A TANDEM DIAMETER GAUGE FOR USE IN ANTARCTIC ICE HOLE

Renji NARUSE, Kunio SHIMBORI, Eizi AKITAYA
and Yosio SUZUKI

Institute of Low Temperature Science, Hokkaido University,
Kita-19, Nishi-8, Kita-ku, Sapporo 060

Abstract: A diameter gauge which has two diameter calipers 0.53 m apart was developed for the Japanese Antarctic Research Expedition. Each caliper has three contact wheels which are spring-loaded through the supporting rods. The use of two calipers makes a better alignment between the axes of the hole and the gauge. Diameters in the range from 90 to 190 mm can be measured with an accuracy of ±1.5 mm.

1. Introduction

Ice is deformed plastically under a stress. When one attempts to drill a deep hole in ice, the contraction of hole can be so rapid that the drill is in danger of trapping in the hole. Hence, monitoring the diameter profile of the drilling hole is vital during a deep drilling operation. Without an adequate diameter gauge, the 24th Japanese Antarctic Research Expedition (JARE-24) stopped their drilling operation at Mizuho Station, East Antarctica, at the depth of 411 m. A simple diameter gauge was provided by us to the JARE-25, who continued the operation by frequently monitoring the diameter profile with the gauge. When the contraction of hole became dangerous for the normal-size drill at about 630 m, they switched to a thinner-sized one and finally performed to reach 700 m in July 1984. The gauge undoubtedly helped them with success.

Diameter measurements of a drilled hole is also interesting from a glaciological point of view. From two measurements of its diameter profile, a closure rate profile can be obtained. Together with the measurement of temperature profile and the analysis of cores taken from the hole, the dependence of ice strain-rate on temperature and overburden pressure (GOW, 1963; PATERSON, 1977) and on the ice properties such as crystal fabrics, dust contents and so on (THWAITES *et al.*, 1984; GUNDESTRUP and HANSEN, 1984) can be studied. Also, if the hole has a recognizable variance in diameter profile, vertical contraction along the hole can be obtained (PATERSON, 1976).

The above-mentioned diameter gauge was not adequate for such glaciological studies, because of its poor alignment with the hole. In the present paper, we introduce an improved diameter gauge which has a better alignment and also has a device to go through an abrupt decrease of the hole diameter both upward and downward.

2. Description of the Improved Gauge

A schematic illustration of the improved gauge (1.4 m long), which can measure diameters in the range from 90 to 190 mm, is shown in Fig. 1 and its photograph in Fig. 2. As seen from Fig. 1, it has two separate diameter calipers 0.53 m apart, each having three contacting steel wheels (W) which are pressed to the hole by a spring (S). As easily understood from Fig. 1, without some device, the wheels in the upper caliper will be unable to pass over an abrupt narrowing of the hole by an amount larger than the radius of their wheels when the gauge proceeds downward, and those in the lower will be unable when the gauge proceeds upward. Two bars (F) connected to the hanger, and a spring (S′) between the hanger and the gauge axis are the device to overcome this difficulty: Namely, when the upper one is stuck, the bar (F_1) will push, and when the lower one is stuck, the bar (F_2) will pull the respective slider so as to detract the wheels. Normally, the movement of the slider of the lower caliper is not hindered by the bar (F_2) because of the effect of sping (S′).

Now, the radius r of circle circumscribing three wheels is given by

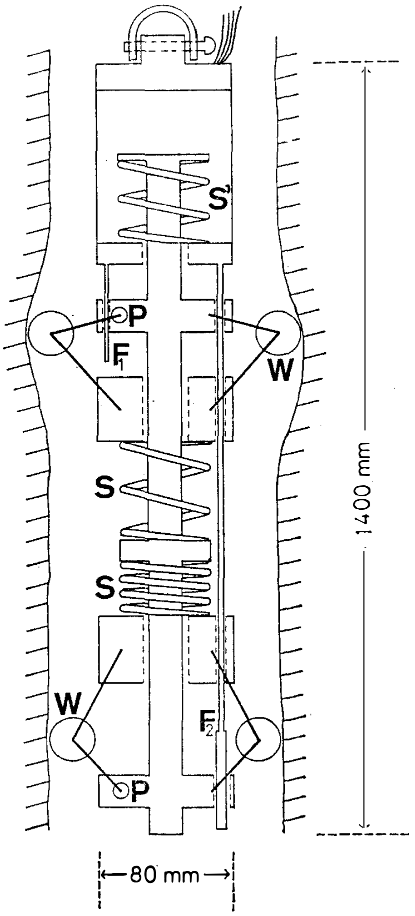

Fig. 1. Schematic illustration of the device. S: Compressive spring, W: Wheel, P: Rotational potentiometer, F: Rod for release.

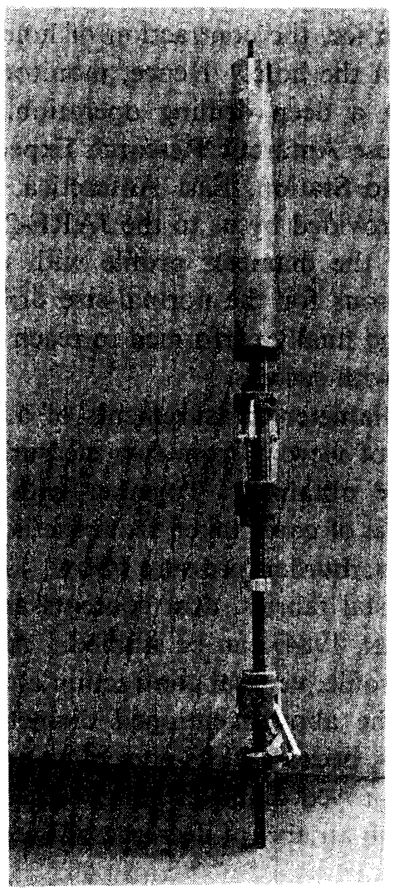

Fig. 2. Photograph of the gauge with two calipers.

$$r=A+L\sin\phi\,,$$

where A is the sum of the wheel radius and the distance of the axle of an arm from the axis of gauge, L the effective length of the arm, and ϕ the angle between the arm and the axis of gauge. Now ϕ is given in degrees by 355 E/E_0, where E is the output and E_0 the input voltage of a potentiometer (P) mounted on an axle of one arm of each caliper, and the constant 355 is a characteristic coefficient of P.

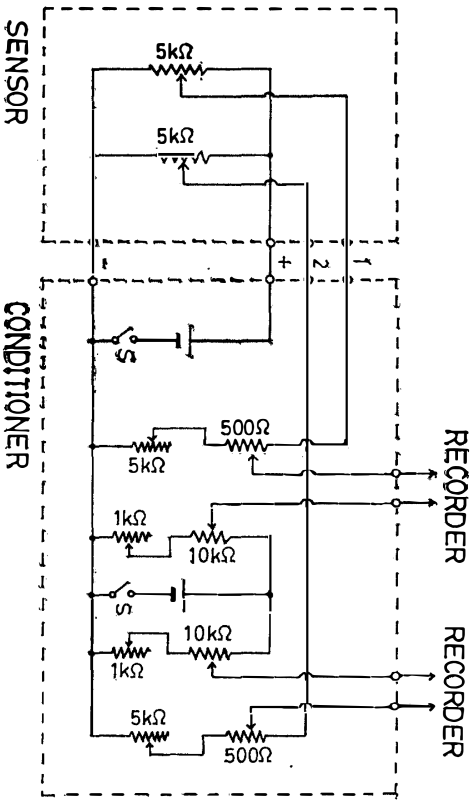

Fig. 3. Schematic diagram of the circuit of measurement system.

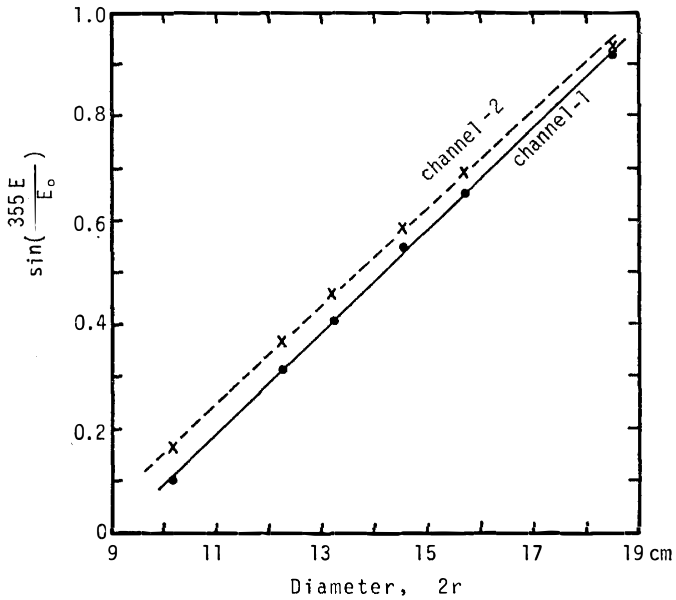

Fig. 4. Result of laboratory tests. E: Output voltage, E_0: Input voltage (constant).

A schematic diagram to supply E_0 and to measure E is shown in Fig. 3, where the conditioner which is placed outside the hole is necessary to compensate the resistance of the four conductors to the gauge (sensor).

Example of the diameter measurements of steel pipes of known diameter is shown in Fig. 4, which shows linear dependence of sin (355 E/E_0) on diameters as expected. Based on the deviation of measured values, the accuracy of the gauge is estimated within $\pm$1.5 mm.

3. Conclusion

Because of the tandem use of two calipers, the gauge has a better alignment with the axis of the hole. Also, as the hole diameter at a depth can be measured twice, accidental error due to loose contact of the wheels or malfunction of the potentiometer should be more prevented.

The gauge will be used by JARE-26 and -27 to measure the change in the diameter profile of the 700-m hole drilled by JARE-24 and -25 at Mizuho Station. The results will contribute to glaciological studies of the Antarctic Ice Sheet as mentioned in the introduction.

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