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Design, transport, construction, and operation of the summer base Kohnen for ice-core drilling in Dronning Maud Land, Antarctica

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Abstract: During the austral summer seasons 1999/2000 and 2000/2001 the summer base "Kohnen" was built as a platform for the EPICA deep ice core drilling in Dronning Maud Land, Antarctica. The design is based on prefabricated container units. The base was erected within two summer seasons. Overland traverses with Pistenbully tractors and cargo sledges moved all needed material and base containers from the German base Neumayer at the Antarctic coast to the base Kohnen 750 km inland. All installations were completed at the end of the 2000/2001 season including the drill and science trench with a cased 100-m borehole. Thus everything is prepared to start the deep drilling operation during the 2001/2002 austral summer season.

1. Introduction

Two major deep drilling operations are underway in Antarctica within the European Project for Ice Coring in Antarctica (EPICA). EPICA is a joint project of ten European nations with the aim to decipher the earth's climatic conditions during the last 500000 years (http://www.esf.org/life/lp/Epica). The first core is drilled at Dome Concordia (DC) (ref. Fig. 1) and addresses, amongst other issues, the question whether the stable climatic conditions during the last 10000 years were exceptional throughout the last five glacial cycles.

The second core will be drilled starting in the 2001/2002 season in Dronning Maud Land (DML) to attain a higher resolution for the last 150000 years and thus link the last glacial cycle being recorded in the Greenlandic cores GRIP (Grip Members, 1993), GISP2 (Grootes *et al.* 1993), and NGRIP (Dahl-Jensen *et al.*, 1997). The drill site of the EPICA Dronning Maud Land core is situated on an ice divide originating at Dome Fuji (DF). The DML record will thus complement the DF (Dome-F Deep Coring Group, 1998) and the DC (Tabacco *et al.*, 1998) records with a much higher resolution over the last glacial cycle.

The drill site for the deep drilling has been chosen after an extensive multinational pre-site survey. The accumulation distribution (Holmlund *et al.*, 2000; Isaksson *et al.*, 1999; Karlöf *et al.*, 2000; Oerter *et al.*, 1999, 2000; Richardson and Holmlund, 1999; Van den Broeke *et al.*, 1999), snow chemistry (Sommer *et al.*, 2000a, b; Stenberg *et al.*, 1999) and ice thickness as well as bedrock topography (Steinhage *et al.*, 1999) have been

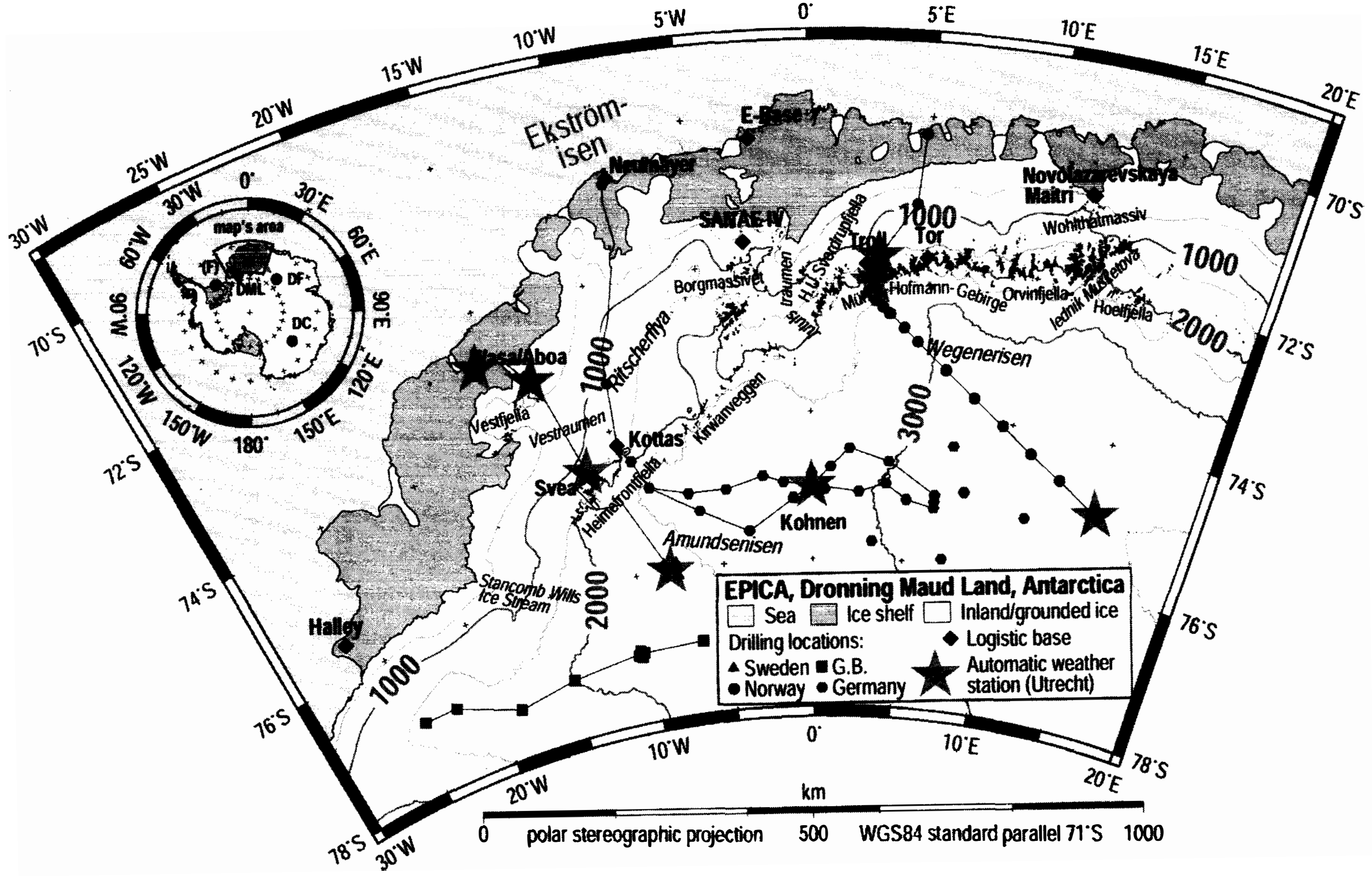

Fig. 1. *Pre-Site Survey Activities in Dronning Maud Land (DML), Antarctica. The three deep drilling locations Dome F (DF), Dome Concordia (DC), Dronning Maud Land (DML), as well as the location of the former German summer base Filchner (F) are indicated in the general map. The map has been generated with Generic Mapping Tools (GMT) (Wessel and Smith, 1998) using coastlines, contour lines and ice shelf outlines from the Antarctic Digital Database (ADD 3.0) (http://www.nerc-bas.ac.uk/public/magic/add_main.html).*

considered in selection of the drill site. The ice thickness at the drill site is 2750±50 m according to airborne electromagnetic reflection survey (Steinhage, 2001). Figure 1 compiles the pre-site survey contributions cited above as well as further activities.

The deep drilling itself requires a camp as a logistic platform. The estimated drilling time to bedrock will be 3 summer seasons. Aspects of design, transport, construction and operation of the summer base Kohnen will be discussed in the following sections. After the location for the deep drilling was selected in autumn 1999, the erection of the base started during the 1999/2000 austral summer season. Half of the 2000/2001 season was needed to complete the main buildings before the base was named in the memory of Dr. Heinz Kohnen (5.2.1938–25.7.1997) on January 11th, 2001. Dr. Heinz Kohnen was the head of AWI's logistics section and a key promoter of German and European polar research, especially the EPICA programme.

One of the most important criteria of polar operations is the meteorological condition on site. Environmental conditions will be summarized first, before the base is described and the logistical operations are discussed.

2. Environmental conditions at the drill site

The metereological conditions at the drill site reflect its position (75°00′06″S, 0°04′04″E) on the interior of the East Antarctic plateau at 2882 m height above sea level (2892 m WGS84). The air temperature during the austral summer (December to February) is in the range of −20°C to −45°C. An automatic weather station installed on site has recorded a temperature as low as −70°C during the winter (Reijmer, 2001). The mean annual temperature calculated from the observed data for 1998 is −46°C and fits well with the firn temperature at 10 m depth of −44.5°C. The weather station recorded wind speeds typically below 11 m s^{-1} and the annual maximum of 16 m s^{-1}. The wind direction is mainly from Northeast to East (approximately 65° true North). The mean accumulation of 60–70 kg m^{-2} yr^{-1} for the last two centuries determined from ice cores fits well with the observed snow deposition of 20–30 cm from snow pit studies and surface measurements, respectively (Oerter *et al.*, 2000). The ice flow is less than 2 m yr^{-1}.

3. Logistics: Transport chain and the fleet

The cargo transport concept from Bremerhaven (Germany) is based on 20' standard ISO container modules. From Bremerhaven to the departure port for Antarctica in the Southern Hemisphere, usually Cape Town (South Africa), or from time to time Punta Arenas (Chile), the containers are either transported on commercial container ships or on the German polar research vessel *Polarstern*. From these ports the containers are shipped either on RV *Polarstern*, or in cooperation with the Republic of South Africa on S.A. *Agulhas*.

The main advantage of using standard ISO containers is the short loading and unloading times required in all ports and in Antarctica at the ice edge of the Ekströmisen or on the sea ice in front of the German base Neumayer.

The land transport for the ISO containers is based on Otaco type sledges (weight 2.7 t) built by "Aalener Baumaschinen GmbH" (http://www.aalener-baumaschinen.de).

These sledges provide fittings to mount 20' ISO containers with marine standard twist lock fittings. Furthermore, they distribute the load evenly on all four skids by allowing the skids to turn around their cardanic suspended axes. Typically two or three sledges are arranged in sledge trains, which are towed by Kässbohrer Pistenbully (http://www.pistenbully.com) tractors (types PB240, PB260 and PB300). Pistenbully tractors were originally

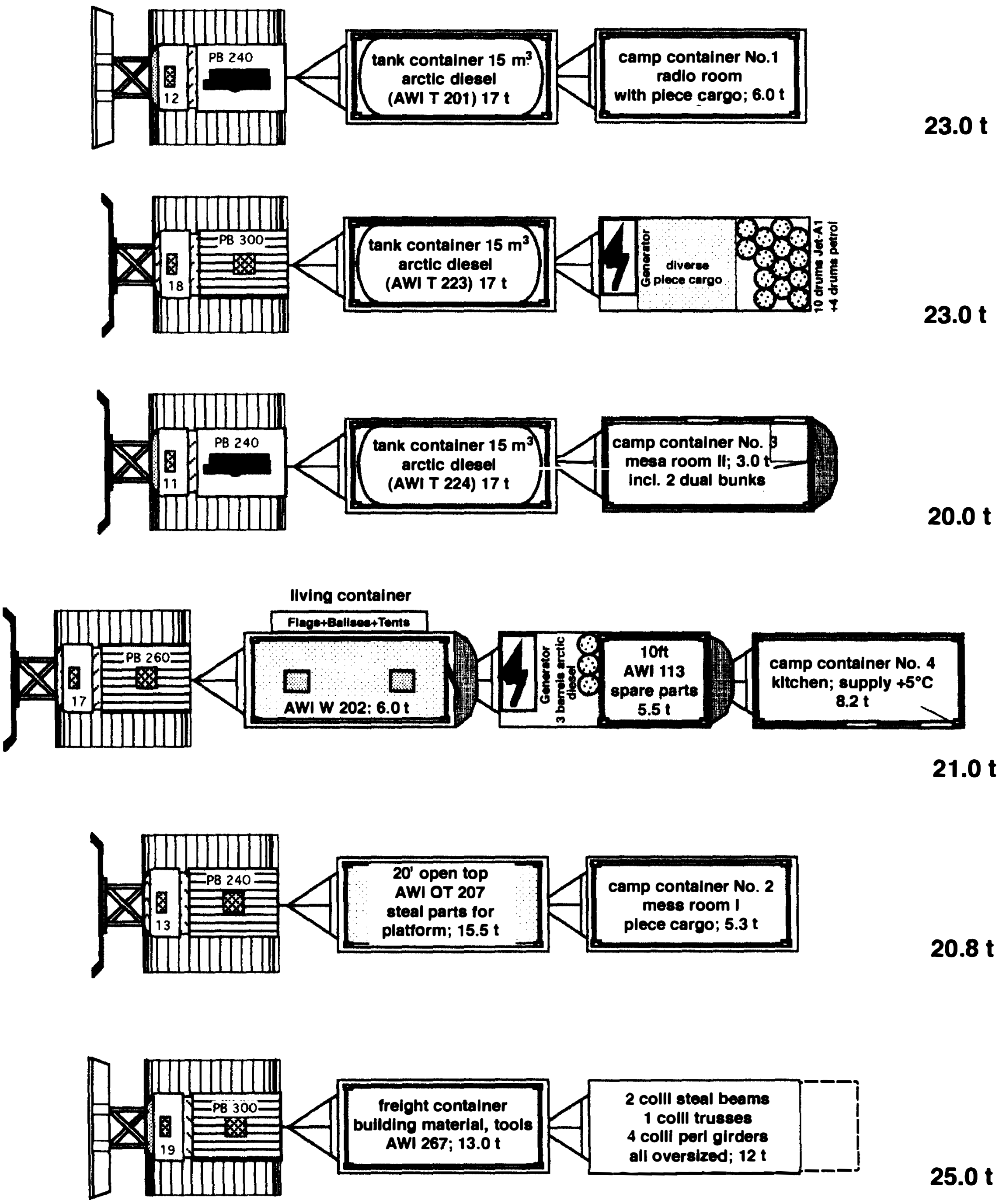

Fig. 2. Load plan for the first traverse of the 1999/2000 season ex Neumayer base to Kohnen base. The given weights illustrate the typical payload of about 20 t per sledge train.

developed for ski slope preparation. The ones used by Alfred-Wegener-Institut (AWI) are equipped either with a personnel cabin or a hydraulic crane with a torque up to 8.4 tm. The front is either equipped with dozer blade or a front shovel. Independent preheaters, trailer couplings, VHF Radio and Global Positioning System (GPS) receivers are standard equipment as well. At the camp site, the snow shovel is useful to carry boxes and the crane is used for construction work. The Kässbohrer Pistenbully with its 5.5 t total weight creates a ground pressure of about 40 g cm^{-2}. Figure 2 presents the load plan of the first traverse from Neumayer base to Kohnen base in the 1999/2000 season. Each Pistenbully pulled more than a 20 t payload. The six sledge trains with a gross weight of 201 t carried a total payload of 133 t. The range before refuelling depends very much on load, surface gradient and snow surface conditions. Typically, it is between 30 and 60 km. The average fuel consumption is calculated to be 3.5 l km^{-1}, varying between 2 l km^{-1} for empty traverse at sea level and 5 l km^{-1} fully loaded at 2800 m height above sea level on soft snow.

The traverse navigates by GPS. Surrounding bases are contacted by HF radio daily and furthermore Inmarsat Standard C Telex and Standard M Phone/Fax communication sets are available.

In 1999 and 2000 two traverses with six and four sledge trains, respectively, were driven the 750 km long route from Neumayer base to Kohnen base. Typically, the ascent takes ten days, while the descent is one day faster. The transported payload totals 210 t, where 47 m^3 vehicle fuel are included. On the way back one Pistenbully was not needed for towing sledges, therefore it was loaded on a sledge, saving 1300 l of fuel (see photograph in Fig. 3).

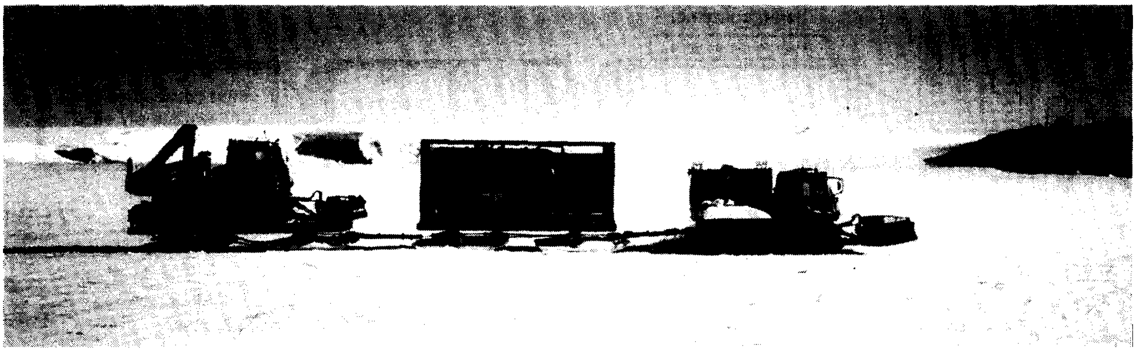

Fig. 3. Vehicles on the traverse: Kässbohrer Pistenbully with cabin and crane respectively. The 20' ISO tank container and the Pistenbully with crane are transported on Otaco type sledges.

4. Base: Environmental issues and specifications

Environmental protection issues have been considered in a comprehensive environmental impact evaluation (CEE) (http://www.awi-bremerhaven.de/AWI/Presse/Docs/EpicaUVSe.pdf), according to the Protocol of Environmental Protection to the Antarctic Treaty. The CEE was forwarded to the parties of the Antarctic Treaty and the Committee of Environmental Protection (CEP). It was discussed during the special Antarctic Treaty Consultative Meeting (ATCM) at The Hague in 2000. Finally the German Umweltbun-

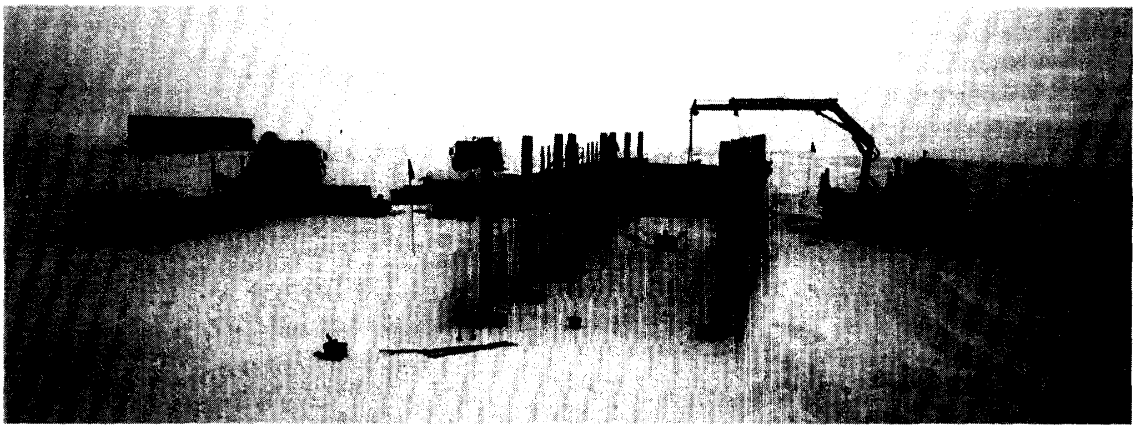

Fig. 4. Construction of the central base building's frame.

desamt (Federal Environmental Office) announced the activity as approved on October 6th, 2000.

The plan to start deep drilling in the 2001/2002 season gave a short time frame for base construction. This implied a station layout with a high level of prefabrication, short mounting times and low transport masses so that the base could be erected during two summer seasons. Seven container units from the former German summer base Filchner were salvaged from a drifting iceberg in the Weddell Sea in February 1999, refurbished and reused.

The central base is arranged with eleven 20' ISO containers (12 m^2 each) on a jackable steel platform, 32 m by 8 m in size. The steel frame stands 2 m above the surface, supported by sixteen pillars. Figure 4 illustrates the construction. A 2 m deep trench has been excavated wherein the pillars are placed on timber footers of different size. The size varies with the load on each pillar and aims for a uniform ground pressure of 350 g cm^{-2}, which is only a little more than two times the pressure created by a 75 kg load on the area of a pair of shoes size 10. The base's 73 t total weight is resting on ground plates of 20.76 m^2 total area. The platform may easily be jacked up by winches according to the accumulated snow effects on the base.

To minimize the accumulated snow drift the central building is aligned with its long face perpendicular to the main wind direction (065° true North). The other camp installations are lined up perpendicular to the main wind direction and keep sufficient clearance of some tens of meters (see Fig. 5). The external living quarters and the fuel container for the generator are on movable sledges. They will be removed from the central camp area during winter time. The drill and science trench are below the surface due to the temperature requirements and will not create additional snow accumulation. The traverse parking area is leeward of the main base platform and a clean snow area is reserved on the windward side to collect snow for the snow melter. All cargo containers are parked 150 m leeward of the platform and the winter depot.

The base is designed to house 20 persons. The assigned functions for each container are given in Fig. 6. The two sections built in 1999/2000 are the radio office, mess room with kitchen as well as the sanitary and sleeping section. During the 2000/2001 season, the base was completed with a generator, a snow melter, a store and a workshop. The

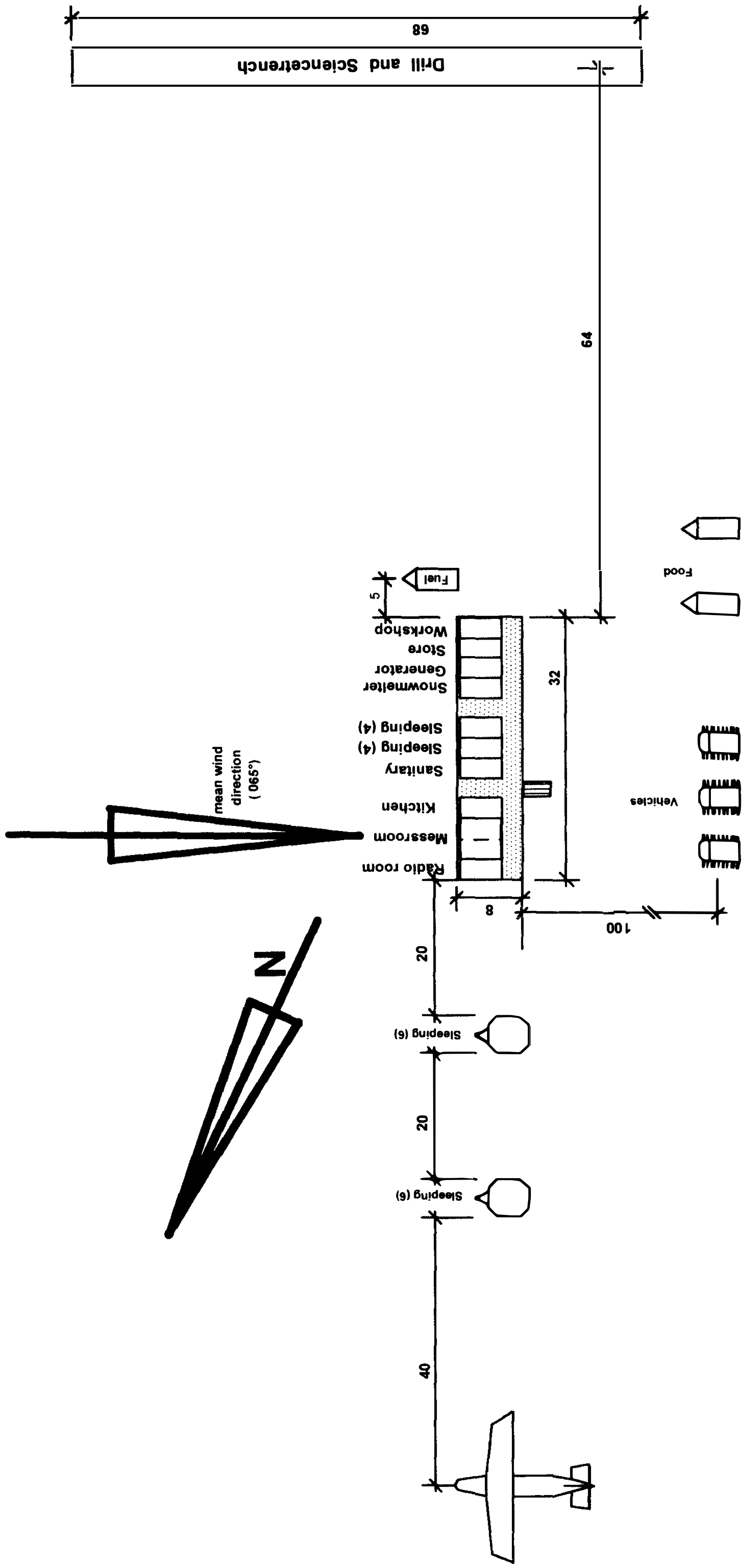

Fig. 5. The layout of Kohnen base. Distances are in m.

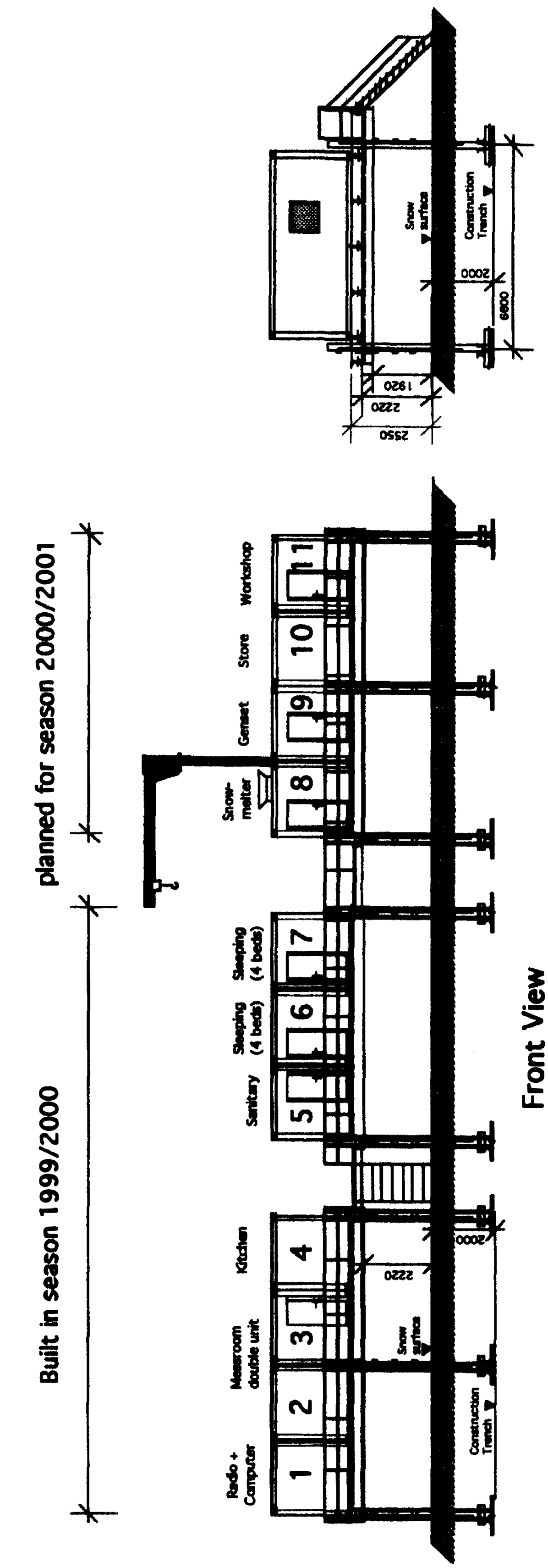

Fig. 6. Views of the central base building.

generator has 100 kVA output at the altitude of the base. It consists of a single Deutz diesel engine and a Stamford generator. The fuel consumption is estimated to be between 250 and 300 l d^{-1}, when the base is in full operation. The fuel is pumped from a 15 m^3 tank container beside the platform into the tank inside the generator container through a permanently installed hose. An external 90 kVA spare generator is available for times of maintenance and standstill of the main generator. The ISO container modules are heated electrically.

A workshop and a store serve as locations for repair works and for holding spare parts and material in stock, respectively.

The snow melter with a volume of 2.5 m^3 is filled by a crane and runs on the waste heat of the main generator, but additionally an oil heater is installed in case the spare generator has to supply the base. Laundry machine and dryer are inside the snow melting container. The kitchen with its dishwasher and the sanitary container with shower, toilets and washbowls are connected to the snow melter with an electric heat traced water pipe. Wastewater is discharged into the firn below the platform according to the CEE.

The messroom is a double unit with 24 m^2 sized for 20 people with direct access to the kitchen.

Two of the containers on the platform serve as sleeping rooms, each with four beds.

Additional living quarters on sledges are placed beside the platform for the summer time and supplied with electric power.

Parking aircraft and traverse vehicles can also be supplied with power by switchboxes 50 m northwest and 100 m southwest of the base. All supply cables outside the platform are dug into the snow at least 1 m deep.

The radio room is linked with the trench by a glassfiber cable for establishing a local area network. The central network and data server will be placed in the radio office and

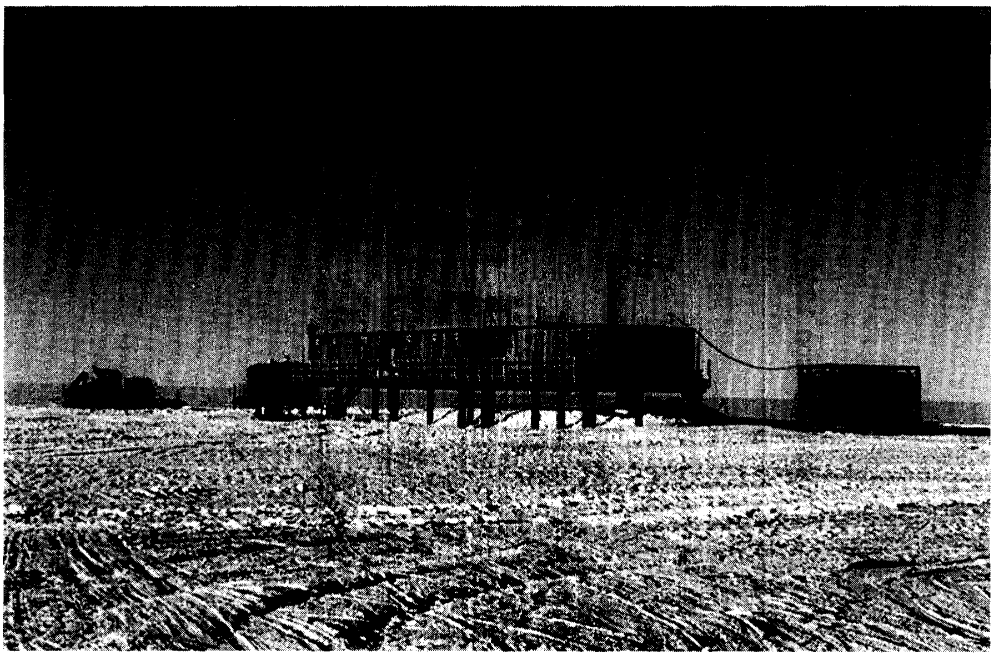

Fig. 7. The central base building at the end of the 1999/2000 season.

backed by a 2 kW uninterruptible power supply (UPS), which lasts for 30 min with full load. The server will be linked to the outside world by an Inmarsat B device providing a high speed data line with 64 kbit s^{-1} bandwidth. The Inmarsat B device provides two phone and one fax lines (9.6 kbits^{-1} bandwidth per line), and a telex line is available as well. The system is backed up by HF radio, Inmarsat C (telex) and Inmarsat M (phone). Figure 7 documents the status of the base in February 2001.

5. Aircraft support and emergency

The three wintering bases Neumayer (Germany), SANAE IV (South Africa) and Halley (United Kingdom) are within 800 km from Kohnen base and thus within the range of small aircraft like the German Polar aircraft (Dornier 228) or Twin Otters. A suitable air strip for small aircraft is maintained allowing supplies and personnel exchange for the base. These aircraft would also be used in case of a medical emergency.

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