Power System for the Continuous
And Efficient Operation of the new CONCORDIA Station

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Background

The French Polar Institute IFRTP and its Italian counterpart ENEA are partners in the installation at Dome C of the permanent research station Concordia. The two organisations have designed a power system that will ensure the continuous, efficient operation of this new station on the Antarctic ice cap. The powerhouse building was entirely mounted in Europe then separated into modules shipped to Antarctica and about to be reassembled on site.

All buildings at Concordia Station are above ground. The two main buildings, Building 1 or "noisy" building and Building 2 or "quiet" building, are two cylindrical structures mounted on piles adjustable in height. Three storey high, these two cylindrical structures contain the research laboratories as well as the living and storage areas. The powerhouse is in a third, modular building mounted on skis. The building is composed of nine modules on a first level and two modules on a 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.

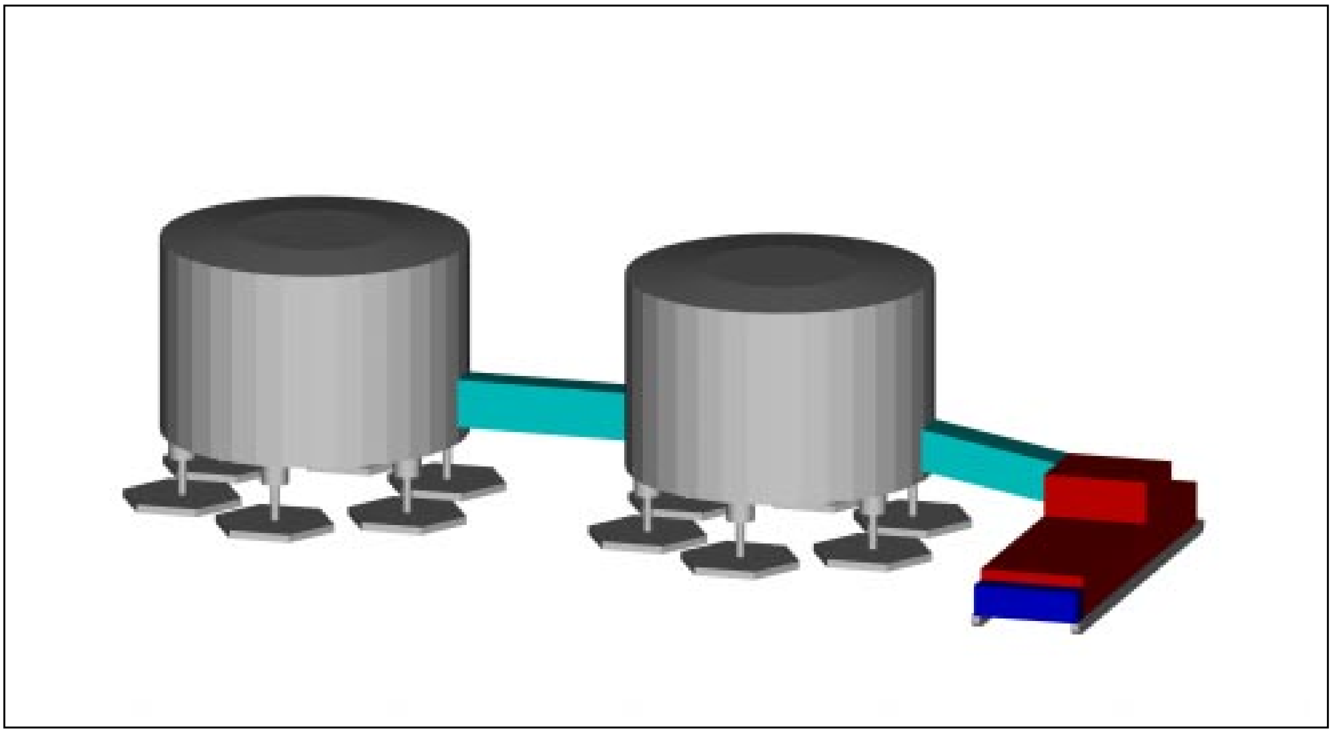

Figure 1 : Concordia station project

Power System Principles

The main design parameter for the station's entire power system was efficiency. The quantity of Diesel fuel consumed at Dome C must be strictly limited both to limit local impacts and limit the quantities of fuel to be transported long distance by tractor trains then stored on site. In normal operations the fuel demand is only driven by the electrical load and by the use of vehicles. All space heating needs are met using Diesel generator set's waste heat recovered from the jacket water cooling system and the exhaust.

The Diesel generator sets can deliver 110 kW electrical at 100% load under Dome C low atmospheric pressure conditions. At this load, manufacturer's specifications indicate that waste heat recovery on the jacket water will provide a similar power of 110kW thermal and recovery on the exhaust will provide a further 45kW thermal.

At full load, 155 kW of waste heat will be successfully recovered in the powerhouse and distributed inside the three station buildings through the heating circuit outlined in this poster. Additional heat will be generated within the buildings by all electrical appliances.

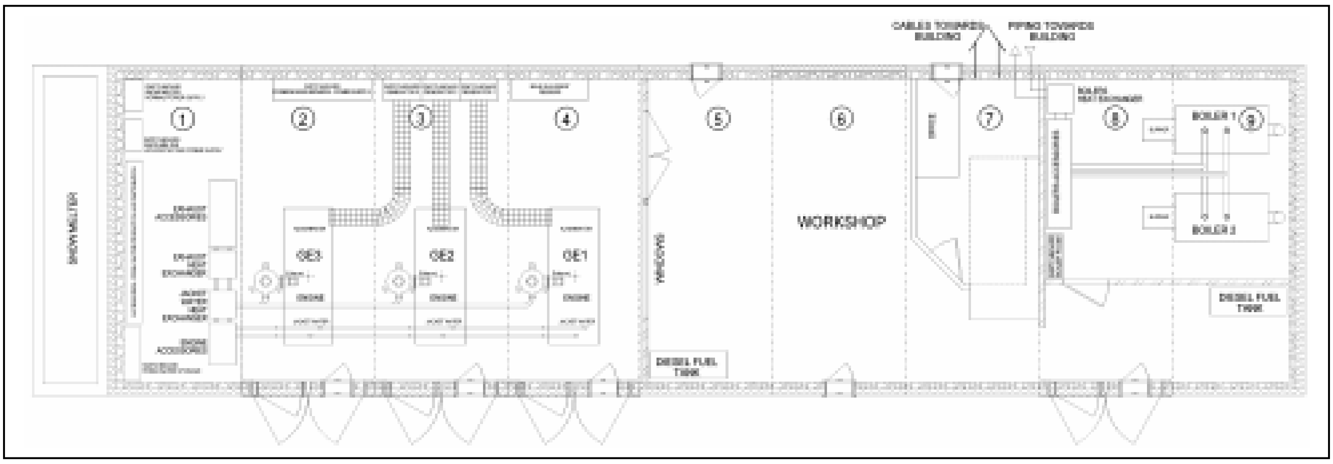

Figure 2: Power house fitting out

Operational simulations of this system indicated that a maximum heat loss of 70 kW for each of the two main buildings would allow the system to run normally without the need for additional heat to be generated in boilers. The external insulation and ventilation system were designed to ensure that heat loss will remain under 70 kW even under the most unfavourable conditions.

Heating Circuit

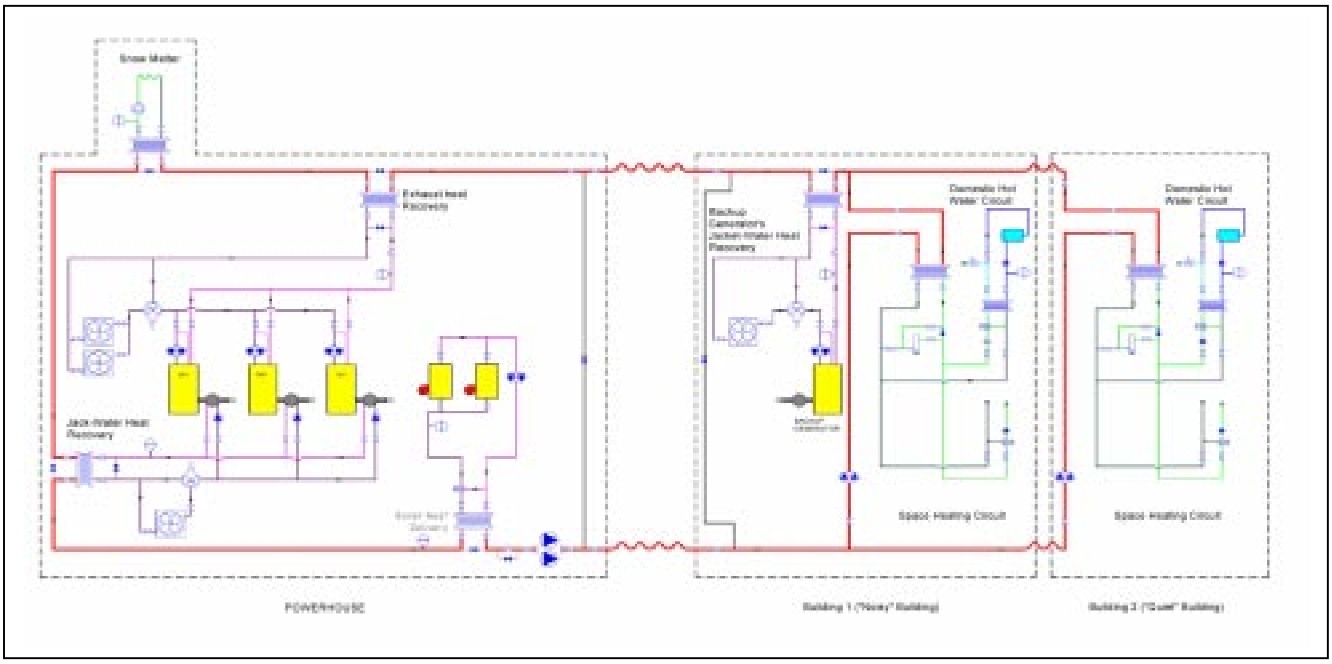

Figure 3: Hydraulic circuits

The heating circuit is separated through heat exchangers in independent circuits. There are three distinct types of circuits: ‘production’, ‘transport’ and ‘user’ circuits. Several independent ‘production’ circuits provide heat to the ‘transport’ circuit which then delivers it to several independent ‘user’ circuits. The domestic hot water ‘user’ circuits are secondary circuits feeding off the buildings’ space heating circuits.

This configuration allows great flexibility and safety in the management of the heating system with extensive isolation capabilities.

- The ‘production’ circuits are shown in red for the flow from the source of heat to the exchangers feeding the ‘transport’ circuits then in yellow for the return.
- The ‘transport’ circuits are shown in orange.
- The domestic hot water ‘user’ circuits are shown in light blue for the cold water feed to the exchanger then in dark blue for the flow of hot water from the exchanger to the taps.
- The other ‘user’ circuits are shown in dark green for the flow from the input exchanger to where the heat is used then in light green for the return
- Bypass installations are shown in black.

‘Production’ Circuits

The jacket-water cooling circuit operates by delivering heat out through an exchanger into the transport circuit. If the cooling is not sufficient, a progressive three-way valve directs some of the jacket-water flow towards a bank of radiators so as to reduce the temperature of the water return to the temperature specified for the engine.

An exhaust cooling circuit delivers heat out through an exchanger into the transport circuit. If the cooling is not sufficient, a progressive three-way valve directs some of the exhaust cooling water flow towards a bank of radiators so as to reduce the temperature of the water return to the specified temperature of 60°C.

A boiler circuit delivers heat out through an exchanger into the transport circuit. The boilers only switch on if there is a deficit of heat; that is if the temperature of the transport circuit flow out of the powerhouse is too low, usually under 85°C.

A backup generator set is installed in Building 1. The jacket-water cooling circuit of this generator operates by delivering heat out through an exchanger into the transport circuit. This generator is not equipped with an exhaust heat recovery system.

<u>'Transport' Circuit</u>

The cooled down water of the transport circuit return enters the powerhouse at the point marked 'E', picks up heat from the jacket water circuit exchanger, goes through the snow melter 'user' exchanger where it delivers heat to melt snow and produce fresh water if necessary, picks up more heat from the exhaust cooling circuit exchanger and from the boiler circuit exchanger then exits the powerhouse at the point marked 'S' towards the two main buildings.

The hot water of the transport circuit flow enters Building 1 where it separates into two lines. One line feeds Building 1's user circuits while the second line goes through to Building 2 where it feeds that building's user circuits. Building 2's return line comes back into Building 1 where it merges with that building's return line. The common return line goes first through the backup generator set's jacket water circuit exchanger where it can pick up heat when the generator is running, then goes out of Building 1 and back into the powerhouse.

The transport circuit can be isolated into two loops, one into the powerhouse and one between the two main buildings. In the powerhouse the excess heat of the jacket-water and the exhaust cooling would then be dissipated into the radiator banks. In the main buildings the backup generator could be used to feed some heat into the transport loop.

<u>Space Heating 'User' Circuits</u>

Each of the two main buildings has one space heating circuit. This circuit includes 24kW of electric heating elements capable of providing significant amounts of heat directly into the circuit if necessary, for example if there is a problem on the transport circuit. Under most normal conditions, the 24kW plus the heat dissipated inside the building by all usual electrical appliances would be sufficient to maintain the building at a reasonable temperature. This means isolating one or both buildings from the transport circuit would not prevent its normal operation. It would only increase the electrical load on the powerhouse and fuel consumption.

<u>Reliability through Simplicity</u>

Dome C is particularly cold and isolated. We considered it dangerous to rely on entirely automated or excessively sophisticated equipment:

- If a fault occurs in the control system, it is better to operate the equipment manually than to spend time investigating the fault then fixing a sophisticated electronic control system.
- The personnel has to be operational quickly upon arrival at the station, which is easier to achieve with a control system requiring little intervention.

At Concordia, the power system does not operate automatically. Generator sets have to be started and stopped by an operator and the frequency and voltage regulators can function manually. There is a high level of redundancy. There are three generator sets in the powerhouse and one in Building 1 while only one is needed at any time. All pumps have one backup unit placed in parallel and switching from one to the other only requires the simple, manual operation of a set of valves.

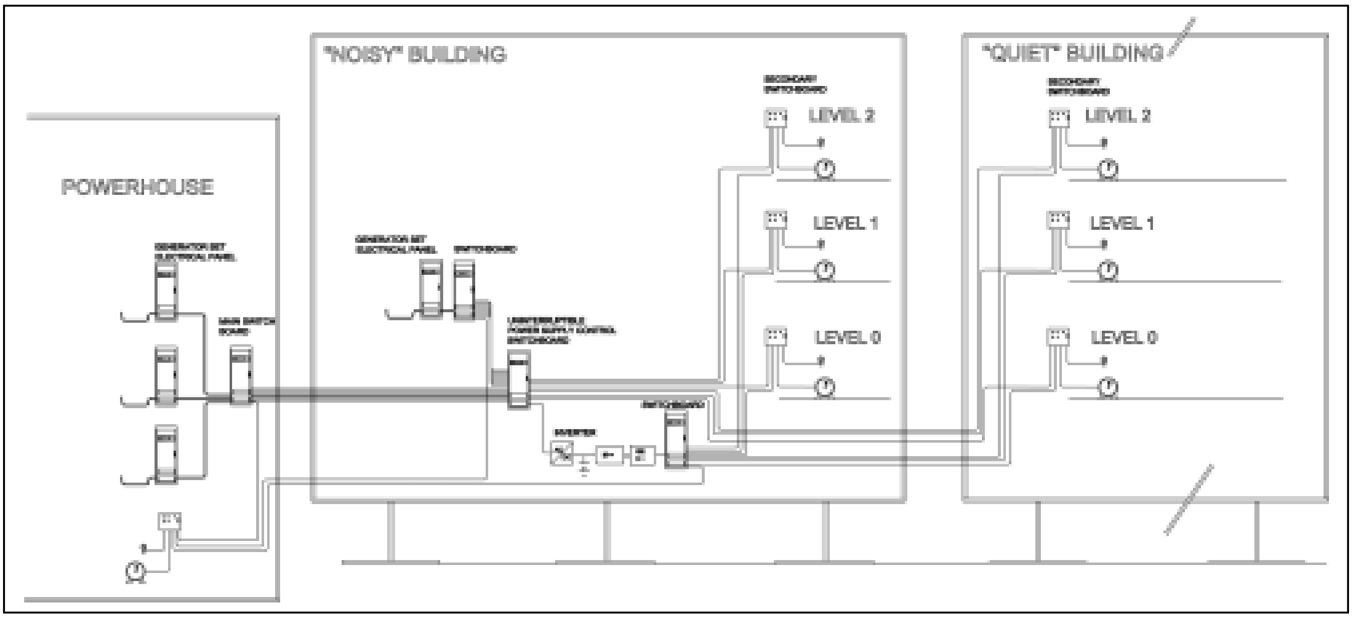

Figure 4 : Electrical grid

Monitoring

An extensive monitoring network constantly sends information to a central alarm panel. The parameters monitored and controlled include:

- Pressure, temperature and flow of the liquid circuits, all pressurised between 50 and 100 kPa.
- Status (starting, on, off, faulty) of all appliances.
- Temperatures in buildings and status of all external doors.

Uninterruptible Electrical Supply

Three dynamic inverters connected to a battery bank provide an uninterruptible electrical supply system. Dynamic inverters were preferred to static inverters. Static inverters are more complicated to maintain and are sensitive to storage in low temperatures. If the normal electrical supply fails, the system can feed the major appliances, including lighting, for about one hour.

Fire Protection

The powerhouse building is made of non-combustible materials: steel-rockwool sandwich panels for the walls, cellular concrete for the floor. Generators and boilers are installed in two separate rooms.

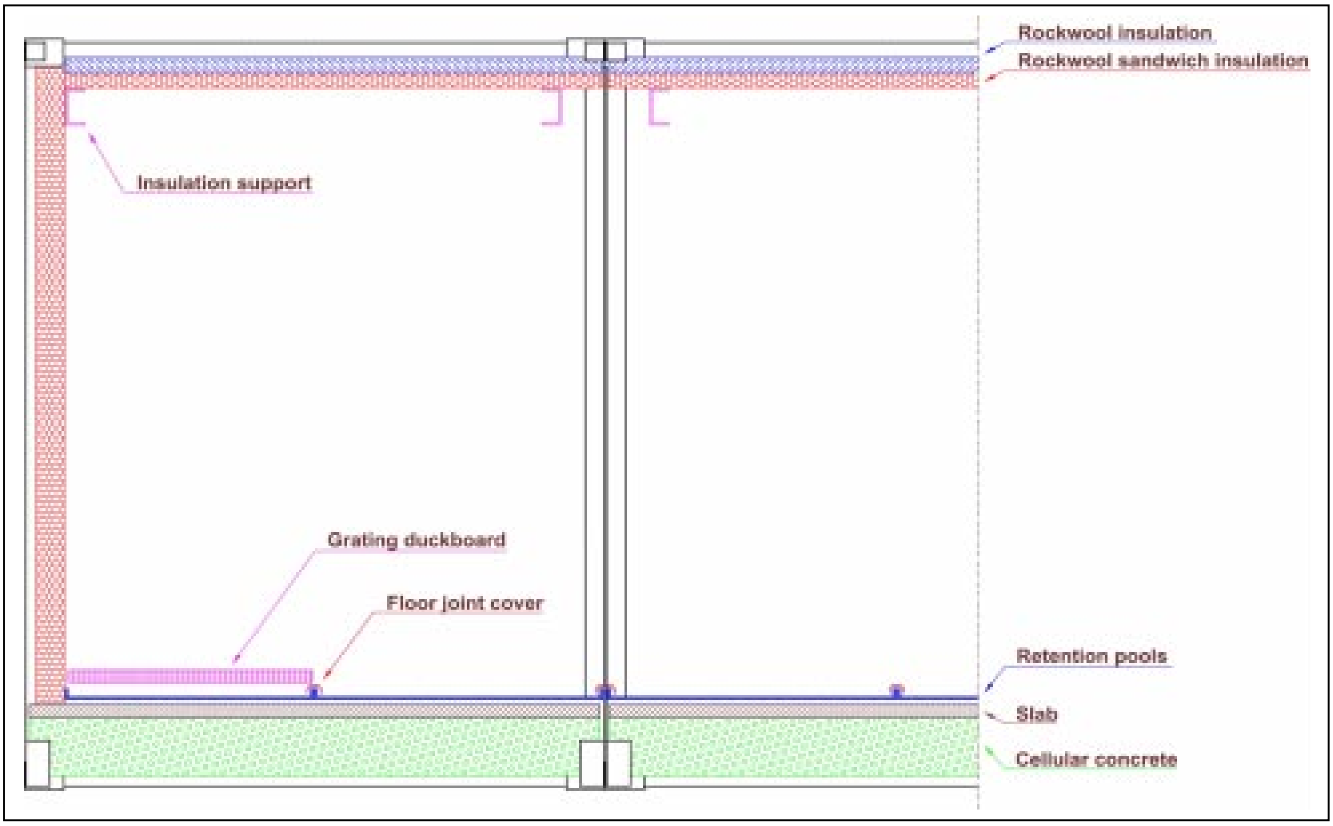

Figure 5: Power house units, tranversal section

Two separate, parallel networks of extinguishers provide a high level of fire fighting capabilities:

- A network of individual extinguishers.
  Each generator set and boiler is fitted with a totally independent fire extinguisher. This extinguisher is equipped with a simple, mechanical automated trigger system backed up by a manual trigger system that can be activated either locally, or remotely from the powerhouse control room.

- Two large extinguishers
  Both the generator and the boiler rooms have a separate, large extinguisher bank for the entire room.

The whole three station buildings have fire detection sensors feeding information constantly into a dedicated fire alarm panel.

<u>Environmental Protection</u>

The exhaust cooling system installed on the Diesel generator sets does not only allow the recovery of waste heat. It also allows the condensation of some of the water vapour produced in the engine combustion process, thus reducing the impact of water vapour on the quality and clarity of the atmosphere surrounding the station.

The latest catalytic converters will be be fitted to clean out exhaust gases.

The floor of each module of the powerhouse building is fitted with a four centimetre deep retention pool to contain possible spills of liquids: heating water, coolant, lubricant or fuel. Where necessary, grids provide a walking path above the retention pool.

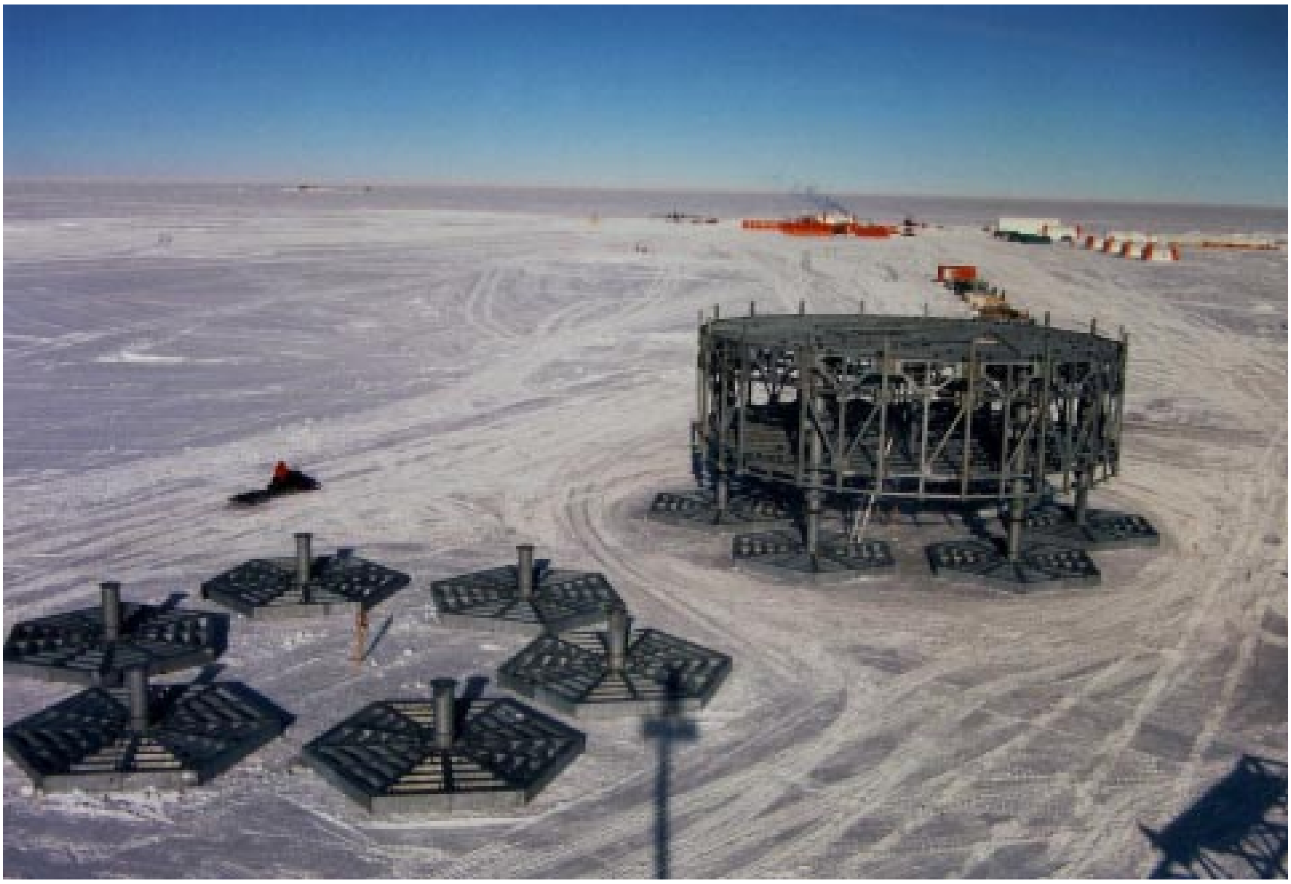

Figure 6: View of the construction site

Figure 7: View of the power station during mock mounting

Figure 8: View of the power station during mock mounting

Figure 9: View of the power station during mock mounting