Journal of Glaciology, Vol. 31, No. 109, 1985

INSTRUMENTS AND METHODS

ICE-CORE DRILLING AT 5700 m POWERED BY A SOLAR VOLTAIC ARRAY

By BRUCE R. KOCI

(Polar Ice Coring Office, University of Nebraska–Lincoln, Lincoln, Nebraska 68588-0200, U.S.A.)

ABSTRACT. During the summer of 1983 a 2 kW array of solar voltaic panels was used to power a drill which collected two cores of 154 m and 163 m length to bedrock on the Quelccaya ice cap in Peru. The operation and performance of this array are discussed, considering the need for future requirements in remote pristine areas of the world.

RÉSUMÉ. *Utilisation de panneaux solaires pour carotter à 5700 m d'altitude.* Au cours de l'été 1983 un panneau solaire de 2 kW constitué de cellules photovoltaïque a été utilisé comme source d'énergie pour effectuer deux carottages (154 et 163 m) atteignant le lit de la calotte de Quelccaya (Pérou). L'utilisation et les performances de ce dispositif sont examinées compte tenu des besoins futurs dans les régions vierges et lointaines.

ZUSAMMENFASSUNG. *Eiskernbohrung in 5700 m Höhe mit Hilfe von Solar-Zellen.* Im Sommer 1983 wurde ein 2 kW-System von Solar-Zellen zum Antrieb eines Bohrers benutzt, der zwei Kerne von 154 m und 163 m Länge bis zum Untergrund der Quelccaya-Eiskappe in Perú lieferte. Die Wirkungsweise und Leistung dieses Systems werden unter dem Aspekt des zukünftigen Gerätebedarfs in abgelegenen Gebieten der Erde diskutiert.

INTRODUCTION

Recent interest in coring high-altitude, low-latitude glaciers for climate records has created a demand for an electrical power source that can be transported in packages weighing less than 20 kg while providing a high degree of reliability. In addition, the desire to leave study areas in a pristine condition rules out the use of fossil fuels as a power source. Since wind velocities on these glaciers rarely reach a reasonable level for wind-power generation, solar voltaics have been investigated as a prime energy source. Experience on the Quelccaya ice cap, Peru, has shown that a 2 kW array of 48 solar panels can be transported by horse and Man to remote areas, and with 100% reliability used to power a core-drilling rig for the duration of a field season.

BACKGROUND

The Polar Ice Coring Office (PICO) began experimenting with solar voltaics in 1980, first with one panel, then with a 250 W array used for powering PICO's lightweight hand-coring auger to depths of 40 m. Information gathered from core drilling in Greenland and Antarctica suggested the combination of high altitude, cold, and the reflectivity of a fresh snow surface combined to give a power output per panel approximately 25% above the normal sea-level rating. In addition, the ability of tempered glass panels to survive the rigors of transportation under abnormal conditions was demonstrated. Bags were designed to hold three panels while providing protection for the panels and whatever was carrying them. 2.5 cm of foam padding was provided on all sides with additional 2.5 cm pads between panels. Plywood was used between the padding and panel frames to prevent small objects from penetrating the glass. This design proved effective since none of the panels was broken in transit.

In 1979, an ice-core-drilling project on the Quelccaya ce cap, at 5700 m elevation, was abandoned because it was impossible to break the 5 kW generator into small enough pieces to be transported by horse and Man 50 km to the summit. In addition, the weight of fuel needed for the generator was nearly 400 kg. These factors coupled with the problem of site contamination led us to consider the use of solar voltaics. It was determined that a 300 kg array could provide enough power to run the complete drill system while allowing the drilling of multiple holes if time permitted.

During the summer of 1983, PICO was again contracted to collect ice cores from the Quelccaya ice cap in support of a glaciological/climatological research project by Dr L. Thompson, Ohio State University Institute of Polar Studies (OSU–IPS). An electromechanical drill was used to core through the firn to a depth of 35 m, starting two holes. Thereafter, a thermal drill was used to collect core to bedrock reached at depths of 163 m and 154 m in the two holes (Thompson and others, 1985).

ARRAY DESCRIPTION

A modular array was chosen since each tripod of panels linked to the system as a unit made trouble-shooting easy while making it possible to disconnect any module that was non-workable.

Six Solarex HE 60 panels were attached to each of eight tripods (Fig. 1), each giving approximately 120 V open circuit and 2 A when shorted. Two arrays of 24 panels were then brought to a central switching panel where power could be switched from 120 V, 16 A to 240 V, 8 A. This was necessary since the thermal drill required approximately 200 V while the winch motor required approximately 100 V. This set-up proved to be effective, although connecting the panels in parallel before making the series connection would have been more effective in eliminating any mismatch effects. Each panel was protected with a by-pass diode.

SYSTEM COST

The cost of solar voltaics has been decreasing since the beginning of this project. New methods of assembly and increasing acceptance of this technology are responsible for this decrease. In 1978 we paid approximately $20/W which has since been reduced to $8/W. Further decreases, perhaps dramatic, can be anticipated if new processes work out.

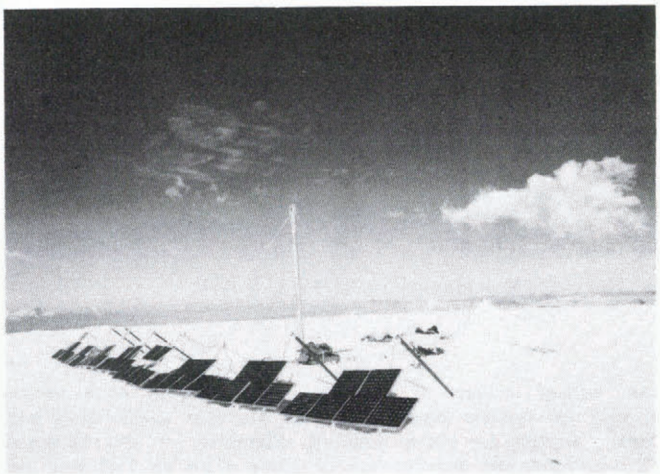

Fig. 1. Solar panels and drill at the summit of Quelccaya ice cap, Peru.

OPERATING CHARACTERISTICS

During the summer of 1983, on the Quelccaya ice cap, the net incoming radiation varied from 6 to 10% less than levels experienced in preceding seasons. This resulted in slightly degraded panel performance but still above the sea-level rating. A 37 W panel produced 38.4 W with net incoming radiation of 940 W/m^2, of which 830 W/m^2 were direct beam and 110 W/m^2 were diffuse. Reflected radiation was 760 W/m^2.

Performance of a panel was measured with changing angle from the horizontal. A 45° inclination produced maximum current, while the inclination had to change ±20° to cause a 5% power change. Rotating the panel horizontally showed similar insensitivities to inclination from the Sun.

As a result of these tests, a decision was made not to attempt adjustment of the panels during the 5–5½ h drilling day. Late-afternoon drilling was accomplished with a 20–30% power reduction which did not slow progress enough to justify relocating the panels. Incoming radiation was reduced at this time of day as clouds began building up around the ice cap.

Drilling generally proceeded most days despite periods of clouds. Reduced power output (50% reduction) during cloudy periods was offset by periods of 150% normal power just before or just after the Sun was covered by clouds. We tried to adjust the drilling so the drill was up-hole when cloudiness was maximum.

Performance of the array was somewhat less than expected because the panels used were not a matched set. The panels varied in output between 30 and 41 W. As a result, internal losses in the array were 300 to 400 W. Each panel acts as a generator or resistance circuit. Any panel that is at the low end of the power output will dissipate some heat until all the power curves match. Each set of panels should have matched power curves to avoid this inefficiency and should be ordered as a matched set. An extreme example of this would be placing a panel in shade that is in the power circuit. Heat build-up in the panel would be sufficient to destroy this unprotected panel. This mismatch was a result of last-minute efforts on our part to put together a system to demonstrate the capabilities of soiar voltaics in remote areas.

CONCLUSION

During the summer of 1983, the use of solar voltaics to generate power for a drilling project at 5700 m on the Quelccaya ice cap in Peru demonstrated their ability to provide adequate power in a reliable manner for remote areas. Future arrays will use a Kevlar–Nomex honeycomb or aluminum frame, and plastic rather than glass for the panel front. Weight for a 40 W panel will thus be reduced from 5.5 to 1.4 kg. Recent tests have proved the reliability and performance of this type of panel.

The two holes were drilled to bedrock with no equipment failures and no maintenance problems. The solar panels have proved that it is possible to transport a power source in primitive ways to remote regions while expecting a high degree of reliability.

ACKNOWLEDGEMENTS

The author wishes to thank Solarex Corporation for their interest in this program and Mr K. Mountain for collection of data on solar panel performance. Funding was provided by the National Science Foundation Division of Polar Programs to the Polar Ice Coring Office at the University of Nebraska–Lincoln under contract DPP74-08414. The drilling was done in support of a research grant by Dr L. Thompson, Ohio State University Institute of Polar Studies, funded by the NSF Division of Climate Dynamics.

REFERENCE

Thompson, L.G., *and others*. 1985. A 1500-year record of tropical precipitation in ice cores from the Quelccaya ice cap, Peru, by L.G. Thompson, E. Mosley-Thompson, J.F. Bolzan, and B.R. Koci. *Science*, Vol. 229, No. 4717, p. 971-73.

MS. received 9 September 1985 and in revised form 21 October 1985