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Development of unmanned magnetometer stations for use in Antarctica

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Abstract: Unmanned magnetometer stations (UMS) have been developed and were installed at remote location near Syowa station, Antarctica (69°S, 40°E) to perform field tests in the harsh Antarctic environment. The UMS was powered by a thermo-electric generator fuelled by kerosene (LTEG) which supplies 87 Watts continuously to the load. The LTEG and instrumentation (fluxgate magnetometer, data logger, chronometer) were installed in a thermally insulated shelter (0.9 m by 1.8 m by 1.9 m). The shelter and an 800 l fuel tank were mounted on a sled, and were towed by snow tractor. The UMS were installed at Kizahasi beach, Skarvsnes (50 km south-west of Syowa) and at H-100 of the Mizuho route (100 km south of Syowa) in the early spring of 1988 and operated until the end of the year. The data obtained will be used for a study of the spatial phase and amplitude structure of the ionospheric current systems and a response of the local induction currents to them.

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Introduction

In the earth's magnetosphere, there appear a variety of electromagnetic phenomena associated with solar wind-magnetosphere interaction processes. In co-operation with magnetospheric observations made by satellite and ionospheric observations by radar backscatter, ground magnetometer networks have been found to be a powerful tool for the study of plasma processes in the earth's magnetosphere. Many such observations have been carried out since the 1970's in northern Canada, Alaska, Scandinavia, Greenland and Iceland. In spite of the strong need for network studies of conjugate relationships between the northern and southern auroral zones, there exists a difficulty in constructing networks in the southern auroral zone because of the harsh Antarctic climate and problems of transportation. Using advanced technology, efforts have been made by the United States in recent years to develop an automatic geophysical observatory (AGO) at Amundsen-Scott Base (Doolittle, 1986).

Japanese Antarctic Research Expedition (JARE) teams have been conducting field testing of a wind-drive generator since 1974 for use at an automatic unmanned observatory. However, a reliable generator system has not yet been established (Ayukawa *et al*, 1986, Ishizawa, 1988).

A new approach to Unmanned Magnetometer Stations (UMS) was planned by the 29th JARE team (1987–1989) using the Liquid-fuelled Thermo-Electric Generator (LTEG) of electricity at the remote station instead of using wind energy. The facility was subjected to field tests in the Antarctic winter of 1988, and finally became available for unmanned magnetic field observatories during August to December of 1988. In this paper, we present a technical description of the UMS and results of four months of operation.

Technical description of UMS

A. Power Generator

A Liquid-fuelled Thermo-Electric Generator (LTEG) developed by the NEC Corporation (Uchida, 1986) has been used to supply electricity to the UMS. The LTEG produces electrical power through the direct conversion of heat energy into electrical energy (Seebeck effect). Kerosene (Jet A-1) is used to maintain the hot junction of the thermocouples at a high temperature whilst the cold junction is maintained by an array of cooling fins which transfer heat away to the surrounding air. The temperature difference between the hot and cold junctions, and therefore the amount of power produced, depends on the rate at which fuel is supplied to the burner. The operation of the LTEG is controlled by adjusting the fuel flow to the burner.

A front view of the LTEG is presented in Fig. 1, in which three main units can be seen: from top to bottom, they are the controller/converter limiter, the combustion chamber, and the blower/fuel pump. The fuel supplied at a rate of 0.4 l/hour by the fuel pump is mixed with air from the blower in a combustion chamber. The power controller monitors the LTEG output and controls the flow of fuel to run at a maximum power output of 120 Watts. The converter limiter provides a constant load (0.4 Ohm) to the power unit,

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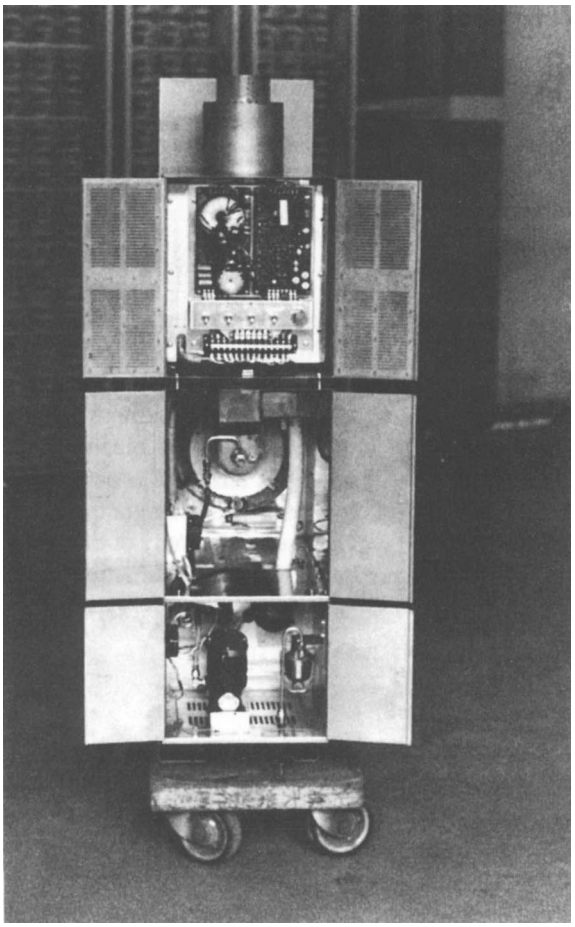


Fig. 1. The LTEG showing the inside of the controller, burner and fuel pump units, with the doors open.

irrespective of load fluctuations caused by the on/off operations of the heater and by the instrumentation. The technical parameters of the LTEG are listed in Table I.

Table I

Output gross power	:	120 W at 6.75 V
Converter output power	:	87 Wat 24 V
Fuel	:	Jet A-1
Fuel consumption	:	0.4 l h^{-1}
Weight	:	100 kg
Dimensions	:	1.3m x 0.3m x 0.77m

B. Field deployment

To facilitate field deployment, the UMS was assembled on a sled (length: 4.2m, width: 1.6m, height: 0.4m) and towed by snow tractor. Fig. 2 shows a schematic illustration of the UMS mounted on the sled. It consists of the shelter ,in which the LTEG and the instrumentation are installed, the fuel tank and air intake buffer (see Fig. 3). Fuel capacity is 800 l giving 80 days of running, without servicing. Air is sucked in by a small fan through an air intake filled with glasswool to prevent snow entering. The exhaust pipe is flexibly connected to the outlet on the roof to prevent the burner from being extinguished during severe wind conditions. The flow of air in the shelter is shown in Fig. 2.

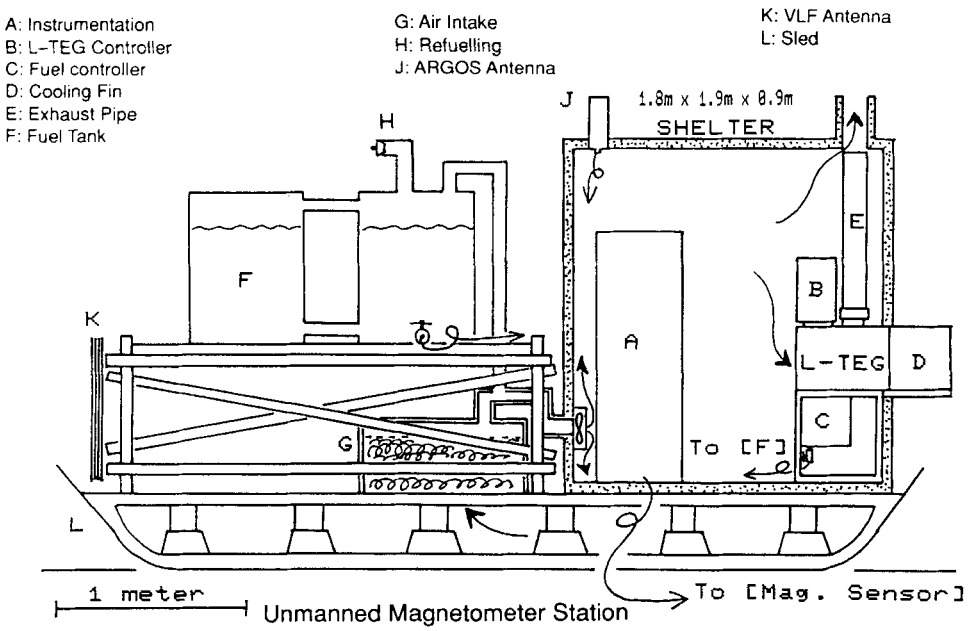


Fig. 2. Schematic illustration of the UMS; the prevailing wind is from the right hand side of the figure.

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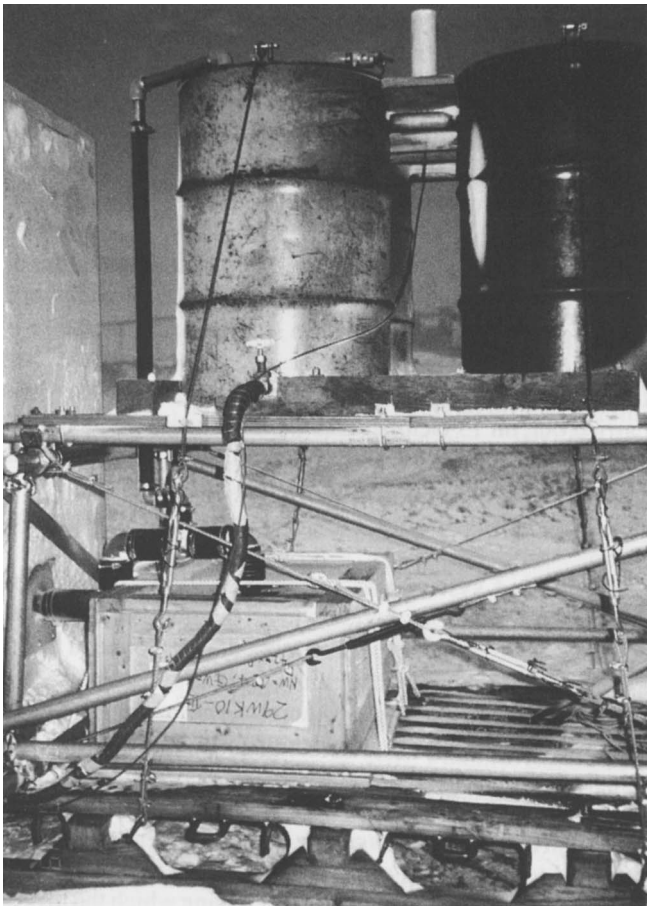


Fig. 3. Photograph showing the air intake buffer and fuel tank assembly mounted on the sled.

The two UMS constructed at the Syowa base were deployed at Kizahasi Beach, Skarvsnes; 50 km south-west of Syowa base (Fig. 4) and at H-100 on the Mizuho Route (100 km south of Syowa Base (Fig. 5). The locations of these sites are shown in Fig. 6.

C. Magnetometer and data logger

The UMS is equipped with a three component fluxgate magnetometer. The data stored in a buffer memory are dumped once every one hour onto magnetic tape. The tape capacity of 16 Mbytes gives 4.5 months of continuous recordings at a sampling interval of three seconds. The clock of the system was automatically kept within 100 msec accuracy by receiving Omega VLF navigation signals transmitted from La Reunion, 6000 km from the UMS site. The data system contains a VLF receiver, chronometer, tape driver, system controller equipped with two HD6303 microprocessors, and power distribution panel. The total power consumption of the data system and fluxgate magnetometer was 16.8 W. These instruments were put in a box of 0.9m by 0.64m by 0.37m, with a 24 W heater to keep the inside temperature above 0°C.



Fig. 4. Photograph of the UMS at Kizahasi Beach.

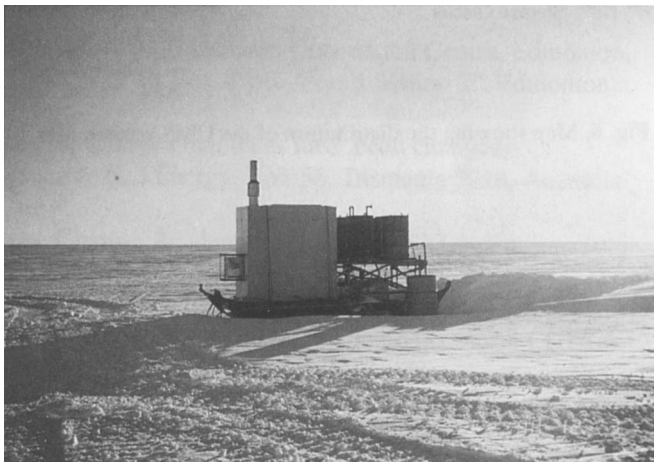


Fig. 5. Photograph of the UMS at H-100.

Field Operation

The construction and preliminary testing of the UMS began in March 1988 at Syowa and continued until the end of July to make improvements on the system configuration. Before starting the network observations, a final check of the UMS system was carried out at site F22, located 10 km from Syowa (see Fig. 6). In that area weather conditions are usually worse (more windy, colder, and more drifting snow) than at Syowa . Wind speed and ambient temperature were measured once very hour and were recorded on the tape recorder of the data system during its operation there from 8 August to 2 September 1988 (Fig. 7). As can be seen from the figure, the UMS was subjected to severe blizzards on 9 and 16 August when the maximum wind speeds recorded were 23 m s^{-1} and 30 m s^{-1} respectively. The UMS ran without trouble during these severe weather conditions. One UMS was then installed at Kizahasi beach, Skarvsnes on 8 September and the other was set up at H-100 of Mizuho

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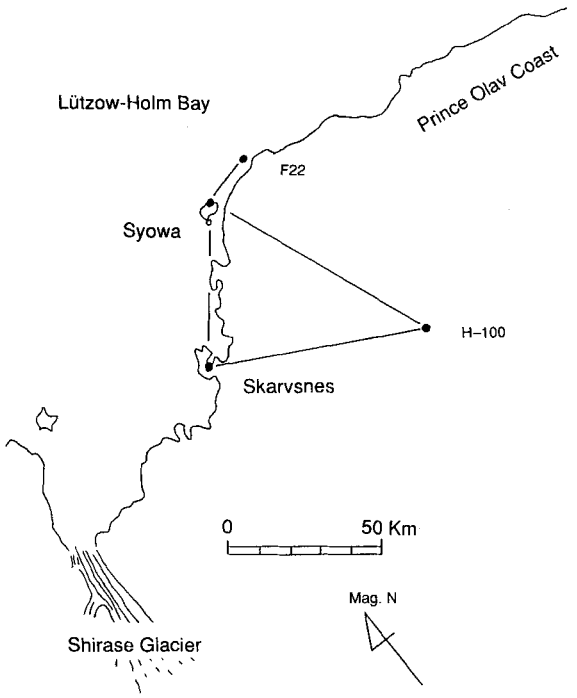


Fig. 6. Map showing the distribution of the UMS remote sites.

route on 4 October 1988.

Fig. 8 shows the ambient temperature and instrumentation temperature inside the box recorded at Kizahasi beach from 8 September to 18 December 1988. At the top of the figure, the H component of the magnetic variation is shown for reference. The baseline shift on 15 October was artificial. The ambient temperature shows a large diurnal variation, of ca 30° C probably due to heating of the temperature sensor by sunshine during the daytime. The lowest temperature of -27°C was recorded during the night of 18 September . Although the diurnal fluctuation of the box temperature is much smaller than that of the ambient temperature, the long term variation is similar to it. At this site, refuelling was carried out, on 15 October and the UMS was operated until the fuel ran out on 18 December. Further refuelling was impossible because of loss of sea ice. The UMS at this site ran continuously for more than hundred days without any trouble.

The second system was installed at the H-100 site on 4 October. On 31 October, however, the observations were interrupted as the generator stopped. We found a short circuit in the tape controller unit of the data system which we suspected overloaded the generator, because the power controller of the LTEG was designed to interrupt the fuel supply to protect the thermocouples against thermal damage in case of overloading. The LTEG was re-started on December 4, though the logger was not repaired, and has run until it was returned to the Syowa on 31 December . In Fig. 9, the one month of data available from H-100, during which the logger operated are plotted together with those from Kizahasi Beach for comparison. The lowest temperature recorded at

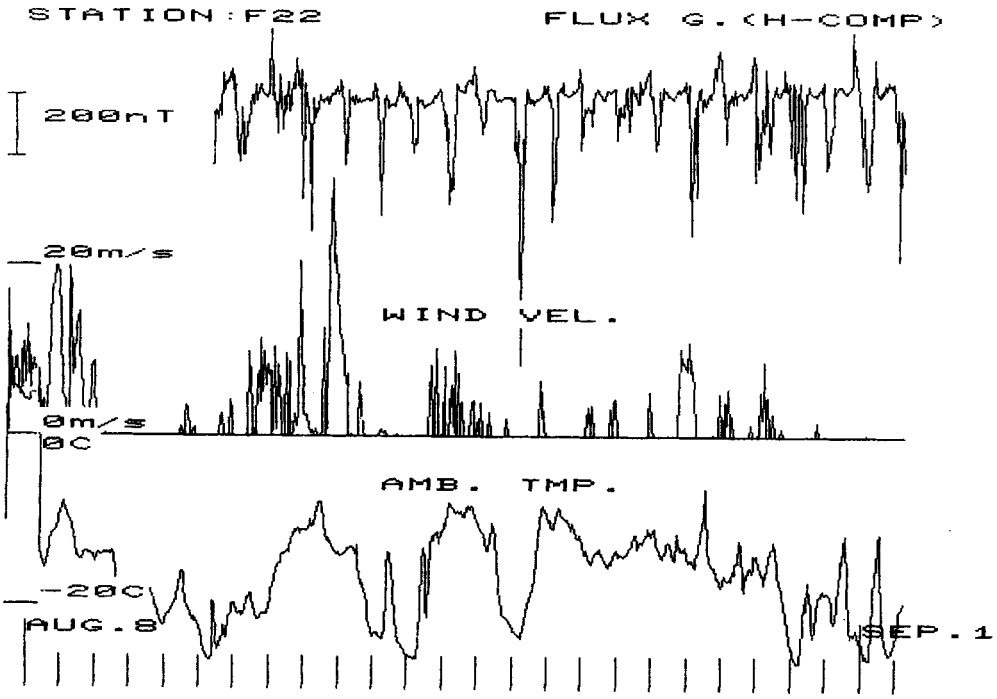


Fig. 7. Housekeeping (HK) data at F22. Wind velocity and ambient temperature are sampled once every hour and recorded onto magnetic tape.

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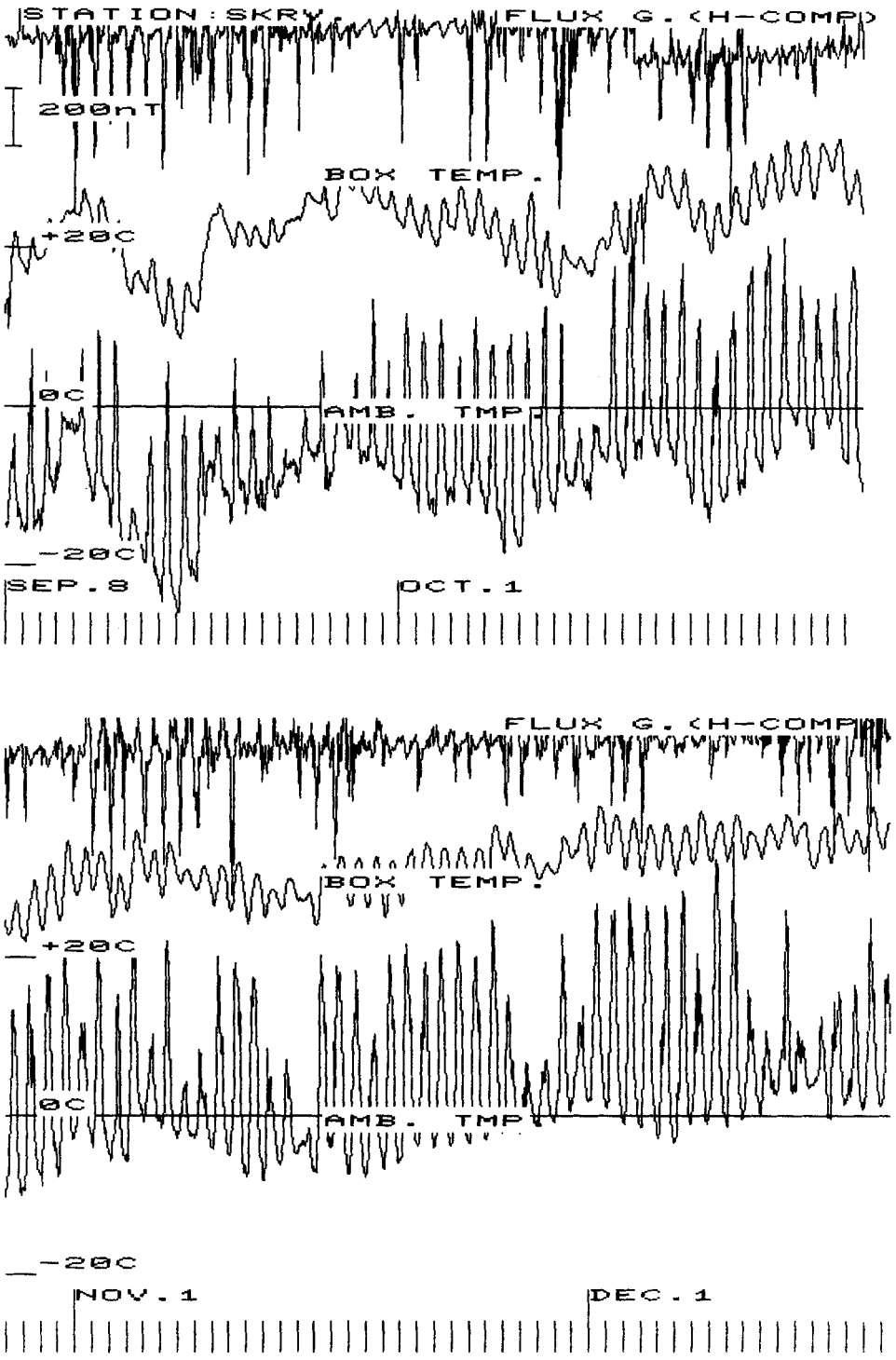


Fig. 8. The HK data during the whole period of operation at Kizahasi Beach, Skarvsnes; the data sampling interval is one hour.

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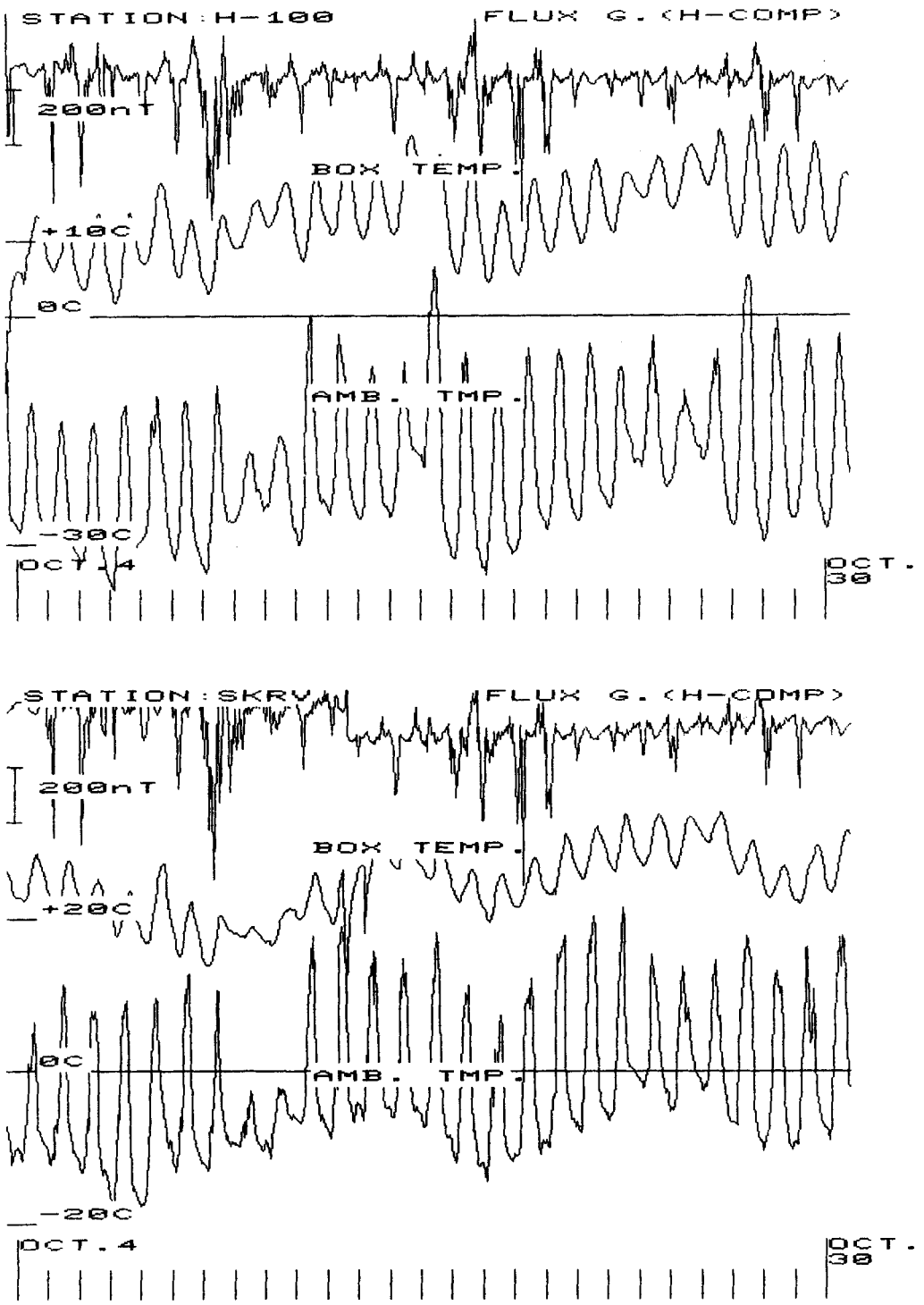


Fig. 9. Comparison of the HK data of H-100, Mizuho route, and those at Kizahasi beach, Skarvsnes.

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H-100 was -35°C on 7 October, about 15°C lower than at Kizahasi Beach.

Itappears from these field tests that the UMS has a capability for year-round operation, without servicing, in the coastal areas of Antarctica if sufficient fuel is supplied. Because the power capacity is large (90 W), the UMS could be suitable for use jointly by several research groups.

In the case of deployment of the UMS to an inland area of the continent, where the lowest temperature could be expected to be below - 50°C, heating of the generator and fuel going in to the combustion chamber must be considered. The large amount of heat from the combustion chamber that is presently wasted could be utilized by a heat exchanger system. Such a system might be expected to have the capability of running down to the freezing temperature of kerosene (-60°C). The area accessible to the new UMS model might extend up to 1000 km from the Syowa, and provide a great deal of knowledge for Antarctic sciences.

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