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NEW BASE FOR THE SOUTH AFRICAN NATIONAL ANTARCTIC EXPEDITION (SANAE 1979)

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NEW BASE FOR THE SOUTH AFRICAN NATIONAL ANTARCTIC EXPEDITION:

SANAE 1979

ABSTRACT

The new design differs from the previous wooden box construction in the following respects with the outer steel shell taking up all the external pressures and an inner box structure providing adequate thermal insulation. The disadvantages of the old base is discussed, followed by the concept and advantages of the new base from the planning stages, through the construction stages up to the maintenance stage. All the problems and solutions are mentioned in the various stages.

INTRODUCTION

South Africa, one of the original members signed the Antarctic Treaty in 1959.

It was decided in 1960 to establish a weather station and research centre at the old Norwegian base which was consequently occupied for a period of 2 years before a new base was erected in 1962. This base lasted until 1971 when it became necessary to construct a new base using a similar design. Due to the short life span and rapid deterioration of the wooden box construction it was decided that a new base, using an entirely new concept, be constructed during the summer of 1978/79. Time was very limited and to meet the challenge a multidiscipline design team was nominated. This team consisted of Technical staff from the Department of Community Development (formally the Public Works Department) and logistic officers from the Department of Transport. The design was completed on schedule due to a splendid effort on the part of the design team and the ship sailed for Antarctica in December 1978 and the new SANAE base was completed by March 1979. By the time of the 1981/82 summer take-over trip the base was completely covered with snow. Settlement observations of the entire base are taken each year during the maintenance period and plotted.

1.0 THE ADVANTAGES AND DISADVANTAGES OF THE PREVIOUS TWO BASES BUILT IN 1962 AND 1971.

1.1 Report of Symposium on Antarctic Logistics held at Boulder, Colorado - August 1962.

A full description and photos were given of the design and construction of the 1962 Base in Section III: Buildings: Page 301 of the above Report. This design was copied for the 1971 Base and to a large degree was a copy of the old Norwegian Base.

1.1.1 Structural Concept.

The structure comprised a timber raft foundation, with timber roof beams, supported by timber wall panels.

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The roof and wall panels were a sandwich construction, consisting of a 85 mm glass-fibre insulation in plastic envelopes with tempered hardboard on either side. The size of the panels were 1,2 m x 2,4 m and fixed together with wedge clips. Waterproofing was achieved by covering the flat roofs with a neoprene membrane. The buildings were constructed on the snow surface and were gradually covered and burried by snow accumulation.

1.1.2 Advantages

- A simple form of design.
- Type of construction not unduly difficult to erect in Antarctica conditions.
- No heavy plant required for construction.
- Structural maintenance mainly consists of the replacement of beams and columns. A relatively simple task until deflections get too large.

1.1.3 Disadvantages

- Relative short life expectancy of six years.
- Gradual accumulation of snow causes loads on the structure to increase.
- Box shape of structure causes uneven load distribution on structural members with ultimate failure.
- Direct contact between outer insulated timber wall and roof panels of interior heated structure and surrounding snow.
- Uneven heat escape from outer wall and roof panels causing snow to melt. Cavities form, causing snow bridges with resulting failure of structure due to excessive point loads.
- Due to uneven point loads from ice bridges, differential settlement occurs with excessive stresses developing in the structure.
- Internal heating and lack of moisture causes excessive drying out and weakening of the timber.
- Outer roof and wall panels need to be designed for both strength and insulating requirements.
- Breaking away of large icicles in cavities above the roof, endangers lives of occupants.

Having/3.....

- Having no vapour barrier in the panels the moisture activated in the buildings tends to migrate from the hot internal area to the cold external area and reaches freezing point in the glassfibre area of the panel. This continuous moisture migration leads to the build up of ice within the panels with the result of bursting forces in the panel getting increasingly bigger until failure occurs.
- The psychological effect on occupants noticing the deterioration of the buildings in direct contact with the snow.
- Heat escape from lights and airconditioning ducts against the roof causes early melting of the snow in contact with the roof.
- Gradual consolidation and plastic flow of the snow causes the hessian side covering of the snow passages to be pressed inwards, thus reducing packing space and walking area.
- Condensation in the snow passage causes the floor to be wet, slippery and dirty.
- The method of storing fuel in drums causes loss of the fuel with double and tripple handling.
- The storage and supply method of fuel from the snow passage to the power room causes pollution and spillage resulting in a fire hazard.
- The lack of landings in the vertical access shafts pose a danger hazard with increasing ladder length as the snow accumulates.

1.1.4 Secondary effects of heat loss.

- From investigations carried out it was seen that on either side of the buildings a cavity in the form of half an arch existed. This arch extended from the floor beam to the roof level and was about 2 metres in diameter. It was clear that the wallpanel insulation was insufficient as explained previously. The neoprene rubber membrane on the flat roofs seemed to help with the thermal insulation to some degree as cavities between the roof and ice above it did not exist for all buildings, but only those where excessive heat was generated.

- Ice in general has got a natural arching effect, but by widening the base of such an arch, (as done by the cavities on either side of the building) the downward pressure from the ice on the roof increased, causing the roof beams to crack at midspan.

- In some cases like the power hut, where air cooled engines were used the arching effect extended above roof level, thus forming an ice pillar in the centre of the roof.

- The presence of some smaller ice pillars on the roof was further increased by the ice melting in one position and freezing again at another point, so forming a type of stalactite that eventually becomes an ice pillar resting on the roof.

- No air-locks were provided at any of the buildings. When the doors leading from the buildings to the snow passage were opened there was a direct escape of hot air causing unwanted melting. The continuous opening of the doors (it was noticed that the doors were sometimes left open for long periods) eventually caused similar arching and cavities to develop.

- The main snow passage passed too near to the row of buildings situated in a North-South direction along its full length. Initially the distance seemed in order. (About 3 metres). Due to the cavity arching effect described above the resultant thickness of the ice wall left between the buildings and the passage varied from 1 metre to holes developing in it. This situation placed the thin wall of ice under very high pressure with the resulting differential settlement and further damage to the buildings.

- It was interesting to note that the corrugated iron sheeting used as the roofing material for the passages bonded to the frozen ice above it. In this way a composite action between the ice and sheeting developed and thus very large pressures could be supported by the ceiling while no deflection of the sheeting took place. As soon as hot air (coming from open doors or electric bulbs in the passage at ceiling level) melted the ice above the sheeting,the bond was broken and deflection and damage started occuring.

1.1.5 <u>The disposal of urine and waste water</u>

The disposal of urine and waste water was done by gravitation into pits directly below the buildings at the point of discharge.

This practice caused unwanted settlement of the buildings in all the areas of discharge due to the forming of large cavities, later sealing off and causing the accumulation of urine and waste water under buildings. The urine was not frozen and still in a fluid state. It seemed to dissolve the frozen ice below the floor beams to a certain extent, thus causing the sagging of the building while at the other end of the building there was solid ice around the floor beams, thus giving a rigid support to the structure.

1.1.6 Emergency Base

The emergency base is in a satisfactory condition although it was erected during 1970 using the exact same methods and design as the 1962 and 1971 bases. As the base only gets used for short periods during take-over in the summer there is only minor evidence of deterioration that can be contributed to the following two factors: Relative little heat generation for short periods at a time and less snow accumulation than over the other two main bases.

2.0 CONSIDERATIONS FOR A NEW BASE

2.1 General points

The abovementioned disadvantages, reports from previous teams, developments at other bases, technological development and the tremendous cost of a new base prompted the design team to take a fresh look at the whole concept.

In considering a new base the following points are of prime importance.

- If the life span of the base is to be longer adequate structural protection must be given to the occupants due to the greater snow loads.
- The insulating properties of the building panels are of prime importance, and should include an effective vapour barrier.
- The building components must be light, easy to handle, easy to erect and economical.
- Fire protection properties of the materials to be used are extremely important.
- Controlled heating and ventilation to avoid any hot spots developing and causing snow to melt is of prime importance.
- Removal of waste water out of the base to a position where it can be discharged without effecting the building structure is essential.

- A longer life span must be achieved and reclaiming of components, material and equipment for re-use must be possible.

2.2 Building alternatives for the floating ice shelf

Without going into too much detail the following alternatives were available to South Africa when the new concepts were considered.

- Norwegian design (old SANAE base). The design, with its disadvantages, has been fully described.
- Structures on jacking stilts above the snow. This system has an economic advantage, but the strong winds, vibrations, oscillation and many other problems are yet to be overcome. It was therefore the intention to use one of the outside buildings for an experiment in this regard.
- Tunnel design. A very large tunnel is excavated in the snow with a roof over and with the buildings inside. The logistic requirements are too big for present South African logistic facilities.
- Steel tunnel design Armco shell. The base is capsulated by a protective structural steel shell. With this design the buildings are reclaimable and the British Antarctic Survey has proved this system to be very successful.
- It was decided by the design team to concentrate on the Armco design. For this purpose three types of building systems were considered to go into the Armco shells:

  (a) A conventional woodpanel system.

  (b) A fibreglass reinforced precast cement polystyrene insulated panel.

  (c) A cold room type panel developed for very large cold and deep freeze rooms known as the "Linde System."

2.3 Choosing the Linde System for the Internal Buildings

In choosing the Linde System as opposed to the systems offered by Isowall and others the following advantages are apparent.

2.3.1.0 Construction of panels:

2.3.1.1 Bond

Injection process of polyurethane results in a better bond between the insulation material and the outer cladding than can be obtained by a lamination process. This bond is further improved by coating the cladding with a layer of paint which reacts chemically with the polyurethane to ensure a uniform bond.

2.3.1.2 Flange - Web Construction

The external plates are separated by a rigid plastic web which is popriveted to the plates to form a flange-web construction before injection. This resultsin a structurally sound and stable panel. Any differential movement which may occur as a result of the temperature gradient across the panel will be absorbed by the joint thus considerably reducing the risk of delamination of the cladding and consequent destruction of the vapour barrier. The other systemsrely on the bond between the cladding and the insulation material for structural stability.

2.3.1.3 Openings required in Panels

During manufacture provision can be made for all holes and openings required for service ducts and pipes by providing an adequate vapour seal before the injection. The bond between this seal and the insulation material will be as in 1.1 above. The insulation properties of the material are not affected because no cells are cut. The method of manufacture of the other systems necessitate that all openings will have to be cut and sealed after manufacture which is undersirable because as soon as a cell is cut it absorbs water reducing its insulating ability. Bond between the insulation and seal will also be a problem.

2.3.1.4 External fixtures to Panels.

Where necessary provision is made during manufacture for additional fixing facilities eg electrical fittings, by providing steel plates or wooden strips in the panel fixed to the internal skin before injection takes place.

The other systems cannot supply this requirement where necessary.

Where possible fixing will take place by means of 'coach-screws' screwed into the plastic web plate which will not affect the vapour barrier or insulation while giving adequate support. Special fixing arrangements will have to be made if the other systems are used to prevent damage to the insulation materials.

2.3.2.0 Polyurethane or polystyrene?

Polyurethane offers the following advantages when compared to polystyrene in panel construction.

2.3.2.1 Insulation:

The insulation properties of plyurethane necessitates a 110 mm thick panel compared to 150 mm polystyrene panel in Antartic conditions with a consequent saving in valuable space.

2.3.2.2 Cellular Construction

Polyurethane has a finer cellular construction than polystyrene which results in a intrinsically stronger panel as there is a far greater surface area of cells in contact with one another. This intrinsic strength is demonstrated when samples are subjected to moments. The polyurethane breaks locally at the point of application of the moment whereas polystyrene breaks in a line, normally at an incline but its position varies. The force required to break the 150 mm polystyrene panel is also less than that required to break the 110 mm polyurethane panel.

2.3.3.0 External Panel Cladding

All the systems use a galvanised metal sheet as a vapour barrier which is cladded with a P.V.C. type material hot-rolled onto the sheet during the manufacturing process. The "Linde System" however imports these sheets (trade name 'PLATAL') whereas the other systems use a locally manufactured product. The imported has the following advantages.

2.3.3.1 Surface

'Platal' has a harder surface which does not scratch through to the metal sheet which occurs in the locally manufactured product.

2.3.3.2 Heat Reflection

Due to the harder surface, the 'Platal' has better heat reflection properties than the locally manufactured product.

2.3.3.3 Bonding of the cladding to the Galvanised Sheet

The bonding of the P.V.C. on the local product has not been perfected as air pockets on the surface are in evidence. Delamination has occured when bending the local product. This problem has not been experienced with 'Platal.'

Joints...../9

2.3.4.0 Joints in Panels

2.3.4.1 Vapour Migration through Butt Joints

Any moisture that does pass the internal vapour seal where the panels butt is still trapped between the plastic web and cannot enter the insulation material.

In the "ISOWALL SYSTEM" virgin material butts at joints in the panels, thus if moisture does penetrate the internal vapour seal it will enter the insulation material. This problem is aggravated because at the joints the cells of the polystyrene have been cut enabling them to absorb moisture which expands when frozen and further cells can break.

2.3.5.0 General

In conculsion the "Linde System" offers the following advantages:

2.3.5.1 Easy to erect.

2.3.5.2 Speed of erection.

2.3.5.3 Panels not easily damaged in transit and erection.

2.3.5.4 Method of packaging ensures fewer damages.

2.3.5.5 Finishes and workmanship of the Linde Panel are of a higher standard.

2.3.6.0 Disadvantages

The "Linde" panel is superior in all aspects except that it is heavier than panels of other systems. This disadvantage is offset by the ease with which it can be erected.

. . . .

2.4 Choosing the Steel tunnel Armco Shell

Buried corrugated-metal conduits have been used as drainage structures for many years, and in the past two decades, as grade separations, bridge substitutes, protective structures and to a lesser degree in Antarctica in various forms. Such structures, other than the very smallest, are constructed by bolting together curved, corrugated metal plates. The size of these structures has continued to grow to the point where culverts with spans as large as 15,5 m have been successfully constructed and have performed satisfactorily.

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In practice, once the spans begin to exceed 4,6 to 7,6 m, changes in the design criteria and construction procedures are made to insure satisfactory performance. The larger structures which fall into this catergory are termed "long-span" corrugated-metal or structural-plate buried structures.

2.4.1 Design concepts of Steel Shell

It must be clearly stated that this concept is based on the steel shell and soil interaction theory. No design formulae could be found for the steel shell and snow interaction due to the unknown variables of the properties of snow. The design problem had to be simplified by making various assumptions.

2.4.1.1 Snow-Structure Interaction Concepts

The fundamental idea behind the use of flexible corrugated metal as a conduit wall for long-span structures is to use the snow as the principal load bearing and transmitting element of the system. The metal may be viewed as a form which maintains a desired shape of opening in the snow medium and which carries some of the load during service.

To carry out the design of the conduit wall, two equally significant stages must be accounted for.

(a) During construction, the conduit must be stiff enough to support its own weight, to maintain the shape and to permit satisfactory construction of the surrounding embankment.

(b) During service, the snow-structure system must be able to carry the applied dead and live loadings, and the conduit wall must accept its share of these loads with an adequate factor of safety against failure by means of excessive deflection, wall yielding under circumferential stress, buckling, and seam (joint) failure.

To date, successful design for in-service conditions has been based primarily on very simplified theories of soil-structure interaction, and experience. One of the best known of these simplified theories is the ring compression theory.

Arching....../11

2.4.1.2. Arching

Arching is a second simplified soil-structure interaction concept which plays a key role in most of the empirical design approaches in conjuction with the ring compression theory. In effect, arching is the behavior of the soil-structure system involving redistribution of soil stresses around the structure from the values that would occur if the structure was not present. In positive arching, a portion of the dead and live loading over the structure is transmitted to the soil around the conduit, therefore, the soil pressure used in the ring compression theory to compute the thrust in the conduit wall is less than that arising from the actual depth of cover. In negative arching, stresses are concentrated on the structure and correspondingly reduced in the surrounding soil. Positive arching may occur in one or more of the following ways:-

a. The conduit section may be significantly more compressible than an equivalent area of soil because of joint slippage.

b. The conduit may be founded on a soft, compressible zone so that under loading it settles relative to the surrounding backfill placed over a firmer foundation.

c. The conduit may deform because of its low bending stiffness.

d. The backfilling and covering process can be designed to promote arching.

2.4.2 Disadvantages

- Longer overall erection time.
- Higher initial cost.

2.4.3 Advantages

- Minimum life expectancy of 12 years.
- The outer shell provided adequate protection and an ideal working area for the internal construction in adverse weather conditions.
- Initial accumulation of snow against the shell can be carried out mechanically and not by uneven gradual accumulation.
- Snow compaction is controlled and a more uniform distribution of loading is achieved.

The ..../12.

- The circular form of the outer shell ensures further uniform distribution of loads in the ultimate buried condition.
- No direct contact between the internal heated structure and snow.
- Air space between outer shell and internal structure can effectively be ventilated and the extraction of heated air controlled. Melting of snow in contact with the shell is thus eliminated. Due to the melting of snow being controlled, forming of cavities are prevented and an even load distribution on the shell is maintained with resulting extended life and reduced maintenance requirements.
- Internal accommodation does not have to be designed to withstand external loadings, but for insulating and fire resisting properties only.
- No sudden distortion of internal structure as even settlement of the outer shell occurs.
- As the internal structure is not subject to external loadings, there is no visible damage and therefore no adverse psychological affects on the occupants.
- Recovery of the complete internal structure for use in future base requirements, thus reducing future costs.

3.0 DESIGN CRITERIA

3.1 Life Span of Base

The minimum anticipated life span for the base is 12 years. Records of the annual natural accumulation of snow measured at SANAE for the past 15 years indicates that a mean accumulation of 772,8 mm/year (std. dev. $\pm$ 196,3) is expected.

Structurally the base could have been designed for a greater life span but due to practical considerations, for example the access to the base and the new concept which still has to be tested under actual conditions, it is felt that a 12 years life span would be most economical.

Provided there is no vapour migration through the external wall and roof panels, of the internal structure these should be completely recoverable after the 12 year period. Another important factor towards the increased life span of the base is the effective control of heat loss into the air void between the internal building and the steel shell.

Prevailing ..../13.

3.2 Prevailing Winds

Records of the prevailing winds measured at SANAE for the period 1963 to 1975 indicated a mean annual overall wind speed of 7 m/sec (mean dev. ± 0,4) for the dominant wind direction which for the above period was E 10° S.

To eliminate accumulation of snow from one building on to the next, the buildings were placed in a straight line perpendicular to the direction of the dominant winds i.e. N 10°E.

3.3 Temperature

Temperature. The annual mean surface air temperature for the period 1963 - 1975 was - 17,7°C (mean dev. ± 0,4). The temperatures ranged from a maximum of ± 7,3 °C (mean ± 5,7 °C, dev. ± 1,0) to a minimum of -51,0 °C (mean -48,9 °C dev. ± 1,8).

These results were used for calculating the ventilation requirements for the structure.

3.4 Siting of the Base and Glacier movement

The old base was situated approximately 16 km from the ice shelf at co-ordinates 70° 19'13" S - 2° 21'54" W. (1974 values). In order to establish the most suitable position of the new base, careful consideration of the following factors were required:

- The ice shelf moves at a rate of approximately 210 m per year with accelerated movement recorded towards the icefront itself.

- According to scientific investigations, the possibility exists of a crevace forming between Blaskimen and Apollo ice risesin longitudinal direction about 8 km from the ice shelf, thus causing a break from the main shelf. The new base had to be beyond this line. Because of snow accumulation caused by past activity, the area on the leeward (western) side of the old base was uneven and not suitable for development up to about 3 km from the old base.

- In order to accommodate the construction team in the emergency base, development had to be close by.

- The slope of the ice lenses had to be checked to determine the flow direction of waste water migration.

- Line of movement between the new base and the ice shelf in order to avoid travelling over the old base, thereby avoiding possible caving in.

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- All scientific huts required to remain at surface level were to be placed at least 100 m away from the base to limit accumulation of snow on and in the vicinity of the base.

- In order to satisfy all these factors the base was sited approximately 5 km west from the old base at co-ordinates 70° 18'35" S 02° 24'10" W. (1979 values).

3.5 Logistic Support

All materials and equipment required for the construction of the new base had to be transported by sea on the S.A. Agulhas with normal storage capacity of 1500 tonnes. As helicopters were not available the helipad and hanger was also available for storage.

3.5.1 Storage and handling facilities on the S.A. Augulhas

3.5.1.1 Storage capacity

No.2 hatch openings	: 7,90 x 5,97 m
No.2 tween - Length	: 13,7 m
- Depth	: 2,6 m
No.2 hold - Length	: 10,3 m
- Depth	: 5,7 m
No.2 hold capacity	: 635 m^3
No.3 hatch openings	: 10,62 x 5,97 m
No.3 tween - Length	: 19,2 m
- Depth	: 6,5 m
No.3 capacity	: 1 750 m^3
Effective dry capacity No.2 and 3 tweens	: 1 310 m^3
Effective dry capacity No.2 and 3 holds	: 2 385 m^3
∴ Total dry capacity	: 3 695 m^3
Equivalent mass	: 1 500 tonnes.

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Additional storage space provided by Hanger and Helipad.

Hanger	- Length	:	18,5 m
	- Width	:	15,5 m
	- Height	:	6,0 m
	- Capacity	:	1 720,7 m^3
Helipad	- Length	:	20,0 m
	- Tapering width	:	18 to 15,5 m

3.5.1.2 Crane Handling Facilities

Thompson Derrick

Capacity	:	30 tonnes
Min. outreach at 65° angle off centre line	:	5 m
Min. working angle off horizontal	:	35°

Available for No. 3 hold and 3 tween with duplicate joystick controls on port and starboard wings.

Travelling Crane

Capacity	:	5 tonnes
Max. Outreach	:	12 m
Min. outreach	:	2, 5 m
Lift above deck	:	7 m
Crane above waterline	:	4,5 m
Max. lift	:	30 m
Lift speed	:	20-40 m/min

Can be operated from Port or Starboard.

Coring..../16.

- Coring David

Hook height above helideck	:	10 m
Max. outreach	:	11 m
Capacity at max. reach	:	1 tonne
Capacity at 8 m reach	:	1,75 tonnes

Situated on top of hangar, starboard, 13,5 m above waterline.

3.5.2 Equipment and Plant available for offloading and construction

- Mobile Cranes

  3 Mobile cranes were available. One mounted on a D4 Caterpillar one on a muskeg and one on a sledge.

- Sledges

  18 Sledges with siderails.

  Length : 4,8 m

  Width : 1,4 m

- Four D4D Caterpillars

  2 With dozer blades.

  2 Bacho fittings.

- Six Muskegs.
- One V8 Deutz Off Road Equipment vehicle.
- Two full length cab vehicles for transport

  Sleeping area available for 4 persons per vehicle.

- Two Caravans.

  Sleeping accommodation for 4 persons per caravan.

- Six two berth tents.
- Two snow scooters for quick transport.
- Three portable welding plants.
- One workshop generator for welders, grinders drills, etc.

One ..../17.

- One gantry crane on sledge runners

Capacity	:	5 tonnes
Lifting height	:	4,0 m
Span	:	3,0 - 4,8 m.

During the design and pre-erection stage it became evident that various other equipment had to be purchased in order to successfully erect the base. This equipment is listed in 7.2.1.

3.6 Accommodation Requirements

The 6,1 m (20'- 0") wide buildings of the old base proved to be satisfactory for all the requirements and it was therefore decided to keep to this module using a panel width of 1,2 m giving the buildings an internal width of 6 meters. The following are very brief comments on certain of the building layouts.

- Admin: This building is situated on the Northern side because of the Radio transmission requirements and to keep the interference on other programmes to a minimum.

- Sleeping Quarters:

  The Sleeping Quarters must be kept as quiet as possible and was therefore on a by-pass corridor from the main passage. The rooms are single rooms during the year but a double bunk is provided for take-over periods. The rooms remained 2,4 m x 1,83 m as advised by psychologists for the previous base. The hospital is also situated in this building.

- Toilets: Chemical toilets were provided in a separate building with heated ventilation.

- Power and Workshop:

  The normal associated facilities were provided with a bathroom complex incorporated because of the heat in the building. The building had to be placed relatively central to facilitate the distribution of the various services to and from it, i.e. power cables, fresh - and waste water, etc.

- Bulk Fuel Store:

  Rubber containers (Bladder tanks) were provided in an Armco shell with 4 months supply and gravitation feed to the engines and Wanson burners in the various buildings. For this the fuel store had to be relatively central.

Living ..../18.

- Living Quarters: This complex is considerably larger than the previous one with more recreation space, seperated from the dining room and kitchen area. A by-pass corridor from the main passage was also provided.

- Stores: In the old base all stores were kept in the snow passages. This was done away with by providing a central cold store instead. At present the requirement is approximately 2000 food boxes with a size of 520 x 410 x 260 mm. Providing a mezzanine floor as well it was also possible to provide small storage cubicles for the various science programmes and due to the construction and layout, good control is possible over the stores. An Armco shell was provided to house this store with a by-pass corridor provided off the main passage.

- Science Building:

  The layout of the science room was to a large extent determined by the internal activities and the position of the surface huts. To minimize vehicle movements around the surface huts and to prevent interference of the scientific equipment the building was placed on the Southern side of the base.

- Surface Huts:

  The 10 scientific huts that are spaced around the base on the snow surface were all built on stilts provided with a jacking system in order to keep the buildings above the surface. These are very small huts, the largest being the Balloon hut with a size of 3,6 x 3,6 x 3,0 m high.

4.0 DESIGN OF THE CONCEPT ADOPTED

4.1 Design pressures

4.1.1 Pressure at top of Armco for 15 year period

From accumulation statistics for SANAE we have:

- Mean accumulation per year = 773 mm (loose snow).

- Mean density = 0,529 g/cm^3 = 529 kg/m^3.

- Average cover to base over 15 years = 0,773 x 15 = 11,6 m.

- Average pressure on top of Armco = 529 x 11,6 x 10^{-3} x 9,81 = 60,2kN/m^2.

Pressure ....../19

4.1.2 Pressure of Armco on snow

Weight of shell = 1500 kg/meter with a effective plan width of 6 m.

. Pressure on snow = 2,45 kN/m²

4.1.3 Pressure from Internal Buildings

- Power room and Workshop

Roof and frame on floor	= 230 kg/m
Wall on floor	= 54 kg/m
Floor distributed load	= 54,9 kg/m² (Dead Load)

- All other buildings

Roof and walls on floor	= 104,4 kg/m
Distributed floor load	= 54,9 kg/m² (Dead Load)

4.1.4 Sub-Structure (Steel girders)

Designed to carry 92 kg/m/bearer.

4.1.5 Live Loads

Power room and Workshop	= 23 kN/m²
All other buildings	= 5 kN/m²

4.1.6 Gantry Loads in Workshop

800 kg per side on gantry columns.

4.2 Analysis of Armco Shell for 15 Year Period

The following is an extract of the original calculations.

4.2.1 I.V.U. 18 Profile

Profile size: Width = 7,85 m, height = 6,98 m.

Pressure on top of shell = 60,2 kN/m².

4.2.1.1 Backfill Density — Load Factor K=2

Assume height cover ≥ span or diameter of shell. From load factor chart, say relative compaction is 65% based on AASHO. Although this 65% is for soil, take the applicable load factor for soil and check on end results.

Load factor $K \doteq 2$.

A load factor of K = 1 could be sufficient as the natural cohesion and arching effect of snow is far greater than for soil.

4.2.1.2 Design Pressure Pv — Pv = 120,4 kPa

$Pv = K\ (DL + LL)$

Assume LL = 0

D.L. = 60,2 kPa

$Pv = 2(60,2 + 0) = 120,4$ kPa.

4.2.1.3 Ring Compression C — C = 471 kN/m

$C = Pv \cdot \frac{S}{2}$ S= span in m.

$= 120,4 \cdot \frac{7,85}{2} = 471$ kN/m

4.2.1.4 Allowable Wall Stress fc — fc = 0,0804 kN/mm

D = dia.or span = 7,85 m

r = radius of gyration of corrugated section = 17,5 mm for 5 mm plate thickness (pg.4 A.D.M.)

$D/r = \frac{7850}{17,5} = 448$

Use eq (ii) $fb = 0,2728 - 0,558 \cdot 10^{-6} \left(\frac{D}{r}\right)^2$ — fb = ultimate compr. stress.

when D/r > 294 and < 500

$= 0,2728 - 0,558 \cdot 10^{-6}(448)^2$

$= 0,1608$ kN/mm^2

= ultimate wall stress.

Allowable wall stress =

$Fc = \frac{fb}{2} - \frac{0,1608}{2} = 0,084$ kN/mm^2

<u>NB</u> The value of 75% of $\frac{fb}{2}$ is not applicable as it only applies to arches that are seated on a solid foundation. (Pf. 56 of A.D.M.).

4.2.1.5 <u>Wall thickness A</u>

A = 5,86 mm^2/mm req. < 6,20 mm^2/mm provided.

∴ O.K.

Wall cross-sectional area

$$= A = \frac{C}{f_c} = \frac{471.10^{-2}}{0,0804}$$

$$= 5,86 \ mm^2/mm$$

From table 2 - 4 (pg. 55), a 5 mm wall thickness provides a uncoated wall area of 6,20 mm^2/mm > 5,86 mm^2/mm.

∴ O.K.

4.2.1.6 <u>Handling Stiffness FF</u> (During construction)

FF > 114 max provide support.

$$FF = \frac{D^2}{EI} = \text{Flexibility factor}$$

= 114 mm/kN max.

From Table 2 - 4 (pg. 55), for a 5 mm thickness I = 1899 mm^4/mm.

$$\therefore FF = \frac{(7,85)^2.10^6}{205.1899} = 158 \text{ mm/kN}$$

> 114 mm/kN max.

Supports must be provided (Scaffolding).

4.2.1.7 <u>Check Bolted Seams</u>

S.F. = 3,13

< 4

> 2

Ring compression = 471 kN/m. For 5 mm plate & 2 Bolts per corrigation, the ultimate strength of bolted structural plate longitudinal seams is = 1475 kN/m.

$$\text{Factor of safety} = \frac{1475}{471} = 3.13.$$

< 4 minimum

> 2 (if Armco approved).

Remember Load Factor of K = 2 could increase the safety factor if K was made < 2.

4.2.1.8 Maximum corner pressure Pc — Pc = 240 kPa. < 285 kPa.

$$Pc = Pv \times \frac{Rt}{Rc}$$

Rt = 3725 mm

Rc = 1955 mm.

$$= 120 \times \frac{3935}{1955}$$

$$= 240 \text{ kN/m}^2$$

Required snow density for $\sigma = 240$ kN/m² is ≑ 0,45 g/cm³ (Actual 0,44 g/cm³).

This could be reached within 15 years if a good pre-compaction was applied.

4.2.1.9 Armco plate thickness:

- Bottom and corner plates = 7 mm.
- Sides and top plates = 5 mm.

4.2.2 I.V.U. 6 Profile (Toilet shell)

Profile size: Width = 4,66 m, height = 4,12 m. Additional snow height of 2 m must be added to I.V.U. 18 profile using the same snow density.

4.2.2.1. Backfill Density

Pressure on top of shell

$$= \frac{(11,6 + 2).60,2}{11,6}$$

$$= 70,5 \text{ kPa.}$$

Pv = 141,2 kPa.

4.2.2.2 Design Pressure Pv

$$Pv = K(DL) = 2(70,6) = 141,2 \text{ kPa.}$$

4.2.2.3 Ring Compression C — C = 329 kN/m.

$$C = Pv.\frac{S}{2}$$ S = Span in m.

$$= 141,2 \cdot \frac{4,66}{2} = 329 \text{ kN/m.}$$

4.2.2.4 Allowable Wall Stress fc — $fc = 0{,}1134\ kN/mm^2$

$$D/r = \frac{4660}{17{,}5} = 266 < 294$$

$$fc = fy = 0{,}2275\ kN/mm^2$$

$$fc = \frac{0{,}2275}{2} = 0{,}1134\ kN/mm^2$$

4.2.2.5 Wall thickness A — $A = 3{,}85 < 6.20$ ∴ O.K.

$$A = C/fc = \frac{329.10}{0{,}1134}$$

$$= 3{,}85\ mm^2/mm < 6{,}20\ mm^2/mm.$$

4.2.2.7 Check bolted seams — S.F. = 4,48 > 4 ∴ O.K.

$$S.F. = \frac{1475}{329} = 4{,}48 > 4 \quad \therefore \text{ O.K.}$$

4.2.2.8 Max. corner pressure — Pc = 294 kPa. >285 kPa.

$$Pc = Pv\frac{Rt}{Rc} = 141{,}2.\ \frac{2328}{1117}$$

$$= 294\ kN/m^2$$

Required snow density $> 0{,}45\ g/cm^3$.

4.2.2.9 Armco plate thickness:

- All plates = 5 mm.

4.2.3 I.P.U. 2 Profile (Passage).

Profile size: Width = 2,52 m, height = 2,34 m

Additional snow height of 3,5 must be added to that of I.V.U. 18 profile. Use same snow density.

4.2.3.1 Backfill Density

Pressure on top of shell

$$= \frac{(11{,}6 + 3{,}5)}{11{,}6}\ .60{,}2$$

$$= 78{,}4\ kPa.$$

4.2.3.2 Design Pressure Pv — Pv = 156,8 kPa.

$$Pv = 2(78{,}4) = 156{,}8\ kPa.$$

Allowable ..../24.

4.2.3.4 Allowable wall stress fc — $fc = 0{,}1134\ kN/mm^2$

$$D/r = \frac{2520}{17{,}5} = 144 < 294$$

$$\therefore\ fb = fy = 0{,}2275\ kN/mm^2$$

$$fc = \frac{0{,}2275}{2} = 0{,}1134\ kN/mm^2$$

4.2.3.5 Wall thickness A — $A = 1{,}74 < 6{,}20\ mm^2/m$ Provided.

$$A = C/fc = \frac{197{,}6.10^{-3}}{0{,}1134} = 1{,}74\ mm^2/mm$$

$$< 6{,}20\ mm^2/mm \text{ provided.}$$

4.2.3.6 Handling stiffness:

No problem.

4.2.3.7 Bolted seams

$$S.F = \frac{1435}{197{,}6} = 7{,}46 > 4 \quad \therefore \quad O.K.$$

4.2.3.8 Max. Corner pressure — $Pc = 272\ kPa < 285\ kPa.$

$$Pc = 156{,}8 . \frac{1146}{725} = 248\ kPa.$$

$$\text{or } 156{,}8 . \frac{1260}{725} = 272\ kPa.$$

Say 272 kPa.

4.2.3.9 Armco plate thickness: All plates = 5 mm.

4.3 STEEL GIRDERS FOR BUILDING SUPPORTS

In order to get a smooth level surface for the erection of all the internal buildings a steel girder system was designed consisting of the following main features. (See drawing S 6993/A/3).

- Each girder is supported at 7 points on the ARMCO shell and shaped to the profile of the shell.
- A girder provides 9 supports to the cross beam supporting a steel floor made up of shutter panels.
- These 9 supports are provided with a screw jack each to facilitate the initial and future levelling of the sub-floor.
- The girders are adequately braced in the horisontal direction in order to minimize vertical deflections due to deformation of the ARMCO shell.

4.3.1 Design Loads

- The most critical load configuration appeared in the workshop area due to the access of vehicles into this building. With the girders spaced at 750 mm $^{c}/c$ each support was designed to carry a load of 15 kN. The same girder was used for all other buildings but with a spacing of 1500 mm $^{c}/c$.

- Welding was restricted to a minimum and therefore friction grip bolts were used where possible. This also reduced the build up of internal forces due to temperature changes during the manufacturing and erection stages. Only after the erection was completed were the bolts tightened to the required torque value.

- The girder was also designed to accommodate the settlement of any two supports under full load by redistribution of the internal forces in its various members.

4.4 LAMINATED WOOD BEARERS

- The main fuction of the laminated wood bearers is to adequately support the steel girders and to transfer the loads of the superstructure to the Armco shell giving an even distribution. As snow was the only founding material the design method used was the "Beams on Elastic foundation" theory taking into account the support stiffness of the Armco steel shell.

- The final size required was two beams at each support with a size of 100 mm x 150 mm.

- For the store that consists of tubular scaffold piping instead of steel girders a size of 200 mm x 200 mm was used.

4.5 GABLE END DESIGN

All the ends of the steel shells were sealed off as follows:

- Vertical telescopic girders (ladder beams)

The girders were fixed to the Armco shell in a vertical position and provided with telescopic action at both ends in order to accommodate any deflection that can take place in the steel shell. Two girders were provided to act in pairs at 1500 mm $^{c}/c$.

- Horizontal pipes

  Scaffold piping was clamped to the vertical girders in a horizontal position at 500 mm c/c and also provided with telescopic action at the ends.

- Marine plywood cladding

  Marine ply cladding of 25 mm thickness was then fixed to the horizontal pipes while all the joints were sealed with a hardboard strip. The joint along the circumference of the steel shell and marine ply was sealed off with a rubber neoprene sheet securely fixed to both the members.

- Design load

  Due to the plastic flow and creep properties of the snow a design load of 40 kPa was taken as acting perpendicular to the marine ply.

- Intersection between passage and main shell

  Where the steel passages joined up to the main shell an opening was cut into the marine ply and steel pipe-work in order to allow the passage to protrude into the main shell for about 300 mm - 500 mm. The same fixing arrangement for the steel girders and scaffold pipes as mentioned above was applied. A snow proof joint similar to the above was applied between the passage and the marine ply.

4.6 Vertical Air Shafts

All vertical shafts for cold air intake and hot air extract were constructed on the outside of the gable ends. The components consisted of a scaffold pipe frame-work cladded with 25 mm marine plywood and sealed as for the gable ends. The hot air ducting was placed in this shaft. See further details under Mechanical Work.

4.7 Incline Shaft

The incline shaft was designed using the same Armco profile as the toilet block. The road surface was made up of sand bags packed into the bottom portion of the shell to form a horizontal surface onto which a grid of 75 mm x 225 mm timber beams were placed. On top of the timber beams old tire treads were bolted in order to provide traction for the vehicles when required to travel to the Workshop area. The initial slope of the incline shaft was 3° and changed gradually to 10°. A timber door was built to seal of the incline shaft at the snow surface.

Snow......../27

4.8 Snow Foundation

The founding potential of snow depends on the strength of the snow that is again dependant on its density and temperature. The magnitude of the resulting settlement of any structure placed on the snow is therefore hard to predict. In order to obtain the best possible foundation design it should be a raft like base resulting in a as low as possible bearing on the underlying snow surface and having the maximum practical insulation between the building and snow surface. The practical design pressure for surface snow under the varying factors as mentioned above can be anything between 25 - 100 kN/m². The following table gives approximate values for the compressive yield strengths of deposited snow.

Density of deposited snow	Compressive Yield Strength of deposited snow.
Very low	0 - 1 kN/m²
Low	1 - 10 kN/m²
Medium	10 - 100 kN/m²
High	100 - 1000 kN/m²
Very high	> 1000 - kN/m².

4.8.1 Design of snow foundation

From pit and core profiles taken at SANAE the snow density was recorded at various depths. From this information it was possible to determine the density and depth of the lower snow layers. From the "Journal of Glaciology, Volume 4, October 1963" it was possible to determine the allowable bearing pressure for a given snow density at a temperature of -10°C. From the above information it was decided that the founding level had to be at least 2 m below the natural snow surface in order to found on a medium dense snow surface. In order to form a type of a raft foundation it was decided to construct the foundation in the following manner.

- After removal of the upper 2 metres of snow the surface had to be levelled and a compacted layer of 150 mm was formed.
- On top of this compacted surface a layer of "Typar" had to be placed. "Typar" is a very tough versatile polypropylene spun-bonded fabric with a weight of 200 gm/m².

- It's prime function is to act as a soil stabilisation mat in roadbuilding applications and improves the load bearing capacity of the subsoil by spreading vehicle wheel loads. As the following properties of 1) high tensile strength and toughness, 2) good resistance to rot, 3) no wet shrinkage or growth, 4) open surface structure allowing high permeability and 5) workability and easy handling at low temperature, were suitable for the snow conditions, it was worth using.
- On top of the "Typar" a layer of snow had to be well compacted with another layer of "Typar" on top of it.
- After placing a further 150 mm layer of soft snow on top of this, the Armco shell could be erected.

4.9 Vertical access shafts

The basic construction of these shafts consisted of the same method and materials used for the vertical air shafts. The only difference being the following:

- A shaft was provided on the extreme northern and southern side of the base ajoining the hot air extract shafts as emergency escape shafts of 1,2 m x 1,2 m each.
- The main shaft of 2,4 m x 3,6 m was supplied with a special purpose made staircase with landings for safe access to the base and was placed opposite the entrance of the Living Quarters.
- A goods shaft of 1,8 m x 1,8 m with hoisting facilities was placed opposite the general cold store.

4.10 Toilet disposal system

Due to the difficulty of sewerage disposal systems at sub-zero temperatures it was decided to use chemical toilets similar to that used on most airlines. A special chemical was developed that would not be affected by low temperatures. Once the clean fresh water and chemical is put into the closed system the toilet can be used and flushed for approximately 600 cycles.

After each period of use the contents are pumped into disposable containers and removed from the base. With good house keeping this system proved very satisfactory as regular maintenance to each toilet can be done by simply removing it for service and replacing it with another. With heated ventilation provided it is a pleasant change from the previous cold air open drum system.

Apart from the above facility urinals were provided in the Sleeping and Science buildings. This disposal system will be discussed under the mechnical section of this report.

4.11 Power-room and Workshop

In order to facilitate maintenance on vehicles and the power generators an overhead gantry was provided with a lifting capacity of 2000 kg. The roof of this building had to be a pitched roof to provide adequate lifting space. A double steel portal frame had to be provided to accommodate both the pitched roof and the gantry so that they could perform their functions independently.

4.12 Bulk fuel store

This store was equipped with a lower floor and a mezzanine floor each supporting 4 rubber containers (bladder tanks). Each container has a capacity of 14500 litres giving a total storage capacity of 116 000 litres. At full load of the generators this is adequate for a 5 month period especially during the winter months. The sub-structure to support the lower steel floor is similar to that of all the other buildings while the mezzanine floor is supported on steel beams that are supported by a steel scaffolding system. This scaffolding system was extended above the mezzanine floor level to provide a smaller platform for the elevated gravity tank of 2000 litres. A vertical shaft was provided at the gable end for a flexible extension pipe so that fuel can be pumped from the surface into the tanks.

4.13 Buildings in general

As this whole concept revolves around the very important factor of preventing hot air escaping from the buildings into the voids above them each entrance to every building was provided with a double air-tight door system giving the effect of an air-lock and thus effectively controlling any hot air escape.

Armco ..../30.

4.14 Armco Corridors

In the previous base the corridors were used for storage but as there were so many disadvatages in that method, no storage was provided in the new corridors. The corridors were fitted with a grating type floor which will allow snow and ice on boots to fall through and which can be removed on a regular basis. It was also designed to be strong enough to cater for rubber wheeled trollies to be used in the corridors to transport stores and equipment from one end of the base to the other.

5.0 ELECTRICAL AND MECHANICAL SERVICES

Apart from the structural requirements which have been outlined in the basic concept description, which are of vital importance for the life span of the building, the ancillary services are equally important because all systems must be very reliable and easy to maintain with no destructive effect on the base as a whole.

5.1 Electrical Services

5.1.1 The design of the base required an electrical load of 143 kW. From experience and taking future expansion into account, a 150 kVA generating plant was considered to be sufficient. To ensure that good quality power is supplied for the various scientific programmes, a 175 kVA alternator had to be used with a 150 kW engine. The power room was designed to accommodate three generating sets. No parallel or automatic synchronizing facilities were provided. Investigation into the advantages and disadvantages of water as opposed to air-cooled engines was done but due to ventilation problems having been experienced with water cooled engines under varying loads together with long delivery periods being anticipated as against time available, it was decided that air cooled engines should be installed.

5.1.2 Based on the above, it was strongly recommended that the following units be purschased: Three 150 kW air cooled Deutz engines coupled to 175 kVA Le Roy alternators. The motivation was as follows:-

- The Deutz engine has a high local content which will ensure that spare parts will always be available.
- Many of the vehicles are also equipped with Deutz engines and inter-changeability of parts is therefore possible.

Training ..../31.

- Training of the diesel mechanics is simplified.

- Owing to the fact that many problems have been experienced in the past with alternators it was decided to adopt the Le Roy alternator which has proved very successful on Gough Island.

5.1.3 Cables

After thorough investigation the following type of cables were used:-

- For all internal wiring p.v.c. armoured 4 core cable was used with the armouring as an earth wire.

- External wires used between the main base and the various scientific huts were E.P.M. Rubber cable with the number of cores as may be required. The cable was mounted on a strainer wire 1 metre above snow level fixed to wooden poles which are extended from time to time so that maintenance will be easier and reclaiming will also be possible. The cable is suitable for very low temperatures.

5.1.4 Lighting for the base was supplied as follows:

- 2 x 1,8 m or 1 x 1,8 m florescent fittings throughout the base equal or similar to Phillips Colour 84 having a colour rendering index of less than 85% and an efficiency of not less than 80 Lumens per Watt.

- Emergency lighting from a 12 volt nickel cadmium battery system was provided at important points where it is essential to have continuous supply or for emergencies.

- All electrical cables, lights, power points, etc. were surface mounted due to the panel construction and for ease of maintenance.

5.1.4 Emergency Power Supply

As the present emergency base is equipped with its own generator and emergency transmitter, the installation of a separate emergency power plant in the new base was at first not considered necessary but due to the importance of continuous power supply for the scientific programmes it was decided to install a 50 kVA power plant in the Administration building in a separate standby plantroom.

This ...../32.

This room has to be soundproof as not to interfere with the radio tansmission activities. A duplication of all the power cables was also made in order to have the emergency power function satisfactory to all other buildings.

5.2 MECHANICAL SERVICES

5.2.1 General

The mechanical services for this base include the following:-

- Heating and ventilating of the various buildings.
- The provision of a snow melter and the cold water reticulation system to the various buildings.
- The provision of a waste water disposal system.
- The fuel reticulation system.

5.2.2 The heating system

- The buildings that have heating are the Admin building, Sleeping Quarters, Living Quarters and Science building.

- The heating system in each building is comprised of an oil fired air heater which delivers hot air through ducts to the various rooms. Exhaust and return air, flows via the passage to outside and to the plant room respectively.

- Only a portion of the total supply of air from the air heater is fresh air from outside. The rest of the air is recirculated. The reason for recirculating the air is to reduce the total heating required and to decrease the temperature rise of the air across the air heater. During winter the outside temperature could be as low as -50 °C which means a temperature rise of ± 80 °C over the heater if full outside air is used. The air heaters were designed for a maximum temperature rise of 50 °C. At least 40% of the supply air should then be recirculated. Dampers were provided for the manual adjustment of outside and return air quantities.

- Supply ducts in the various rooms were provided against the outside walls at floor level with supply air grills on top for vertical air discharge. Relief air grills were provided in all doors leading into the passage at low level.

- The access door to the plantroom was placed within the air lock to prevent oil fumes penetrating through the building. As a further precaution, all fresh and return air in the plantrooms flow through sheet metal ducts.

- The workshop and power complex is heated by means of the heat generated by the engines.

5.2.3 <u>The ventilation system</u>

Outside air is required throughout the year for fresh air requirements, for cooling of the Armco shell and passages and for ventilation of the power hut and workshop. The air is conveyed to each building by means of 600 x 600 mm shafts connected to the gable end of each building. Exhaust air from each building and Armco shell is extracted by means of axial flow fans discharging into ducting contained in a combined emergency exit shaft and duct shaft. This shaft is situated against the gable end of the opposite side of the Armco shell to that of the air inlet shaft. Each diesel-operated heating installation is housed in a plant room situated next to the exhaust shaft, thus providing a short and direct route to the surface for both exhaust ducting and flues for the oilfired heaters.

- The ventilation system above creates an air flow in the corridors that contributes to the cooling of the corridor Armco shell as well. Precautions had to be taken at the Sleeping and Living quarters to prevent a short circuit of the air flow between the corridor and the hot air extract shaft by means of sealing the gap between the building and the end of the corridor.

- The power hut and workshop ventilation requirements were similarly treated. One fan was provided for air movement between the Armco shell and hut and two fans used to control the temperature in the hut. All fans are thermostatically controlled. It should be noted that the outside (surface) temperature could rise above 0 °C thus allowing insufficient cooling of the space between huts and Armco shells, Under these conditions melting may occur.

- The air inlet shaft in the power room is separated from the engine exhaust pipe and ice chute for the snow melter. The exhaust pipe is inside the ice chute. The inlet shaft is situated near the diesel engines and the extract shaft at the other end of the workshop.

5.2.4 <u>Humidification</u>

- With no humidification the air in buildings with heating will be very dry due to the very low outside temperatures. This may be unsatisfactory for human comfort.

- Problems could however arise with humidification in that ice formations will occur in outside wall panels where the interior vapour seals are broken and this will result in the deterioration of the insulation material.

- It was finally decided not to provide any humidification facilities.

5.2.5 Snow melter and water supply

- The design of the new exhaust gas heated snow melter differs from the previous cylindrical shaped snow melter in that its shape is rectangular (1,2 x 1,2 x 1,5 m) with a corrugated base to the inner tank so as to present a larger heating surface to the exhaust gases. This will double the snow melting rate.

- In addition, three x 3 kW electric heaters were also installed. These heaters only come into operation when the operating load at the diesel generators falls below a predetermined figure. This assists in maintaining a constant load on the diesel engines.

- The snow melter was installed at a high level with a gravity feed pipe to a 4000 litre steel storage vessel. The water in the storage tank is allowed to cool under natural conditions. Two supply pumps, one used as a standby, provides cold water to the various buildings through a galvanized steel pipe reticulation system. A "Jacuzzi" type mechanical pressurizer was provided in the supply water piping to produce a flow of water at a uniform pressure. Water pipes in unheated spaces are heated by low voltage electric heating tapes, and covered with polystyrene lagging.

- Electric geysers were provided for hot water in the various buildings.

5.2.6 Waste water disposal system

- Certain buildings were provided with a central stainless steel waste water storage tank from where the waste water is pumped to a main storage tank provided in the power hut. The stainless steel tanks are positioned below the raised floors of the shower in the Sleeping quarters, the scullery in the Living qaurters and photografic laboratory in the Science building. The urinals of these buildings discharge into the same tanks.

Copper ..../35

- Copper piping was used for all the internal requirements with low voltage heating tapes and polystyrene lagging in unheated areas.

- From the main storage tank in the power hut (positioned under the raised bathroom floor) the waste water is pumped through a steel pipe up to the snow surface and discharged 200 metres away from the base. Heater tape and lagging was also provided for this pipe.

- All pumps are duplicated to provide standby facilities.

- All basins, baths etc. were placed at a high enough level to provide sufficient free drainage to the storage tank.

- Suitable strainers and traps were provided in the system with easy access for maintenance.

5.2.7 Fuel System

In the Bulk Fuel store the fuel is pumped from the rubber tanks into the elevated gravity tank from where it gravitates to the oil fired heaters in the various buildings and the diesel engines. The oil fired heaters were directly connected to the reticulation system thereby eliminating the use of day tanks. Copper piping was utilized for the fuel reticulation system.

6.0 FIRE PROTECTION

Fires with the attendant risk of loss of life is a reality which cannot be overlooked in Antarctic bases and South Africa's experience in this regard is an endorsement that great care must be exercised in the design of a new base.

6.1 The fire hazard

To prevent or to stop a fire, heat must be removed, oxygen excluded or the fuel removed. The first two elements are of prime importance for survival in Antarctica while the third element, combustible material, is usually present in vast quanitities. It is therefore necessary that fire protection receives a very high priority in the choice of material and in the formation of any principle decisions.

Water was not available for fire protection in previous S.A. Bases.

In ..../36.

In the new base this very old and reliable fire fighting media is available in limited quantities, which certainly increases the fire fighting effectiveness considerably.

6.2 Choice of Materials

The choice of the materials to be used was based on the following qualities:-

- Good insulation.
- Effective vapour barrier.
- Cellular structure.
- Structurally self supporting.
- Low maintenance.
- Easy to work.
- Easy to erect.
- Low smoke contribution index.
- Low flame spread.
- Low heat development.

Wood panels have proved to very difficult to seal for vapour penetration. The safe-type insulating materials such as the glass and mineral fibres get ice-logged in a very short period of time and consequently lose all their insulating properties as proved at the previous base. The formation of thermalbridges also presents a problem.

The only alternative to the insulation problem is a foamed plastic. This immediately spells DANGER - a factor that must be handled with great care. The insulation properties approximately double when using the following materials of a given thickness: fibreboard, mineral wool, polystyrene and polyurethane.

It was decided to use polyurethane as all the concept requirements could be achieved.

6.3 Facilities provided

- An ionization type fire detection system was installed throughout the complex, with heat detectors in the power plant and areas where unwarrented alarms may occur.

- Because the buildings are separated by a cold corridor, the buildings are already compartmented and with the introduction of an airlock with two self-closing doors at each end of the building, the likelihood of a fire spreading from one building to another is very remote.

Appropriate ..../37.

- Appropriate types of fire extinguishers were mounted in each building, including asbestos blankets and a specially developed fire hose which operates at a low flow from the water supplied by the 4 m^3 tank in the power room. The power room and workshop is protected with an automatic extinguishing CO_2 system with automatic fire dampers fitted to the outlet side of the forced air fans.

- Should a fire occur, all supply fans for that particular building will stop and only exhaust fans will operate to create a negative pressure and thereby prevent smoke spread. Breathing apparatus was also mounted throughout the base.

- To assist in the most effective action during a fire situation, a loudspeaker system was installed for audible alarm instead of bells or sirens. Tone generators will generate alert and evacuation signals and speach is also possible to assist with evacuation procedure.

- It must also be borne in mind that some of the programmes work on a shift basis so that people will always be present and around.

7. GENERAL PREPARATIONS

7.1 Colour coding

Due to the vast quantity of building materials and equipment that had to be shipped to SANAE, handled and stored until required, it was decided to make use of a colour coding system as follows:

- Armco:- A colour code for each main building shell was provided as well as for each section of the corridor.

- Buildings and equipment:- All the crates that contained the building material and equipment that had to be used for a specific building were marked with the similar colour to that of the corresponding steel shell.

- Surface huts:- The same was done with all the crates that contained the material and equipment of the surface huts.

- Spare material:- All spares and extras were left unmarked.

Pre-erection ....../38

7.2 Pre-erection

As the new concept also meant new building material and techniques it was decided to have a pre-erection of certain buildings and Armco sections for the following reasons:

- Construction methods and sequence of erection could be determined to assist further planning of the construction stage and to determine extra equipment requirements.

7.2.1 Additional Equipment

The following is a short list of additional equipment bought at this stage to facilitate the erection.

- "Hilti" guns and fastners.
- Torgue wrenches.
- Jig saws.
- Portable welding plant.
- Angle grinders and safety goggles.
- Air compressor with guns for sealing purpose.
- "Cum-a-longs" (Turfers).
- Selection of steel cable slings.
- Step ladders.
- Extra scaffolding.
- Drilling machines.
- Waterproof suits to assist with Armco erection.
- Safety helmets with ear-mufflers.

7.2.2 Checking and crating of Materials and Equipment

All building material and equipment was delivered to the pre-erection site where the quantity and quality was checked before it was packed into suitable containers and crates and then colour coded as mentioned above.

7.2.3 Loading of Ship

The ship was loaded according to a pre-determined schedule so that materials and equipment that was required first could be off-loaded first.

Construction ...../39.

8.0 CONSTRUCTION STAGE AT SANAE

8.1 The Depot

The very important factors to keep in mind when establishing a depot where all the building material and equipment can be stored until required is as follows:-

- The position relative to the building site, i.e. distance from site, traffic control, vehicle manoeuvrability, snow deposit direction during a storm, etc.

- The layout of the depot, i.e. accessibility for sledge trains, marking the position of material and equipment, a good record system, etc.

In order to facilitate the above requirements a system of marker poles and coloured flags was used. By forming a predetermined grid system with the variety of flags each block was numbered and colour coded to facilitate the keeping of records of each and every item delivered to the depot. The width of the storage rows was kept relatively narrow providing access on both sides for slegde trains. This system proved to be very valuable because after a snow storm occurred idividual items could still be uncovered in their exact position.

8.2 Construction team

The construction team and other available labour consisted of the following persons:-

- 40 Members from the Department of Community Delop-ment consisting of Engineers, Technicians and Artisans, forming the erection team.

- 4 Logistic members of the Department of Transport.

- 16 SANAE members of the old team as extra labour.

- 18 SANAE members of the new team as extra labour.

- 10 Scientists from various institutions for the installation of special equipment and assisting as extra labour.

8.3 Advance Party

While the unloading of the ship continued an advance party of 15 persons left for the existing Emergency base for the following two reasons.

- Accommodation had to be provided for the Erection and Logistic team by using the Emergency base and erecting additional huts on the surface. The surface accommodation consisted of a fully equipped kitchen, three sleeping huts and diningroom.

Linde huts ....../40.

Linde huts were used for the sleeping and kitchen facilities while a typical hot house (aluminimum framework and plastic sheeting) construction was used for the diningroom. The facilities provided were for 50 people.

- The position of the construction site had to be established, surveyed, pegged out and snow cores drilled to determine snow densities, The depot was also marked out as described above.

8.4 Construction procedure

- Due to a shorter construction period available than originally anticipated it was decided to to erect the buildings in the following sequence. First the Powerroom and workshop, followed by the Bulk Fuel Store, the sleeping quarters, the Administrative building, the Living quarters the Science block, the Stores and the Toilet block.

- Excavations for the Powerroom and Workshop started on 11 January 1979, the snow foundation was prepared on 12th, the Armco shell was started on the 13th and completed on the 15th. During the excavations for this building it was decided to divert from the planned snow foundation and only provide a single layer of "Typar" on a 150 mm compacted snow surface. The reasons for this decision were the time consuming effort of compacting each snow layer to achieve the 1 metre sandwich construction and the accessibility of the compacting equipment in the excavation.

- Once an Armco shell was completed work immediately started on the gable ends and the placing of the floor substructure. This method was followed throughout so as to prevent snow buildup in a shell if a snow storm took place.

- Close radio contact was kept with the ship and the temporary "bukta" depot for the correct supply of building material as required.

- Only after all the building material and equipment was unloaded from the ship on 17 January the full construction team was available. This made it possible for the various specialist teams to be formed so that all the different tasks could proceed simultaneously according to the predetermined priorities.

- All material from the "bukta" depot was delivered to the construction site depot by 6 February 1979.

- The main Armco shells were completed on 5 February.

Backfilling ..../41

- Backfilling under all the Armco corner plates was done by means of a small snow plough in order to provide a better bearing support to the corner plates. Further backfilling was then carried out to the original snow level by means of bull dozers.

- The Armco corridors were started on 16 February. As the corridors had to connect up to the main buildings at snow surface level it was decided to only place a layer of "Typar" on the unconsolidated snow surface and provide a 150 mm compacted snow layer above it.

- At this time all the buildings were in various stages of completion and the available construction team, sub-divided into specialist groups, were racing to complete the base before departure.

- By the time of departure on 7 March 1979 the base was 99% complete with only a few minor finishes that had to be done by the two artisans left behind for that year.

8.5 Tables of interest

Table 1 indicates the total time in which some items were completed and the number of persons used. The time given includes all rest periods.

Table 2 gives the figures of the actual construction time spent on the various Armco shells and the rate of construction in metres per hour.

TABLE I A

	Power hut and Workshop	Bulk Fuel store	Sleeping quarters	Admin Building
. Excavation	24h/12p	24h/12p	12h/12p	4h/8p
. Levelling & Foundation	24h/12p	8h/5p	12h/12p	12h/8p
. Armco	46h/12p	30h/12p	100h/9p	54/10p
. Gable end - 1	48h/4p	72h/4p	60h/4p	60h/4p
- 2	48h/4p	72h/4p	60h/4p	60h/4p
. Sub-floor	60h/8p	36h/6p	72h/7p	78h/7p
. Mezzanine floor	NA	24h/5p	NA	NA
. Linde - Ext	180h/8p	NA	48h/8p	24h/5p
- Int	132h/4p	NA	136h/6p	108h/4p
. Portal frame	18h/14p	NA	NA	NA
. Header tank	NA	4h/4p	NA	NA
. Hatches	8h/2p	4h/2p	/3p	/3p
. Mechanical	400h/4p		48h/3p	96h/3p
. Electrical	156h/3p		60h/3p	180h/2p

Note h = hours
p = people required
NA = not applicable.

TABLE I B

	Living quarters	Science Building	Store	Tiolet
. Excavation	12h/12p	12h/10p	18h/8p	4h/6p
. Levelling & Foundation	24h/10p	8h/10p	12h/8p	4h/6p
. Armco	90h/12p	40h/12p	42h/12p	12h/8p
. Gable ends - 1	60h/4p	48h/4p	42h/4p	12h/4p
- 2	50h/4p	48h/4p	42h/4p	16h/4p
. Sub-floor	72h/6p	48h/6p	36h/5p	12h/2p
. Mezzanine floor	NA	NA	48h/6p	NA
. Linde - Ext	60h/6p	66h/8p	NA	16h/4p
Int	96h/4p	120h/3p	NA	16h/4p
. Portal frame	NA	NA	NA	NA
. Header tank	NA	NA	NA	NA
. Hatches	/4p	/4p	NA	/2p
. Mechanical	90h/3p	90h/3p		/1p
. Electrical	84h/2p	168h/3p		/2p

Note: h = hours
p = people required
NA = not applicable.

TABLE 2

Building	Length of Armco shell (m)	Actual time spent (hours)	Metres/hour
Power hut and Workshop	26,84 m	33 h	0,81 m/h
Bulk fuel store	17,08 m	30 h	0,57 m/h
Sleeping quarters	29,28 m	50 h	0,58 m/h
Admin Building	17,08 m	27 h	0,63 m/h
Living quarters	29,28 m	51 h	0,57 m/h
Science quarters	24,4 m	34 h	0,72 m/h
Store	17,08 m	22 h	0,78 m/h

Note:

- The rate of construction for the Powerhut and Workshop of 0,81 metres per hour can be ascribed to the competition that existed between the two teams erecting the shell, each team working a 12 hour shift,
- A single team was appointed from the second shell for the rest of the construction period.

9.0 MAINTENANCE PERIOD

Since the construction of the Base a team is sent down to SANAE each year during the take-over period to do base maintenance and alterations as required. This period is termed the maintenance period and the following points are of interest.

9.1 Heating

It is intersting to note that due to the efficiency of the 150 mm polyurethane panels it has not been necessary to use the oil fired heaters in any of the various building units. The equipment and body heat gain from the occupants of the buildings is sufficient to maintain an acceptable temperature level. Ventilation only is in operation.

9.2 Power Hut and Workshop

Problems were experienced with the dissipation of heat in the power hut due to the heat generated by the air cooled Deutz engines. The induced draught extract system could not cope with the heat load. Four axial flow fans were installed in the louvred air inlet openings and cold outside air was forced into the room to mix with the hot air from the engines. The forced draught fans each have half the capacity of the two induced draught fans. Either two or four forced draught fans operate in conjunction with one or two induced draught fans as demanded by the thermostats. It appears that this measure has been successful as the operating temperatures in the power hut have fallen to $\pm$ 16°C.

9.3 The H-vents

Problems were experienced with the H-vents during high winds or blizzard conditions as drift snow would find its way into the vents and cause blockages. Rotating weather vane type vents were installed and it will be interesting to record the results of this exercise.

9.4 Base settlement

9.4.1 During each take-over period a survey is done througout the base in order to determine the settlement of the Armco structures relative to each other. As the datum is also subject to movement the readings are adjusted in order to give an indication of the settlement that has taken place. Each year's results are super-imposed one upon the other and various deductions can than be made as follows:

- Settlement of the main corridor is more pronounced than that of the buildings. This is due to the fact that the snow foundation of the corridor had to be placed on the natural snow level where the bearing pressure was much lower than that for the building shells.

In ..../46

- In the buildings where heat is generated there is a direct relationship between the heat loss and the amount of settlement.

- Vehicles travelling over the shells have an influence on the settlement.

- A slight tilt of the shell and buildings has taken place. This is possibly due to the effect of the prevailing wind direction and snow buildup.

- It is expected that the settlement of all the buildings and the corridor will reduce as the bearing pressure of the snow increases, as well as the fact that the steel shells are now protected from the influence of the sun.

10. CONCLUSION

The success of the new Base will be determined by future maintenance, good house-keeping and experience still to be gained, but the Base as a whole is at present functioning most satisfactory.

11. ACKNOWLEDGEMENTS

The author wishes to thank all the members of the Department of Transport and the Department of Community Development (previously the Department of Public Works) who formed part of the Design Team, including the Construction Team, for their contributions towards the SANAE project.

APPENDIX A : PHOTOGRAPHS

Photo 1 : Ice arching in old base due to heat loss.

Photo 2 : Bay ice conditions during unloading of the ship.

Photo 3 : Preparation of snow foundation.

Photo 4 : Armco under construction.

Photo 5 : Completed Armco shell.

Photo 6 : Armco showing wooden bearers and ladder beams.

Photo 7 : View of steel girders supporting sub-floor.

Photo 8 : Ladder beams and steel floor.

Photo 9 : Gable end sealed off.

Photo 10 : Corridor entering gable end of main shell.

Photo 11 : Inside view of partially completed Linde building.

Photo 12 : Internal portal frames of Power hut.

Photo 13 : Corridor intersection.

Photo 14 : Services fixed to top of corridors.

Photo 15 : Chemical toilet.

Photo 16 : Main hatch staircase.

Photo 17 : Surface huts.

Photo 18 : Completed SANAE Base.

APPENDIX B : DRAWINGS

Drawing 1 : Site Layout.

Drawing 2 : Base Layout.

Drawing 3 : Typical Section of Buildings.

Drawing 4 : Typical section of Store

Drawing 5 : Bar chart of actual construction times.

Drawing 6 : Settlement survey of Base.


Photo 1


Photo 2


Photo 3

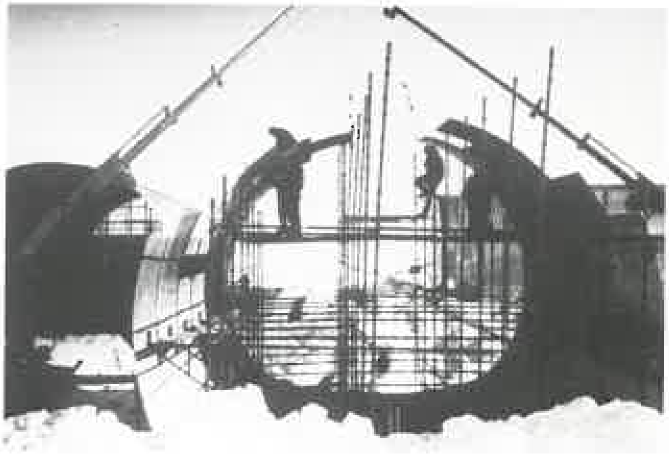
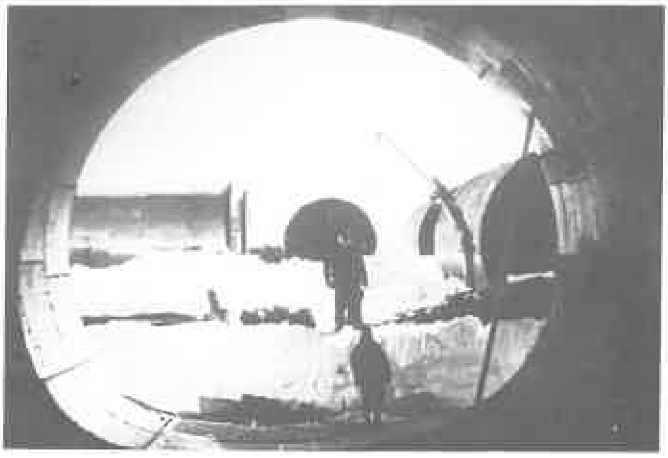


Photo 4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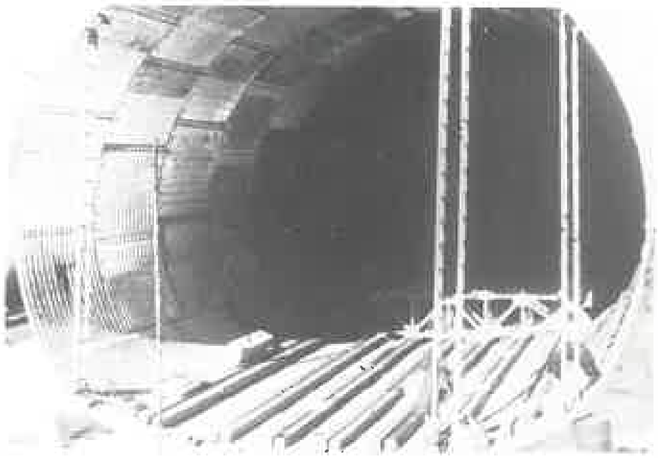
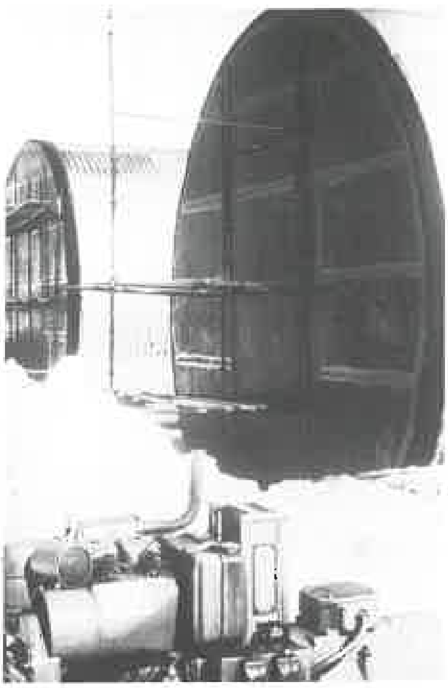


Photo 6

Photo 7

Photo 8



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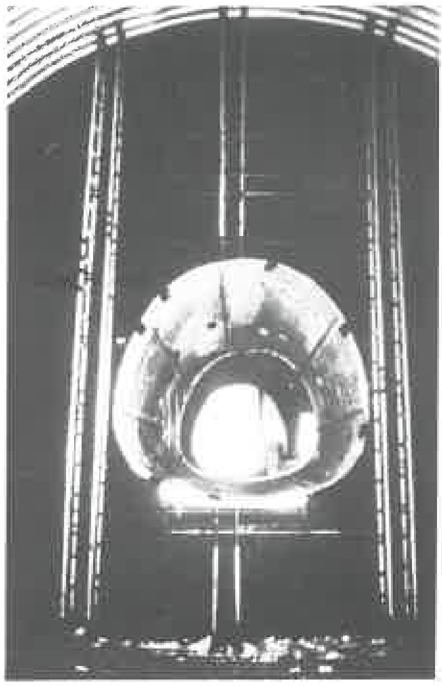
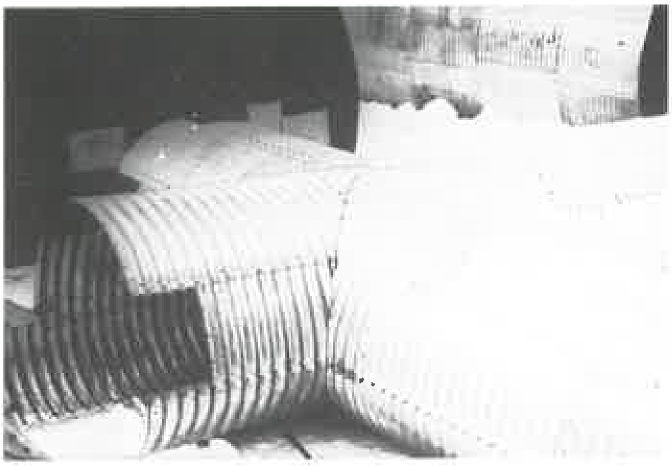


Photo 10

Photo 11

Photo 12



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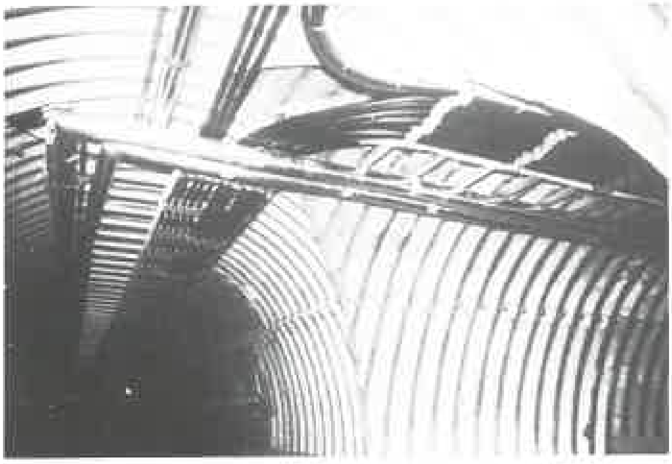

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Photo 15

Photo 16

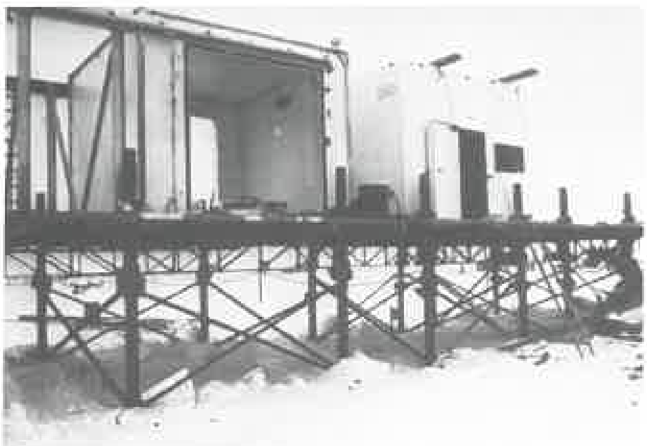
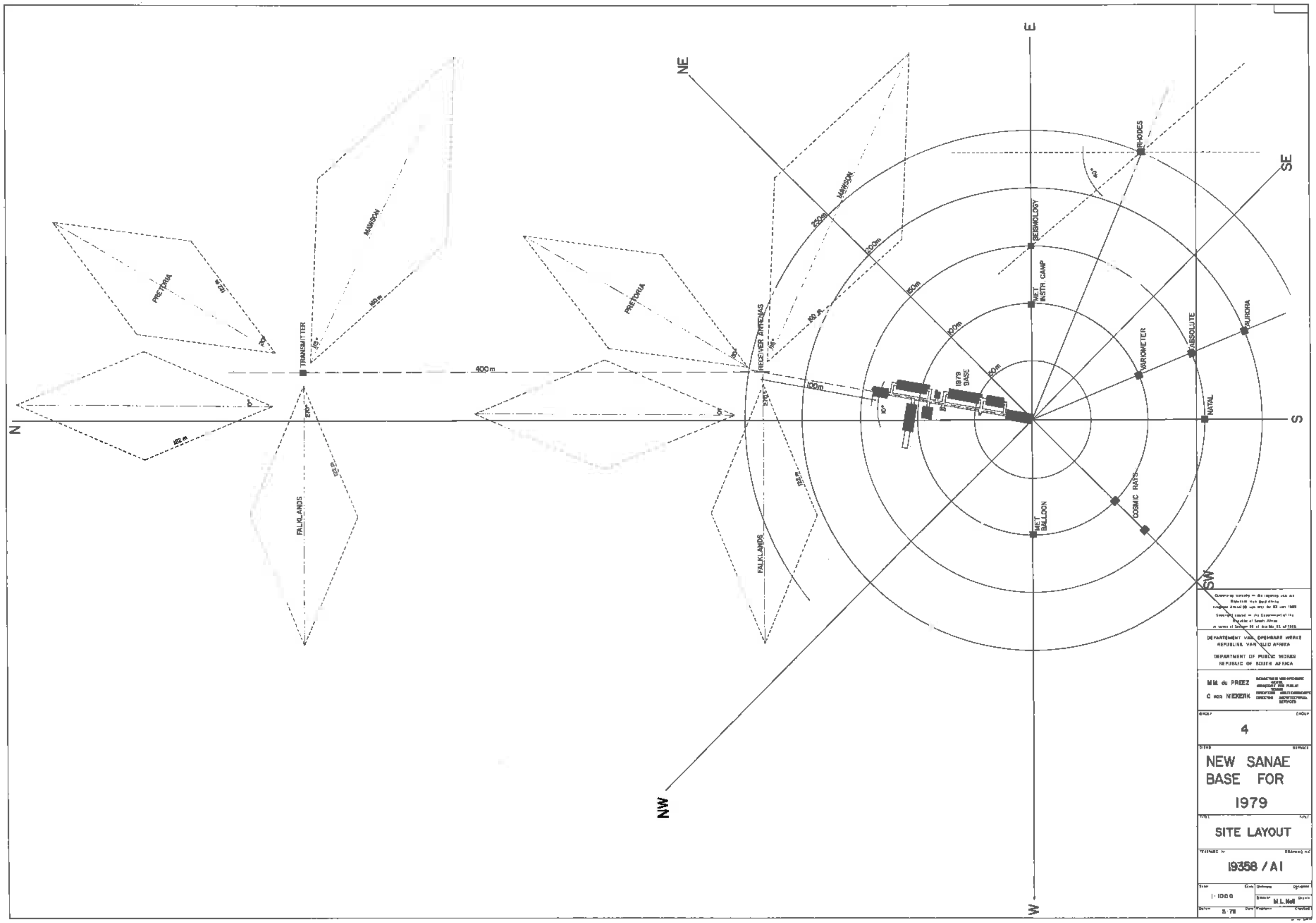


Photo 17

Photo 18


N
S
E
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SW
TRANSMITTER
RECEIVER ANTENNAS
PRETORIA
MAWSON
FALKLANDS
400 m
100m
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100m
150m
200m
250m
1979 BASE
MET INSTR. CAMP
SEISMOLOGY
RHODES
VARIOMETER
ABSOLUTE
AURORA
NATAL
MET BALLOON
COSMIC RAYS
DEPARTEMENT VAN OPENBARE WERKE REPUBLIEK VAN SUID AFRIKA
DEPARTMENT OF PUBLIC WORKS REPUBLIC OF SOUTH AFRICA
M.M. du PREEZ
C van NIEKERK
4
NEW SANAE BASE FOR 1979
SITE LAYOUT
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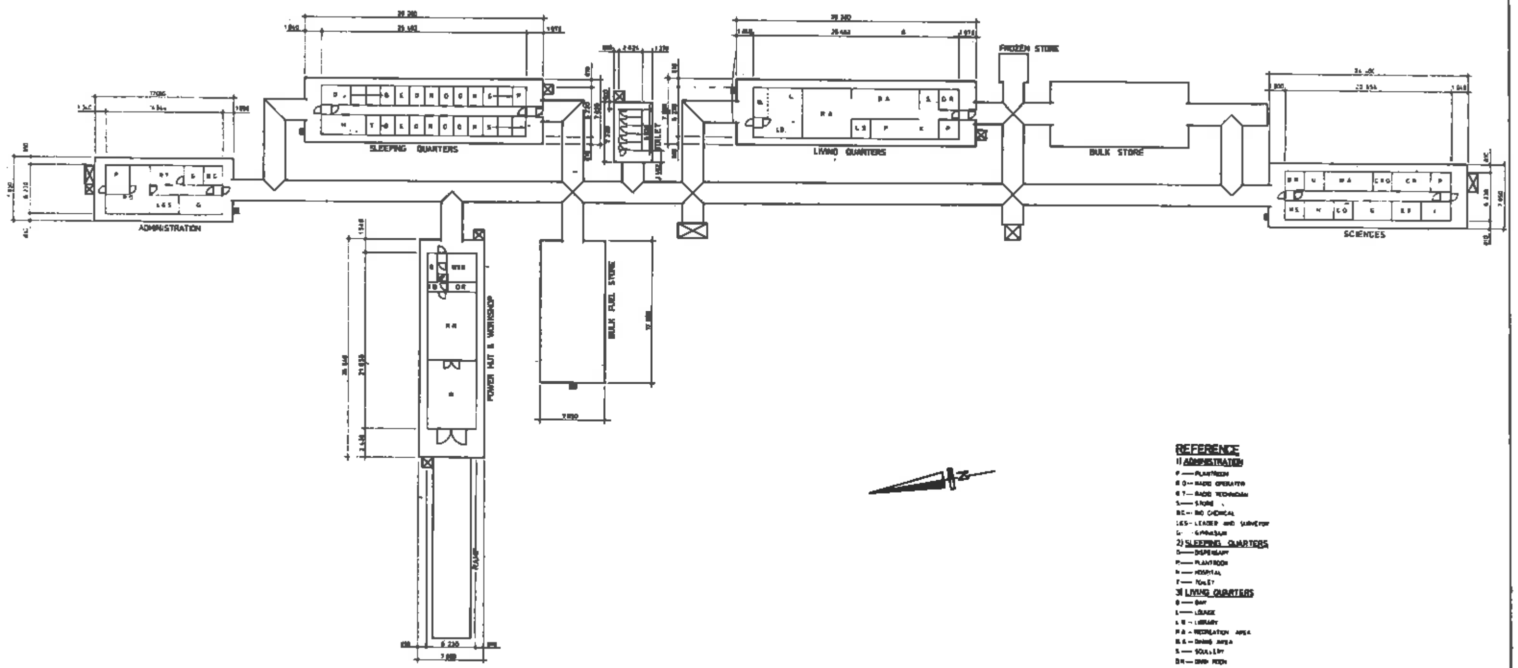
1 : 1000
M.L. Nell
5 - 78

PW457



REFERENCE

1) **ADMINISTRATION**
P — PLANTROOM
R O — RADIO OPERATOR
R T — RADIO TECHNICIAN
S — STORE
BC — BIO CHEMICAL
LES — LEADER AND SURVEYOR
G — GYMNASIUM

2) **SLEEPING QUARTERS**
D — DISPENSARY
P — PLANTROOM
H — HOSPITAL
T — TOILET

3) **LIVING QUARTERS**
B — BAR
L — LOUNGE
L B — LIBRARY
R A — RECREATION AREA
D A — DINING AREA
S — SCULLERY
D R — DARK ROOM
L S — LIQUOR STORE
P — PANTRY
K — KITCHEN
P — PLANTROOM

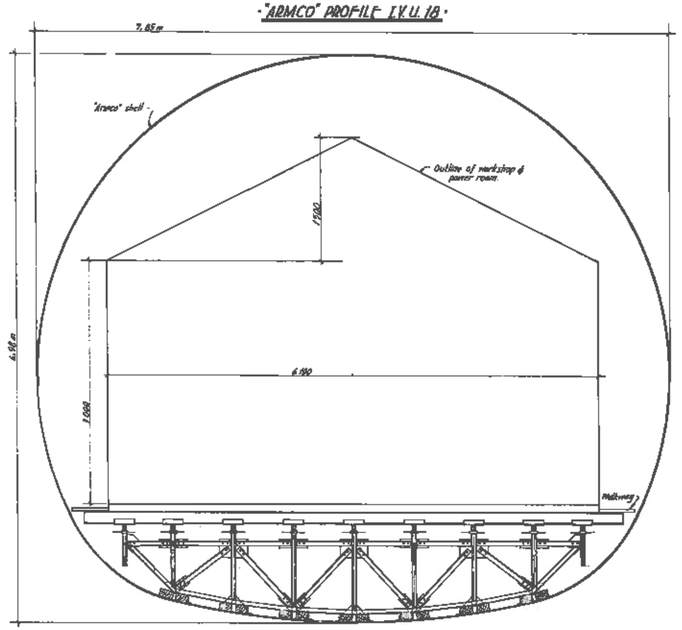
4) **SCIENCES**
D R — DARK ROOM
U — URINAL
W A — WHISTLER AURORA
C R O — COSMIC RAYS OFFICE
C R — COSMIC RAYS
P — PLANTROOM
M S — MET STORE
M — METEOROLOGY
C O — COMPUTING OFFICE
G — GEOMAGNETISM
E E — ELECTRONIC ENG
I — IONOSPHERICS

5) **POWER HUT AND WORKSHOP**
W — WORKSHOP
M R — MACHINE ROOM
I B — IRON BOARD
B — BOTTLES CO_2
W B — WASH AND BATHROOM
D R — DRYING ROOM

***NOTE*:**
All overall longitudinal dimensions of "Armco" are between end holes in "Armco" sheeting.

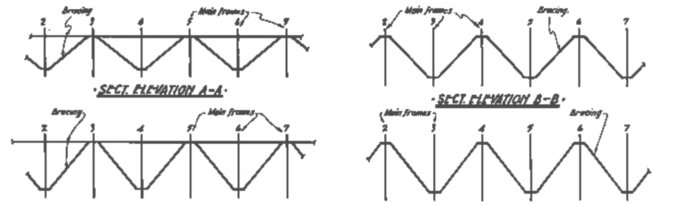
PW457

·"ARMCO" PROFILE I.V.U. 18·



·TYPICAL SECTION SHOWING OUTLINE OF WORKSHOP·
1:20.

·LINE DIAGRAMS OF BRACING· 1:22.

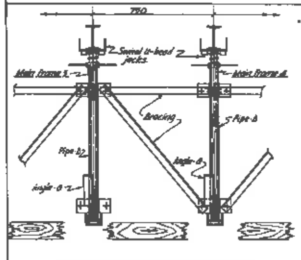


·SECT. ELEVATION A-A·

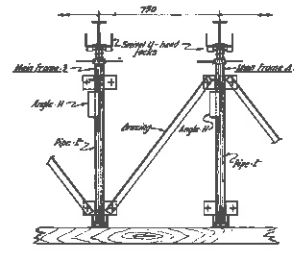
·SECT. ELEVATION B-B·

·SECT. ELEVATION C-C·

·DETAILS OF BRACING·
1:10.



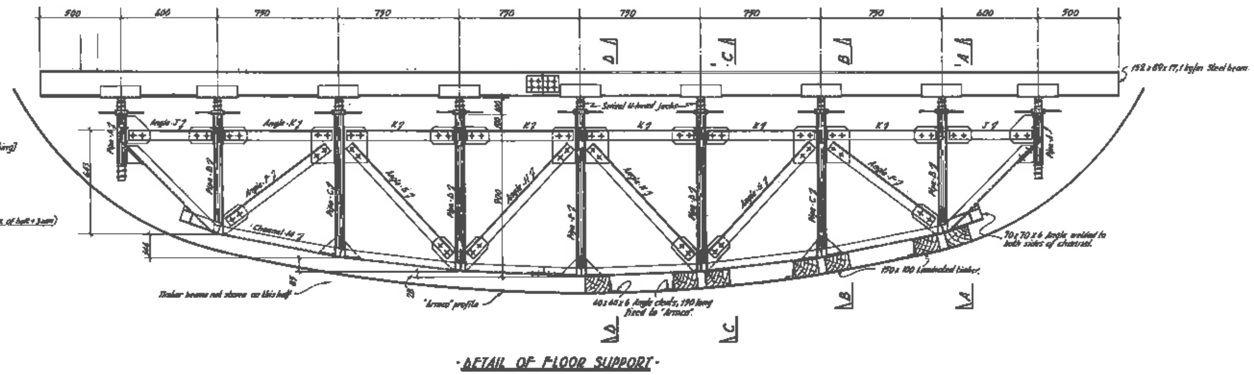
·TYPICAL SECT. ELEVATION C-C·



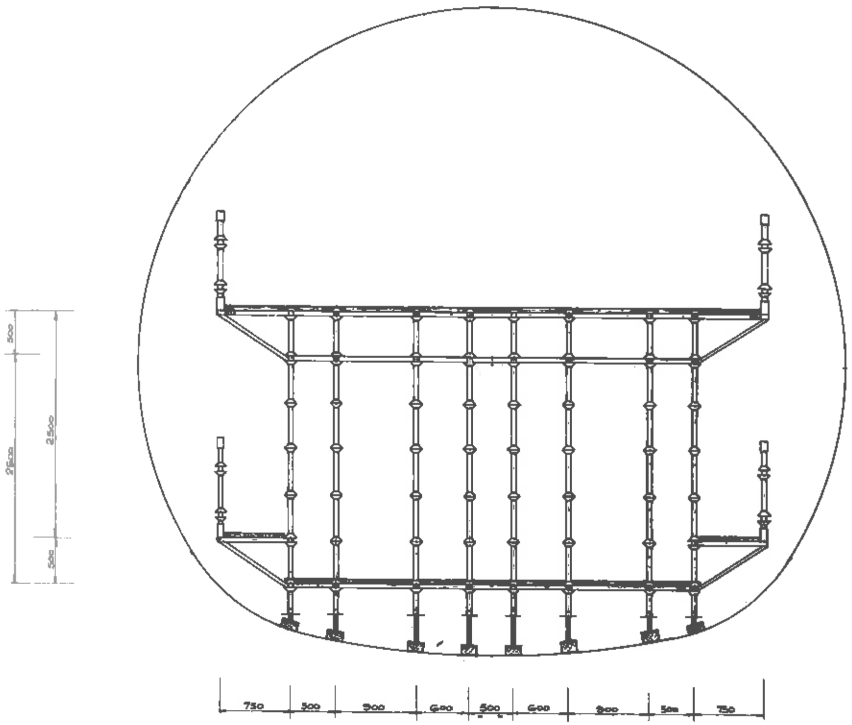
·TYPICAL SECT. ELEVATION D-D·

NOTE:

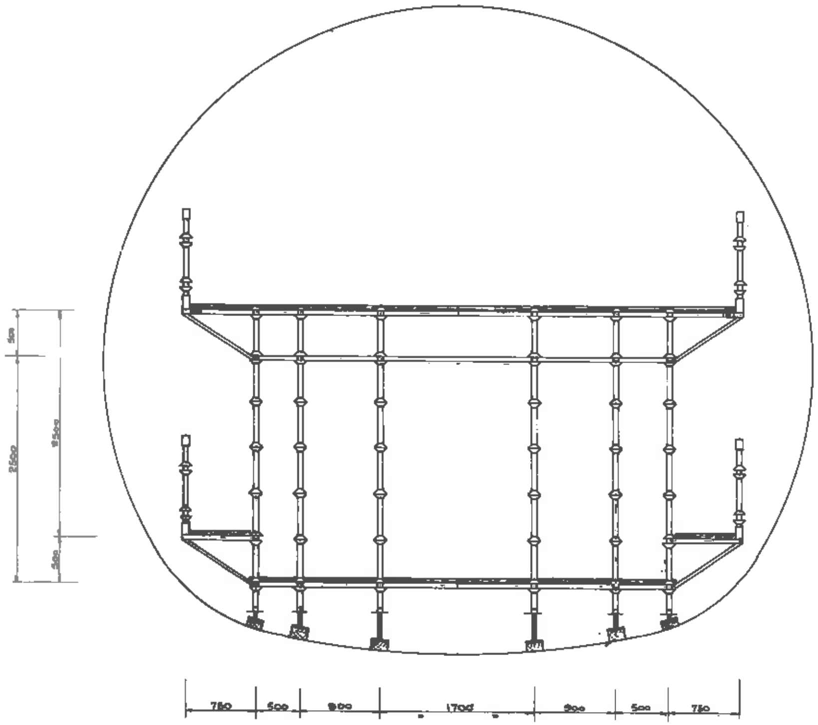
Pipes A to E are 48.4mm O.D. wall thickness 3.35mm (H.T steel) [Standard scaffold tubing]
Angles F to J are 60x60x6 mild steel.
Channel M is 100x50x10.6 kg/m mild steel.
All gusset plates are 8mm thick unless otherwise shown.
Bolts in main frame are 16mm & those in bracing are 12mm H.T. Friction grip.
All fillet welds to be 5mm. All welding rods to conform to A.N.S.E. 7011.
All bolt holes are to be slotted & washers must be used throughout (Slots to be 2 x diam. of bolt + 3mm)
All bracing is 40x40x5 mild steel.



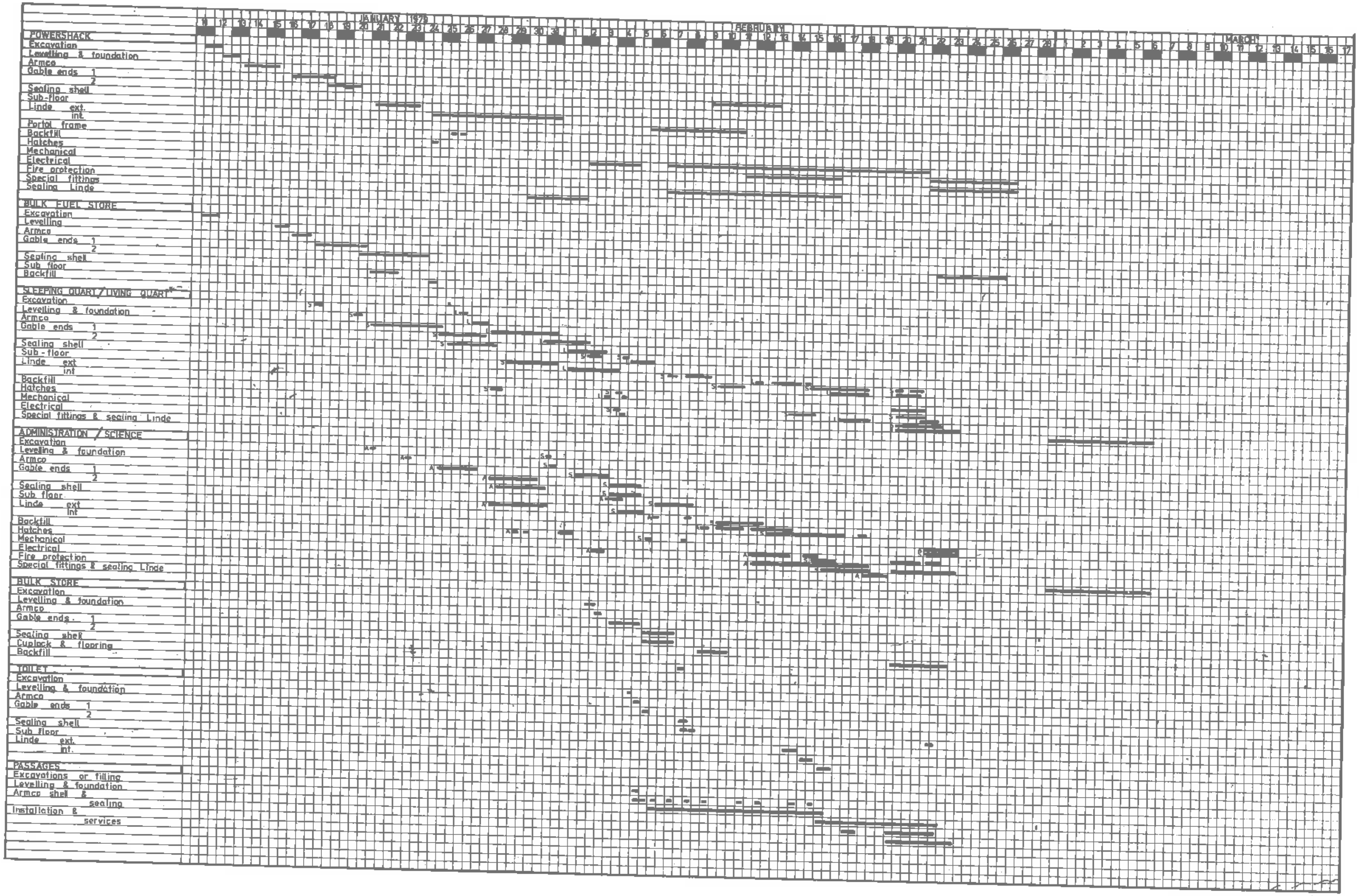
·DETAIL OF FLOOR SUPPORT·
1:10.

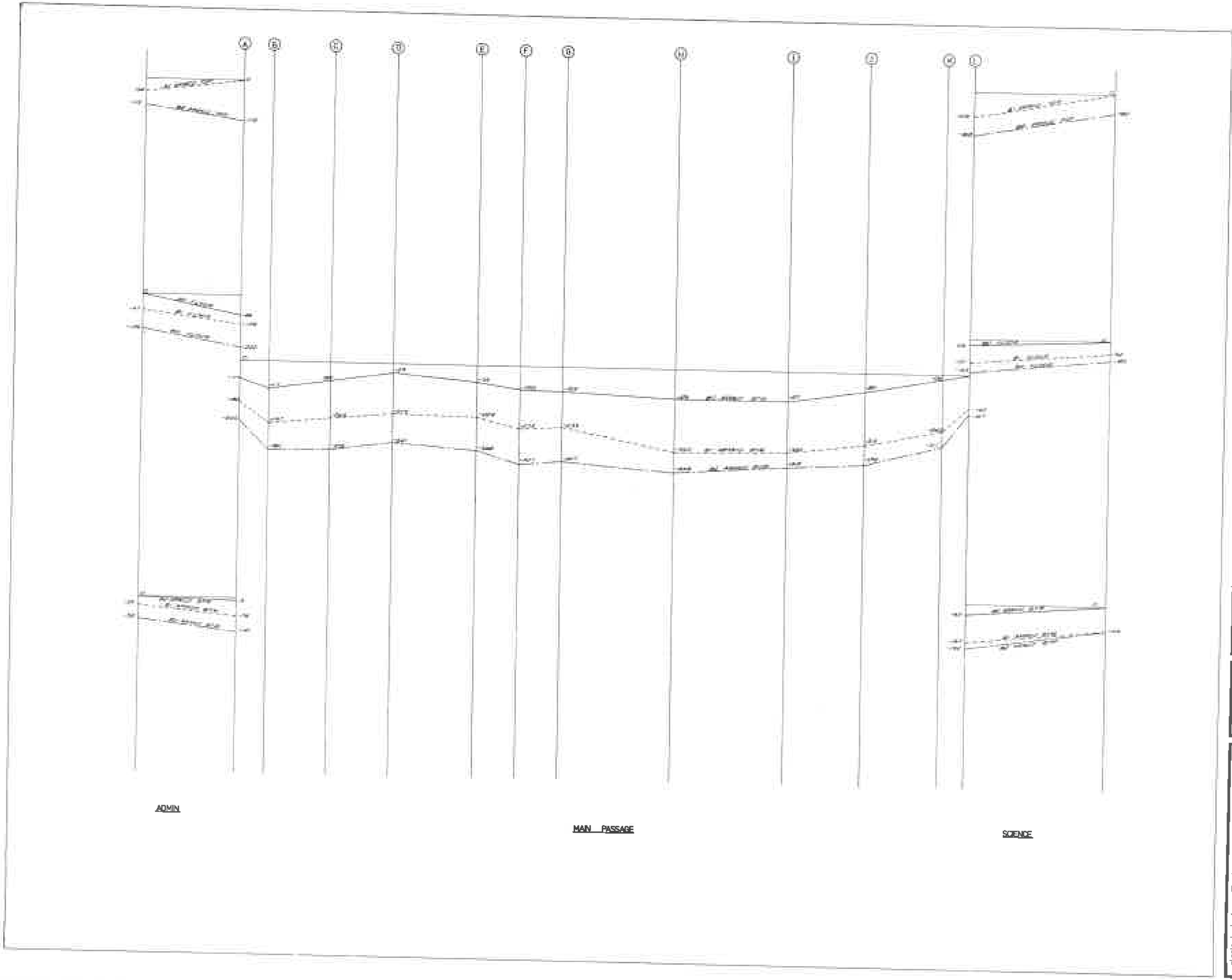


SECTION B-B



SECTION 'C-C'


JANUARY 1979
FEBRUARY
MARCH
POWERSHACK
Excavation
Levelling & foundation
Armco
Gable ends 1
2
Sealing shell
Sub-floor
Linde ext.
int.
Portal frame
Backfill
Hatches
Mechanical
Electrical
Fire protection
Special fittings
Sealing Linde
BULK FUEL STORE
Excavation
Levelling
Armco
Gable ends 1
2
Sealing shell
Sub floor
Backfill
SLEEPING QUART./LIVING QUART.
Excavation
Levelling & foundation
Armco
Gable ends 1
2
Sealing shell
Sub-floor
Linde ext
int
Backfill
Hatches
Mechanical
Electrical
Special fittings & sealing Linde
ADMINISTRATION / SCIENCE
Excavation
Levelling & foundation
Armco
Gable ends 1
2
Sealing shell
Sub floor
Linde ext
int
Backfill
Hatches
Mechanical
Electrical
Fire protection
Special fittings & sealing Linde
BULK STORE
Excavation
Levelling & foundation
Armco
Gable ends 1
2
Sealing shell
Cuplock & flooring
Backfill
TOILET
Excavation
Levelling & foundation
Armco
Gable ends 1
2
Sealing shell
Sub floor
Linde ext.
int.
PASSAGES
Excavations or filling
Levelling & foundation
Armco shell & sealing
Installation & services



Departement van Gemeenskapsontwikkeling
Department of Community Development

ANTARCTIC BASE
SANAE

STABILITY SURVEY

LONGITUDINAL SECTIONS
OF BASE

S7731/4