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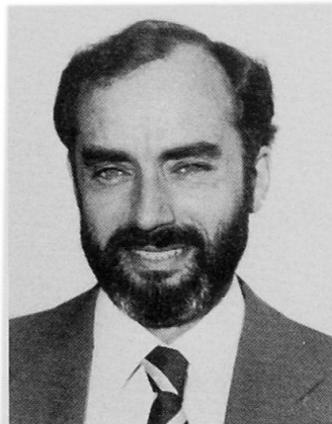
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## Rebuilding of Australia's Three Antarctic Stations

Reconstruction des trois bases australiennes en Antarctique

Wiederaufbau der drei australischen Forschungsstationen in der Antarktis

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### SUMMARY

Antarctica is the coldest, windiest, driest and most remote continent on earth and Australia is at present completely rebuilding its three permanent stations. This paper discusses the Rebuilding Program with particular emphasis on the development of the building system, structural design philosophy and solutions adopted for footings, framing systems, cladding systems, and associated testing and development work.

### RESUME

L'Antarctique est le continent le plus froid, le plus sec, le plus isolé et le plus balayé par les vents. L'Australie a entrepris de reconstruire entièrement ses trois bases permanentes sur ce continent. L'article examine le programme de reconstruction, et met particulièrement l'accent sur les méthodes de construction, les motivations qui ont présidé à la conception des nouvelles structures, ainsi que les solutions adoptées pour les fondations, les systèmes de coffrage et de revêtement, les contrôles de qualité et la mise au point des techniques.

### ZUSAMMENFASSUNG

Die Antarktis ist der kälteste, windigste, trockenste und abgelegenste Ort auf der Erde. Zur Zeit werden die drei festen australischen Forschungsstationen neu aufgebaut. Der Beitrag beschreibt das Bauprogramm und geht insbesondere auf die Entwicklung des Bausystems und die Konstruktionsprinzipien ein. Das Fundationssystem, die Ausbildung der Tragstruktur, die Verkleidung und die damit zusammenhängenden Qualitätsprüfungen und Entwicklungsarbeiten werden beschrieben.



## 1. ANTARCTICA - BACKGROUND

Antarctica is the highest, coldest, stormiest and driest continent on earth. It is an immense ice dome of more than 13 million square kilometres overlying a rock mass much of which is depressed below sea level. At its highest point the ice is over 4 kilometres above sea level. While ice predominates, small areas of bare rock occur. In mid winter the continent experiences continuous darkness whilst in mid summer it experiences continuous daylight. Australia has been active in research and exploration in Antarctica for the past 80 years. In 1936 Australia became responsible for the Australian Antarctic Territory - almost half the total area of the continent.

## 2. AUSTRALIA'S ANTARCTIC STATIONS

The three permanent Australian Stations on the Antarctic continent at Casey, Davis and Mawson are located on coastal ice free rocky outcrops. The ambient temperature at each station ranges from -40°C to +5°C, with air of a very low specific humidity. The sites are subjected to winds of up to 280 kph, which carry fine dry drift snow and occasionally, wet snow and sleet in summer. For approximately 9 months of the year, wind blown drift snow covers each site. During summer this snow usually melts leaving all buildings free of snow. Access to these stations is by ship for 3 months during summer when the sea ice temporarily breaks up.

Mawson station is located on solid granite rock. Davis station is located on moderately weathered metamorphic rock (mainly gneiss), crossed with numerous basic dykes (mainly dolerite) and covered in many places with moraine deposits ranging in size from fine silty sands to large boulders. Casey station is located on slightly weathered rock (mainly gneiss) and moraine deposits.

## 3. BUILDING SYSTEM

### 3.1 Historical Development

Building design philosophy for Australia's Antarctic stations has been continually developed since the establishment of Mawson Station in 1954. Buildings erected before 1976 at Mawson and Davis were relatively small and comprised post tensioned, load bearing insulated panels with external guys; they were located directly on ground and were designed for rapid erection during the short summer season. However, the designs suffered shortcomings including inadequate vapour barrier provision, inability to replace damaged external panels, noise and vibration problems, access difficulty for snow clearing equipment due to the guys, and the congested sites increasing the problems of snow drifting. At Casey, a similar building design philosophy was adopted, although elevated above ground to preclude snow drift accumulation, deterioration was accelerated by exposure to salt spray. By mid 1970's, buildings and services at all stations had deteriorated to an unacceptable standard and new building systems were investigated.

### 3.2 New Building System

The main features of the new building system are:

- larger and more efficient buildings;

- braced steel framed structures on concrete footings anchored to the ground, without need for external guying;
- external insulated sandwich panels which are durable and readily removed for maintenance;
- provision of vapour barriers on the inside and moisture barriers on the outside of buildings, and prevention of 'cold paths';
- maximum use of standard and prefabricated components, within the constraints of the available shipping and material handling facilities;
- simplified construction details to minimise the extent of site labour during the brief summer outside construction period (3 to 4 months);
- trial erection of building structures in mainland Australia to minimise the risk of delays to work on site;
- careful location of buildings minimising the drift problem. All buildings (rectangular in plan) are oriented with their long sides parallel to the prevailing (strong) winds, which carry the drift. Doors, windows and openings are only permitted on these sides, and drift snow generally accumulates either end of the building and tends to blow clear on the sides;
- fire prevention, detection and control.

### 3.3 Rebuilding Program

In 1981 the Australian Government gave approval to redevelop the three stations at a cost of A\$58m (1980), with completion planned for 1990. The Department of Housing and Construction assumed full responsibility for program management, design, fabrication, construction and commissioning of all facilities.

Separate buildings are being provided at each Station for Operations, Living, Science, Services, Power Houses, Workshops, Communications, etc. Other facilities include roads, bulk fuel depots, cargo handling facilities, and helipads. Feasibility studies are continuing on the construction of airstrips.

All buildings are linked by external service reticulation comprising separate, insulated and heat-traced pipes and electrical cable trays supported above ground on structural scaffold tube supports and anchors. These service lines are crossed by road and pedestrian bridges. Service lines over ice are supported on timber piles.

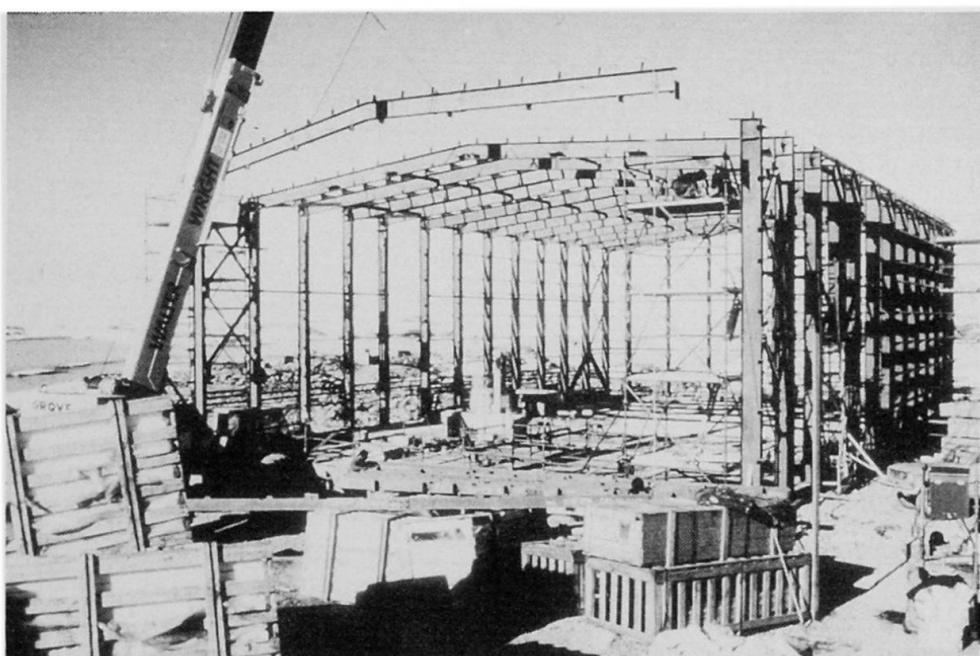


Fig. 1. Casey store under construction



## 4. WIND LOAD DESIGN PHILOSOPHY

### 4.1 Wind Loads

Wind loads are the dominant design loads on structures at Australia's three Stations and detailed wind load design guidelines have been prepared. Wind loadings are based on a 2-3 sec. gust using the 'quasi-static' approach in Australian Standard AS 1170 Part 2, and using a statistical analysis of daily maximum extreme values recorded at each Station.

The strong wind (prevailing wind) at each Station is unidirectional and is taken to act within an arc of 45°. The weak wind (of lower magnitude) acts outside this arc. The 25 year return period local wind velocity at 10.0m height for Terrain Category 2 at each Station is:

- strong wind 72 m/sec.
- weak wind 48 m/sec.

The design wind velocity is adjusted for local terrain and height of structure.

### 4.2 Limit State Design

The Limit States used for all Antarctic structures are:

- Ultimate Limit State: the wind velocity used for strength requirements has a 1.5% probability of occurrence during the 25 year life of the structure.
- Serviceability Limit State: the 25 year return period wind velocity is used for serviceability requirements.

### 4.3 Wind Pressures

Since internal wind pressures are dependent on wind direction and building penetrations, the following design policy on penetrations was formulated after extensive testing:

- doors, windows and openings are not permitted on the windward wall for the strong wind;
- doors may be opened at any time, for both Limit States;
- windows may be fractured by flying debris for Ultimate Limit State only;
- cladding remains intact for both Limit States.

A study of the latest experimental data resulted in the adoption of higher values of both average and local external pressures on walls and roofs, than those recommended in AS 1170 Part 2 1981.

## 5. FOUNDATIONS

### 5.1 Site Investigation

A continuing Geotechnical Investigation Program is examining the following critical aspects:

- Ground Conditions: differ markedly from Station to Station (Section 2). Frozen ground has three important properties:
  - impermeability: resulting in poor drainage;
  - ground ice content: bonding the soil particles together, which when melted can cause soft areas (Casey and Davis);

thermal sensitivity: alteration to existing state of thermal equilibrium can cause settlement of structures, although this problem is minimal for moraine material.

Ground Temperatures: have been monitored to a depth of 10.0m. Frozen ground generally consists of two layers: the upper (or active) layer, and the lower (or permafrost) layer, which is the perenially frozen layer. The greatest fluctuation of temperatures occurs in the active layer and is potentially the principal cause of damage to structures. Below 10.0m the temperature remains fairly constant at -9°C whilst above this depth the temperatures are influenced by the seasonal variation of air temperature, the maximum depth of thaw being 1.0m approximately.

- Ground Compaction: tests on moraine and crushed rock.
- Ground Level Survey.
- Water Quality: studies performed at Casey and Davis.

## 5.2 Substructure Types

There are two main types of substructure used:

- Slabs: for heated buildings the concrete ground floor (Fig. 2) is cast directly onto 150mm thick polystyrene insulation with penetrations in the insulation to permit support of the slab directly on the ground (usually via rubber bearing pads); whilst for unheated buildings the insulation is deleted.
- Pedestal/Shear Wall: these heated buildings have suspended ground floors supported off pedestals (braced by shear walls), to cater for extensive subfloor services and/or steeply sloping sites.

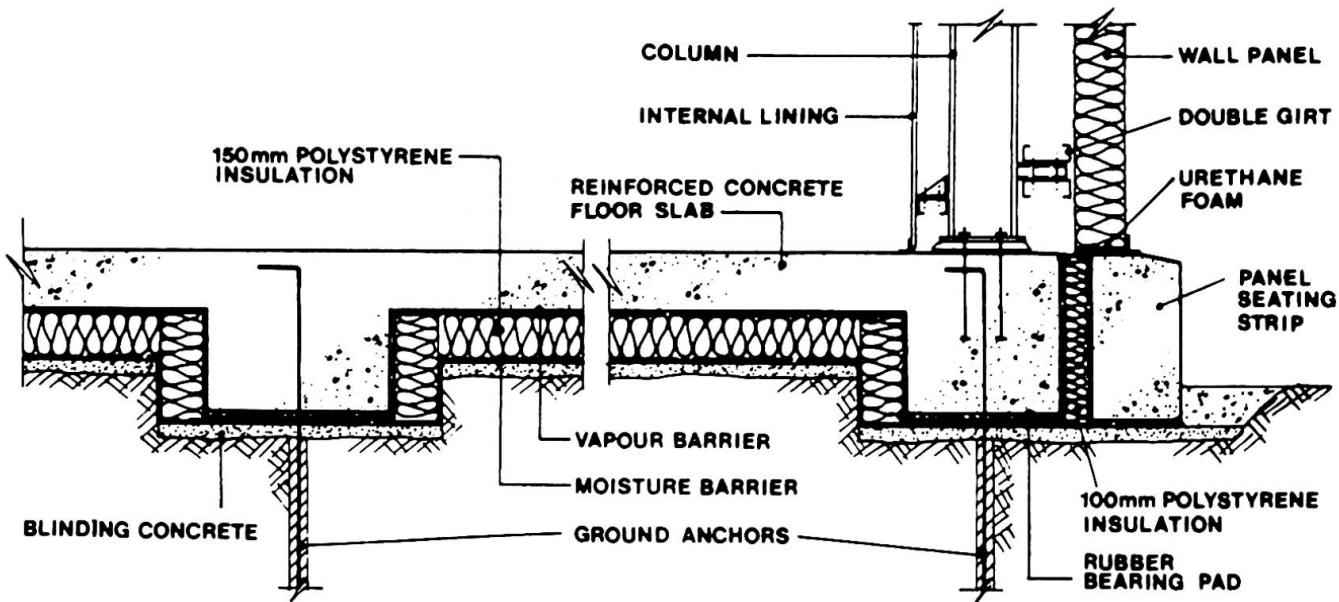


Fig. 2. Typical substructure for heated building

## 5.3 Ground Anchors

In view of the extreme wind velocities at each Station a system of ground anchors has been developed to reduce the mass of concrete footings. Extensive laboratory and site tests proved epoxy, sulphur and a range of mechanically



expanding and split-set anchors performed well in sound rock, whilst a frozen cement grout system performed well at all Stations. However in 1982 a magnesium phosphate chemical grout became available. This grout is high strength, rapid setting and self curing at temperatures down to  $-10^{\circ}\text{C}$ , and gave excellent results in tests at all Stations. The ground anchor system adopted is:

- Y20 reinforcing bar - grouted length 3.0m in 64mm dia. hole;
- magnesium phosphate grout mixed with 10% water;
- proof testing of a percentage of all anchors on each structure;
- the min. ultimate pullout loads are 80kN (Casey and Davis) and 130kN (Mawson). Limit State load combinations have been developed for both strength and stability.

## 6. FRAMING SYSTEM

### 6.1 General

The structural system consists of a structural steel frame which is fully braced at roof level and on all four walls to satisfy strength and serviceability requirements. The modular frame spacing is based on the cladding panel module of 1230mm (1200mm wide panel and 30mm gap). Cost comparisons of alternative structural systems (including secondary steelwork) resulted in the adoption of the following frame spacings:

- small buildings	2460mm spacing
- medium buildings	3690mm spacing
- large store-type buildings	4920mm spacing

### 6.2 Details

The steelwork for buildings is completely trial erected in mainland Australia to minimise site problems. Steelwork is shop welded (in Australia) and field bolted (in Antarctica). All electrodes used are of a low hydrogen type and strict requirements are laid down for welding procedures.

Hot rolled steelwork complies with AS 1204 Grade 250 (min. yield 250 MPa) and is painted with self-curing inorganic zinc silicate, except for exposed steelwork which is hot dipped galvanised. Purlin and girt sections are cold rolled zinc coated steel conforming to AS 1397-G450-Z300 (min. yield 450 MPa).

Panel bolts, purlin/girt bolts and holding down bolts are commercial grade 4.6 to AS. 1111 (min. tensile strength 400 MPa). All other structural bolts are high strength grade 8.8 to AS. 1252 (min. tensile strength 800 MPa). All bolts are hot dip galvanised, except for panel bolts which are electroplated zinc.

## 7. CLADDING SYSTEM

The cladding system consists of sandwich panels which are fixed to a supporting framework of double "C" section purlins and girts (Fig. 3). The cladding panels, produced on a continuous laminating machine, are 1200mm wide and 150mm thick, and consist of polystyrene foam sandwiched between two 0.6mm thick precoated "Zincalume" steel sheets. The rigid cellular polystyrene is Class M, in accordance with AS 1366, Part 3. The purlins and girts consist of two cold formed steel "C" sections back to back and separated by 50mm wide rectangular hollow sections each containing a captive nut for the panel fixing bolt.

Extensive testing has been completed on the individual components and full scale tests on the complete roof and wall system (including windows and doors), using a suction box. These tests showed that:

- correct oven drying of polystyrene foam is critical;
- correct glueing of polystyrene foam butt joints and foam/steel skin joints is also critical;
- panels with unbonded butt joints suffer premature shear failure at these joints;
- dynamic loading effects are insignificant;
- panels have good impact properties;
- strict quality control testing is essential during panel manufacture since their strength is very dependent on the standard of workmanship.

Delamination of some older panels has been a problem and thermal cycling tests are planned. Tests have been performed on the double purlin/girt system to confirm the joining requirements of the composite system.

The main design considerations for the cladding system are:

- bending and shear of the polystyrene cladding panels;
- pullout of the panel fixing bolts and plates through the panel;
- lateral buckling of the double purlins/girts.

In zones of high external wind pressure special attention is paid to purlin/girt spacing (550mm max.), elsewhere across the building the maximum purlin/girt spacing is 1100mm. The roofs are kept snow free by the continual winds and minimal roof projections. The dead load of wall panels is supported by the concrete panel seating strip, and not by the girts.

Windows are triple glazed factory sealed units and are generally fitted into panels during prefabrication. The doors have been developed from standard cool room doors with special latches and gaskets.

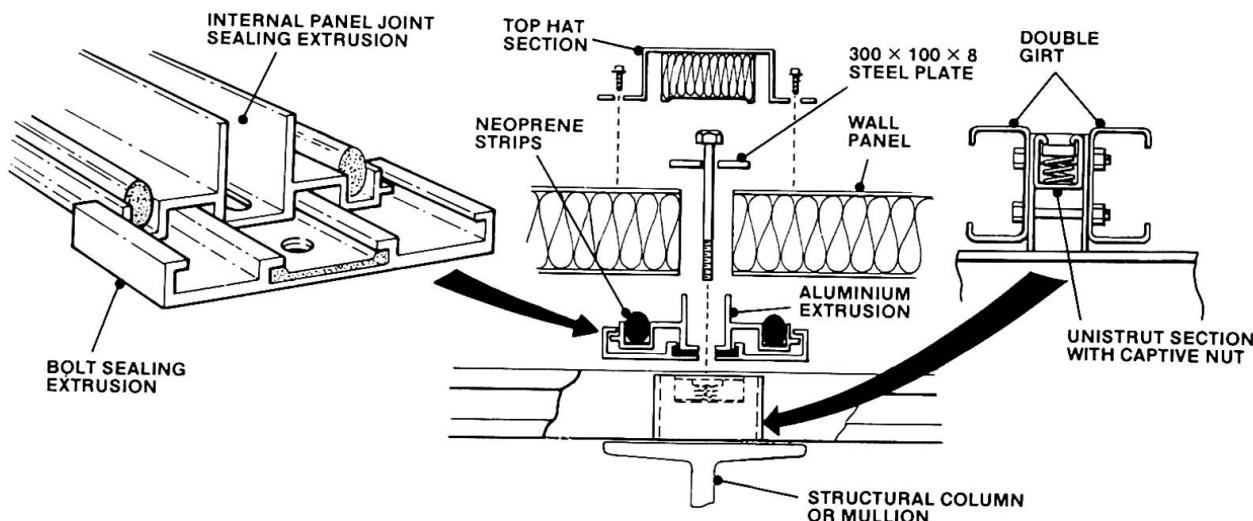


Fig. 3. Typical wall panel fixing system

## 8. CONCRETE

### 8.1 General

Successful techniques [1] are being used in Antarctica to ensure the efficient production of sound concrete structures. Concrete has proved eminently suitable for structural footings, heavily loaded floors, suspended floors and machine bases. Difficulties in concreting arise because of the short outdoor



construction period available and the harsh environment. Insitu concrete is minimized by the use of pre-cast concrete (floors and bridges) and ground anchors (instead of mass concrete). Detailed cost comparisions of the relative merits of precast and insitu concrete in Antarctica have been undertaken.

Material for in-situ concrete is supplied to Antarctica in pre-mix form in 40kg bags (multiwall paper bags inside heat sealed polythene bags), and delivered in waterproof lined 2 tonne cases. A strict quality control program covers all aspects of material and mix design, manufacture, packaging and crating. The main requirements of the pre-mix concrete specification are:

- min. cement content (Type B - high early strength) is 7.5kg per bag;
- concrete characteristic strength to AS 1480 at 7 days with entrained air content of  $5\pm 1\%$  is 30MPa;
- max. moisture content after bagging is 0.25%;
- slump  $70\pm 10\text{mm}$ .

## 8.2 Site Concreting

Concrete admixtures (air entraining agent and accelerator) and water are added to the pre-mix on site in pre-determined quantities. Air entraining admixtures improve workability and freeze/thaw resistance of the concrete, whilst accelerating admixtures (chloride free) hasten initial set and strength development. Concrete strengths of 25MPa at 14 days are consistently being obtained.

Detailed instructions are contained in an Erection Manual on all aspects of concreting, particularly subgrade preparation, mixing, placing, compaction, finishing, curing and quality control. Concrete is never placed at ambient temperatures below  $-10^{\circ}\text{C}$ . The mixing water is heated to  $40^{\circ}\text{C}$  approximately, and the concrete mixed in 0.8 cu.m. agitator trucks and placed at  $10^{\circ}$  to  $15^{\circ}\text{C}$ . The placed concrete must be kept above  $10^{\circ}\text{C}$  for a minimum prehardening period to ensure a strength of 7MPa (min.) to prevent permanent damage from freezing. Concrete curing is continued for a min. of 7 days, to ensure attainment of its design strength, using some of these techniques:

- preventing early stripping of formwork;
- covering with non-porous polythene membrane, insulation blankets and tarpaulins;
- application of hot air (above the membrane) or low pressure steam inside enclosure around members - not generally needed;
- care to prevent thermal shock after curing.

A detailed quality control program is used on site and full details are forwarded to the design office regarding:

- batching;
- site sampling and testing (inc. slump and air entrainment);
- cylinder and cube testing;
- monitoring of concrete temperatures during mixing, placing and curing.

## 8.3 Formwork

The following types of formwork are used:

- A modular system of steel framed and stiffened plywood panels.
- Pre-insulated sandwich panel of polystyrene foam core and structural plywood. This system is used for pedestals, walls etc., where there exists a high ratio of surface area to volume of concrete.
- Ribbed steel decking for suspended floors in lieu of precast panels.

#### 8.4 Reinforcement

The reinforcement generally used is Tempcore bar, ideally suited to use in Antarctica with its good ductility, toughness and high strength. Tempcore complies with AS 1302 Grade 410Y and has a 410MPa min. yield strength and low carbon equivalent. Precast concrete is reinforced with Tempcore bar or prestressed using low relaxation stress relieved super grade strand to AS 1311.

#### 9. CONCLUSION

The complete rebuilding of Australia's three Antarctic Stations is a challenging task in view of their remote location and the severe environmental and logistical constraints. The success of the Rebuilding Program is dependent on good planning and management, innovative and cost effective design, detailed and accurate documentation, technical standards based on a testing and development program and site feedback, and strict quality control and supervision.

#### 10. ACKNOWLEDGEMENT

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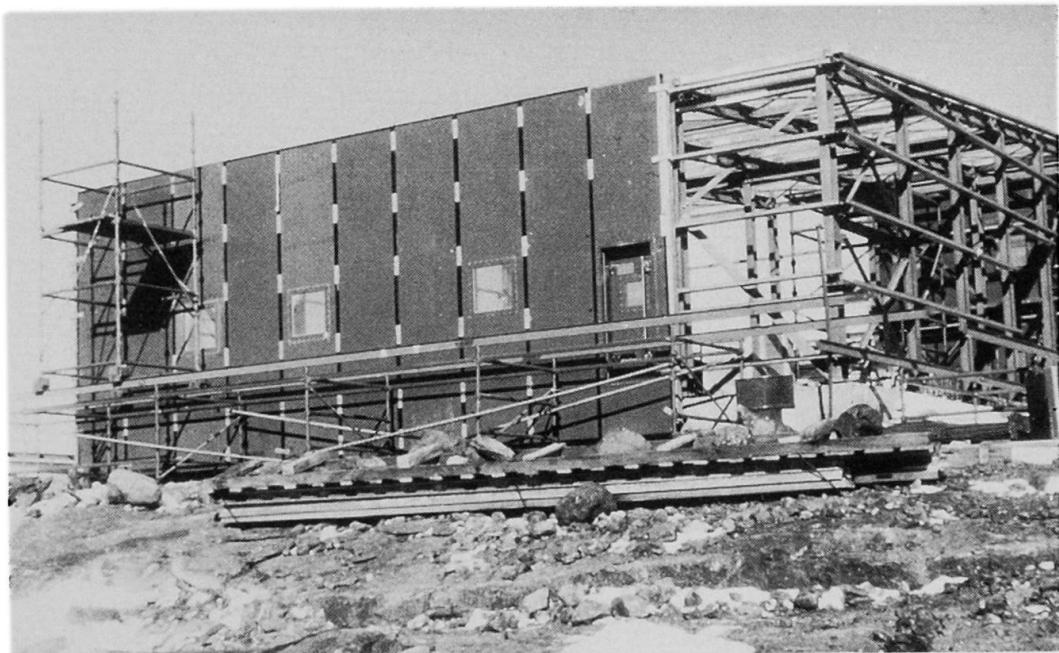


Fig. 4. Mawson Tank House under construction

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