A Steam-Operated Drill Used by the 14th Japanese Antarctic Research Expedition (1972–1974)

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南極観測隊用スチームドリルの試作

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要旨：第14次南極観測隊（1973～74）において，氷床の10m 深の雪温測定のために使用されたスチームドリル（HODGE型）について，その装置と結果について述べる．

スチームドリルは次の各部分よりなる．プロパンタンク，ボイラー（耐圧10気圧，常用使用圧力3気圧），耐圧ゴムホース（長さ10m）．ゴムホースの先端にガイドパイプ（長さ1.5m）とノズル（直径 2.5 cm，蒸気噴出穴7個）が接続される．

みずほ高原表層の積雪（密度0.4 g/cm³）に対する3回の10 m 深掘削について，平均所要時間は22分であった（気温 −15～−20°C，風速 8～10 m/s）．この時，消費した水の量は 2 kg，掘削された穴の内径は約3 cm であった．掘削後，10 m 深の穴の底の温度が一定値を示すまでに，およそ12時間要した．ボイラーからノズルに至る間に，ホースから逃げる熱の損失は約80%と見積られる．

Abstract: A steam-operated drill similar to that of S. M. HODGE was used to measure 10 m snow temperature at Mizuho Plateau, East Antarctica, in 1973/74. The average drilling time for firn was 22 min (depth 10 m, diameter 3 cm, firn temperature about −20°C).

1. Introduction

A version of the HODGE's steam-operated drill (HODGE, 1971) was used by the 14th Japanese Antarctic Research Expedition (1972–1974) to drill holes (10 m deep, 3 cm in diameter) for measurements of snow temperatures at a 10 m depth during the oversnow traverses over Mizuho Plateau, East Antarctica (NARUSE, 1975). In this paper, the design and the performance of the drill will be described.

2. Instrument

The drill consists of three parts: a boiler, a propane tank with a burner, and a

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steam hose with a guide tube and a nozzle. Similar to HODGE's, the boiler is of a fire tube type, but it is a cylindrical one 20 cm in diameter and 40 cm in length and has twelve fire tubes. It can hold 9 *l* of water, of which 6 *l* can be safely vapourized. It is designed to withstand a pressure of 10×10^5 N m^{-2} (*ca.* 10 atm.) and has a safety valve set to work at 6×10^5 N m^{-2}. Normal operating pressure was 3×10^5 N m^{-2}. The boiler has the overall dimensions of about $60\times30\times50$ cm^3. The net weight (without water and propane) is about 60 kg. A schematic drawing of the boiler is shown in Fig. 1.

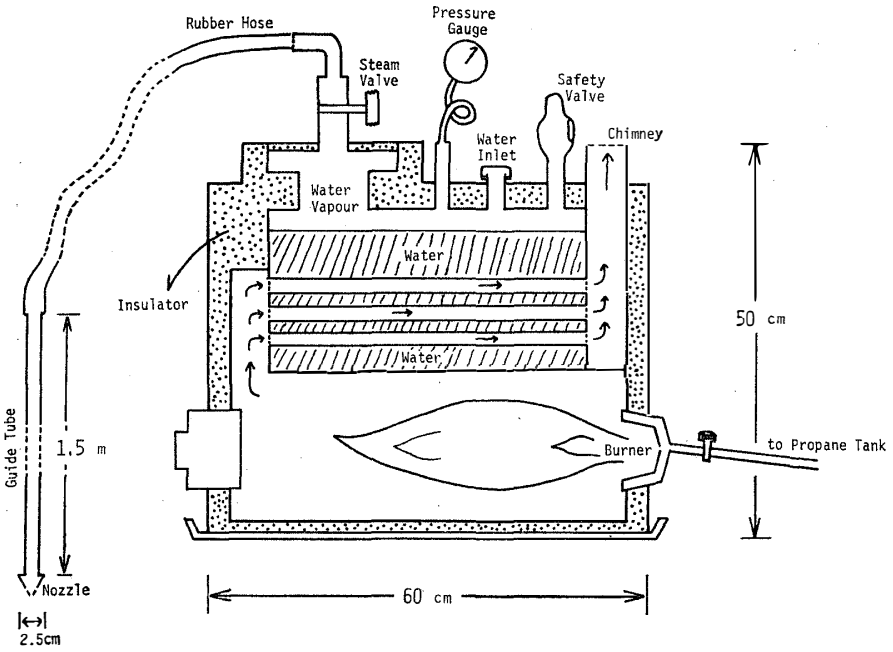

Fig. 1. A schematic drawing of the steam drill. The rubber hose, the burner and the pressure gauge are detached during the transportation on a sledge.

The propane tank can hold 20 kg of propane. A commercial propane burner for smoothing asphalt pavements is modified to fit the boiler and is connected to the tank through a rubber hose.

The steam hose is a pressure-proof rubber one used for a steam cleaner and is 2.5 cm in diameter and 10 m long. A steel guide pipe 1.5 m long with a brass nozzle of 2.5 cm in diameter is connected to the hose. The nozzle has seven holes each 1.5 mm in diameter, one being central and six radiating at an angle of 30° from the central hole.

3. Operation and Performance

The drill was transported on a wooden sledge throughout the traverses. At

drilling sites, the boiler was placed on snow several meters apart from the propane tank. After filling the boiler with warm water (20°C) previously prepared in an oversnow vehicle, the burner was put on. At an ambient temperature of −20°C, it took about 30 minutes for the boiler to attain the operating pressure of 3×10^5 N m^{-2}. A photograph of the drill operation is shown in Fig. 2. The mean diameter of the holes was approximately 3 cm.

An example of the drilling rate into a firn is shown in Fig. 3. The average rate of the three drillings was 10 m/22 min and the amount of consumed water was about 2 kg/10 m.

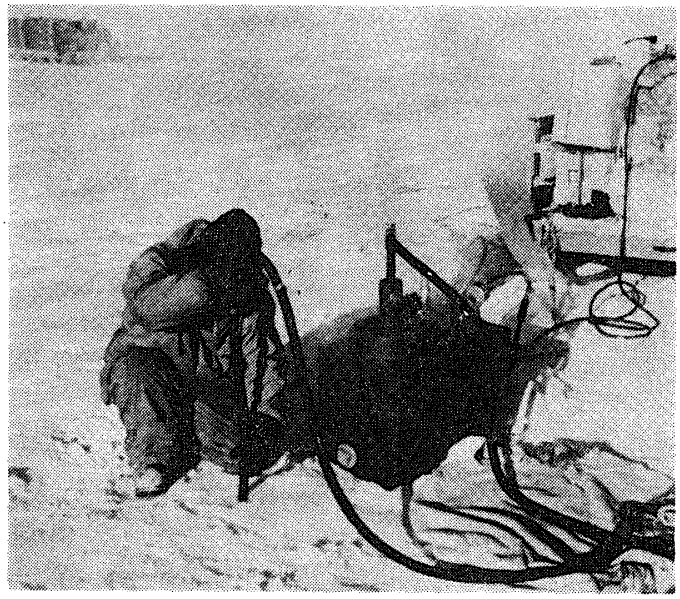

Fig. 2. Drilling with the steam drill on the snow at Mizuho Plateau, East Antarctica. A propane tank is placed on the sledge.

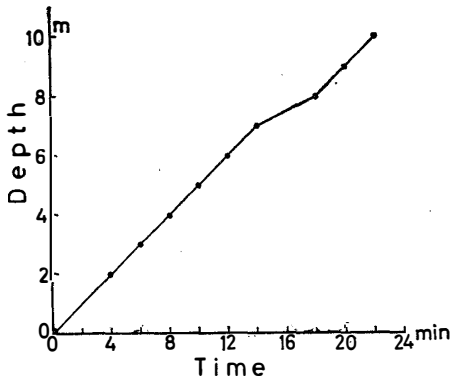

Fig. 3. Drilling rate for the firn at Mizuho Plateau. Station, H101; Elevation, 1309 m; Date, 11 November 1973; Air temperature, −17.5°C; Wind speed, 9 m/s; 10 m snow temperature, −20.1°C.

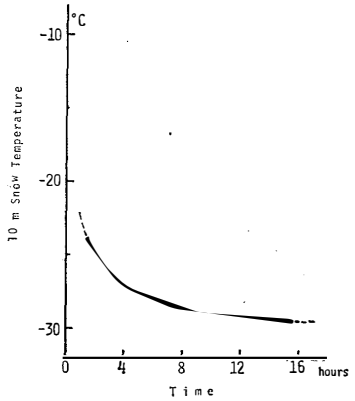

Fig. 4. The 10 m snow temperature versus the time which has elapsed after the end of drilling at Mizuho Plateau. Station, C98; Elevation, 1820 m; Date, 21–22 November 1973.

The snow temperature at the bottom of the 10 m deep hole was measured with a thermistor-thermometer. As shown in Fig. 4, it gradually approached to a value which should be considered the 10 m snow temperature. From the figure, it is evident that to estimate the 10 m snow temperature, one should measure the temperature at the bottom at least 12 hours after boring the hole.

4. Discussion

To make a hole 10 m deep and 3 cm in diameter in a firn of 0.4 g/cm^3, one needs to melt 2.8 kg of ice, or, assuming the average temperature of the firn −20°C one must supply some 250 kcal of heat. Some additional heat is required to warm the surrounding firn. But the amount of the additional heat may not be very large compared with that released by refreezing of melt water in the surrounding firn.

Now, 2 kg of water vapour of 3×10^5 N m^{-2} releases some 1300 kcal when it is transforming into 0°C water. Hence the loss of heat transfer through the hose may be as large as 80%, considerably large compared with the 50% loss for a 8 m hose of the HODGE's drill (HODGE, 1971). By improving the hose, one may expect to attain a drilling rate two or three times as large as the present one.

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