Concordia

A new permanent, international research support facility
high on the Antarctic ice cap

Technical Overview

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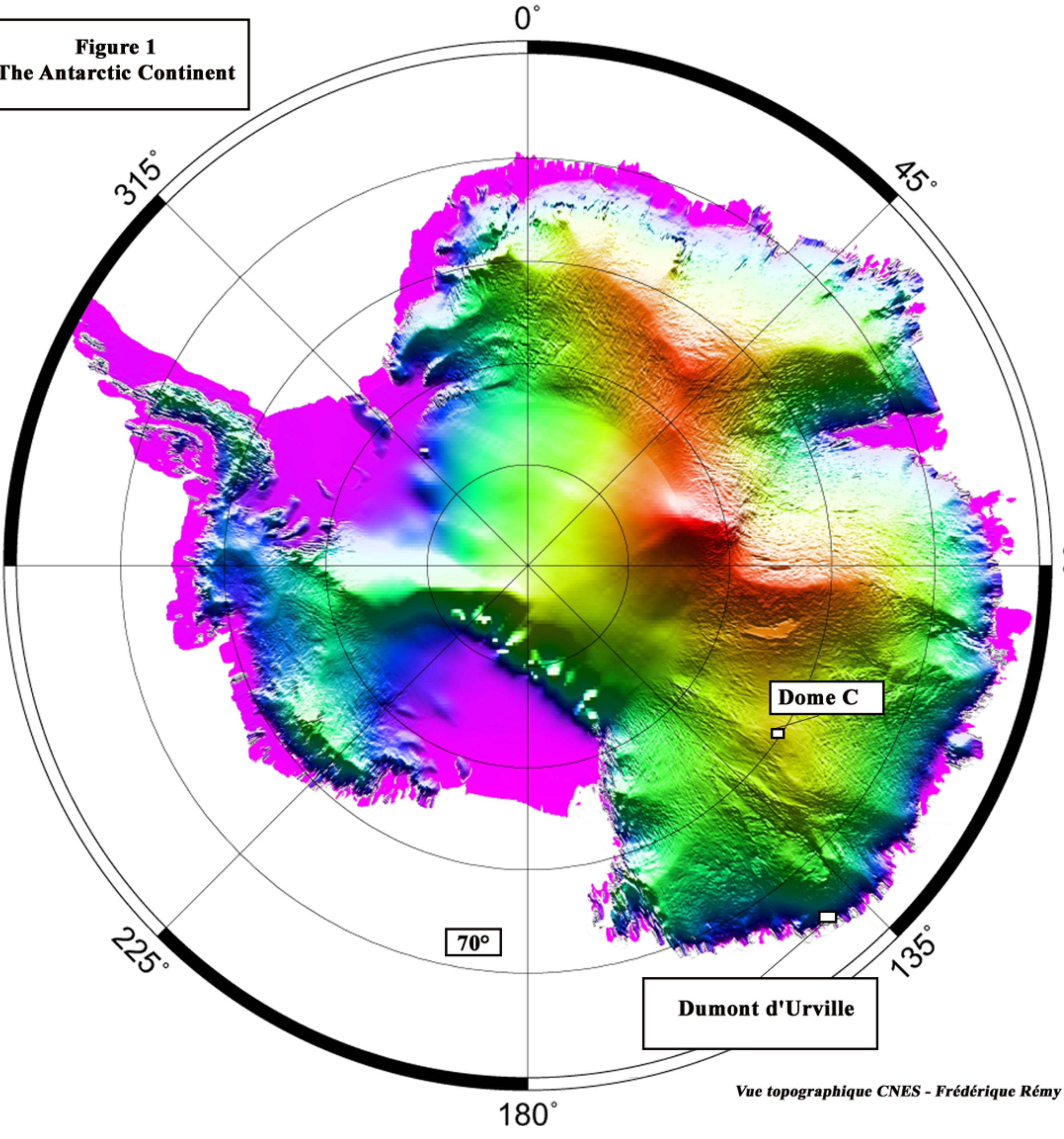
Figure 1
The Antarctic Continent



Vue topographique CNES - Frédérique Rémy

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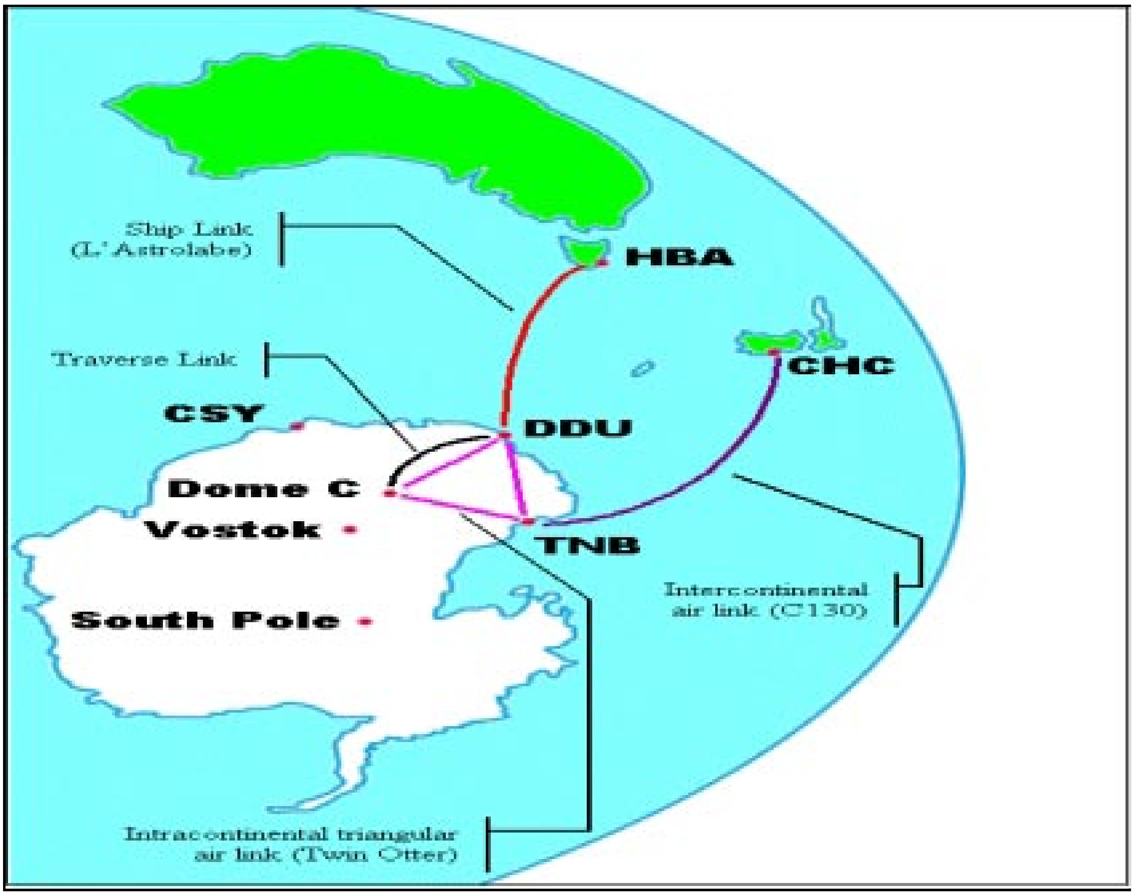


Figure 2: *Map showing Antarctica, Australia, New-Zealand, Concordia Logistic Structure and Gateways (HBA=Hobart, CHC=Christchurch, CSY=Case, DDU=Dumont d'Urville, TNB=Terra Nova Bay)*

Concordia - Technical Overview
A new permanent, international research support facility high on the Antarctic ice cap

1 - INTRODUCTION

While there is a continuously increasing awareness of the importance of Antarctic research, the 14 million square kilometres Antarctic continent still only houses two permanent inland research stations, Amundsen-Scott and Vostok opened in Nov 1956 and Dec 1957 respectively. Recognising the unique research opportunities offered by the Antarctic Plateau, the French and Italian Antarctic programmes have agreed in 1993 to cooperate in developing a permanent research support facility at Dome C, high on the ice cap. The facility is named “Concordia”.

Concordia consists of a core group of three ‘winter’ buildings flanked by a summer camp doubling up as emergency camp. All structures are on or above ground. Access is by traverse tractor trains for heavy equipment and by light ski-equipped plane for personnel and selected light cargo. Jointly operated by France and Italy, Concordia is open for research to the worldwide scientific community. Officially open for routine summer operation in Dec 1997, Concordia should be open year round from 2003 upon completion of the core winter buildings. Facilities are designed for a winter population of 16 expeditioners, nine persons conducting scientific experiments and seven support staff. Concordia pioneers an advanced concept in Antarctic operations, the integral self-elevating building, and introduces a new generation of regular, long-range logistic traverses.

1.1 – Why Dome C *(Figure 3 page 8)*

Dome C was originally selected for glaciological research: a substantial layer of ice, about 3,200m thick, offers great potential for climatic reconstruction of the last 500,000 years. But Dome C has other valuable characteristics that support the installation of a permanent scientific station:

- Dome C is located inside the polar vortex where the ozone hole can be detected in the austral spring.
- The Antarctic Plateau is a well recognised, favourable site for astronomic observations due to its geographic location and its extremely dry, cold and rarefied atmosphere.
- Dome C, far away from any marine perturbations, is an ideal place for studying Solid Earth Geophysics, especially seismology.
- Dome C, at 3,200m above the continental crust, is protected from any magnetic perturbations by earth crust anomalies and is an ideal place for studying magnetism.
- Dome C is as a very isolated site with severe climatic conditions. It will be an excellent site for evaluating techniques and procedures for future work on other planets. It is also an excellent site for studying small groups of people in conditions close to those encountered in space vehicles or orbital stations.

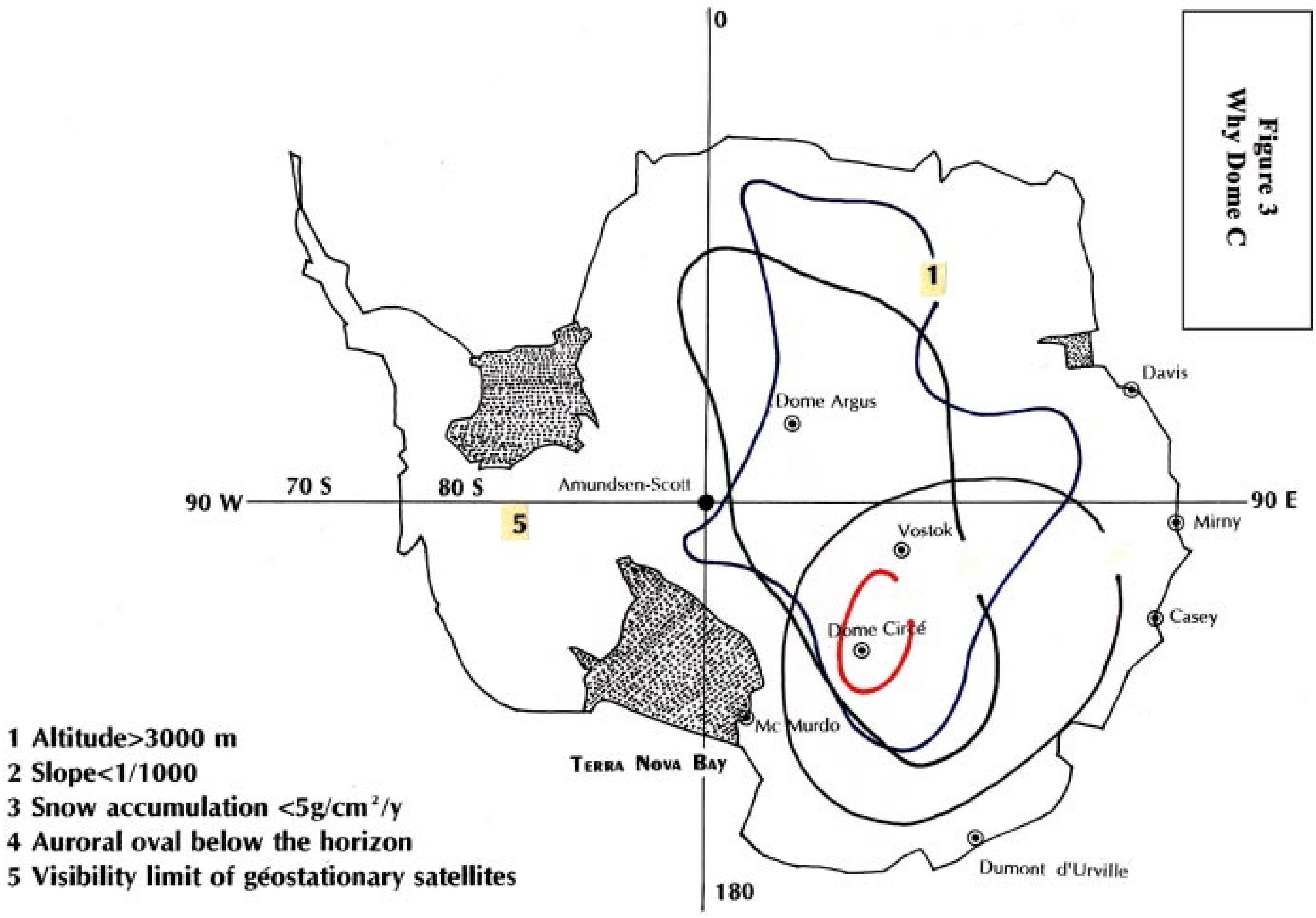


Figure 3
Why Dome C

1.2 – The Dome C Site

Dome C is located at 75°06'South and 123°23' East, 950 km inland from Banzare coast, at 3,200 m altitude on sub-horizontal ice ground with no crevasses. There is no local fauna or flora. While the closest station is Vostok (Russia) 560 km away, the closest coastal stations with good shipping access are well over 1,000 km away. Dumont d'Urville (France) and Casey (Australia) are about 1,100 km away to the North over the ice cap while Terra Nova Bay (Italy) is about 1,200 km away to the East behind the Transantarctic mountain range.

Meteorological conditions are characterised by low wind speeds, low precipitation - 2 to 10 cm of snow per year - and low temperatures. 14 years of Automatic Weather Station (AWS) records by the University of Wisconsin show an average wind speed of 2.8 m/s (5.4 knots) and an average temperature of –50.7°C (-59.3°F) with a minimum of –84.6°C (-120.3°F). Typical summer monthly average is around –30°C (-22°F) and typical winter monthly average around –60°C (-76°F).

1.3 – CONCORDIA, a French-Italian Project

The project of a new research station at Dome C was initiated by the French Antarctic Program operator 'Expeditions Polaires Françaises' (EPF) in the 1980s. The initial, general financial and technical study of the project was completed in October 1991 by EPF's engineering department. It covered the station at Dome C, the transport system and the coastal base camp. At the same time the Italian Antarctic Program (PNRA) through its operator (ENEA - Progetto Antartide) expressed its interest in developing scientific and technological research in the Antarctic and in taking part in the Dome C project. The interest of collaborating on such a project was evident and an agreement was signed on 9 March 1993 between ENEA-Progetto Antartide and EPF's successor Institut Français pour la Recherche et la Technologie Polaires (IFRTP). This agreement establishes the two national operators as equal partners in the construction and operation of the station at Dome C, now named 'CONCORDIA'.

2 - TRANSPORT SYSTEM

There is an important need for cargo transport in addition to personnel transport. The initial construction of Concordia Station and the conduction of the associated European drilling program EPICA require the delivery of some 2,800 tonnes of heavy equipment including bulk fuel. After commissioning, Concordia will require every year for routine operation the delivery of some 300 tonnes of equipment and supplies and the retrieval of several tonnes of waste and reformed equipment.

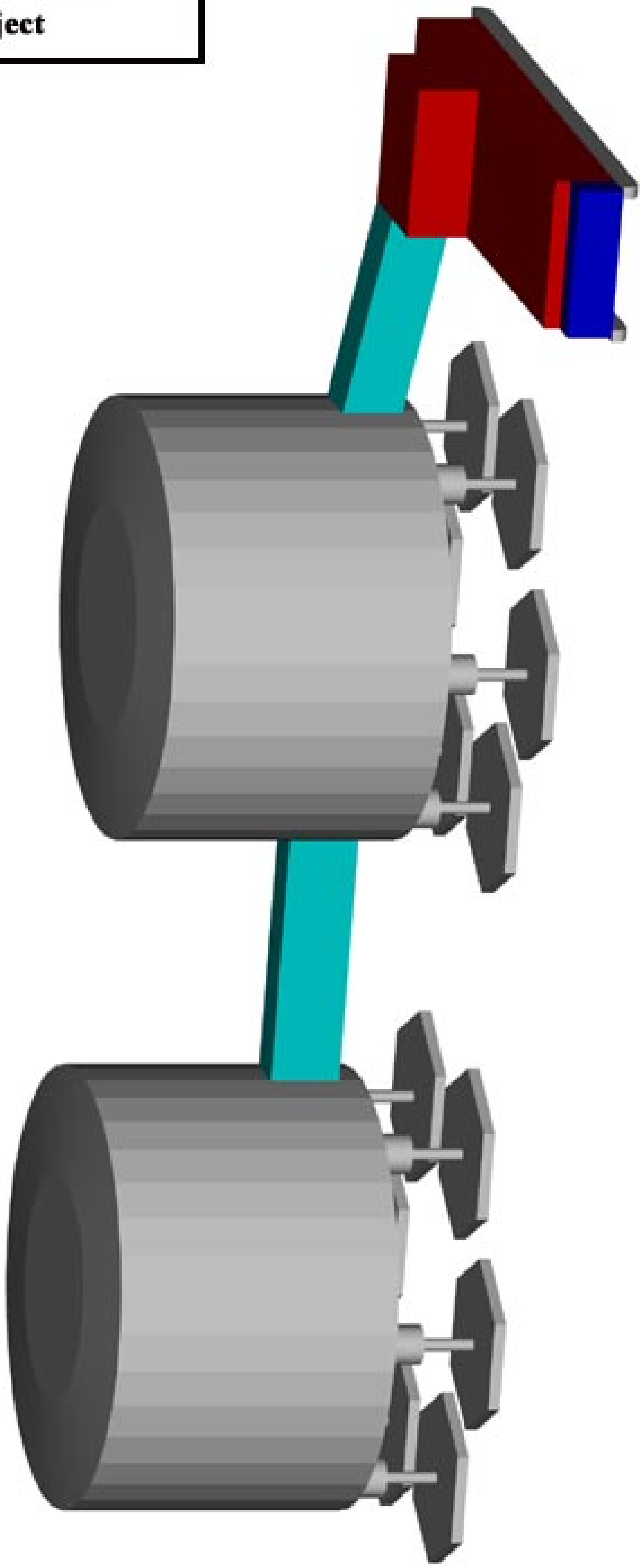
Three main means of transport are available on the Antarctic plateau:

- For heavy loads: heavy aircraft and surface 'traverses'
- For light loads, including passengers: light aircraft

2.1 - Heavy Loads: Traverses

Despite its potential speed of deployment and high service frequency the heavy aircraft option was ruled out because of its high cost and higher risks. The solution chosen was the organisation of a new generation of regular, heavy, long range traverses between Dumont d'Urville and Dome C, a run of some 1,100 km requiring a 20 to 25 day round trip.

Figure 4
Concordia Station
Project



Two different, complementary types of tractors were selected in collaboration with international experts then adapted to their use in traverses. New sleds and trailers, mobile fuel tanks, living units and workshops were designed, tested and fine-tuned. Advanced navigation systems were designed to speed up traverses and icrease safety.

The resulting surface transport 'traverse' system is now fully operational and has proved its efficiency and reliability over several seasons. *It is described in the appendix 'Informations on the traverse system set up for servicing the Dome C site'.*

2.2 - Light Loads and Passengers: Aircraft

Personnel and selected light cargo are transported to and from Dome C by a ski equipped Twin Otter aircraft operating out of Terra Nova Bay on the triangular route Terra Nova Bay – Dome C – Dumont d'Urville. The Twin Otter, has on the distance considered (1,000 to 1,200 km), a useful payload of 1 tonne. Some 40 twin otter flights are received each season at Dome C on a 3,000 m levelled snow runway.

Travel in and out of Antarctica for Dome C personnel is primarily by air between Christchurch in New Zealand and either Terra Nova Bay or McMurdo station and secondarily by sea between Hobart in Tasmania and Dumont d'Urville.

3 –STATION DESIGN *(Figure 4)*

3.1 – General Concepts

The initial, essential requirements and primary solutions were:

- Personnel saftey, obtained through the use of materials and equipment well tested in very low temperatures and through redundancy of vital components.
- Personnel comfort, obtained through a clear separation between areas where noise is produced and areas where peace and quiet are wanted.
- Low Operational Costs, obtained through low fuel needs.
- Easy on-site Assembling, obtained with light elements and simple, rustic assembling methods.

Two solutions were considered:

1- Underground construction
2- On or above ground construction

The underground construction has been the most widely used solution. It takes advantage of the good insulation properties of snow and reduces snowdrift problems. But the heat generated by the building slowly melts the surrounding snow. The building has to deal with a large amount of moisture on its external skin, slowly starts to sink into the snow and becomes subject to increasing pressures that finally crush it.

The above ground construction solution was chosen to provide the station with a long life span. The meteorological conditions of the site are well known which allows satisfactory evaluation of insulation requirements.

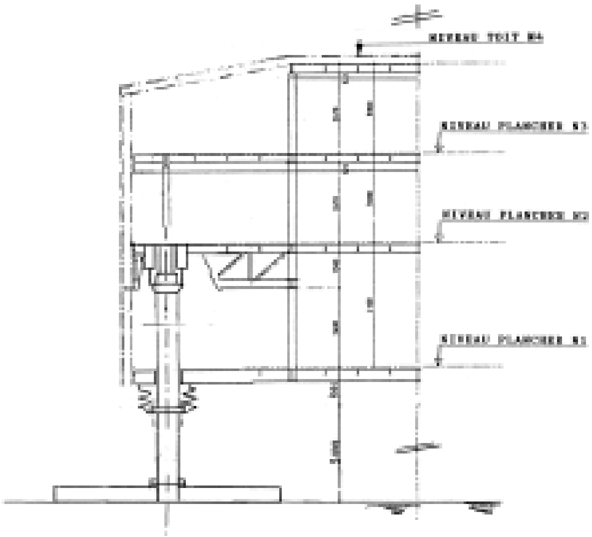


Figure 5: Legs and Jacks

Figure 6: Legs and Jacks

Concordia Station consists of one core of three 'winter' buildings flanked by a summer camp that also acts as emergency shelter. All structures are on or above ground. Two of the three winter buildings are unique integral self-elevating buildings forming the station's main living and working area. The third winter building housing the main energy and mechanical services, the summer/emergency camp and all satellite installations are all modular units set low over ground on skids. These units can be towed away to avoid progressive burial by snow accumulation.

3.2 – Main, 'Self-Elevating' Buildings

3.21 – Building concept : The two main buildings are elevated, faceted vertical cylinders with 18 faces and 3 floor levels. The roof may support observation skylights and external scientific equipment. Each building is supported by six legs or piles. Each leg is sitting on a large 'footing' pad spreading the load over the snow. Each leg can move up and down relative to the body of the building via a hydraulic jack ***(Figures 5 and 6)***. A leg can be jacked up relative to the building and snow packed under its footing. Once all six legs have been subject to this operation the body of the building can be raised above the new ground surface by jacking the legs back down relative to the body. This allows the entire structure to leap frog its way up over the ice as the ground level rises with snow accumulation.

The originality of this design is to make the entire structure upwardly mobile to preserve its integrity. The usual jack-up building design widely used is based on the body of the building sliding upward along fixed legs. As snow accumulates and the ground level rises, an increasingly longer section of the legs is entrapped underground and subject to differential movements of the ice. This progressively ruins the foundations and ultimately deforms the legs to the point of preventing further jacking-up operations. The self-elevating design adopted for Concordia requires a heavier, sturdier structure to allow for the variations in structural loads during elevation operations but guarantees long-term integrity of the building structure.

3.22 – Layout: The two buildings will be connected at Level 1 by an aerial intercommunication tunnel about 10 m long. This solution provides a clear separation between areas where noise is produced and areas where peace and quiet are wanted by locating them in two well separated buildings, the "noisy" and the "quiet" buildings. It also allows to separate the activities with high fire risk (kitchen, workshops) from the living quarters. Normal access to the buildings is through the aerial tunnel. Both buildings have an emergency exit. An outside deck all around each building along level 2 will facilitate maintenance operations.

The buildings are designed for 16 personnel over winter, nine persons running scientific programs and equipments, five technical support personnel, one medical officer and one chef. Scientific programs will be integrated to maximise scientific output. Occupancy will double for about a month during the annual change-over period. Each room will include a second folding bed for use during change-over.

3.23. - Structure: ***(Figure 7 and 8 page 14)*** outlines the structure of a building. Level 2 constitutes the master structure supported by the piles. It forms with level 1 a frame providing wind-bracing for the whole building by taking horizontal loads. Levels 3 and the roof are built over level 2 and will be braced to take local wind loads induced by the supports of the lateral envelope.

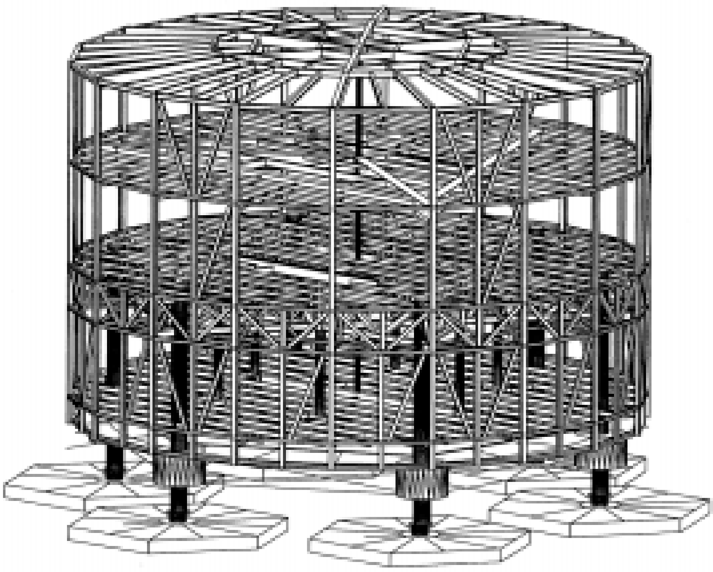


Figure 7: Main building steel frame

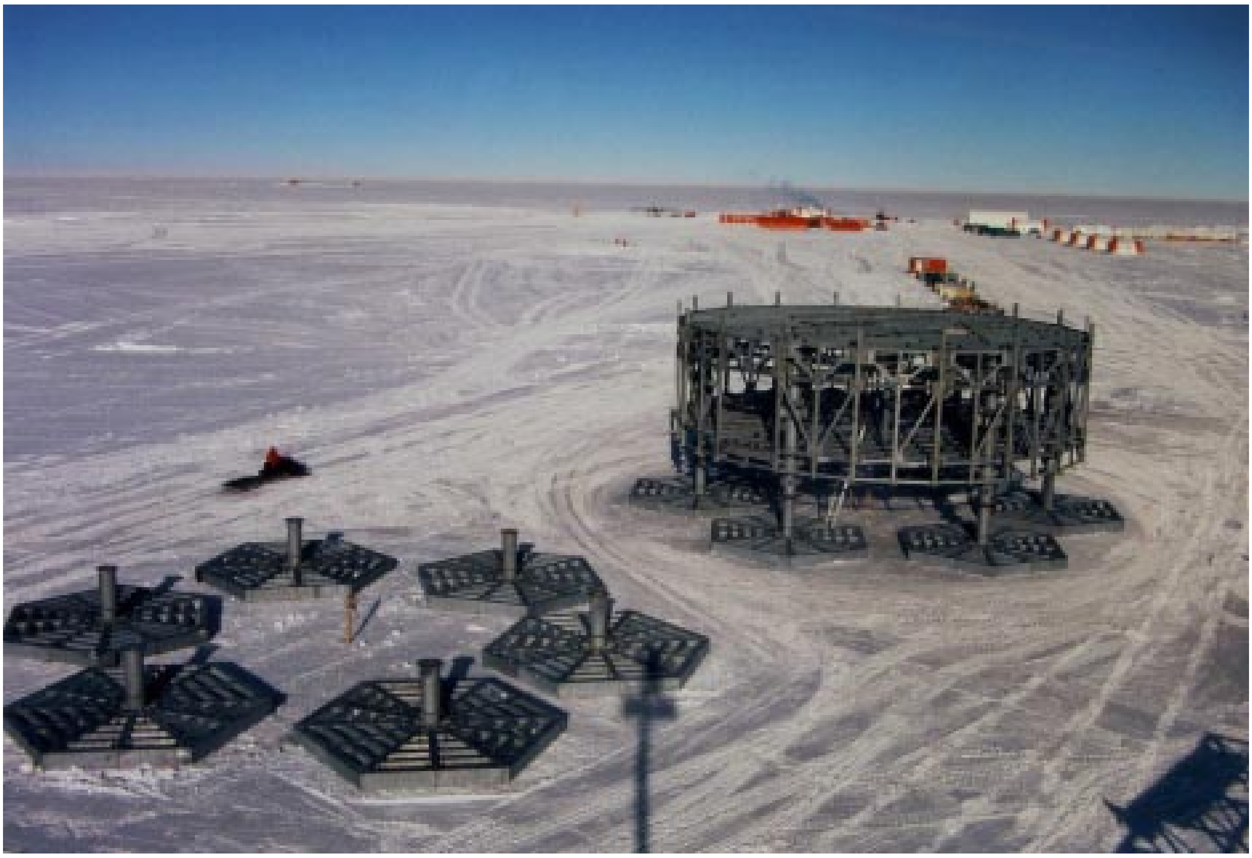


Figure 8 : Main building Steel Frame

Sizing of the structure will follow metallic framing rules. It was shown that for use in such temperatures the cheapest satisfactory material was still E24-2 steel. The structure design complies with the special case regulations specified both by the guideline AFNOR A36-010 and by the Technical Office for the Use of Steel (Office Technique d'Utilisation des Aciers -OTUA-) and was controlled and accepted by the controlling agency SOCOTEC.

The frames are galvanised to avoid further surface treatment and all beams are articulated at their extremities to avoid stress concentrations generated by interlocking joints. No welding is required on site and high resistance bolts are used for all joints.

3.24 – Envelope: The envelope is made of external panels attached to the structure and kept independent from each other. The panels are 160mm panels made of M1 polyurethane foam sandwiched between polyester sheets. Substantial seals keep the whole envelope water and air-tight. ***Figure 9*** shows how envelope panels are attached to the building structure. It allows the transfer of wind loads to the building structure, leaves the panels independent and allows thermal expansion of the building structure which can experience a 70°C temperature differential between the end of the construction and the heating of the building to its nominal operating temperature.

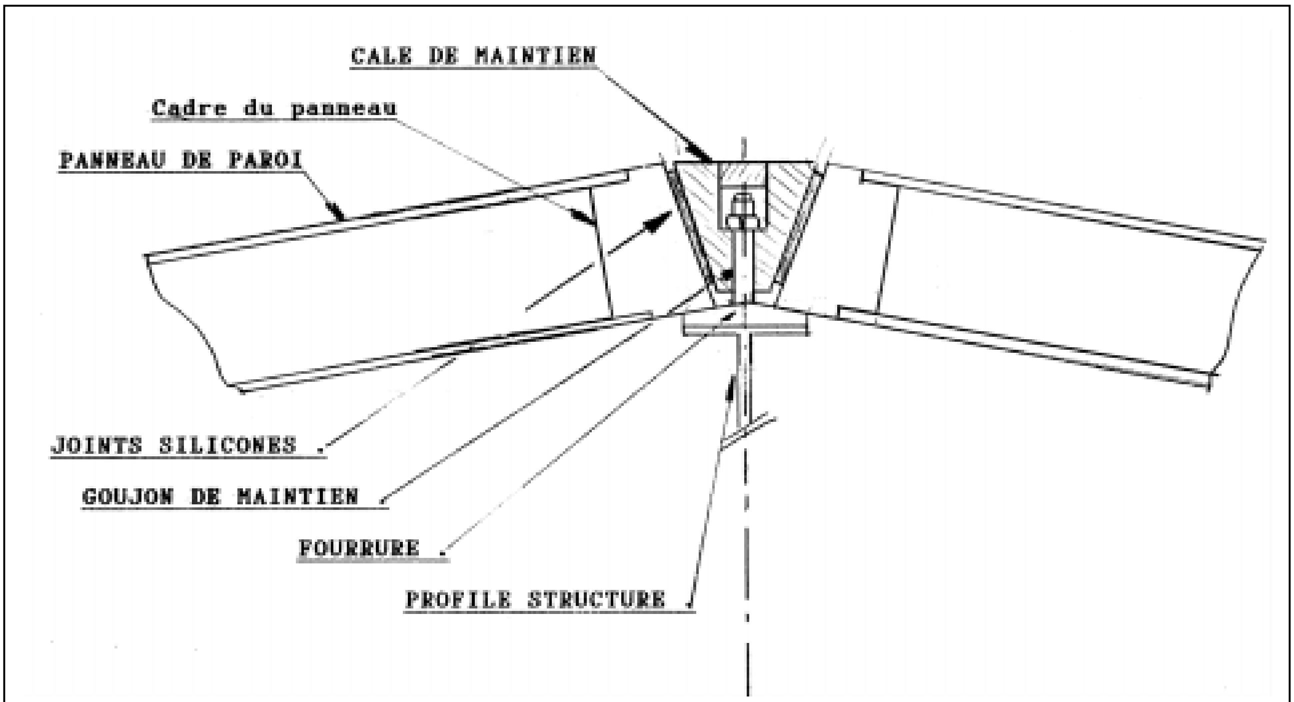


Figure 9:Panel and Frame

3.25 - Legs: Each building is supported by 6 legs set on 6 hexagonal pads about 6 m in diameter and 0.5 m thick. When the building is in operation the pads will exert on the ground a pressure of about 15.7 kPa (160 g/cm^2 or 2.3 psi). An insulating disc is inserted in each leg to break the thermal bridge where the leg crosses the envelope of the building (at Level 1).

In normal operation, each pair of jacks (1 pair for each leg) will be isolated and its hydraulic pressure monitored from the station's central alarm panel. The horizontal stress that could be induced by the drifting of a pad will also be monitored from this alarm panel.

Figure 10
level 1 - quiet building

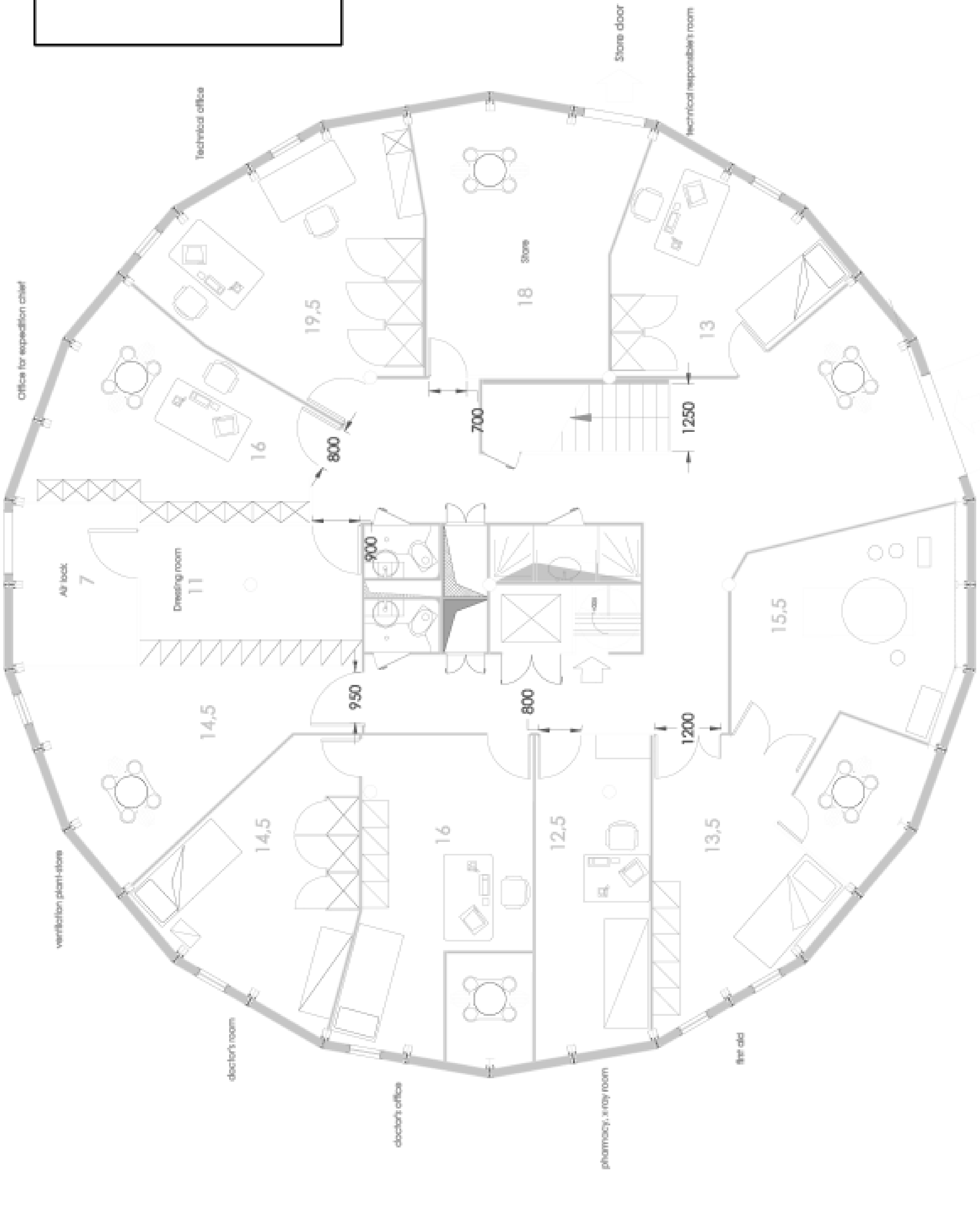


Figure 11
Internal layout
level 2 - quiet building

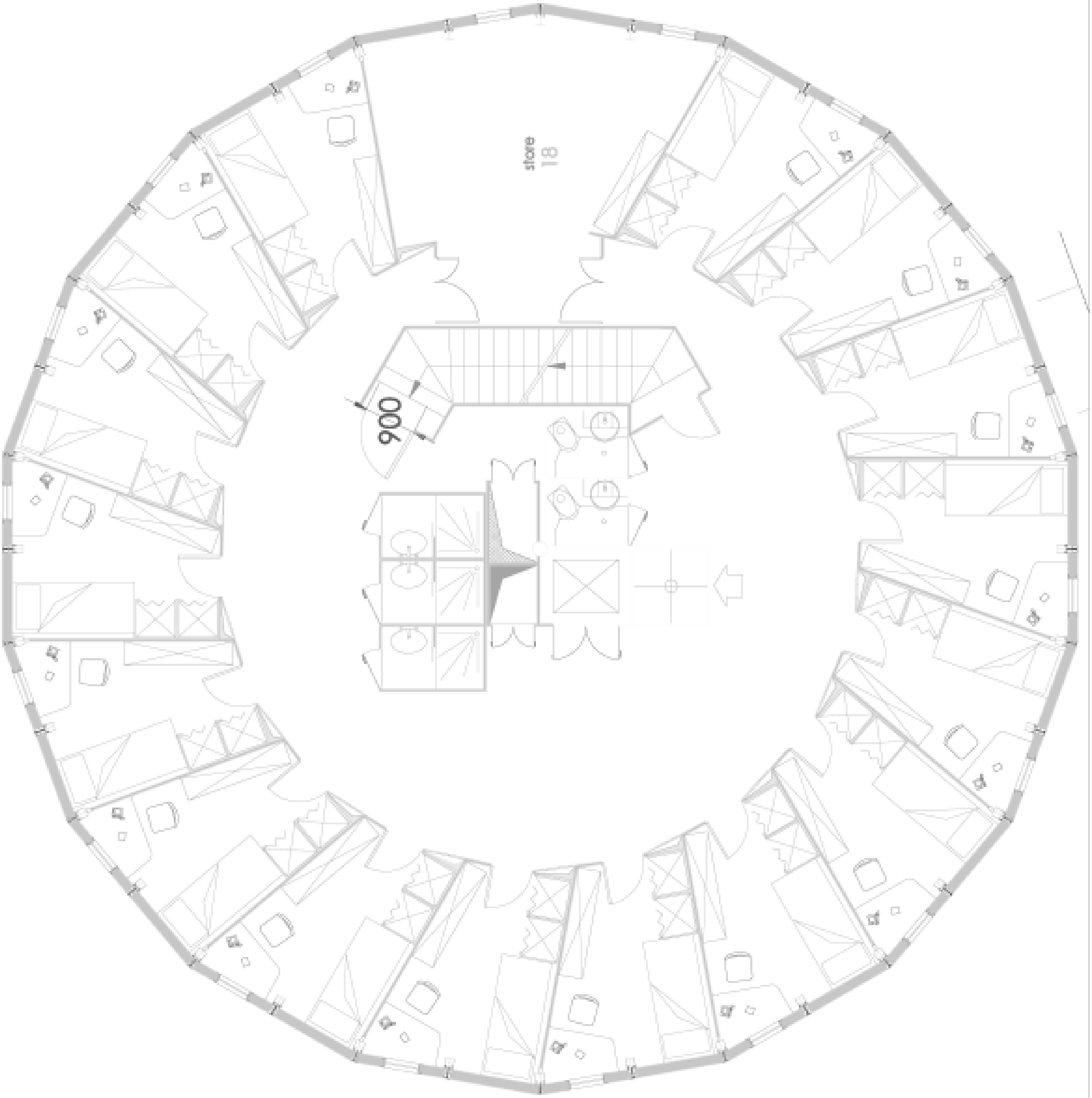


Figure 12
Internal layout
level 3 - quiet building

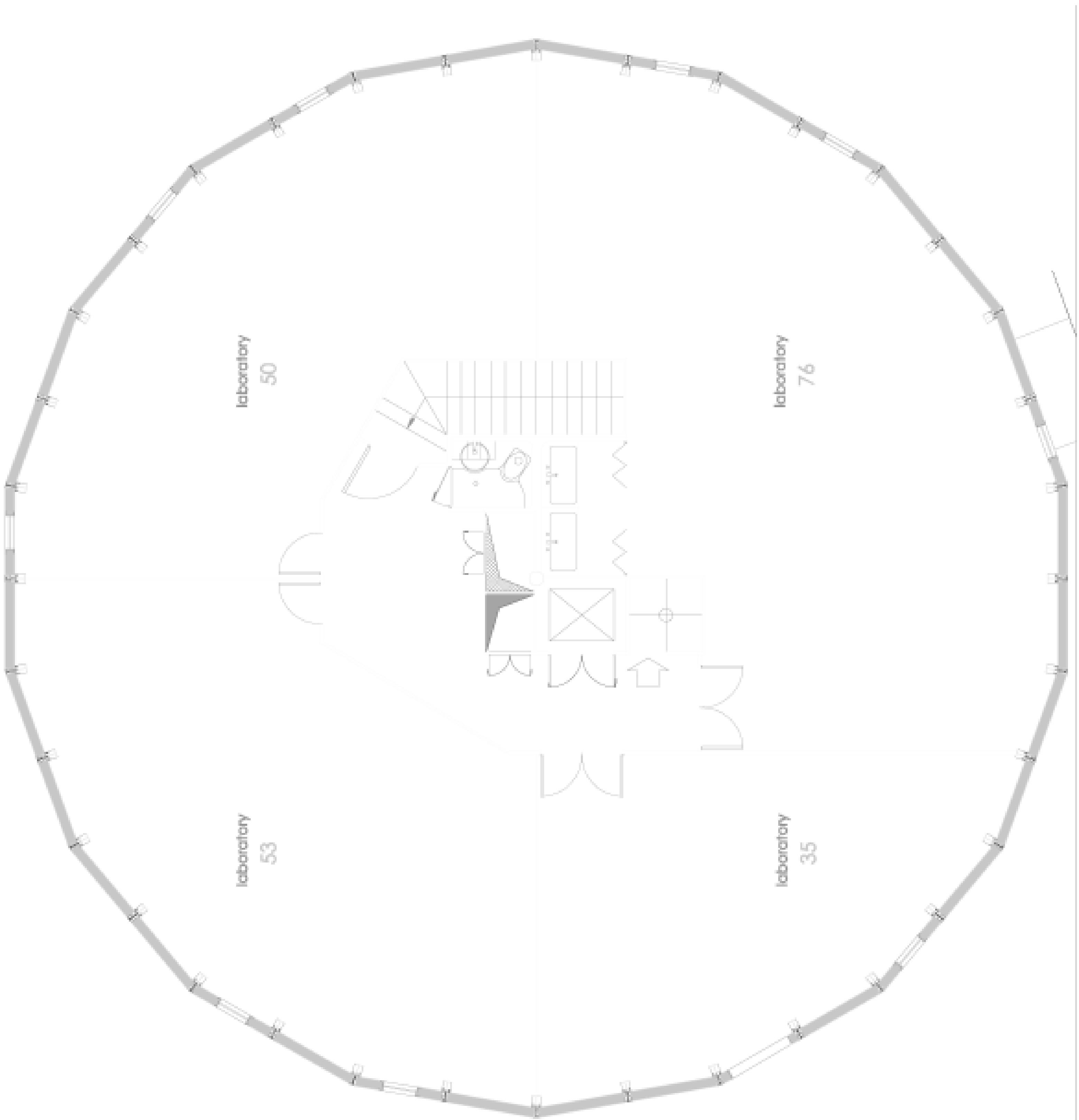


Figure 13
Internal layout
level 1 - noisy building

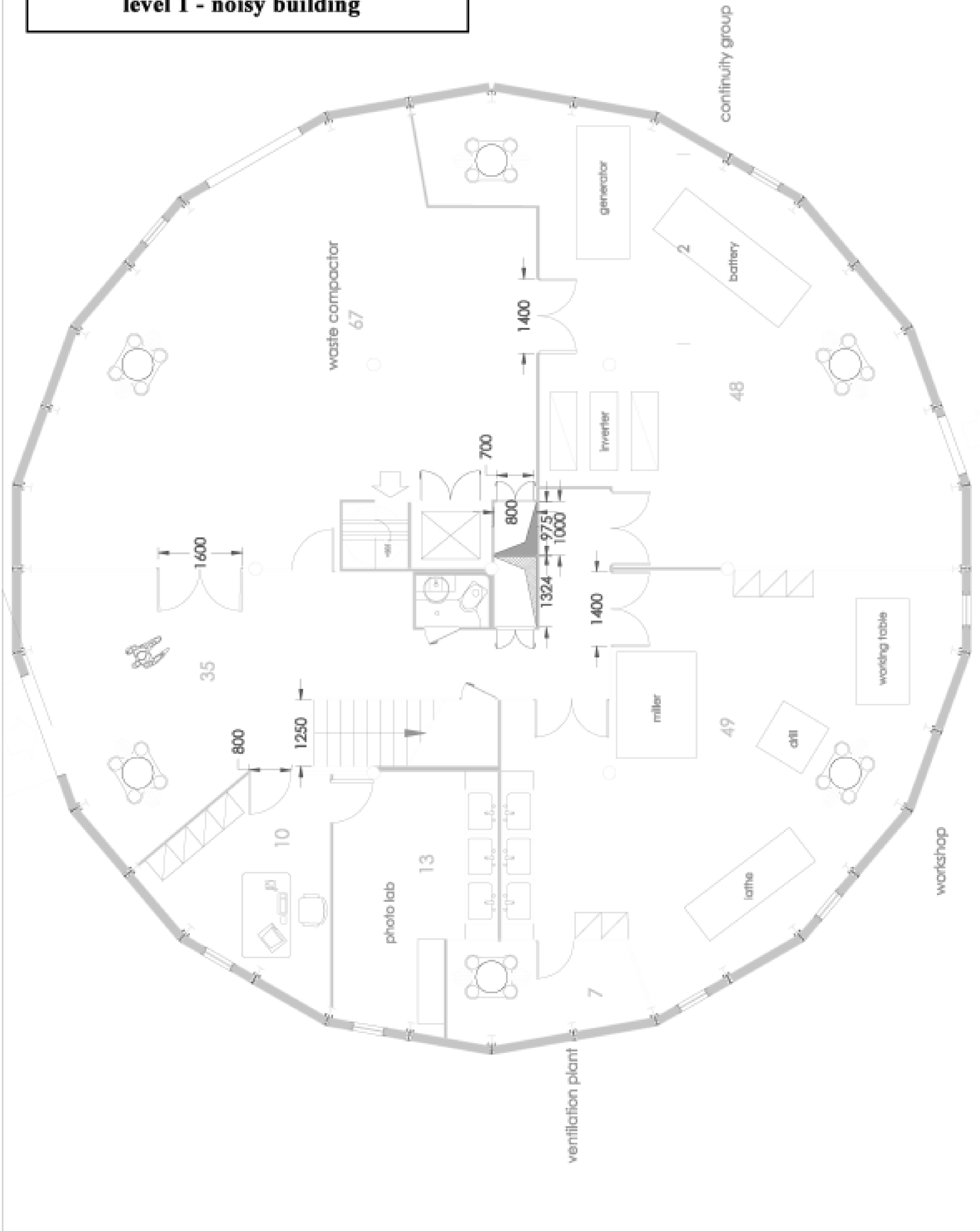


Figure 14
Internal layout
level 2 - noisy bulding

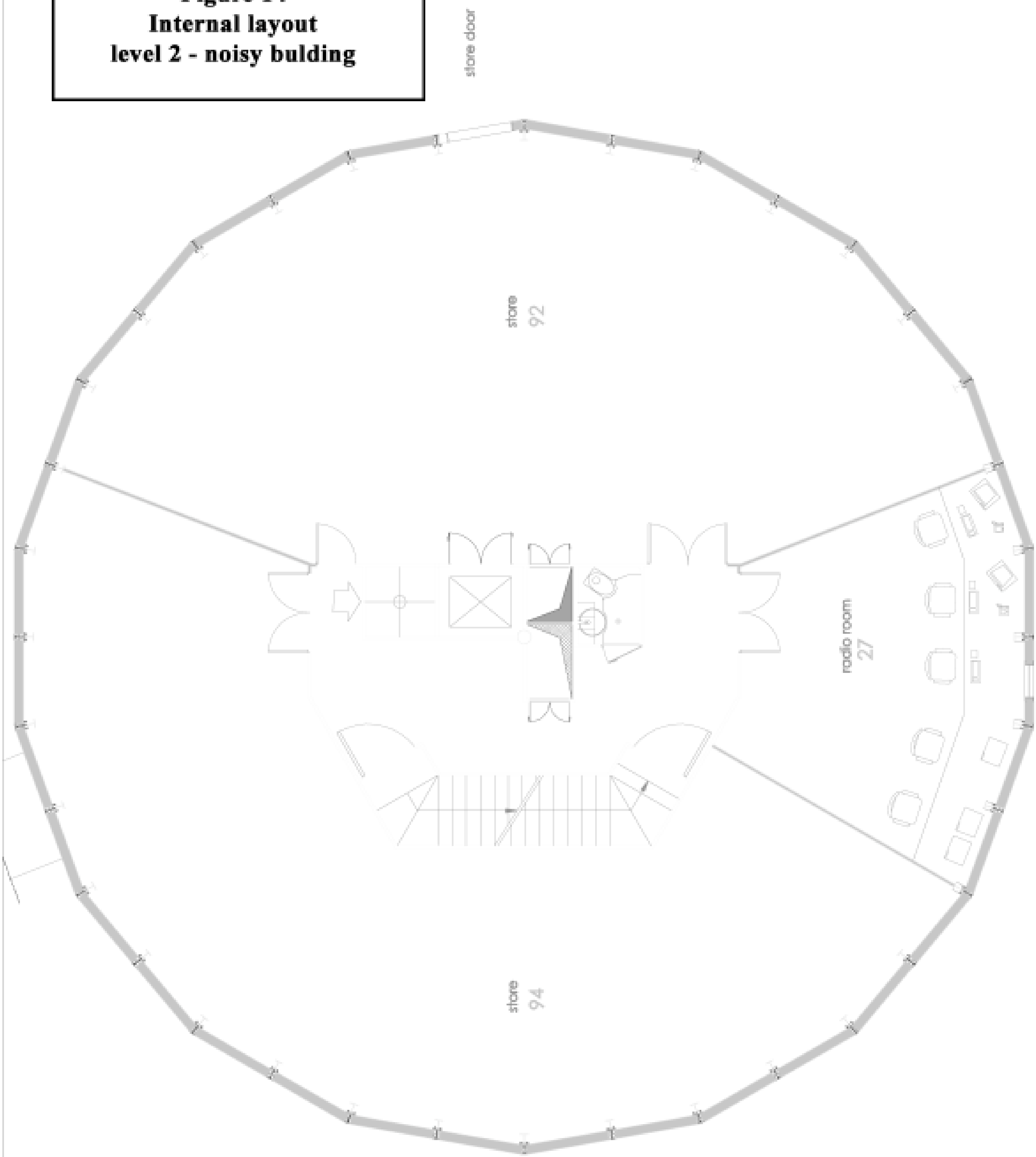
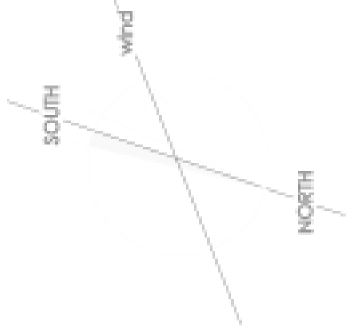


Figure 15
Internal layout
level 3 - noisy building



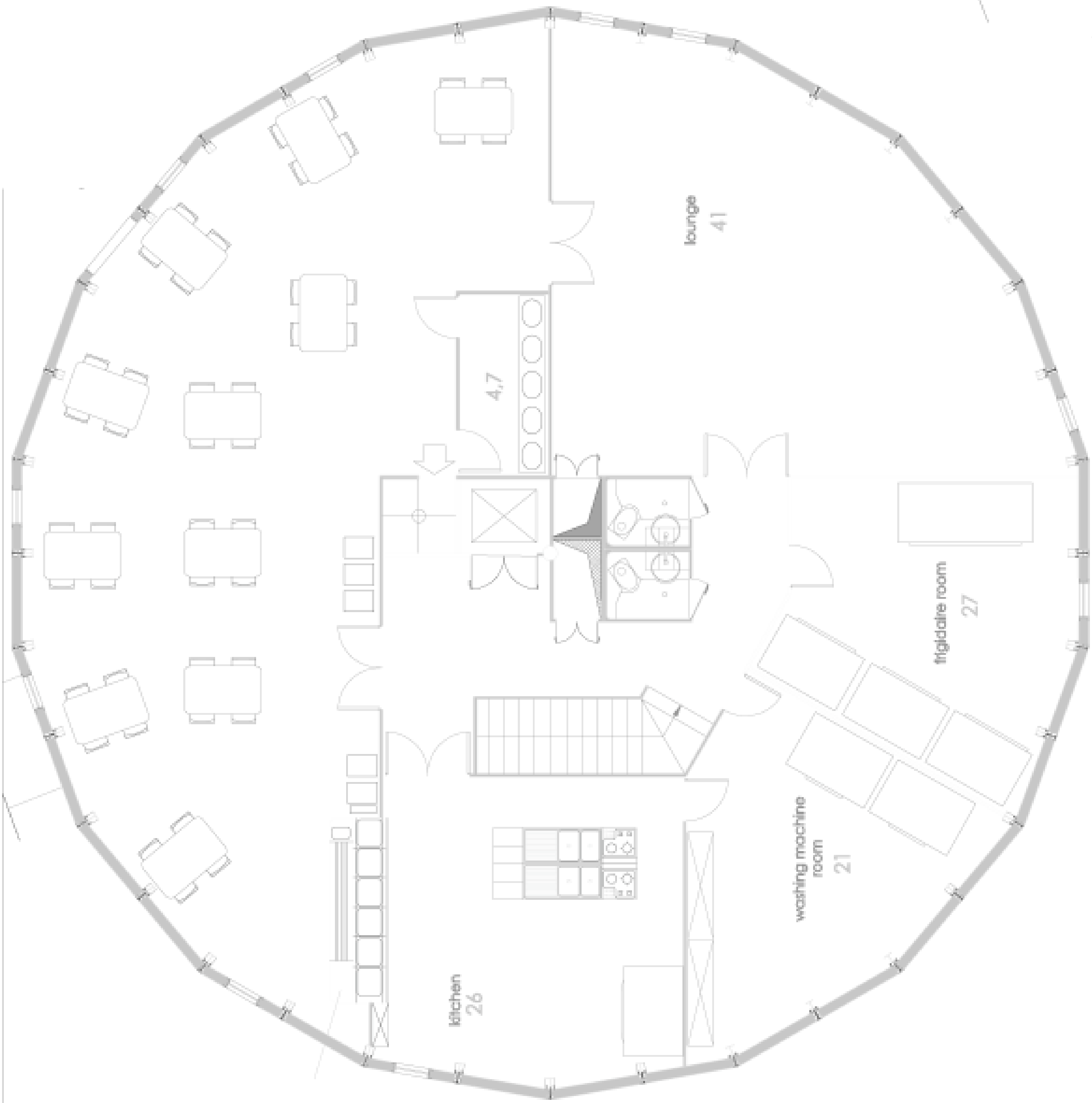


Figure 16
Power station units
schematic transversal section

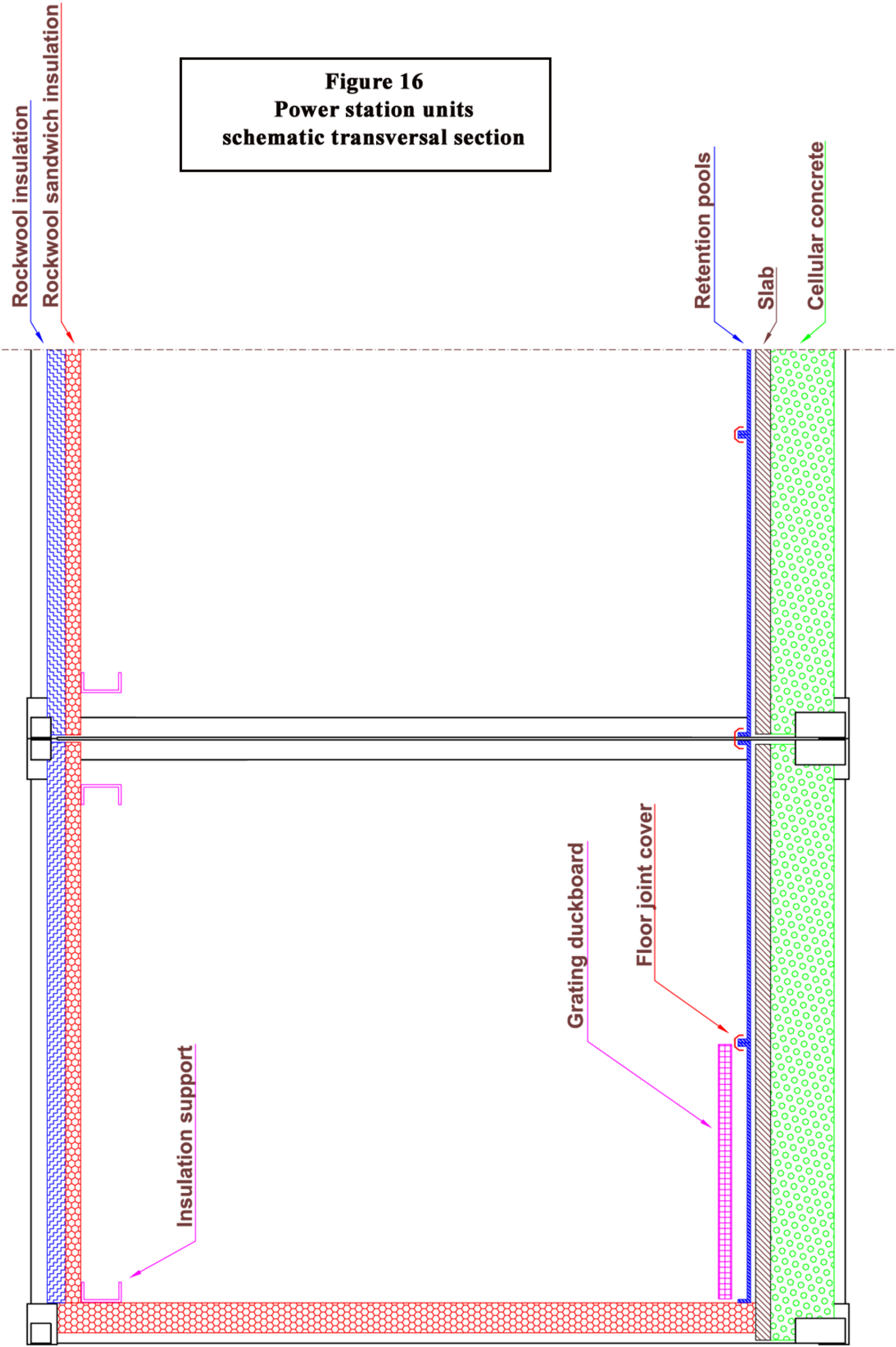
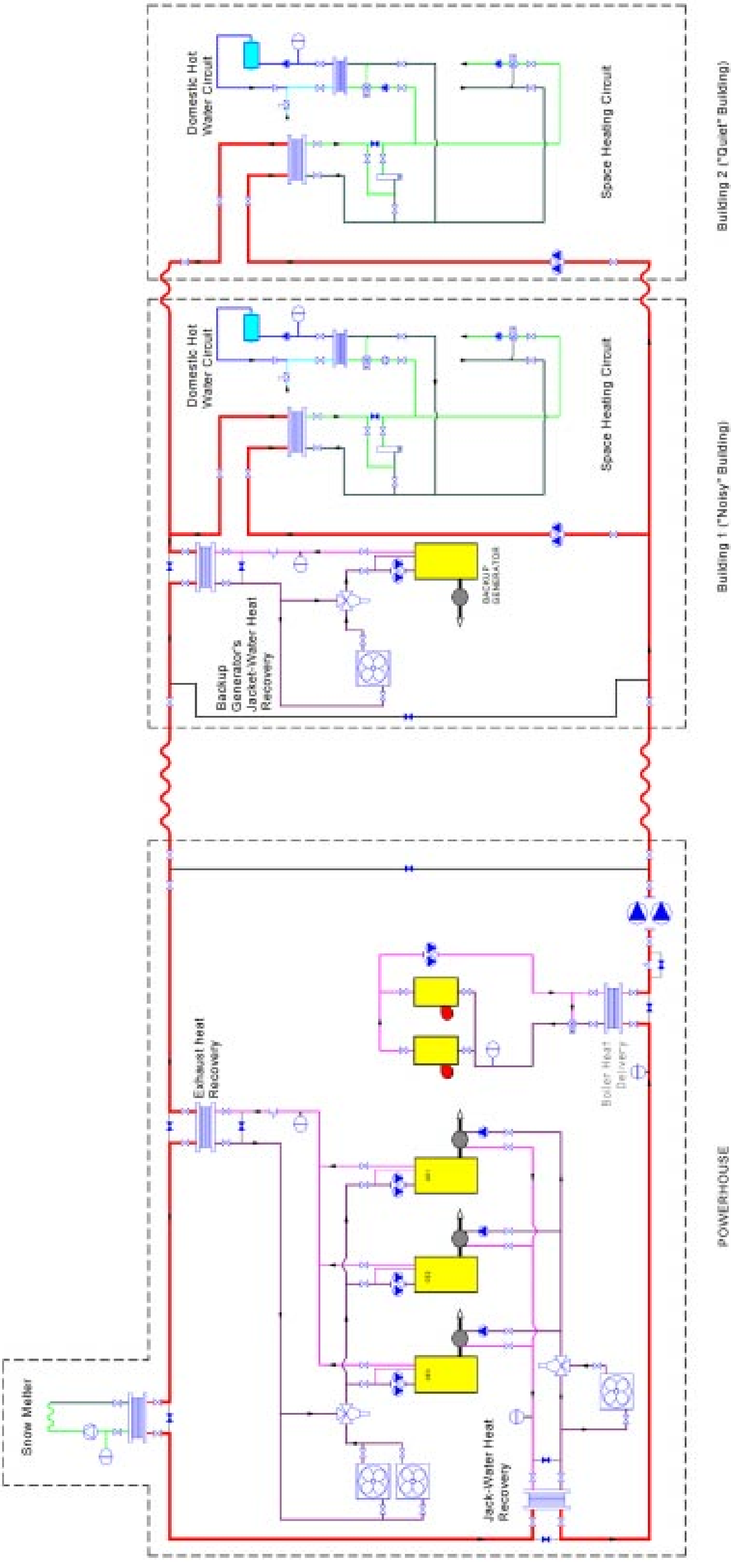


Figure 17 : power station - heating hot water circuits



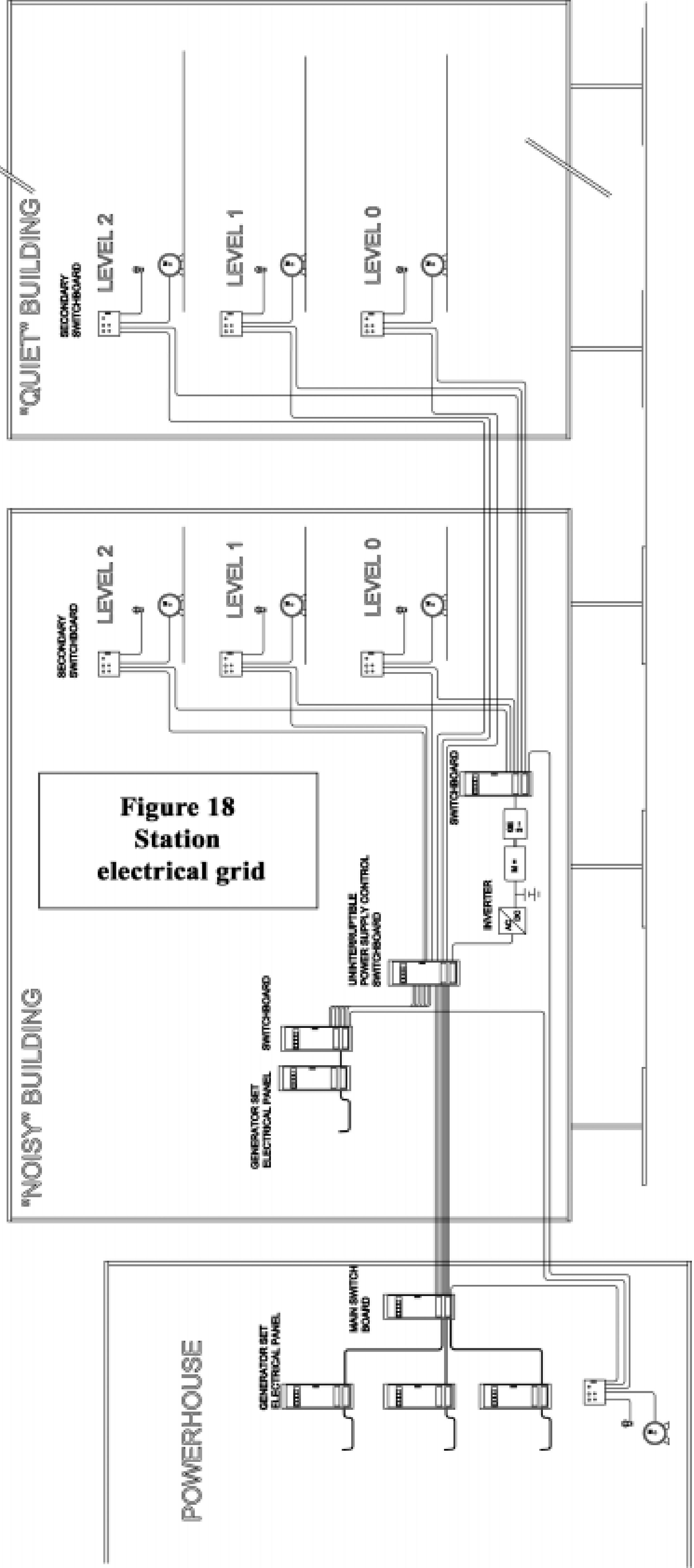


Figure 18 Station electrical grid

3.26 - Indoor Fittings: Dividing walls will be made of modular panels classified M0, in steel/rockwool or similar type. Internal layout configuration is shown on ***Figures 10 to 15, pages 16 to 21***. The dividing walls between scientific laboratories are not represented.

<u>3.3 – Power Module</u> *Figures 16 page 22, 17 page 23, 18 page 24 and 19 page 26)*

The 'Power Module' is the third building completing the core station besides the two main, self-elevating buildings. It is a two storey modular building mounted on skis and composed of ten modules on the first level and five modules on the second level. Being on skis, the building can be towed away from time to time to level the snow drifts and grade the ground back to its original level. The power module includes the main power generation, water production and water regeneration installations.

3.31 – Power: Power services use standard, reliable technologies in a simple, streamlined system. The core station's power module will include boilers and three 140kVA generator sets capable of delivering 110kW electrical under Dome C's low atmospheric pressure conditions. Only one of the three generator sets will be needed at any time. Engine heat is recovered for station heating and snow melting with the boilers satisfying any additional heating requirements. Annual fuel consumption is expected to be around $250m^3$ or 200 tonnes of Diesel fuel to meet average electrical and heating loads around 100 and 75 kW respectively. The power generation and energy management systems are described in the appendix 'Concordia Power Systems'.

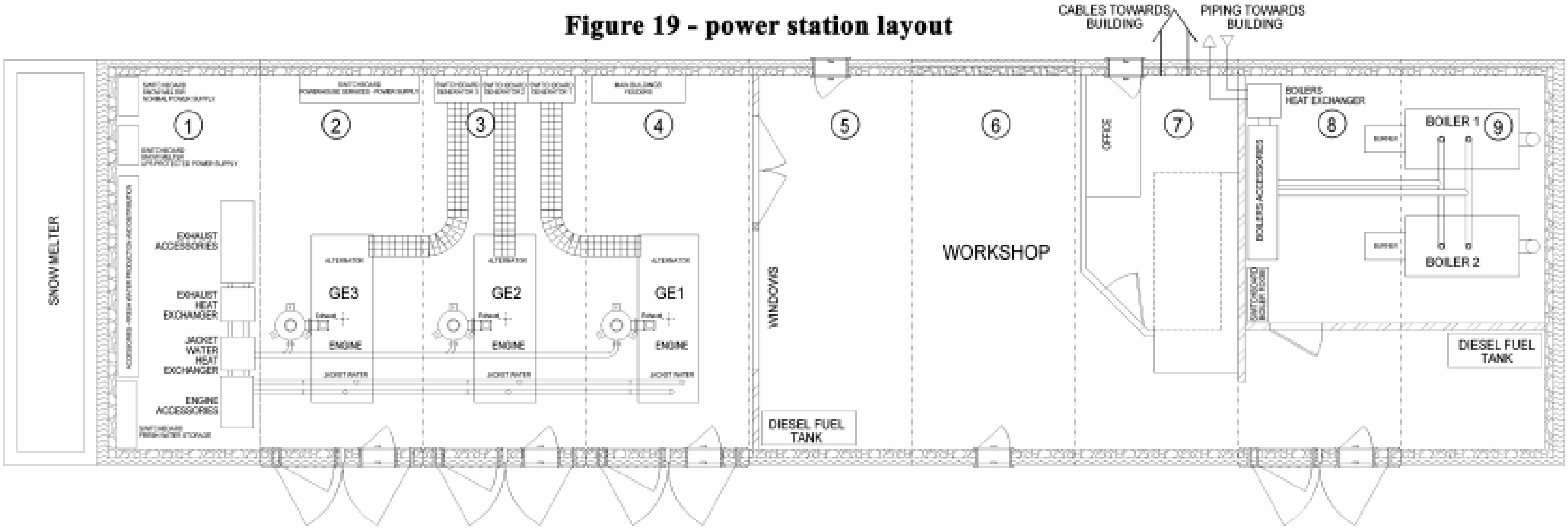
3.32 – Water: "Primary" freshwater will be produced by melting snow in summer when there is excess heat available and stored outside in mobile, temperature regulated tanks. Insulation of the tanks will be calculated so that the heat produced by the 200 W immersed circulating pump used to break the thermal gradient can maintain a temperature above 0°C in the peak of winter.

Waste water will be treated through a regeration process allowing the recovery of 90% of the water as "secondary" freshwater complying with 'potable water' standards. The water regeneration unit will be capable of treating 3,000 litres of waste water per day with a second unit kept as back-up. To avoid possible psychological problems only 'primary' water will be supplied to the kitchen and 'drinking taps' while 'secondary' water will be supplied to all other services.

The daily requirements for the entire station are estimated at 300 litres of "primary" water and a combined maximum of 3,000 litres. Excess 'secondary' water would be disposed of in the ice at some distance of the buildings. The water regeneration process will limit the quantity of wastes to be repatriated and will minimise the quantity of energy required to produce 'primary' water.

Water mixed with noxious chemicals is not fed into the water regeneration process. This water, estimated at about 10 litres per day, will be stored and repatriated.

Figure 19 - power station layout



3.4 - Fire Safety and Alarms

In terms of fire protection, the station will primarily follow the principles of preventive safety. Materials and services will limit the risks of fire ignition and combustion and each room will be monitored with a combustion gas detector linked to a centralised control panel.

A network of alarms will also monitor the operation of technical installations (powerhouse, ventilation, space heating, UPSs, hydraulic jacks...) and important parameters (room temperatures, local circuit breakers status...)

4 - ENVIRONMENT

A strong emphasis was placed on minimising the risks of physical and chemical pollution, in excess of SCAR and Antarctic Treaty recommendations and regulations, with an additional emphasis on minimising the impact on scientific observations.

Recommendations of SCAR XIII and XIV are fully followed, and in addition:

- Fuels and lubricants used do not contain heavy metals and have low sulfur components
- Condensation of exhaust gases from the power house trap sulfuric acids
- All sludge from the water regeneration process is stored then repatriated
- Most other waste is not incinerated but rather stored then repatriated

4.1 - Waste Management

4.11-Waste Products Classification

Waste Group N°	Waste Group Denomination	Description
1	Waste of human or organic origin	Food scraps, excrements, kitchen and laundry effluents
2	Liquid chemicals	Photographic processing chemicals, lubricants, solvents
3	Solid, combustible	Timber, cardboard, paper, plastics, rubber
4	Solid, non combustible	Cans, batteries, empty drums, used spare parts, Glass, heavy metals, copper and alloys, scrap metal,
5	Radioactive waste	None
6	Medical waste	Reformed drugs, medical consumables (needles, bandages...)
7	gaseous effluents	Fuel combustion gases from powerhouse and vehicles

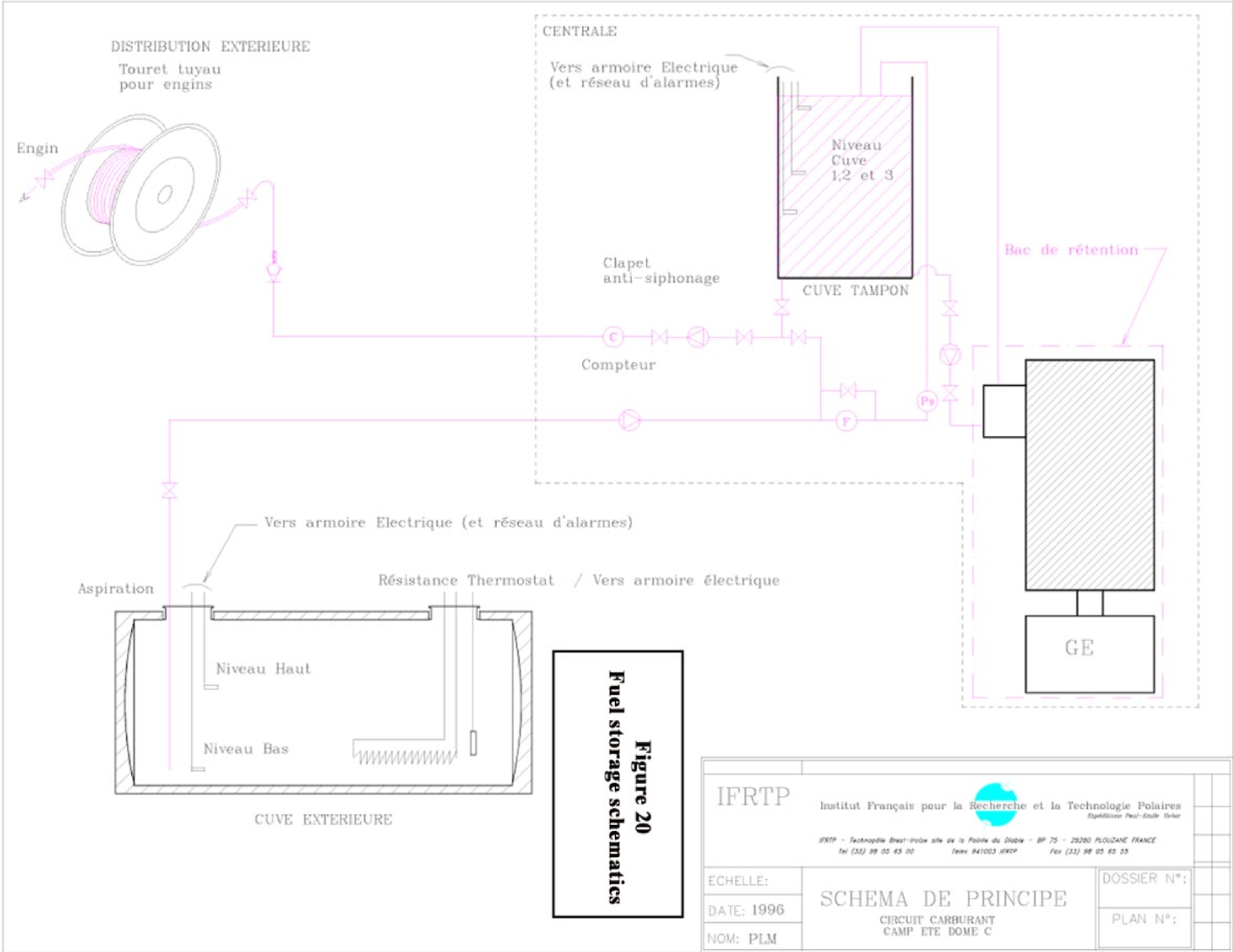


Figure 20
Fuel storage schematics

4.12 -Waste Quantities and Disposal Methods

Waste Group	Waste Type	Yearly Quantity	Processing and Disposal
1	Sludge from water regeneration Sludge from food scraps	8 t 6 t	Storage then repatriation following summer "
2	Photogaphic chemicals Lubricants Solvents	60 kg 1 t 200 kg	" " "
3	Timber and by-products Plastics, rubber	2 t 15 t	On site incineration Grinding, compacting and repatriation
4	Various non combustible solids	3 t	Storage and repatriation
5	Radioactive waste	*-none-*	*-not applicable-*
6	Medical waste	100 kg	Storage and repatriation
7	Gaseous effluents	*-see text-*	filtration, then rejection in the atmosphere

4.13 - Compactable Waste: Compactable waste will be temporarily kept in a dedicated store in one of the two main buildings, then transferred outside on sleds for repatriation by traverse.

4.14 - Non-Compactable Solid Waste: Non-compactable items such as used spare parts will be stored outside on sleds for repatriation by traverse.

4.15 – Sludge: The sludge resulting from the water regeneration process will be stored then repatriated in mobile 20 m^3, double envelope, insulated storage tanks kept at constant temperature by a 200 W electrical heating element.

4.16 – Lubricants: Synthetic lubricants which last longer than mineral lubricants will be used both in the powerhouse and in vehicles. This will reduce the quantities to be stored and transported. Used lubricants will be stored in dedicated tanks (2 or 3 tanks of 1m^3 capacity), then repatriated.

5 – SATELLITE INSTALLATIONS

5.1 – at Dome C

5.11 - Fuel Storage ***(Figure 20 page 28)*****:** Fuel will be stored in mobile, double envelope steel tanks mounted on skids. The tank depot will be at some distance of the buildings with only one tank kept at any one time next to the buildings to feed the generator sets and boilers. Rotation of the tanks will be made with a tractor kept on site.

The double envelope prevents leaking with the inner space between the two envelopes constantly monitored. Tank volumes are limited to 20 m^3. The tanks are safe ‘top tanks’ with no fill, draw-off or drain at the bottom of the tanks to prevent leaking from a faulty tap or ruptured connection and additional valves making it impossible to extract fuel by simple siphoning-off. Top fill and draw-offs are grouped on a plate mounted on one of the two manholes..

20 months worth of fuel will be stored at the station at the beginning of each winter to allow normal operation during a full year plus an additional winter. The maximum volume of fuel stored on site (summer camp excepted) will be about 440 m^3 stored in 22 tanks of 20 m^3 capacity.

5.12 - Water and Sludge Tanks: As for the fuel tanks, water and sludge tanks are mobile, insulated and heated safe ‘top tanks’ kept in a depot at some distance of the buildings and towed towards the buildings when needed. Station needs in primary water will be about 80 m^3 for the entire winter period stored in four 20 m^3 tanks.

The annual production of sludge, after concentration, will be around 20 m^3. There will be a total of three 20 m^3 sludge tanks, one kept near the main buildings for filling, one kept at the summer camp and one in transit between Dome C and the coast.

5.13 - Construction Camp: The construction camp will be identical to the mobile units used to accommodate traverse personnel. The emergency base capable of housing all personnel in case of major problem will be composed of:

- An accommodation unit for 15 persons, with 7 regular twin rooms plus a room for the doctor and a possible patient
- A kitchen + bathroom unit.
- A restaurant unit.
- A communication unit.
- A powerhouse unit housing 2 generators of 140 kVA.
- Two tents on metal structure ("Weatherhaven") used as construction workshops (braziery, woodwork, plumbing).
- Emergency hospital rooms.

5.14 - Emergency Generator: An emergency generator set similar to those used in the main power module will be kept in the first floor on the < noisy > building.

5.15 - Vehicle Garage and Workshop: A mobile vehicle garage and workshop will be installed in an insulated tent mounted on a platform set on skids. Vehicles up to 15 tonnes can be loaded on the platform. The tent will be heated by a boiler to maintain a minimum temperature of -20°C and provide +15 to +18°C during interventions on vehicles. This tent will be recycled from the equipment used by the construction team

5.16 - Summer Camp: The summer camp can an any one time accommodate 40 persons. Summer personnel can stay at Dome C anything between a few days and 3 months. Most summer personnel will be personnel working on the deep ice drilling project with a team of up to 30 persons. Most of the remainder will be composed of scientists and technicians setting up or upgrading permanent scientific experiments or conducting specific summer programs. There can also be technical staff for specific building or maintenance operations. The capacity .

The summer camp doubles up as emergency camp for the winter. If the main buildings become unavailable during summer while the summer/emergency camp is ‘nominally’ full, personnel will squeeze in it until evacuation.

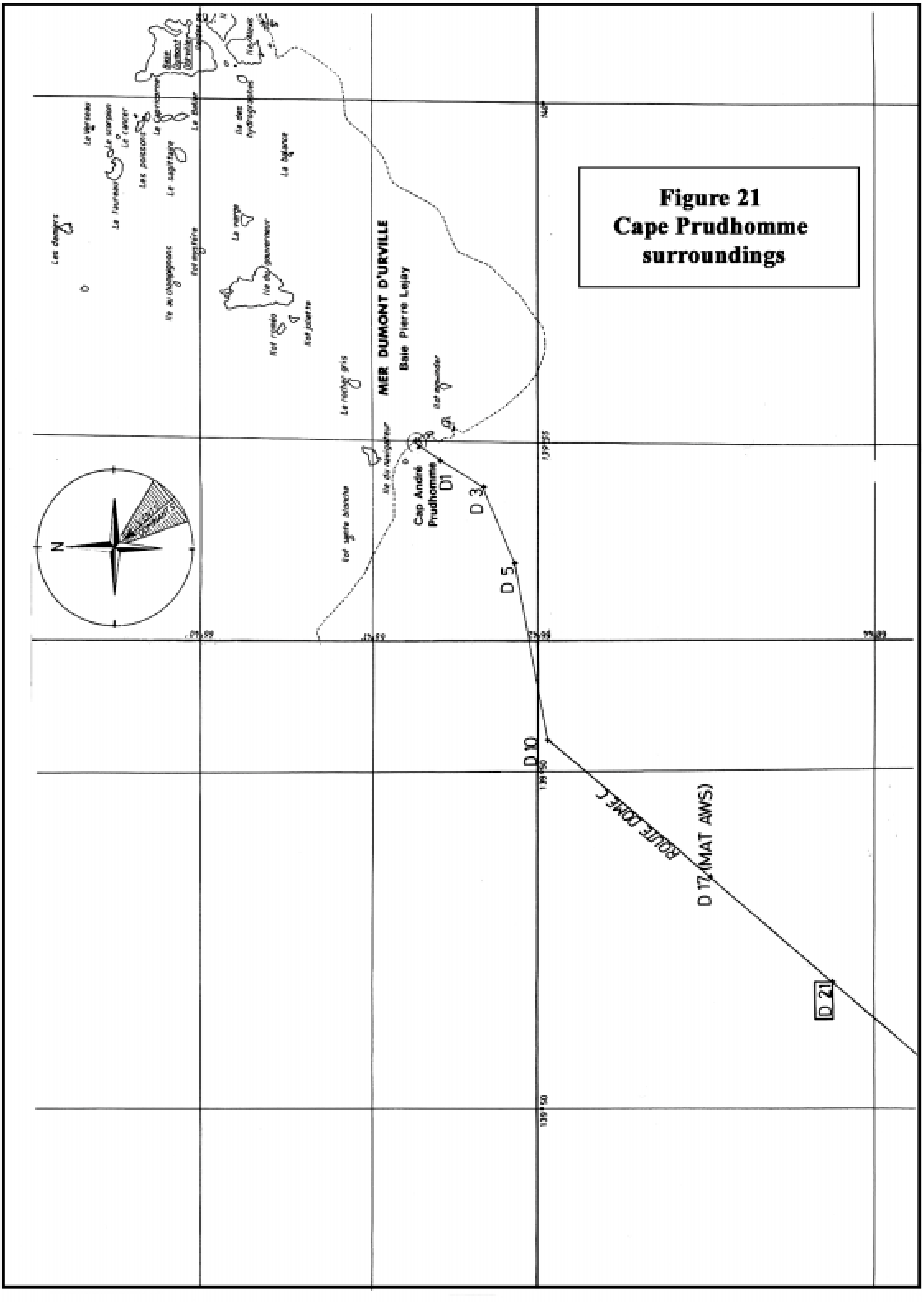


Figure 21
Cape Prudhomme surroundings

5.17 - Station Vehicles : The vehicles stationed at Dome C will include a towing tractor to move loads around the station and a light vehicle used by field parties to access remote sites.

5.2 - At the Coast *(Cape Prudhomme, 66°41' S - 139°55' E and D-10, 66°42' S - 139°50' E)* *- Figure 21 page 32 and 22 page 34 -*

Most of the Adelie Coast is made of 15 to 30 metre high, impassable ice cliffs, moving fronts of the ice cap that slowly flows into the sea. Near Dumont d'Urville Station the only possible access to the continent by surface transport is at Cape Prud'homme, five kilometres from the station. Cape Prud'homme is a rocky promontory which breaks the ice cliff front locally transformed in 25 to 30° ice slopes. In this region surface access has always been difficult and in the past some scientific programmes have experienced significant delays when it was becoming impossible to deliver heavy equipment through cape Prud'homme

The organisation of the Concordia project naturally forced to rethink surface access to the continent and devise specific solutions for the Cape Prud'homme site.

Cape Prud'homme is virtually the access seaport for Dome C and was equipped with facilities and infrastructures capable of dealing reliably and efficiently with the 2,800 tonnes of equipment to be transported to Dome C. This involved :

- Creating of an unloading wharf equipped with a fixed gantry crane for receiving shallow draught pontoons and barges
- Breaking the steepest part of the access slope by building a track on backfill
- Constructing a main building including a living area for the personnel in charge of handling the cargo, a main maintenance workshop and a powerhouse
- Building a fuel depot
- Erecting a second gantry crane on the ice at 'D3' for the loading of cargo onto the traverse vehicles (sleds, trailers…)
- Constructing a 'traverse store' building to store spare parts and provisions for the traverse convoys.

These installations were designed and constructed within the framework of the environmental impact study document "Construction and operation of a scientific station at Dome C, Antarctica" approved by the French Polar Environment Committee and presented in 1995 at the XIXth Antarctic Treaty Consultative Meeting (ATCM). In particular:

- The occupation of naturally exposed rock is limited to the main building and the fuel farm
- The need for locally quarried backfill in the first steep section between the wharf and the main building was reduced by the use of vehicles capable of climbing very steep snow and ice slopes
- When the gantry crane and other high power equipment are not in use the generator set is switched off and electricity for the main building is provided by a solar array composed of 8m^2 of photovoltaic panels. Heat is recovered from the generator set when running and contributes to the building's heating, reducing the fuel consumed in the boilers
- The toilets are incinerator toilets producing only safe, inert ash
- The 310m^3 fuel depot supplying the local Cape Prud'homme site, the traverse convoys and the Dome C site is made of double skin tanks (50m^3 fixed tanks and 20m^3 mobile tanks

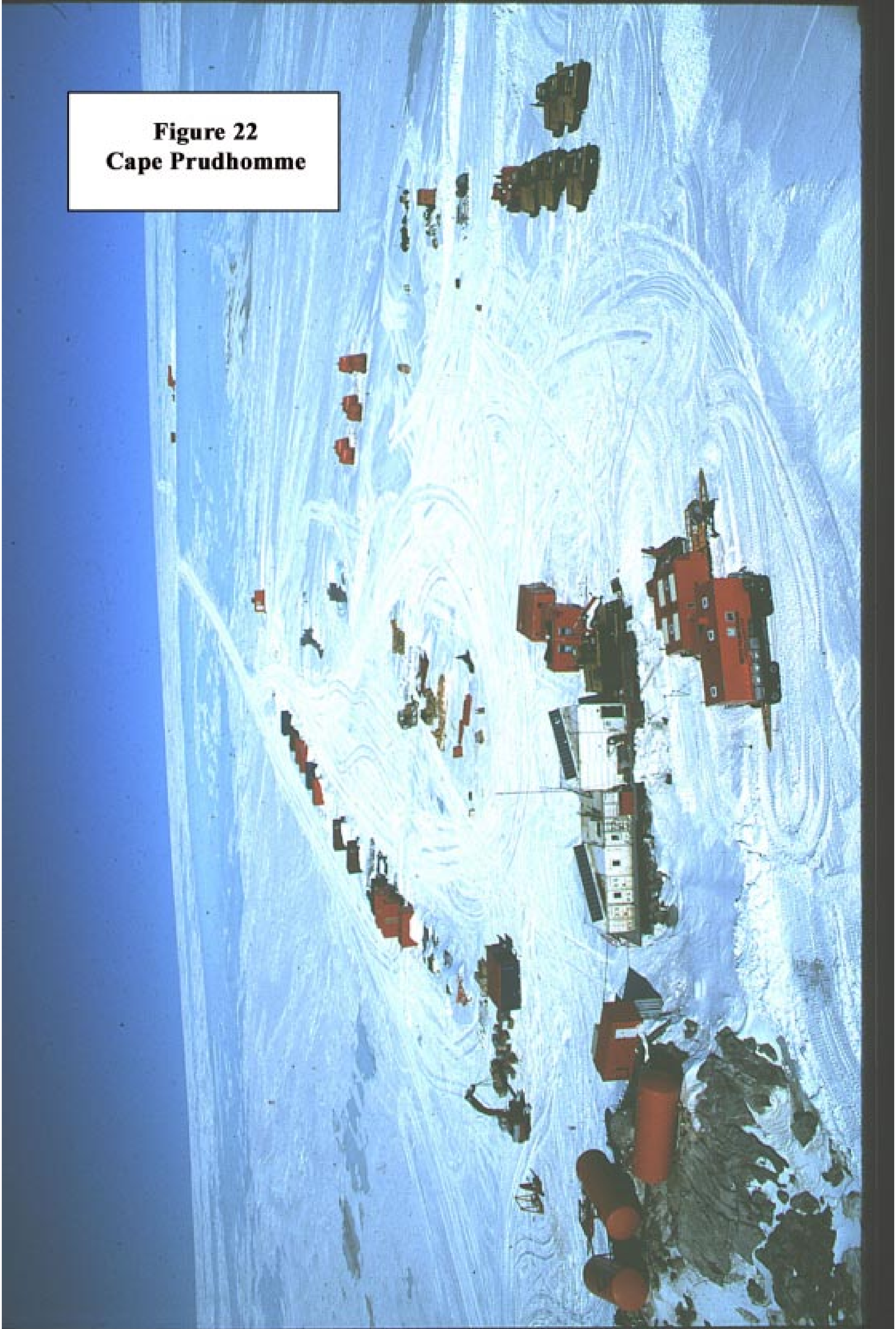


Figure 22
Cape Prudhomme

Figure 23: Cape Prudhomme main building

Figure 24: Vehicles' underground garage

Figure 25: Cape Prudhomme unloading zone

Above Cape Prud'homme is the zone called 'D10', a plateau of about 10 km^2 situated between the steep coastal zone and a zone of crevasses at the root of L'Astrolabe glacier. D10 harbours a skiway for twin otters and underground garages for the traverse vehicles.

5.21 – Main Building ***(Figure 23 page 35)*****:** Constructed progressively between 1992 and 1995 this main building is composed of eight 20 foot modules made primarily of steel and rockwool insulating panels. It includes four double rooms, a kitchen/restaurant area, an ablution area, a powerhouse, toilets, a technical room with the solar array control gear and batteries, a workshop and large external working platform.

5.22 – Traverse Store: Constructed in 1998 this building is also composed of eight 20 foot modules.

5.23 – Underground Garage at D10 ***(figure 24 page 35)*****:** Constructed in 1994 and 1995 this garage made of steel arches used for motorway tunnels provides a 324m2 shelter 6m wide by 54m long. It was built underground right from the start to avoid significant accumulation of snowdrift on surface and alteration of the site. It is used to shelter traverse tractors over winter.

5.24 – Ship Unloading Zone ***(Figure 25)*****:** The wharf and gantry allow the coming alongside and the unloading of the 'Flexifloat' pontoon (80m2 deck and 50 tonne capacity) and the 'Tanguy' barge (20m2 deck and 8 tonne capacity). The installation allows the handling of 20 foot shipping containers up to 15 tonnes. Loads exceeding this limit are, as in the past, towed ashore on the nearby 'beach' area.

5.25 – Traverse Loading Gantry Crane: This second gantry crane built at D3 allows the loading of the traverse vehicles in a much safer way than the usual cranes. The installation allows the handling of 20 foot shipping containers up to 15 tonnes. Loads exceeding this limit are, as in the past, towed onto trailers or sleds lowered into a pit.

5.26 – Storage Platform: This elevated storage platform built on the same principle that the platform at Dumont d'Urville allows the snow and snowdrift free storage of non-fragile equipment: sealed fuel and lubricant drums, compressed gas bottles, wooden beams, steel sections and bulky traverse vehicle spare components such as skis, tracks or engines.

5.27 - Coastal Fuel Depot: The coastal fuel depot is composed of three fixed 50 m^3 tanks and three mobile 20m^3 tanks, all double skin, as well as a set of the 12m^3 traverse 'tank-sleds' ready for the next traverse.