# INSTRUMENTS AND METHODS

## A PROTOTYPE HOTPOINT FOR THERMAL BORING ON THE ATHABASKA GLACIER

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THE hotpoint described in this paper was designed for a geophysical expedition to the Athabaska Glacier which is situated in the Canadian Rockies, lat. 52° 15′ N., long. 117° 15′ W. (approximately). The project was organized by the Universities of British Columbia and Alberta and financed by the National Research Council of Canada. The expedition, which was the first of several seasons' work on the glacier, took place in the summer of 1959.

Thermal boring was one of the projects carried out and this, together with seismic, gravity and surface movement studies, formed part of a programme of research on the mechanics of ice flow.

Power for drilling was provided by a two-stroke petrol driven motor-generator rated at 230 volts, 3,000 watts; its total weight was 140 lb. (64 kg.). This was manufactured by the American "Homelite" Company. The electrical output was made variable from 0-230 volts by the inclusion of a rheostat in the field circuit of the generator. The drill holes were cased with aluminium pipe with a nominal bore of $1\frac{3}{8}$ in. (3·48 cm.). The inclinometer used was a single shot type supplied by the Parsons Survey Company of San Francisco.

### DESCRIPTION OF HOTPOINT

The hotpoint design was developed from that of R. L. Shreve, general information and drawings having been supplied by Professor R. P. Sharp (of the California Institute of Technology). Instead of winding an element from resistance wire, it was decided to use a "Calrod" heater manufactured by the Canadian General Electric Company. The one selected was an electric cooker type No. HX15D2B which is rated at 230 volts, 1,500 watts. It employs a stainless alloy steel sheath 0·3 in. (0·76 cm.) in diameter and has an overall length of 48 in. (1·22 m.). Owing to lack of time for development only three hotpoints were taken to the glacier, each of slightly different design. On all three models the heater was cut to a suitable length, wound into a helix and cast into copper. This process had not been used by previous designers since it is only recently that it has been made possible to cast copper satisfactorily. The heater is designed for running with a maximum sheath temperature of 1,500° F. (816° C.). Under these conditions the power dissipation is 36 watts per inch length of heater (14·2 watts per cm.). Calculations for the hotpoint showed that the normal operating temperature should be well below 1,500° F. Thus the power dissipation was increased to above 36 watts per inch (14·2 watts per cm.). It was not known what safety margin was necessary so two 19 ohm heaters were cut from a standard heater length, while the third was cut to 16 ohms resistance. Each was cast into a copper cylinder and machined to the profile shown in Figure 1.

Stainless steel tubing formed the hotpoint envelope and was silver-soldered at its ends to the copper casting and the brass upper section. Heat flow through the side walls was prevented by "Sil-o-cel" (a diatomaceous earth material) and rock wool insulation. A glass-to-metal seal, silver-soldered in the brass section, carried one electrical connection to the heater, while the metal sheath formed the other side of the circuit. Insulation of the input terminal was achieved by filling the surrounding volume with Araldite—a synthetic resin which has a steel hard surface and excellent bonding properties. A weak joint was provided in the electric cable to allow it to be withdrawn from the hole after drilling. This was simply a



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short length of 18 A.W.G. stranded wire soldered to the 10 A.W.G. input lead of the hotpoint. Above this was connected an extensible helix made from 10 A.W.G. insulated copper wire. This was recommended by R. L. Shreve to protect the weak joint in the event of an accidental jerk on the cable.

Time did not permit extensive laboratory tests to be made. However, it was interesting to measure the temperature at the top of the copper castings when the completed hotpoints were immersed in nearly boiling water. For the 19 ohm type dissipating 2,600 watts (100 watts per inch of heater—39 watts per cm.) the temperature was 700° F. (371° C.). For the 16 ohm model dissipating 3,300 watts (150 watts per inch of heater—59 watts per cm.) the temperature was 900° F. (482° C.).

## Performance in the Field

In the field, when drilling in dense ice, the following results were obtained. The 16 ohm model burned out on an obstruction in a hole 60 ft. (18·3 m.) below the surface. It had then been dissipating 2,400 watts (110 watts per inch of heater—43 watts per cm.). Subsequent examination showed that the whole of the heater had become overheated under these conditions.

One 19 ohm heater failed at the lower termination of the filament. This was not unexpected since a previous test had shown this to be the weakest point in the heater. The other 19 ohm hotpoint drilled two holes, the second hole reaching the bottom of the glacier 1,024 feet (312 m.) below the surface. With a power input of 1,800 watts it proved sturdy enough to run on the bottom for several hours without sustaining damage. Figures for its performance are provided in Table I. The values for the maximum sustained drilling rate are the maximum depths drilled in one hour. The figures indicate a penetration efficiency of about 87 per cent for this model. One hundred per cent penetration efficiency is defined by W. H. Ward* as the rate of penetration obtained when all the electric power goes into melting an ice cylinder of a diameter equal to that of the hotpoint.

Table I. Performance Figures for the 19 ohm Hotpoint

| *Depth of hole* | | *Overall drilling time* | *Overall drilling rate* | | *Maximum sustained rate* | | *Power input at hotpoint* | *Power input per unit length of heater* | | *Penetration efficiency* |
|---|---|---|---|---|---|---|---|---|---|---|
| ft. | m. | hours | ft./hr. | m./hr. | ft./hr. | m./hr. | watts | watts/in. | watts/cm. | % |
| 650 | 198 | 22 | 30 | 9·2 | 38 | 11·6 | 2300 | 88·5 | 35 | 86 |
| 1024 | 312 | 48 | 21 | 6·4 | 30 | 9·2 | 1800 | 69 | 27 | 88 |

Two other hotpoints were used during the summer. They were hurriedly assembled to a somewhat different design while the expedition was in the field. In one of these a silver-soldered envelope joint leaked water, which cast doubt on the strength of this type of joint. On dismantling the original 16 ohm model the strength of its envelope nose joint was also found to be noticeably poor.

During the summer five holes were drilled to depths of 60, 250, 650, 750 and 1,024 feet (18·3, 76, 198, 228 and 313 m. respectively). An inclinometer survey was attempted on the deepest hole but difficulty was experienced in lowering the inclinometer below 450 feet (137 m.). This was due to the small clearance between the instrument and the walls of the pipe, only 1/16 in. (0·158 cm.) all round.

## Conclusions

In order for this hotpoint to be made completely reliable three conditions must be met. These are:

* Unpublished report by W. H. Ward. *Pipeline operation on Odinsbre Icefall*, Cambridge Austerdalsbreen Expedition, 1956.

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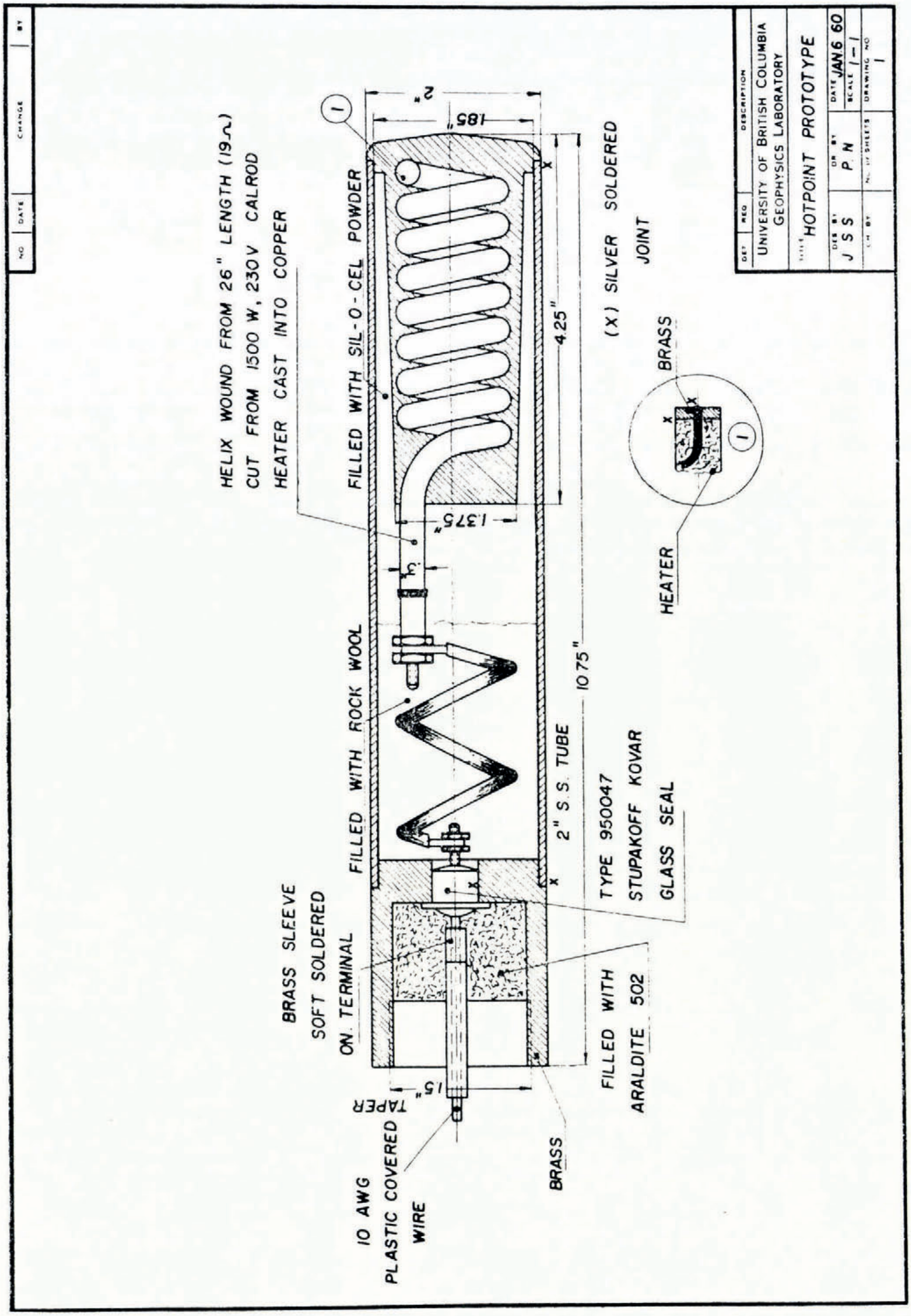


Fig. 1. Hotpoint prototype

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(a) The lower termination of the heater filament must be improved. The manufacturers recommend using a stainless steel plug welded to the sheath and the inner conductor instead of the silver-soldered brass plug shown in Figure 1.

(b) The envelope joints require improvement.

(c) The power input to the hotpoint must be kept down to about 1,800 watts to prevent overheating when an obstruction is encountered. If a thermostat were incorporated in the design this figure could well be increased.

In future models it is proposed to use a centre section of brass instead of stainless steel tube. This will increase the reliability of the silver-soldered joints. The increased heat flow from the sides is not estimated to be serious.

Owing to the trouble experienced in lowering the inclinometer it is proposed to increase the nominal bore of the pipe to $1\frac{5}{8}$ in. (4·1 cm.). This has an outside diameter of 1·9 in. (4·8 cm.) and will require a $2\frac{1}{4}$ in. (5·7 cm.) diameter hotpoint. Much improvement in design can be gained by this increase in diameter. A wider and therefore shorter helix can be made from the heater, which means a lower temperature rise for the same power dissipation. With the larger diameter a drilling rate of 30 ft./hr. (9·2 m./hr.) would be maintained by an input of about 2,250 watts. In spite of the lower temperature rise in the copper the dissipation of 87 watts/in. (35 watts/cm.) might prove excessive under extreme conditions. This figure could be reduced by using an 18 ohm heater made from the longer but more rugged 2,000 watt Calrod type No. HX2D2B. Sixteen hotpoints employing both types of heater are to be built for the 1960 programme. This number will enable extensive laboratory tests to be carried out before embarking on the field work.

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