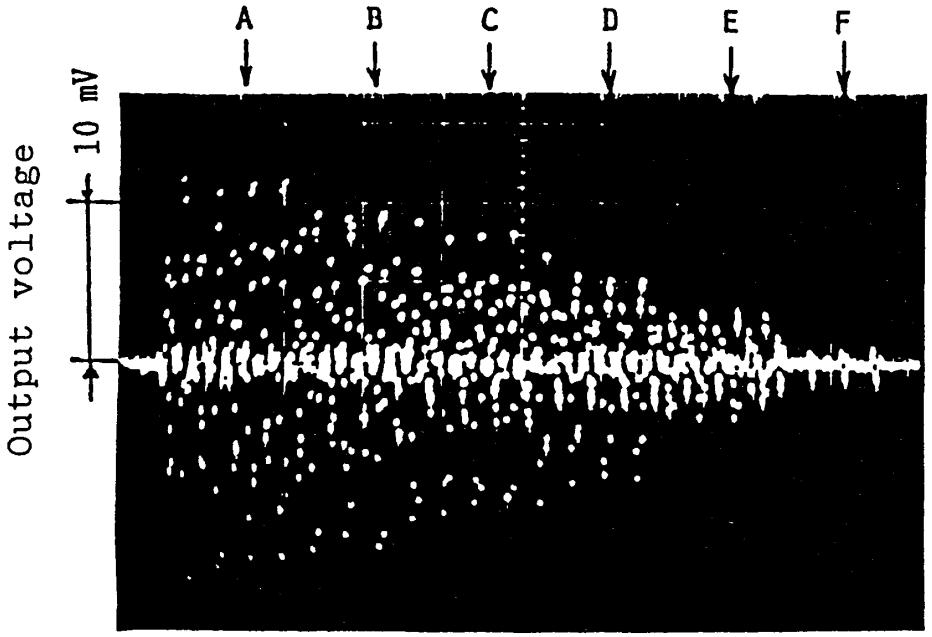

Fig.8. Experimental result in case of Fig.6

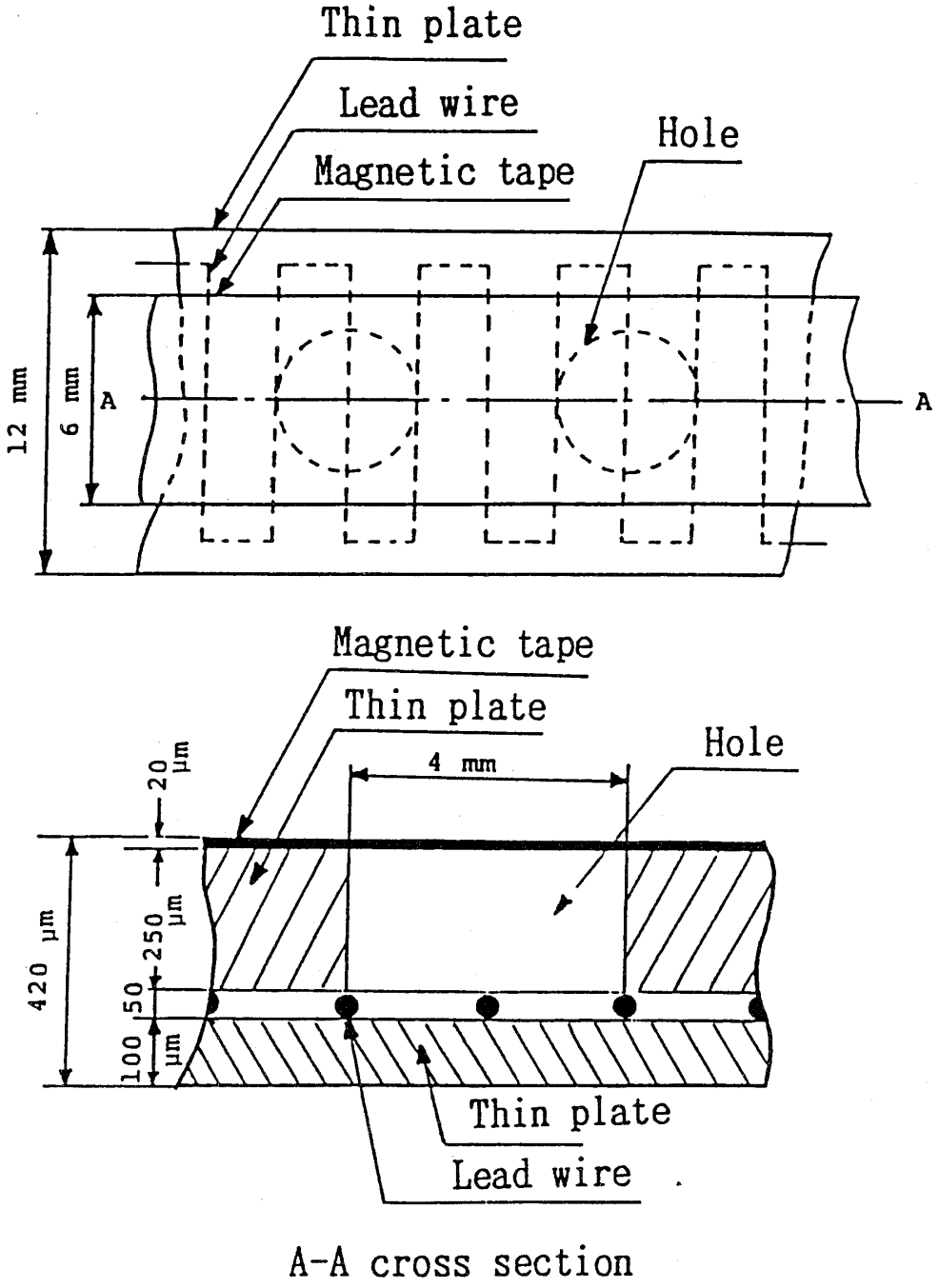

Fig.9. Pressure transducer For pressure distribution measurement

eight positions are obtained simultaneously. Figure 10 shows the relation between the gap length and out put voltage of the pressure transducer shown in Fig.9. Figure 11 is he caliblation curve of the pressure transducer.

As for the application of the newly designed transducer, the measurement of a pressure distribution on the surface of a plate placed perpendicularly to a jet flow is carried out. The experiment can be performed just by putting the sheet of pressure transducers on the surface of the plate without making pressure taps in the model. Furthermore, the pressure distribution is obtained by a single experimental procedure. The measurement result is shown in Fig.12.

For a comparison, another measurement is carried out by using manometers under the same conditions. The rseult is also shown in the same figure. The figure shows that both of the results agree comparatively well with

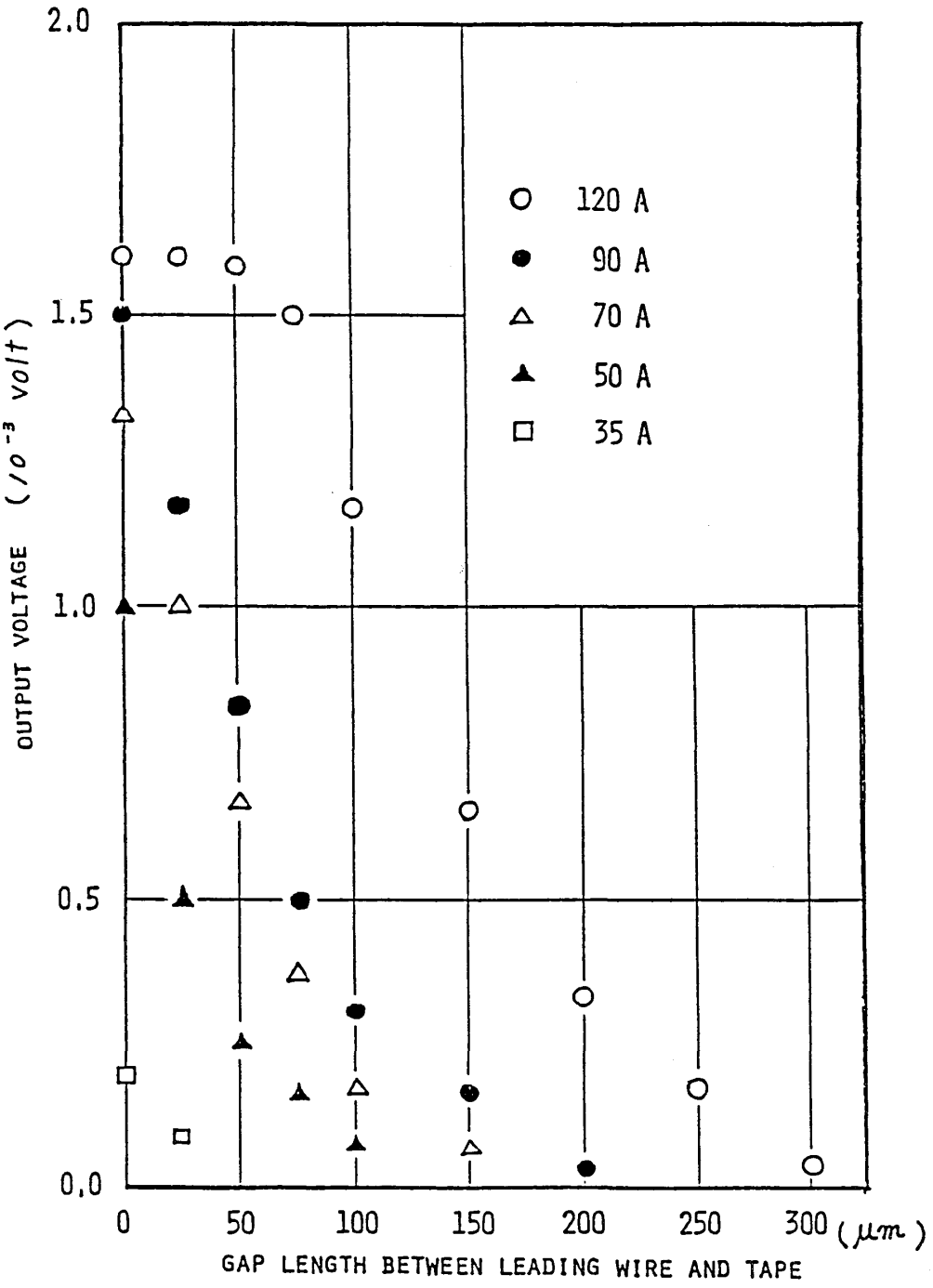

Fig.10. Relationship between gap length and output voltage in case of Fig.9

each other. Therefore, it is confirmed that the newly designed pressure transducer using the magnetic tape is useful for measuring pressure distributions on the surface of models.

4. Conclusions

This paper has described a new method to measure surface pressures by using a magnetic tape. The fundamental idea of this method is as follow; the magnetic tape is magnetized by a magnetic field and the magnetization quantity of the tape is related to the strength of the magnetic field. Therefore, when the diaphragm that the magnetic tape is attached to, is placed in the magnetic field and is deflected by pressure,

the magnetic tape is magnetized. And the magnetization quantity on the tape relates to the pressure value. The pressure value is obtained by reading the magnetization quantity.

It is verified by measuring the pressure values around the circular cylinder that the new method using the magnetic tape is useful for the pressure measurement.

From the measuring principle, the method is considered to be useful for several puposes, such as the measurement of pressure distribution, the measurement of the pressure around rotors, etc.

In this paper, the application to the pressure distribution measurement is carried out by measuring the pressure distribution on the surface of the plate perpendicularly to the jet flow, successfully.

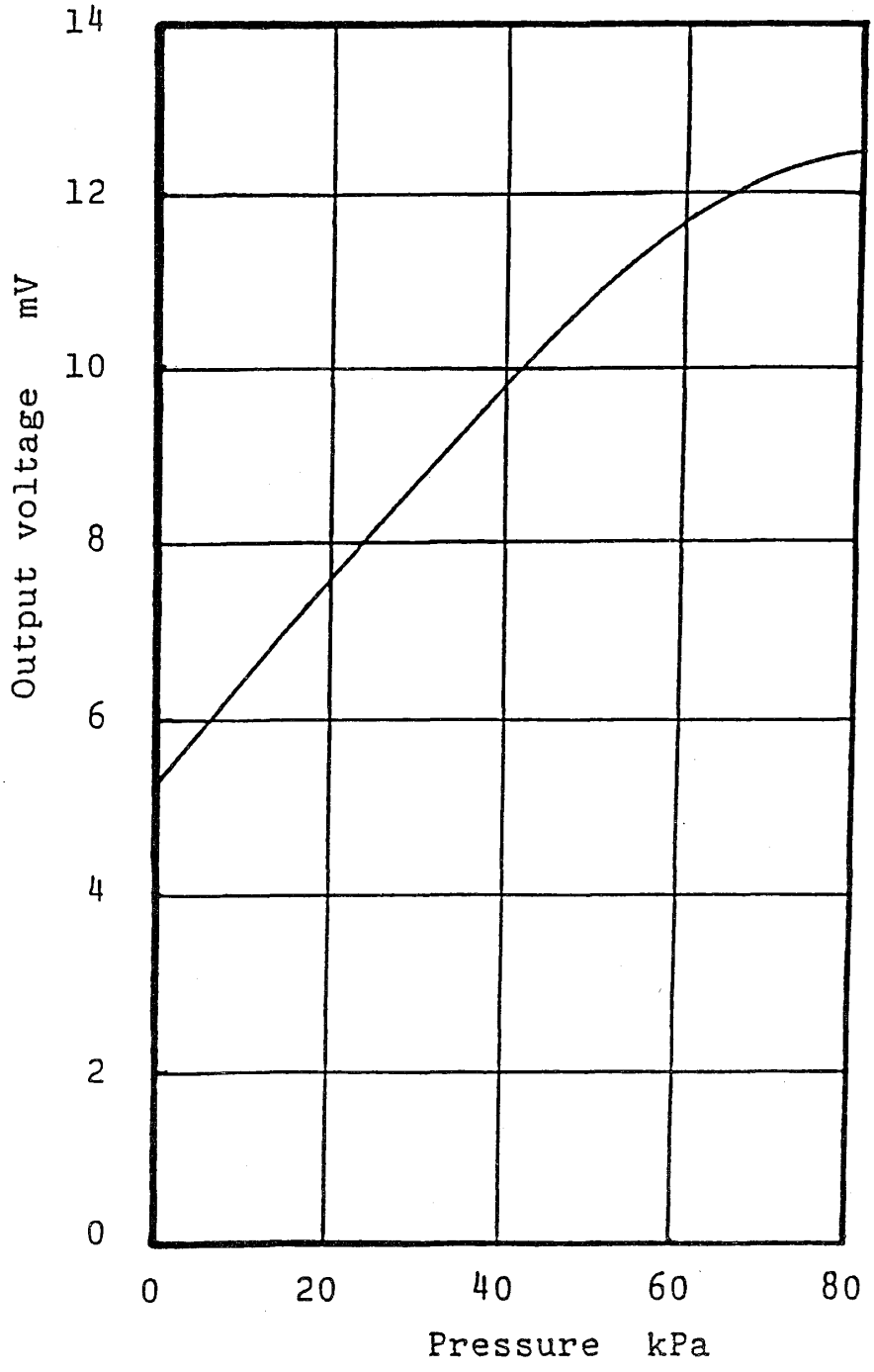

Fig.11. Calibration curve

Reference

1. Viktor K. Pfirrmann, " Method of Determining the Magnetic Field of a Recording Head by Using Tapes of Various Coating Thickness", IEEE Transactions on Magnetics, Vol.Mag-3,No.4, 1967.

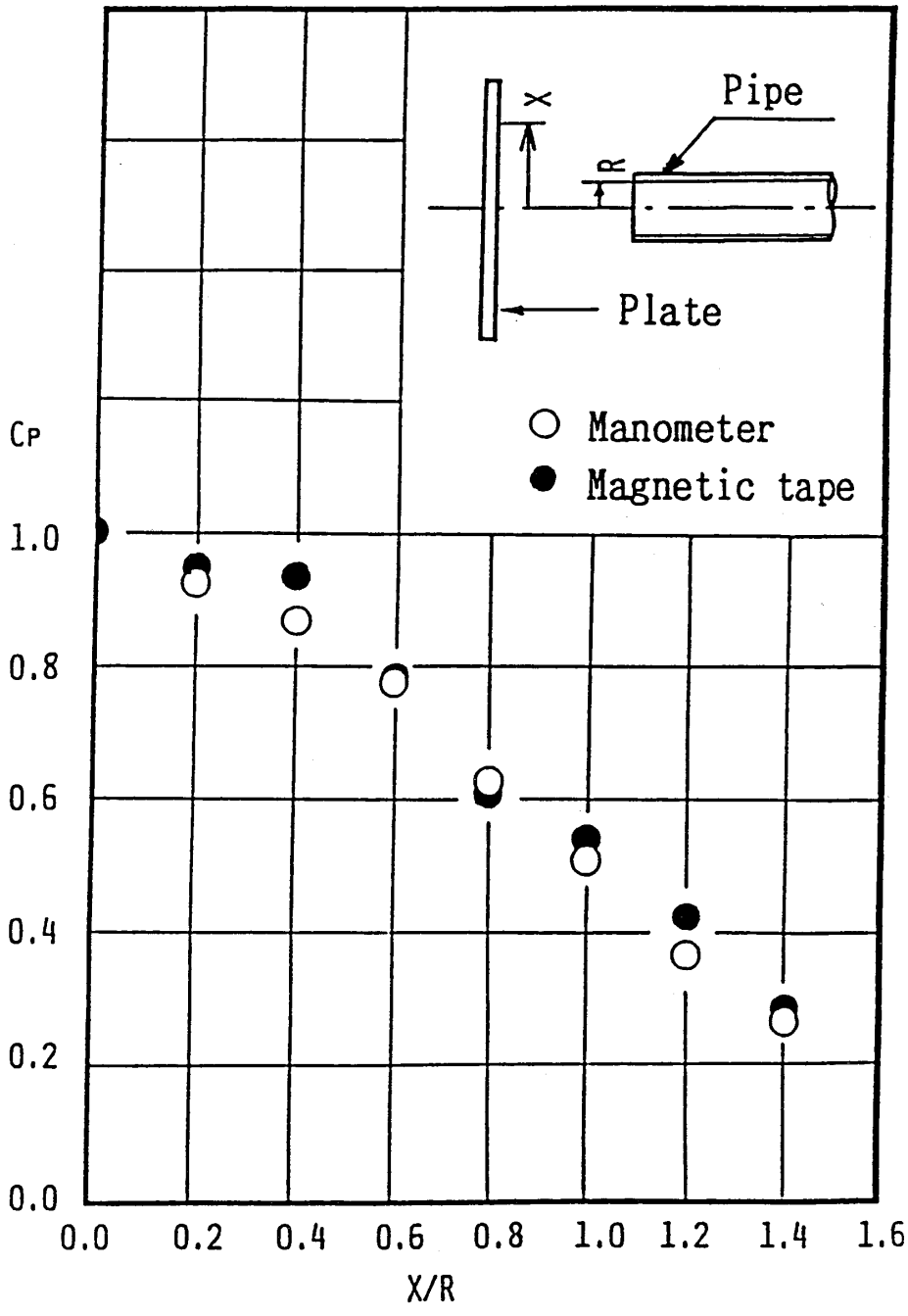

Fig.12. Experimental results