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# THE GRIP DEEP DRILLING CAMP

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***Abstract:*** In order to support the GRIP deep drilling, a permanent camp was erected on top of the Greenland ice sheet at an elevation of more than 3 km, 800 km away from the nearest airport. Day temperatures reached a maximum of −10°C, with typical night temperatures of −30°C. Although the camp was manned only during the three summer months, it was designed to sustain winter temperatures of −60°C. The camp was designed to accommodate 30 people (although the number of inhabitants at times was up to 50), and to include everything needed for the operation, including a 3 km long skiway. The designed lifetime of the camp was 3 years, corresponding to 4 field seasons.

## 1. Introduction

Though the annual snow accumulation at the site (23 cm of ice corresponding to 70 cm of snow) was moderate in general, the snow could pile up in drifts much deeper than that. The only way to avoid snow drifts was simply to place nothing on the surface. This was attempted for the first time on a large scale in 1929 when Commander Byrd build camp "Little America" in Antarctica (BYRD, 1930). All the buildings in this camp were placed under the surface. Access was through interconnecting tunnels. Only the radio antennas indicated the position of the camp. Later, the same principle was used successfully at "Camp Century" in northern Greenland (CLARK, 1965), Byrd Station in Antarctica, the Dye-3 deep drilling (TILLSON and KUIVINEN, 1982) and at several other sites.

The designers of the GRIP camp were faced with other problems, however, such as lack of vehicles for heavy excavation work, and limitations in terms of time and money. Also, if heated dormitories were placed underground, there was a risk of carbon monoxide poisoning. It was decided, therefore, to place all sleeping quarters, as well as generator and kitchen, above the surface and to locate all drilling and scientific activities under- ground.

## 2. General Camp Layout

The camp (Fig. 1) includes 3 permanent dome shaped buildings, temporary buildings, storage areas and trenches. It is constructed to minimize problems with snow build up. The predominant wind direction was known from unmanned US weather stations which had been operating in the area for some years (STEARNS and WEIDNER, 1991). They indicated that the main wind direction was 240° true, and the skiway was therefore given this orientation. The cargo line was placed perpendicular to the skiway, along the road connecting the camp and the skiway. All buildings were also placed in a line perpendicular to the main wind direction. The road between the main camp and the skiway could not pass over the science trench, so that was placed perpendicular to the road.

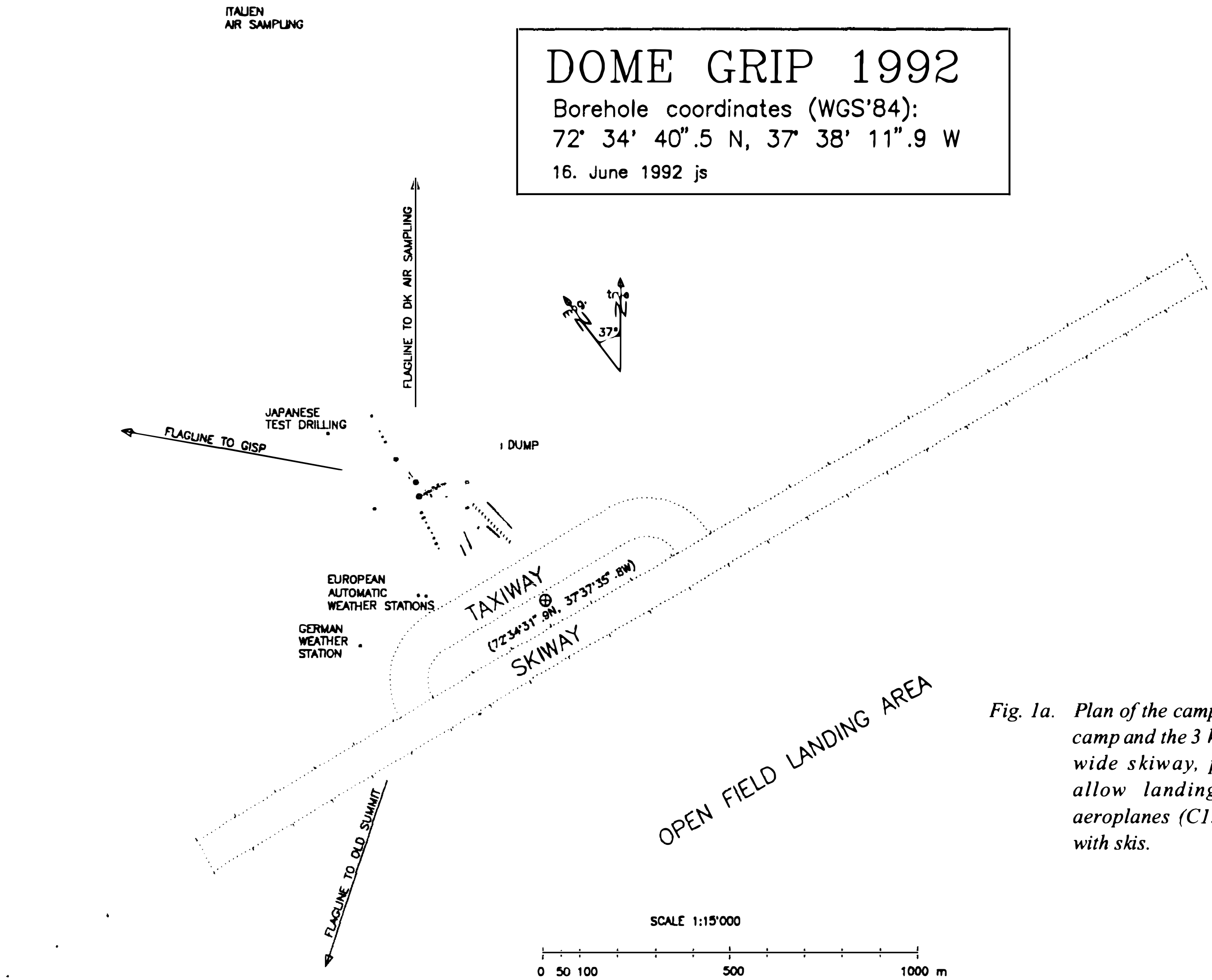


*Fig. 1a.* *Plan of the camp showing the camp and the 3 km long, 60 m wide skiway, prepared to allow landing of heavy aeroplanes (C130 Hercules) with skis.*

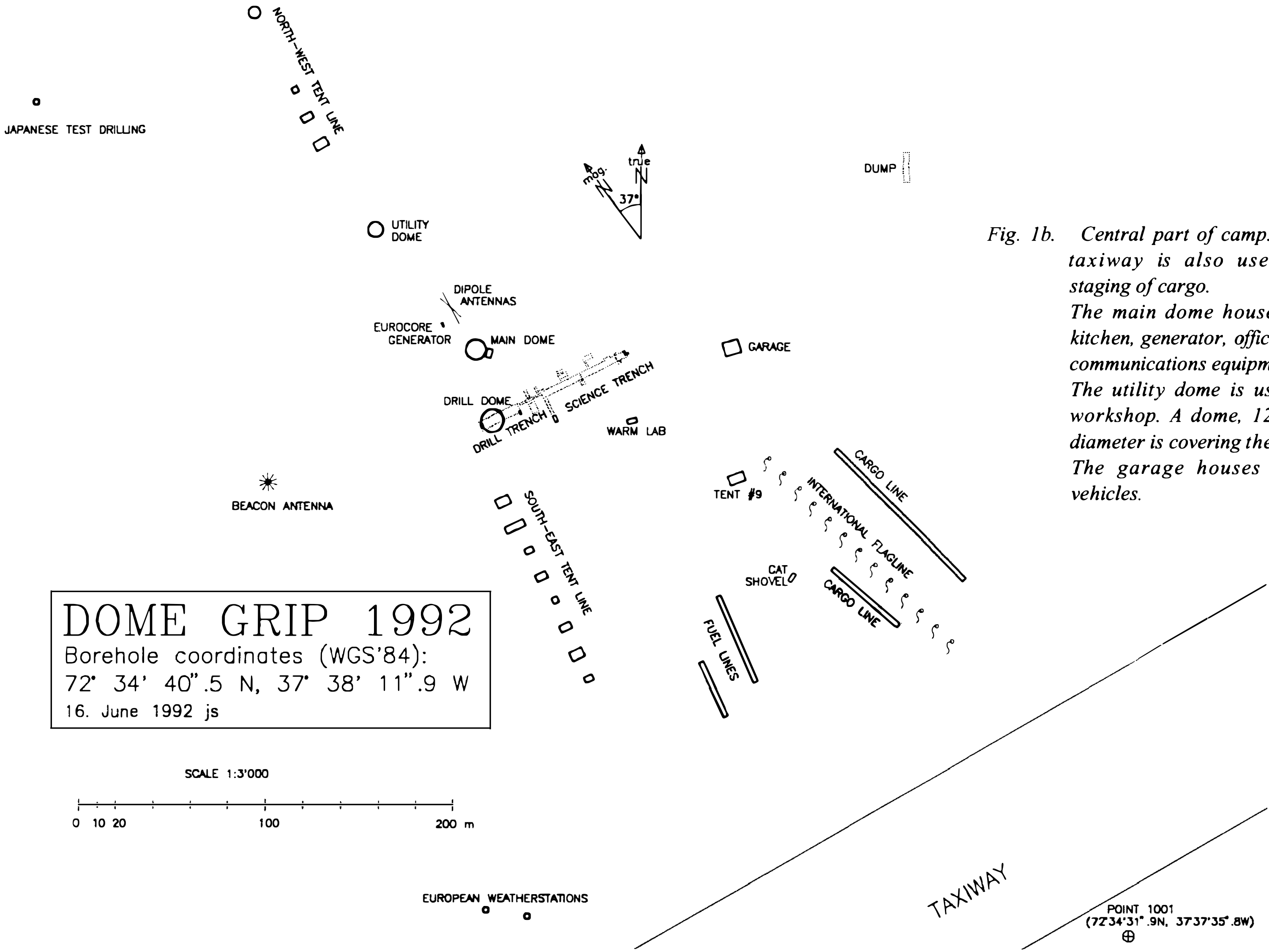


*Fig. 1b.* *Central part of camp. The taxiway is also used for staging of cargo. The main dome houses the kitchen, generator, office, and communications equipment. The utility dome is used as workshop. A dome, 12 m in diameter is covering the drill. The garage houses three vehicles.*

## 3. Permanent Buildings

The three permanent buildings at the surface (main building, utility and drill dome) are dome-shaped (Fig. 2). The advantage of the hemispherical shape is that the wind blows around it, so that the snowdrifts settle 3–4 m from the buildings, without affecting them. The idea is not new - the Eskimos have known about it for millennia, and used it in building their igloos.

This works out very well. The main dome (Fig. 3) is built of wood configured as a 5/8 of a sphere, with a 10.5 m diameter. It is insulated with 5 cm of glassfibre mats. In 1992, three years after the building was erected, there was still no snow accumulating close to the dome. Three m from the dome however, the drifting snow had created a vertical snow wall, 3.5 m high (Fig. 4). This made entering the dome a bit of an experience until a ramp was excavated. The utility dome is 8 m in diameter, and built like the main dome. Again, the wind scouring has kept this dome free of snow. The drill dome is a flat (3/8 of a sphere) dome with a maximum diameter of 11.5 m. Due to the flat shape, the scouring effect is not so effective around this dome – apparently the wind tends to pass over the dome instead of circling around it – and in 1992, there was a significant snow build up around the dome, repeatedly covering the door, air vents, etc.

The distance between the main dome and the drill dome is 40 meters between the centers. Ideally, the distance between the domes should be high enough to assure that the snowdrifts from one building do not interfere with the drift around the neighbouring buildings. Unfortunately, the distance between the Main and drill domes is too small, thereby creating a major snowdrift between the buildings.

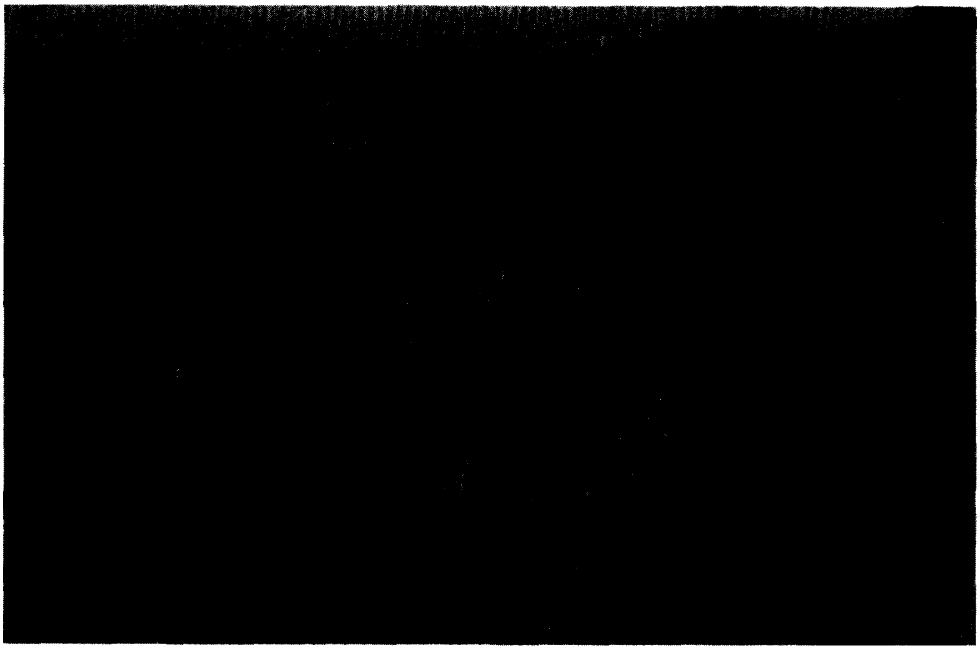

*Fig. 2. The three domes photographed in 1992, three years after construction. The drill dome is at left, the Main dome in the center, and the utility dome at right. The scouring effect around the Main dome is clearly visible. The individual structures can be identified from Fig. 1.*

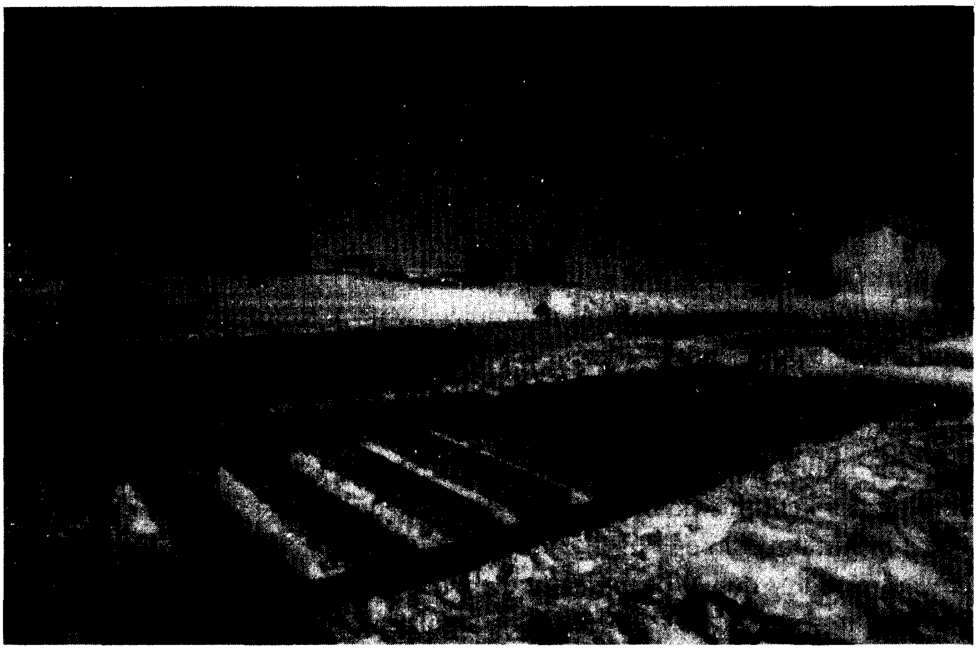

*Fig. 3. In the background the Main Dome under construction. The dome housed the generator, sanitary facilities, office, kitchen and living quarters. The Drill trench with plywood roof on laminated beams is in the foreground. The white dome at right housed the Eurocore drill. This dome is not part of the GRIP camp.*

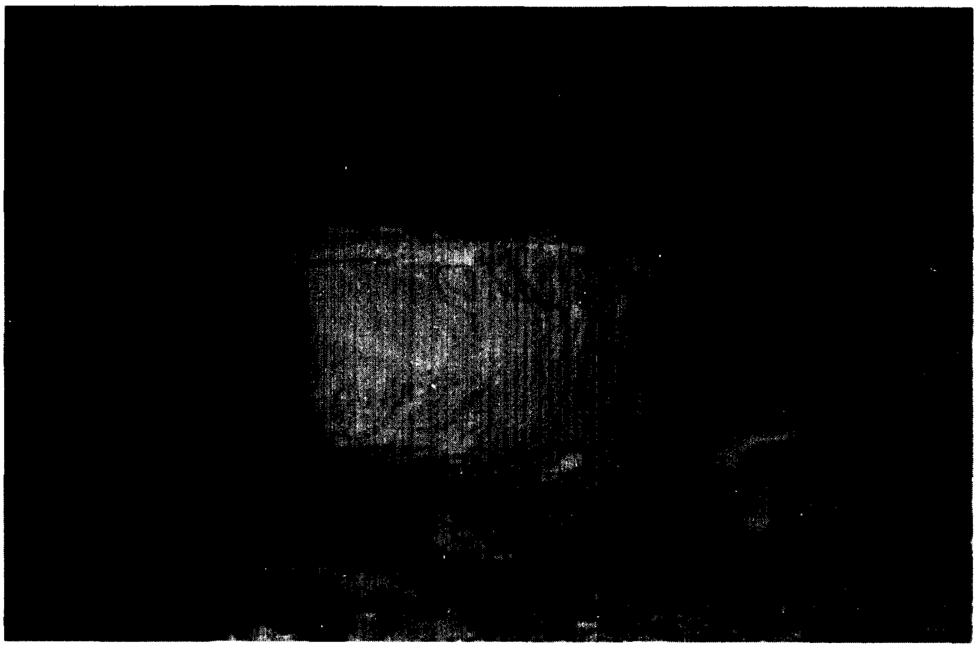

*Fig. 4. In 1991, two years after construction, the main dome still stands clear of snow. A snowdrift 3 m high encircles the building.*

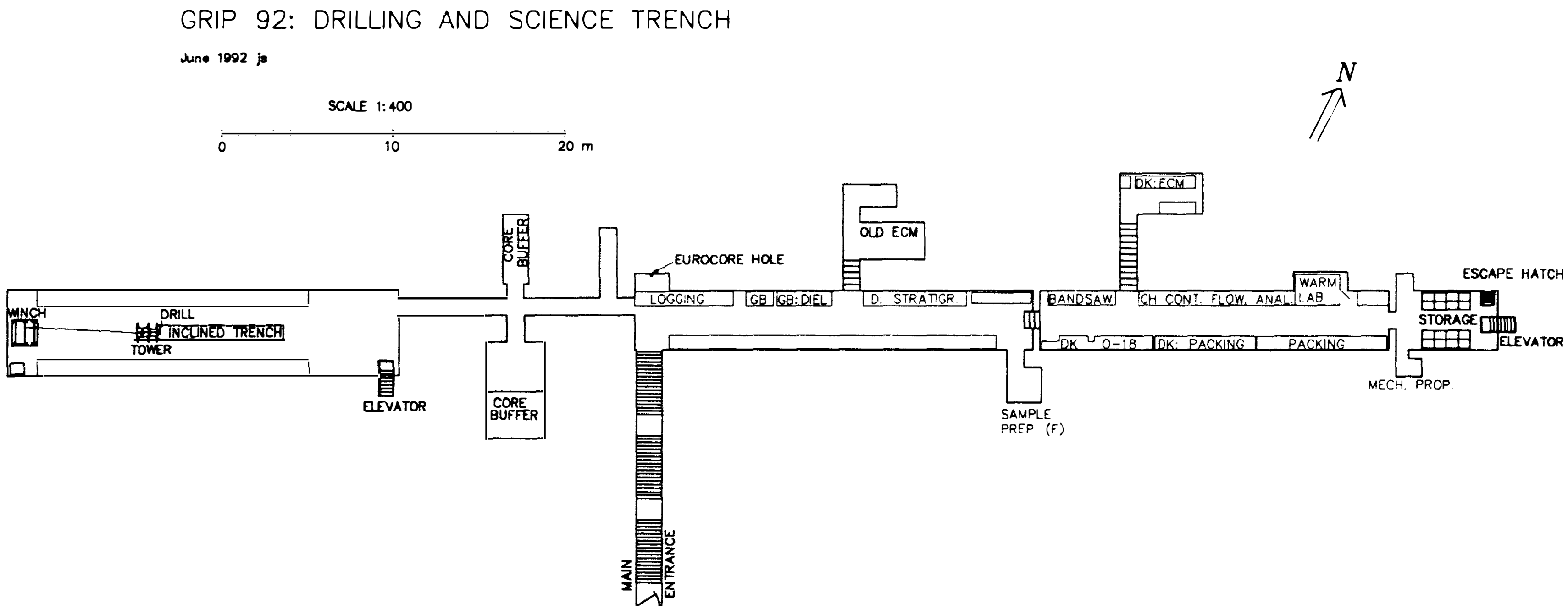


Fig. 5. Plan of Science Trench.

## 4. Trenches

The science trench and the drill trench are 50 m × 3.5 m and 22 m × 5 m, respectively (Fig. 5), and they are connected by a 10 m long tunnel. The trenches were excavated to a depth of 3.5 m with a small snowblower (Fig. 6), and covered with a roof made of plywood on laminated wooden beams. This way of building a roof is quite fast - a welcome feature at a site where the next snowstorm may be just hours away. The snow load on the roof reduced the height of the ceiling from 3.5 m in 1989 to 2.5 m in 1992. Also, the trench floor was 3.5 m below the surface in 1989. In 1992, the floor was 7 m below surface, with up to 4.5 m of snow above the roof.

Two centrifugal type blowers at the trench floor with a capacity of 0.7 $m^3/s$, and a third ventilator with a capacity of 1.4 $m^3/s$ exchange the air in the drill trench. The latter has the air intake at the bottom of the inclined drill pit. With a volume in the drill trench of 380 $m^3$, there is an exchange of the air in the drill trench every 2 to 3 minutes. This ventilation is adequate.

The temperature in the trench could go as high as −10°C late in the season, after several months of operation. Some measurements on the ice require lower temperatures. This is obtained by digging caves into the side of the main science trench, and keeping the floor of the cave 2 m lower than the floor of the trench. This ensures that the temperature in the cave was a maximum of −15°C.

*Fig. 6. The drill trench under excavation.*

## 5. Generator

The electrical power to the camp is produced by a 68 kW turbocharged, radiator-cooled, noise silenced diesel generator.

Cost of fuel is significant. All fuel has to be airlifted to the camp, resulting in a price of FRF 20 per litre of diesel or FRF 7 per kWh of electrical power, ten times the price in

Europe. The generator was therefore placed inside the main dome, so that its waste heat could be used to heat the dome. Also, the snow melter was heated solely by the generator's waste heat.

This system worked so well that at times it was difficult to keep the temperature in the dome down to a comfortable level, in spite of outdoor temperatures around -20°C!

The generator cooling air was sucked from below the building to prevent the generator heat from melting the snow that supports the dome. The capacity of the two fans is 0.7 and 1.8 $m^3/s$, respectively.

With three permanent buildings, ten temporary buildings, a 15 kW winch, and 50 m of scientific trenches, the electrical power distribution network is quite elaborate. From a main distribution panel, the electrical power is distributed to 4 secondary distribution panels. All panels are protected by circuit breakers, and the personnel safety is assured by high sensitivity (25 mA) error current sensing relays. Also, in order to reduce static build-up, all electrical circuits include a common "ground".

In spite of all attempts to keep down the power consumption, the load frequently exceeded the capacity of the generator. In order to avoid power failure caused by overload, all electrical heaters were connected to a common power line. This line was automatically switched off when the generator load got too high.

In order to control the use of electrical power, an inventory of all electrical power consumers was made (see Annex 1). Next, a model of the turnon time for each consumer with time of day was constructed (Fig. 7). After some iterations, this model fit the observed load very well. Camp load at three different times of day is shown in Table 1.

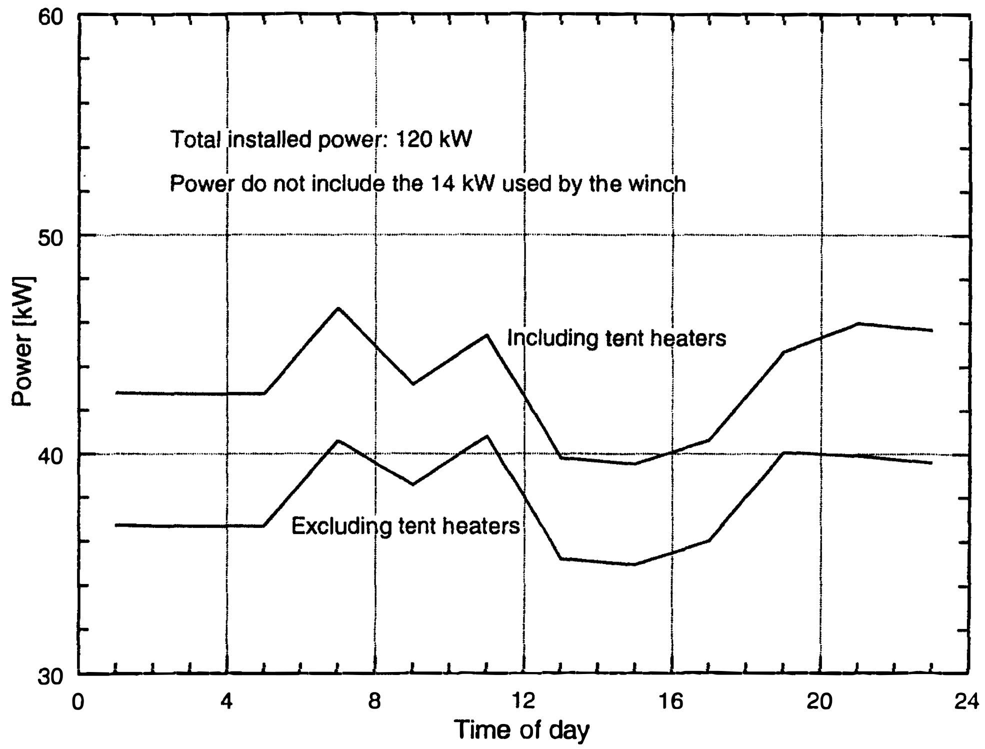


*Fig. 7. Electrical power used during the day for camp operation. Winch power (14 kW) is not included The capacity of the generator is 65 kW, and the total installed power was 120 kW.*

*Table 1 Electrical power used at 3 times a day.*

| Consumer | Time 1 | Time 2 | Time 3 |
|---|---|---|---|
| Main dome ground floor | 14275 | 8435 | 8110 |
| First floor | 1790 | 1760 | 1760 |
| Main panel | 3850 | 3850 | 3850 |
| Utility dome | 1000 | 1000 | 1000 |
| Drill dome | 563 | 258 | 258 |
| Drill trench | 7185 | 7185 | 7185 |
| Science trench | 3006 | 1860 | 1860 |
| Eurocore trench | 2272 | 2150 | 2150 |
| Core storage/Hitoshi | 165 | 150 | 150 |
| Conductivity cave | 520 | 520 | 520 |
| French chemistry prep | 660 | 660 | 660 |
| German deformation cave | 140 | 140 | 140 |
| French heated surface lab. | 2850 | 5850 | 5850 |
| Science trench total | 9613 | 11330 | 11330 |
| Italian air sampling | 300 | 300 | 300 |
| Tents (except heat for SE line) | 4600 | 10350 | 10350 |
| Camp total [kW] | 43177 | 44468 | 44143 |

## 6. Radio Interference

Electromagnetic interference (EMI) has been a constant problem. Most likely, the high concentration of electronics including radios, telex, copy machine as well as the generator with its slipring all contributed to the interference. The two worst single sources were the tower tilting and the drill winch, both of which used a variable frequency power inverter. Ironically, the small drive for the tower produced much more interference than the much more powerful winch! Some AC battery backup inverters also produced noise, but using a good brand, and not using these inverters near the shortwave radios kept the interference from this source to a negligible level.

## 7. Communication

Communication with the camp is essential, both for operational reasons, and to ensure the safety of the camp personnel. The main communication channel is an Inmarsat Standard C telex terminal. This ensures communications with any telex terminal in the world. Typically, it takes five minutes from the transmission of a telex until it is received. All reporting, requests, etc., are sent by telex. The reliability of this satellite terminal is very high: it operates constantly, and the maximum delay experienced is 1 hour. In fact, it can be argued that this telex terminal is the main safety item in the camp: using the telex, we can always call for assistance if required.

A shortwave transceiver is also used for routine communications, contacts with aircraft etc. Contacts with the neighbouring U.S. GISPII camp are maintained via VHF, and an airband VHF radio is used to contact aircraft close to the camp.

1990 and 1991 were years with high solar activity, and the short- wave radio became useless for weeks due to "Polar Cap Absorption". In these periods, the Inmarsat STD-C telex was the only means of communication, and during most of the flights between Søndre Strømfjord (SFJ) and Summit there was no contact with the aeroplane.

## 8. Air Support

Everything needed to build and operate a camp, including vehicles, buildings, fuel and food, are flown the 800 km from the base camp in SFJ to the drill site. The cargo is transported on heavy LC-130 ski-equipped cargo planes chartered from the US Air Force and operated by the New York Air National Guard. Each plane carries up to 25000 lb of cargo and passengers. The cargo is strapped down on special air force pallets. The offloading takes place while the plane is slowly taxiing. With the rear ramp of the LC-130 open, the pallets are slid down onto the ice. Next, the retrograde cargo is loaded using a Caterpillar tractor that lifts the retrograde pallets into the plane. Because of the low air pressure at 3 km elevation, the retrograde payload is limited to 10000 lb.

In fact, due to the low air pressure (2/3 atmosphere), the LC-130 operates at the limit of their capabilities: with a total weight of approximately 100000 lb, a few thousand pound payload more or less determines if the aeroplane can take off. Frequently, special Jet Assist rockets attached to the plane assists the takeoff.

In support of this operation, a 3 km long skiway is maintained throughout the season. The snow on the skiway is compressed by dragging a heavy beam along the skiway, and the undulations are removed with a special groomer that cuts away the top level of the surface. The maintenance of this skiway is quite demanding both in terms of personnel, time and the requirements for heavy vehicle support, but there are no alternatives: surface traverses would be even more expensive, and because a surface traverse would have to pass crevassed areas, a surface traverse is associated with a higher risk.

The LC-130 aeroplanes are only stationed in Greenland for a few periods each season. Outside of this period, a smaller twin engine aeroplane (De Havilland Twin Otter) supplies the camp with spare parts, food and brings crew replacements in addition to performing search and rescue (SAR) backup. The Twin Otter is also used to support surface traverses by delivering spare parts, locating crevassed areas, and taking scientists around for minor associated studies.

## 9. Sondrestrom Field Office

All logistical activities are coordinated by the Field Operations Manager (FOM) in Søndre Strømfjord (now renamed Kangerlussuaq). This office controls all cargo and passenger transport to Summit. The FOM decides the flight schedule, and handles onward transport from SFJ to Copenhagen. During each field season, more than 100 tons of supplies and equipment are brought out to the camp site.

The FOM also checks the progress of the surface traverses that operates as part of the drilling project. Each travelling party reports back once a day by radio or telex to SFJ.

The logistical management of the project is a matter of keeping current contact with the camp, exchanging weather reports, loading pallets, and making sure the passengers get to and from the camp quickly, passengers often reach the top of the ice sheet from Copenhagen on the same day. Spare parts have to be ordered, hotel rooms organized, vehicles maintained, reports compiled, etc.

## 10. Conclusions

The basic lay out of the camp worked very well. The use of a noise- silenced generator inside the main building, and the use of waste energy for snow melting saved valuable fuel. The combination of three permanent domes and temporary structures for living quarters worked well. The distance of 40 m between the main dome and the drill dome was too small, and resulted in significant snow accumulation between the two buildings. Also, the trench roof should have been designed to carry the load from snow drifts, and not only for the average snow accumulation.

The distance of 15 m between the weatherports (Fig. 1) was, in general, sufficient, but when the wind was not perpendicular to the tent line, there was also significant interaction between the drifts from the weatherports, which resulted in major snowdrifts.

The cargo and fuel lines were placed perpendicular to the main wind direction. The snow drift around these lines lifted the surface more than 1 m. We considered placing the fuel and cargo lines in the main wind direction, but because the effect of such a change was not known, it was decided to leave it unchanged.

The water systems, with a main snow melter heated by waste heat, and a small stainless 3 kW electrically-heated snow melter for drinking water, worked well. It was difficult to keep the water in the big snow melter drinkable.

The high number of digital equipment items, as well as the generator in the main dome, created some electrical interference problems for the shortwave connections. The generator should have been purchased with extra EMI protection. Also, some PC's generated more noise than others. EMI is definitely a problem in a compact camp.

The power distribution with a common ground, two levels of circuit breakers, and 25 mA error current sensing relays, worked well. On a few occasions, the error relay tripped: at one time due to humidity in a plug, and at another time due to a faulty hand tool.

## Acknowledgments

The camp lay out is based on years of cooperation with Polar Ice coring Office. The logistic support for the two Greenland Summit drilling operations (U.S. GISPII, and the European GRIP) has been closely coordinated between PICO and GOC.

This work is a contribution to the Greenland Ice Core Project (GRIP), a European Science Foundation programme with eight nations collaborating to drill through the central Greenland ice sheet.

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**Electrical Power Used at Dome GRIP**

| Building | Users | Pmax (W) |
|---|---|---|
| Total power installed (kW) | | 119 |
| Main dome ground floor | Dish washer | 6500 |
| | Water melter | 2000 |
| | Refrigerator | 300 |
| | 2 pumps | 1000 |
| | Laundry machine | 3000 |
| | Tumbler | 2000 |
| | Stoves | 16000 |
| | Microwave | 1250 |
| | Toaster | 650 |
| | Coffee machine | 1155 |
| | Kenwood | 650 |
| | Espresso mach. | 600 |
| | 3 LP 60W lamps | 180 |
| | 2 Pactosan | 200 |
| | 2 fans for generator | 2000 |
| | Shoeheater | 300 |
| | Water boiler | 2400 |
| Main panel | Vestibule heaters | 1350 |
| | Heaters for vehicles | 2500 |
| 1st floor | Telex+Victor | 150 |
| | Radios | 300 |
| | Zenith | 40 |
| | Compaq | 40 |
| | Deskjet | 50 |
| | Copier | 1000 |
| | Macintosh | 400 |
| | Compaq (Sepp) | 600 |
| | IBM 486 | 400 |
| | Paintjet | 50 |
| Utility dome | Heater | 2000 |
| | Heater | 1500 |
| Drill dome | 2 15W lamps | 30 |
| | 2 20W lamps | 40 |
| | Table lamp | 60 |
| | 250W lamp | 250 |
| | Junair | 680 |
| | Junair (dry) | 1100 |
| | Grinder | 400 |
| | Drill press | 350 |
| | GPS | 18 |
| Drill trench | 7 LP 60W lamps | 420 |
| | 3 60W lamps | 180 |
| | Glove heater | 2000 |
| | Heater | 2000 |
| | Tape recorder heater | 2000 |
| | Tower tilt control | 250 |

| | | |
|---|---|---|
| | Winch standby | 350 |
| | 3 heat pads | 450 |
| | 2 slush pumps | 1500 |
| | 1 elevator | 1500 |
| | Drill control | 700 |
| | Winch | 10000 |
| | 2 blowers | 2000 |
| | Sprit heater | 1000 |
| | | |
| Science trench warm lab CH | | 760 |
| | Warm box | 600 |
| | Melt head | 200 |
| | Hair dryer (10'/day) | 800 |
| | Jamps FIA | 180 |
| | 4 inca saws | 1760 |
| | John's small app. | 300 |
| | Saw | 250 |
| | Saw | 700 |
| | Lightsticks | 40 |
| | Halogenlamps | 160 |
| | 2 L P 60W lamps | 120 |
| | Swiss saw | 440 |
| | Compressor | 400 |
| | Taperecorder | 15 |
| | | |
| Eurocore tr. | L P 60W lamp | 60 |
| | Halogen | 560 |
| | App. Kipfstuhl | 1000 |
| | App. Moore | 500 |
| | Saw | 550 |
| | Hairblower | 2000 |
| | He Exp pump | 130 |
| | Heater | 2000 |
| | Pattern recognition | 500 |
| | Core buffer lamp | 30 |
| | | |
| Corestorage/Hitoshi | | |
| | Lift | 1500 |
| | Lamps | 150 |
| | | |
| ECM | Computer | 100 |
| | Monitor | 90 |
| | LP 60W lamp | 60 |
| | Lamps | 220 |
| | Chart recorder | 50 |
| French chem prep | | |
| | Lamps | 160 |
| | Laminar flow | 500 |
| | | |
| German mechanical setup | | |
| | Halogen | 80 |
| | Light table | 50 |
| | Microtome (pump) | 200 |
| | LP 60W lamp | 60 |
| | Relaxation meas. | 200 |
| | | |
| French surface lab | | |
| | Stabilizer | 1000 |
| | Heater | 1500 |
| | | 600 |
| Heater | Snowmelter | 2500 |
| | Laminar flow | 500 |
| | Microwave Oven | 1250 |
| | Millipore | 50 |
| | | |
| CO sampling | | 300 |
| Tent #4 | Heater (TC) | 1500 |
| Tent #1 | Battery chg. | 16 |
| Tent #2 | Heater (TC) | 1200 |
| | Heater | 1000 |
| | UPS | 1000 |
| Tent #3 | Heater | 1500 |
| | Microwave | 2000 |
| | Battery chg. | 15 |
| Tent #5 | Heater (TC not used) | 1500 |
| Tent #6 | Heater (TC) | 1000 |
| Tent #7 | — | |
| Tent #8 | Heater (TC) | 600 |
| | Computer | 300 |
| Tent #9 | Heater | 1000 |
| Tent #10 | Heater (TC) | 1500 |
| Tent #11 | Heater (Timer) | 1000 |
| Tent #12 | Heater (TC) | 800 |