Journal of Telecommunications and the Digital Economy

The Australian East-West Radio Relay System Revisited: Thermal Design of Repeater Shelters

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Abstract: The *Journal* revisits two historic papers from 1971 covering the thermal design and environmental controls in repeater shelters of the Australian East-West radio relay system from Northam in Western Australia to Port Pirie in South Australia.

Keywords: History of Australian Telecommunications, East-West Radio Relay System, Repeater Shelters

Introduction

The historic paper in the March 2024 issue of the *Journal* (Moorhead, 2024), covering the design of the Australian East-West radio relay system from Northam in Western Australia to Port Pirie in South Australia in the early 1970s, was well received. Given ongoing interest in passive devices, I have reprised two papers from the same 1971 special issue of the *Telecommunication Journal of Australia* covering the thermal design and environmental controls of the repeater shelters in this system.

The route distance was around 2,400 kilometres and most terrestrial sites would be off the mains power grid. Therefore, reliability in passively cooled equipment shelters and low power consumption were prime considerations. The proposed GEC microwave equipment would be fully solid state, and this allowed passive cooling to be considered.

The first historic paper (Tomlinson & Slattery, 1971) describes the thermal design of naturally cooled repeater shelters. The aim was to design a shelter where the temperature in the equipment room does not exceed the guaranteed operating temperature range of the microwave equipment.

A 'building within a building' concept was conceived and evaluated. It used an outer insulated sunshade with openings to promote convection cooling, over a thin-skinned dust proof metal shelter. A full-scale model was successfully tested with the assistance of the CSIRO Buildings

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Research Branch. This shelter design could be easily translated to suit other power and ambient conditions by adjusting the surface area or leaving off the shade walls.

The second paper (Thomas & Sigal, 1971) describes the work done to take the prototype passive design and produce a practical and durable shelter capable of supporting the equipment weight, and be suitable for long distance transportation. A number of features were incorporated into the final design to optimise access, convection and heat dissipation, which are detailed in the historic paper.

The shelters were manufactured at Sigal Industries in Adelaide and at the peak of production were completed at the rate of more than two per week. The transport to site was achieved using specially designed transporters and heavy-duty prime movers equipped for extended periods of operation in remote regions.

The pre-constructed foundations were designed such that the transporter could be driven into position over them. The inner shelter was then raised using special jacks, the transporter was driven away, and the inner shelter lowered onto the foundations. The inner shelter was then levelled to within 2 millimetres using shims and, finally, the outer radiation screens attached. The radiation screens had internal reflective insulation as well as a 50-millimetre-thick bonded polyurethane thermal barrier to protect the inner shelter.

The successful completion of the project proved that industrialised transportable lightweight passive shelters were a practical solution for housing equipment and controlling the environmental temperatures in remote areas.

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The Historic Papers

THERMAL DESIGN OF NATURALLY COOLED REPEATER SHELTERS

J. TOMLINSON, B.Eng. and R. P. SLATTERY, Dip.M.E., Grad.I.E.(Aust.)***

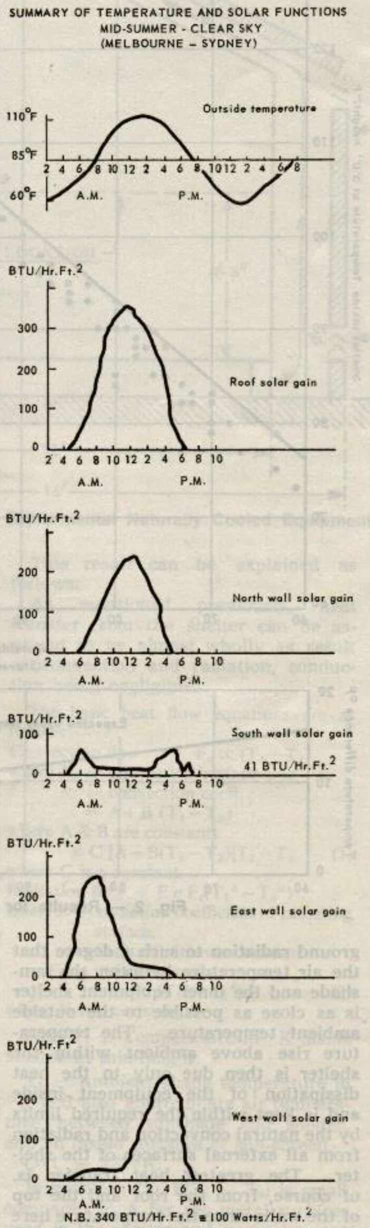
INTRODUCTION.

When the Department decided to install a broadband radio relay system between Port Pirie and Northam to complete the Adelaide to Perth trunk route, one of the important provisioning matters concerned the type of equipment shelter to be provided at the 50 or more unattended repeater stations. The length of the route, about 1500 miles, and the low population density along most of this distance invited consideration of designs other than of normal brick construction. A further factor, also affecting building design, arose at this time. This was the fact that wholly solid state radio equipment suitable for broadband radio relay systems would be offered when tenders were called for the supply of the required plant. It was anticipated that the power consumption of the wholly solid state systems would be less than one-half that of the part valve/part solid state equipment types already in service, and this would ease the problems of cooling and therefore sheltering of the equipment.

Equipment types at present in use on this type of service have required the use of air-conditioned or forced air cooling plant, and have been housed in buildings of normal brick construction, in order to restrict the range of temperature of their environment. This type of construction would have been very costly for the East-West route, and as continuously running ventilation machinery would have required service attention at frequent intervals, it was decided to investigate other forms of construction requiring, if possible, no continuously running ventilation plant.

The most important characteristic of the shelter would be to surround the equipment with a temperature not exceeding that for which the equipment reliability and performance was guaranteed. The shelter would, therefore, have to be capable of dissipating the heat of the ultimate load of the equipment, but at the same time insulate against the effects of direct and indirect radiation from the sun and ground. These latter effects are potentially equivalent to several tens of kilo-watts under clear sky conditions at midday in mid-summer (see Fig. 1).

The equipments likely to be offered had similar temperature characteristics, i.e., full performance to 50 deg. C. and slightly degraded performance to 55 deg. C. As the maximum ambient temperature expected over a long period on the route was 50 deg. C. the shelter design would have to be based on an inside maximum temperature of 55 deg. C. when this ambient temperature was reached.



N.B. 340 BTU/Hr.Ft.^{2} ≡ 100 Watts/Hr.Ft.^{2}

Fig. 1. — Summary of Temperature and Solar Functions, Mid-Summer, Clear Sky (Melbourne-Sydney).

CONCEPTION OF SHELTER DESIGN

A thin-skinned metal shelter with no internal insulation appeared to promise effective natural cooling by convection and radiation, conduction would be negligible because of the long path through the metal cross section. A sunshade appeared to be the inevitable answer to insulation of the shelter from external heat sources, i.e., sun and ground. In addition, because of the high temperature, about 180 deg. F., to be expected on the external surfaces of the sunshade and ground on a day of ambient temperature (120 deg. F. (50 deg. C.), the sunshade itself would have to be insulated on the underside of its roof and the inside of its walls, in order to ensure that these surfaces remained at a lower temperature than the shelter's external surfaces and thus absorb radiated energy from them. Calculations confirmed that this design philosophy was sound. Further, the shelter would be amenable to prefabrication techniques, pre-installation of equipment, and transport of the whole to a site in one operation. These latter features would be of considerable importance to provisioning of systems for routes like Adelaide-Perth or even for single installations in similar hot, remote areas.

As no other organisation in Australia seemed to have encountered this problem, and therefore, the necessity to solve it, it was decided to organise a trial of a full-scale model in the field. At this time the idea was also discussed with the Building Research Branch of C.S.I.R.O. and compared with other possible solutions through C.S.I.R.O. computer programme. One solution, involving a part mass construction (2 earth walls) and part thin metal, gave a slightly better result temperature-wise, but as the all-metal construction was also confirmed as suitable, and was more amenable to prefabrication, as discussed earlier, it was decided that the field trial should be of a shelter design of this form.

EXPERIMENTAL BUILDING

A simple full-scale experimental shelter suitable for dissipating 1kW

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of heat was designed. The dimensions, 12 ft. by 10 ft. floor area and 9 ft. high, were decided after taking into account model tests made in an environmental chamber supplemented by calculations of solar and ground radiation effects. The unit was constructed in the Postal Workshops in Perth and installed in the grounds of the National Broadcasting Service station at Kalgoorlie, this site being on the East-West route and having staff available to supervise the experiment. The shelter was instrumented with calibrated thermo-couples and 12-point pen recorder for continuous measurement of temperature at all important points, including a Stevenson screen for shade temperature measurements. An anemometer was also provided for measurement of wind velocity. The measurements were made in January and February, 1966, and continued in February and March, 1967. The experimental shelter was fully sealed against entry of dust and included a gabled shelter roof and gabled sunshade. The gabled sunshade was vented along the ridge, the vent being covered to keep the direct rays of the sun away from the shelter. The gable construction was provided to increase convection heat transfer by creating a chimney effect between the sunshade and shelter and to guard against condensation falling on equipment, which could have been a problem with a flat roof. The gabled construction also increased the surface area available for convection heat transfer, and created a reservoir at the top of the shelter, above rack height, for the hot air rising from the racks.

TEMPERATURE OBJECTIVE

The objective was for the shelter to suit the temperature characteristics of radio equipment likely to be used on the East-West route, i.e., equipment to perform to full specification in a surround of 50 deg. C. (122 deg. F.), and to slight degradation of performance to 55 deg. C. (131 deg. F.). Thus on a day of ambient temperature 50 deg. C., encountered in the long term along the East-West route, the shelter internal temperature in the vicinity of the radio racks would not have to rise above 55 deg. C.

RESULTS OF EXPERIMENT

The experimental results, shown in Fig. 2, confirmed the success of the design. Fig. 3 shows the basic design idea, which has been accepted for East-West route building design, and is now being translated into a practical and economic building consistent with location.

It should be noted that the sunshade must insulate against the sun and ground radiation to such a degree that the air temperature between the sunshade and the inner equipment shelter is as close as possible to the outside ambient temperature. The temperature rise above ambient within the shelter is then due only to the heat dissipation of the equipment inside and is kept within the required limits by the natural convection and radiation from all external surfaces of the shelter. The greatest heat transfer is, of course, from the roof and the top of the walls since the temperature here is highest compared to the surrounding air and screen inside surface temperatures.

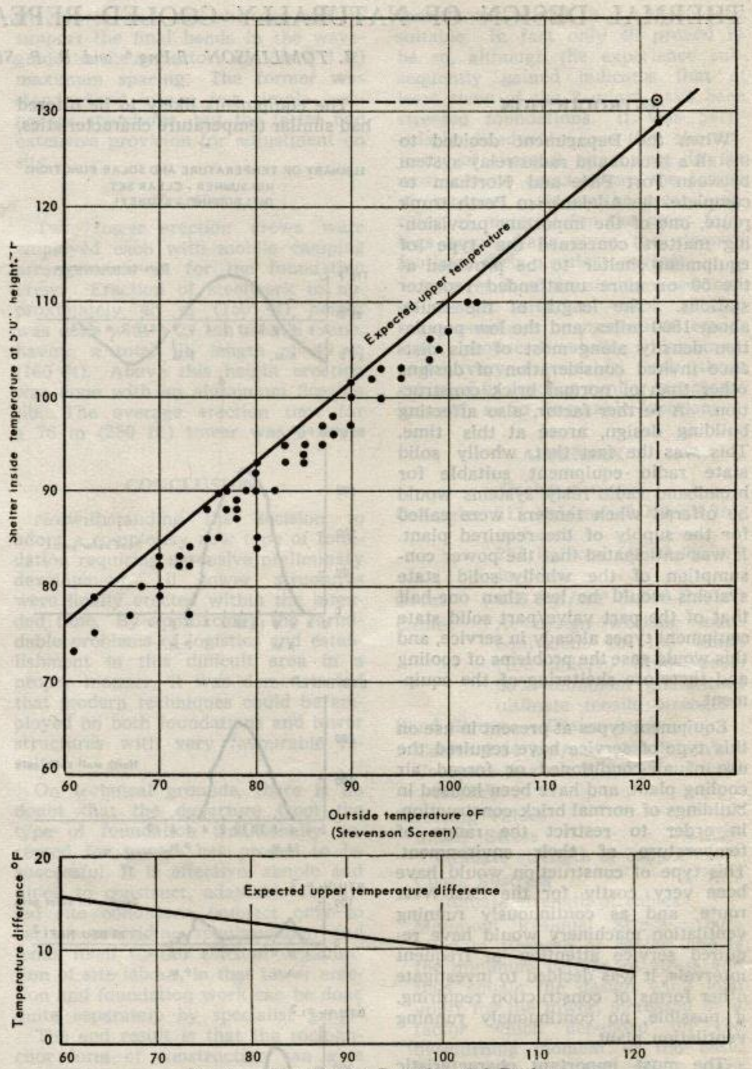

Fig. 2. — Results for Experimental Design.

The shelter can easily be translated to suit other power and ambient temperature conditions by adjustment, up or down, of its surface area dimensions (a law well proven by model measurement) or by leaving off one or more vertical shade walls, etc.

In the practical case of East-West project and many similar uses, fan filter units would be provided for use on the occasion of staff maintenance visits or under thermostatic control, to reduce abnormal temperature conditions which could occur for a very small percentage of time.

It will be realised that the inside temperature conditions in the shelter

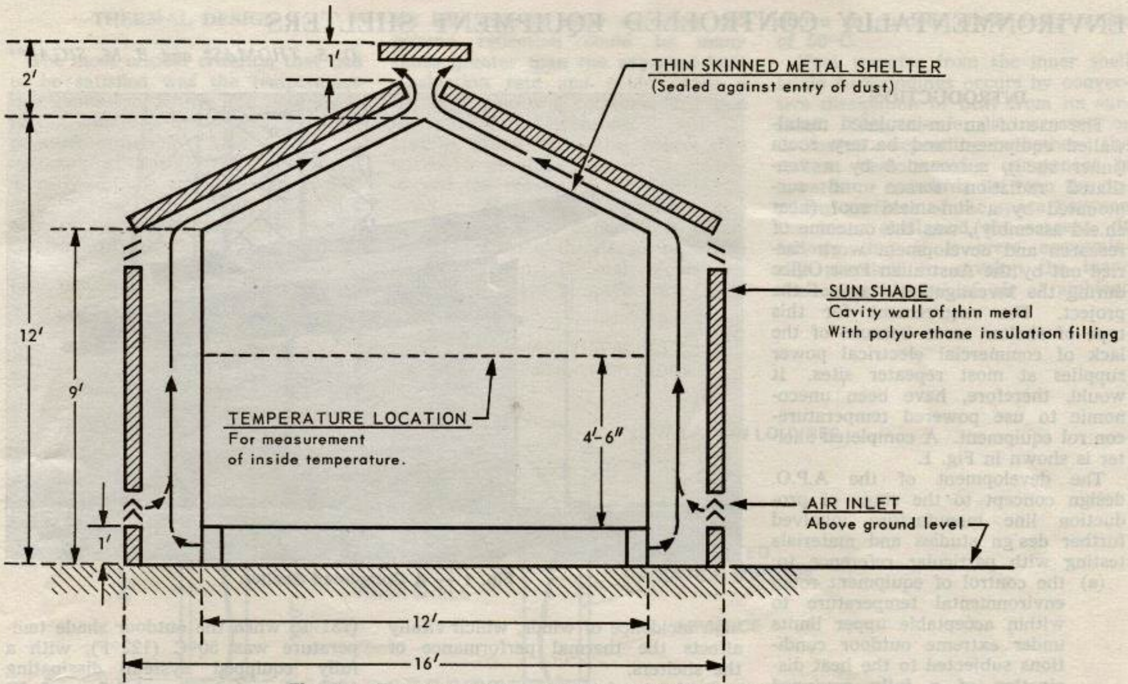

Fig. 3. — Experimental Naturally Cooled Equipment Shelter.

will follow closely the movement of external ambient temperature, but being always higher than ambient by 5 to 15 deg. F. The effects of this daily temperature cycling on components in the equipment cannot be fully assessed; however, the decision has been made that these effects will not have any significant effect on component life, and no attempt will be made by introducing additional heat treatment, to limit the range of temperature cycling beyond the limit imposed by the shelter as designed.

INTERPRETATION OF TEMPERATURE CHARACTERISTICS OF SHELTER

It will be noted more clearly from Fig. 2b that, if the temperature characteristic is drawn in the form inside-outside temperature difference versus outside temperature, the temperature difference is greater at low ambient temperature than at high, indicating that heat flow from the shelter is becoming more effective as the ambient temperature rises, i.e., is proportional to absolute temperature, e.g., at 62 deg. F. ambient the inside building temperature is 16 deg. F. higher (78 deg. F.), but at 122 deg. F. it is only 7 deg. F. higher (129 deg. F.). Thus for each rise of 1 deg. F. in ambient temperature the inside shelter temperature rises by 5/6 deg. approximately.

This result can be explained as follows:

As mentioned previously, heat transfer from the shelter can be assumed to be almost wholly as result of convection and radiation, conduction being negligible.

The basic heat flow equations are as follows:—

Convection flow $= F_c \propto (T_1 - T_2)$
where F_c = convection-surface area
$\propto$ = convection coeff.
$= A + B\,(T_1 - T_2)$
where A & B are constants
$\infty\, C\,[A + B(T_1 - T_2)]T_1 - T_2$ (1)
where C is a constant.
Radiation flow $= E\,\sigma\,F_r(T_1{}^4 - T_2{}^4)$
where E = radiation coefficient of radiating surface.
σ = Stefan/Boltzman constant
F_r = radiating surface area
$\infty\, K\,(T_1{}^4 - T_1{}^4)$ (2)
where K is a constant.

Also T_1 = Temperature in °K inside shelter at mid-height.

T_2 = Ambient shade temperature in °K and also approximate air temperature between sunshade and shelter, and on inside surfaces of sun-screen.

0°C = 273°K.

In equation (1), $B(T_1 - T_2)$ is small compared to A for the metal surfaces used in the shelter and it can be seen therefore that convection heat flow is proportional to $T_1 - T_2$ only, i.e., temperature difference between the convecting surfaces which is less than 5°K.

However, from equation (2), it is seen that radiation flow is proportional to absolute temperature, more clearly shown as follows:—

Let $T_1 = T_2 + \triangle T$

$\triangle T$ being small, <5°K compared to T_1 or T_2 (in the region of 300°K) then substituting in equation (2), expanding and neglecting powers of $\triangle T$ of the order of 2 or more, it can be shown that radiation flow is proportional to $\triangle T.T_2{}^3$.

Now if we take any 2 values for T_2 (ambient temperature) within the operating range of the shelter, say 27°C (300°K) and 47°C (320°K), we find that relative radiation flow at these points is in the ratio $300^3/320^3 = 5/6$.

This ratio agrees closely with that obtained in the practical field test already mentioned above. Thus, as the ambient temperature rises radiation heat flow becomes more effective and therefore more important, convection heat flow remains reasonably constant.

CONCLUSION.

Experience with installed shelters has shown that their temperature performance is well within the Departmental objective, i.e., internal temperature not to rise more than 5°C above shade temperature.

ENVIRONMENTALLY CONTROLLED EQUIPMENT SHELTERS

D. S. THOMAS and B. M. SIGAL***

INTRODUCTION

The use of an un-insulated metal-walled equipment and battery room (inner shell), surrounded by a ventilated radiation screen and surmounted by a sun-shield roof (heat shield assembly), was the outcome of research and development work carried out by the Australian Post Office during the investigation stage of the project. The requirement for this type of shelter arose because of the lack of commercial electrical power supplies at most repeater sites. It would, therefore, have been uneconomic to use powered temperature-control equipment. A completed shelter is shown in Fig. 1.

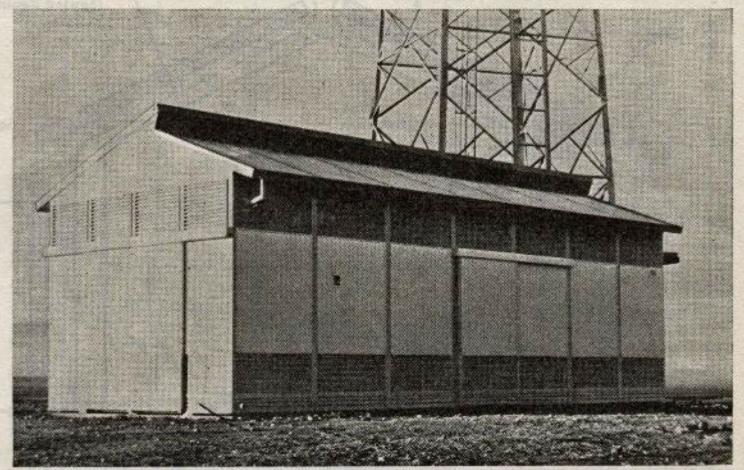

Fig. 1 — A Completed Shelter.

The development of the A.P.O. design concept to the stage of production line manufacture involved further design studies and materials testing with particular reference to:

(a) the control of equipment room environmental temperature to within acceptable upper limits under extreme outdoor conditions subjected to the heat dissipation of a fully equipped system (12 racks of equipment);

(b) the use of materials and finishes having a high durability and requiring the minimum of maintenance attention for an estimated 20 years life;

(c) the use of materials and techniques suitable for production line manufacture and subsequent long distance transport over rough terrain and frequent handling without deterioration.

DESIGN CRITERIA

Climatic Conditions

The route within the southern margins of the Nullarbor Plain is characterised by very high summer temperatures, low overnight and winter temperatures, large diurnal variations, low rainfall, high dust incidence and high solar radiation intensity. A particular feature is the high incidence of winds, which vitally affects the thermal performance of the shelters.

Outdoor reference conditions used for thermal design calculations were:

Outdoor ambient shade (summer), 50°C (122°F);

Outdoor ambient shade (winter) — 1°C (30°F)

Diurnal temperature range, 22°C (40°F);

Number of consecutive days over 38°C (100°F) assumed to be 12;

Relative humidity, 15 to 65%;

Wind velocity, 160 km/h (100 mile/h).

The temperature records taken at stations along the route (see Fig. 2) indicate that the design reference conditions could be expected to occur at any station in the system.

Continuous Heat Dissipation

Radio equipment room
1600 W maximum
Battery room (trickle charge)
400 W

Environmental Temperature Limits

The design was required to ensure that the ambient temperature in the equipment room did not exceed 55°C (131°F) when the outdoor shade temperature was 50°C (122°F), with a fully equipped system dissipating 1600 W, and measured 1.5 m (5 ft) above floor level. The ambient temperature in the battery room was not to exceed 50°C and the temperature rise in the diesel enclosure was not to exceed 50°C above ambient shade.

Equipment Weight

Batteries: 2900 kg (6400 lb)
Control cubicle: 272 kg (600 lb)
Radio equipment and installation materials: 1360 kg (3000 lb)

General

In addition to the quantitative criteria summarised above, other conditions which were required to be satisfied were:

(a) dust infiltration to the equipment room must be prevented

(b) the shelter must be proof against the entry of birds, snakes and other animals

(c) materials of construction must be non-flammable throughout, and timber was not permitted due to fire risk, termite attack and deterioration under the severe climatic conditions.

Station	Merredin	Kalgoorlie	Eyre	Eucla	Fowlers Bay	Ceduna	Kyancutta	Whyalla
Maximum Temperature	45.0°C (113°F)	46.1°C (115°F)	47.1°C (116.8°F)	50.8°C (123.2°F)	48.3°C (119°F)	47.2°C (117°F)	49.3°C (120.7°F)	49.4°C (121°F)
Minimum Temperature	—3.9°C (25°F)	—1.1°C (30°F)	—3.9°C (25°F)	—2.2°C (28°F)	—2.5°C (27.6°F)	—2.8°C (27°F)	—5.6°C (22°F)	—2.8°C (27°F)

Fig. 2 — Maximum and Minimum Temperatures at Typical Stations.

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* Mr. Thomas is Senior Partner of D. S. Thomas and Partners.

** Mr. Sigal is Chairman and Managing Director of the Sigal group of manufacturing companies.

THERMAL DESIGN

The most critical criterion that had to be satisfied was the temperature rise limitation within the equipment room. Although the permissible temperature difference from indoor to outdoors at design reference maximum conditions was specified at 5°C at 50°C shade temperature, it did not necessarily follow that this would ensure adequate heat transfer from the equipment room. The amount of heat flow into the shelter due to direct and indirect solar radiation and ground reflection could be many times greater than the expected heat dissipation rate and could cause a net heat gain and corresponding rise in shelter temperature. Without specific attention to this aspect, the space temperature rise could greatly exceed the maximum permissible.

As the thermal performance of the surfaces could be expected to deteriorate in service, the design reference used in the final thermal calculations was for a space temperature of 2°C above an outdoor shade temperature of 50°C.

Heat transfer from the inner shell to its surroundings occurs by convective dissipation of heat from its surfaces. This transfer is increased or decreased depending whether the radiant heat transfer component is inwards or outwards between the opposing surfaces of the space between the inner shell and the screens. It follows that if it were economically practical to envelop the inner shell in a blanket of air at ambient

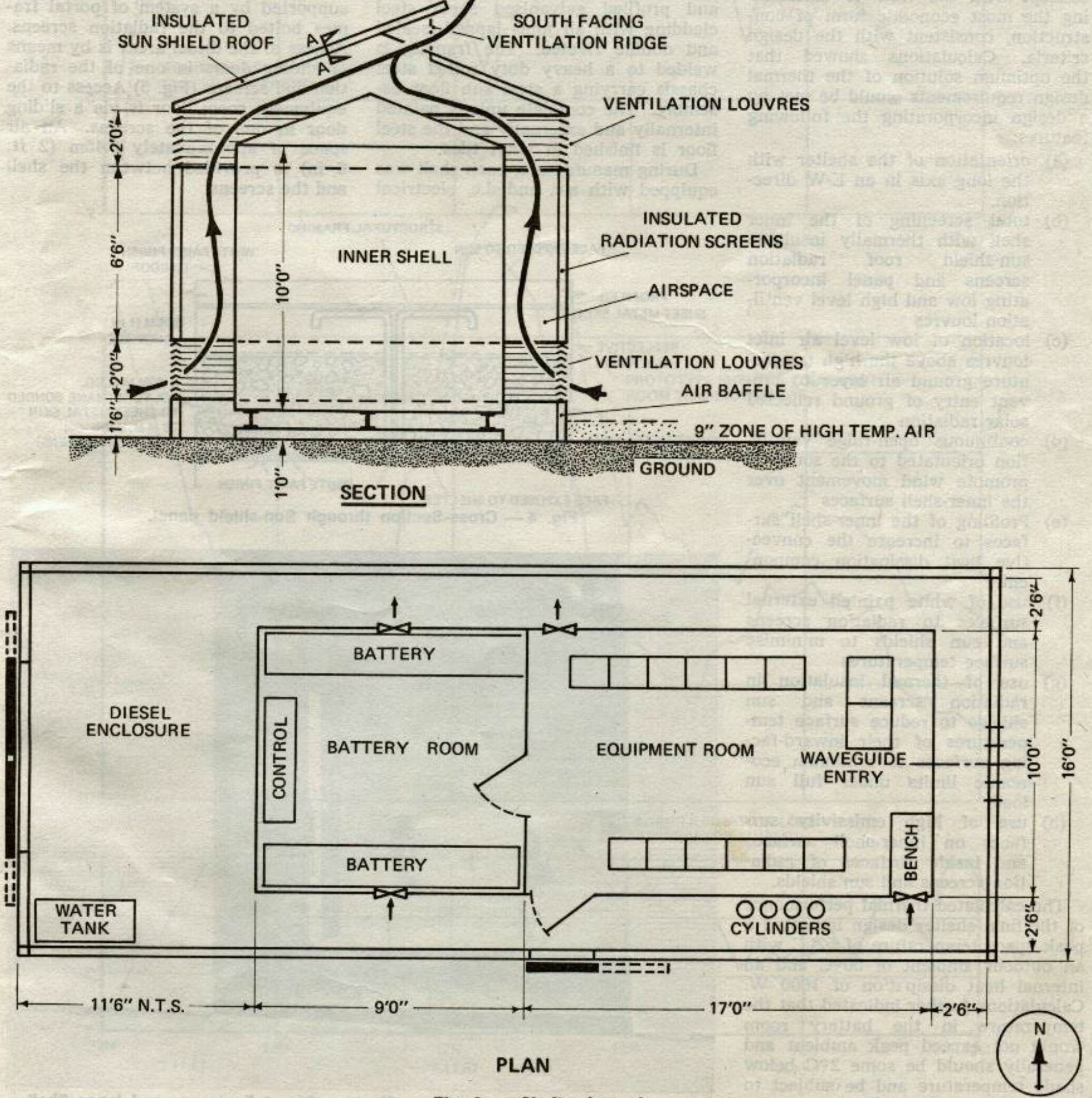

Fig. 3 — Shelter Layout.

shade temperature and to maintain the inner faces of the screens at or close to this temperature, then under peak outdoor ambient temperature conditions, the radiant heat transfer would be outwards from the inner shell. Under night-sky irradiation conditions it could also be expected that the screens would impede radiation losses from the inner shell and tend to minimise the diurnal variation of the inner-shell temperature.

Studies were made of several approaches to the basic shelter design concept with the view to determining the most economic form of construction, consistent with the design criteria. Calculations showed that the optimum solution of the thermal design requirements would be met by a design incorporating the following features:

(a) orientation of the shelter with the long axis in an E-W direction.
(b) total screening of the inner shell with thermally insulated sun-shield roof radiation screens and panel incorporating low and high level ventilation louvres
(c) location of low level air inlet louvres above the high temperature ground air layer to prevent entry of ground reflected solar radiation
(d) continuous open-ridge ventilation orientated to the south to promote wind movement over the inner-shell surfaces
(e) Profiling of the inner-shell surfaces to increase the convective heat dissipation component.
(f) use of white painted external surfaces to radiation screens and sun shields to minimise surface temperatures
(g) use of thermal insulation in radiation screens and sun shields to reduce surface temperatures of their inward-facing surfaces to minimum economic limits under full sun load
(h) use of high emissivity surfaces on inner-shell surfaces and inside surfaces of radiation screens and sun shields.

The calculated thermal performance of the final shelter design indicated a peak space temperature of 52°C with an outdoor ambient of 50°C and an internal heat dissipation of 1600 W. Calculations further indicated that the temperature in the battery room would not exceed peak ambient and generally should be some 2°C below shade temperature and be subject to a substantially reduced diurnal variation due to the thermal storage effects of the batteries.

Subsequent thermal performance tests on the prototype shelter proved that the design calculations were conservative and allowed a substantial margin for deterioration of surface characteristics.

CONSTRUCTION

The general layout is shown in Fig. 3. The inner shell, comprising the equipment and power rooms, is of all-welded construction using cold formed galvanised structural sections and profiled galvanised sheet steel cladding with all joins lapped, sealed and double riveted. The framing is welded to a heavy duty rolled steel chassis carrying a steel sub floor assembly. The complete unit is painted internally and externally and the steel floor is finished in vinyl tiles.

During manufacture, each shell was equipped with a.c. and d.c. electrical installation, cable trays and cable forms, power ducting, battery stands, pressurisation system fittings, rack ironworks, bench and cupboard units, ventilation fan/filter units, lighting fittings, and waveguide entry glands. Doors are steel clad and fitted with air and dust seals.

The radiation screens and sun shields are constructed of galvanised steel structural sections jig-formed into readily transportable modules, insulated and sheeted on both sides (Fig. 4) with galvanised sheet steel paint finished. The sun shields are supported by a system of portal frames bolted to the radiation screens. Access to the diesel areas is by means of sliding doors in one of the radiation end screens (Fig. 5) Access to the equipment room door is via a sliding door in one of the screens. An air space of approximately 0.45m (2 ft. 6 in) is provided between the shell and the screens.

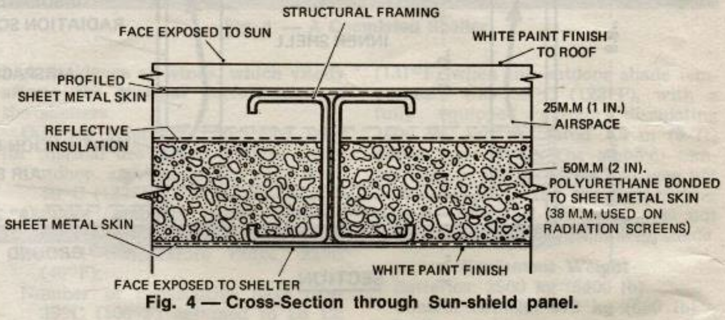

Fig. 4 — Cross-Section through Sun-shield panel.

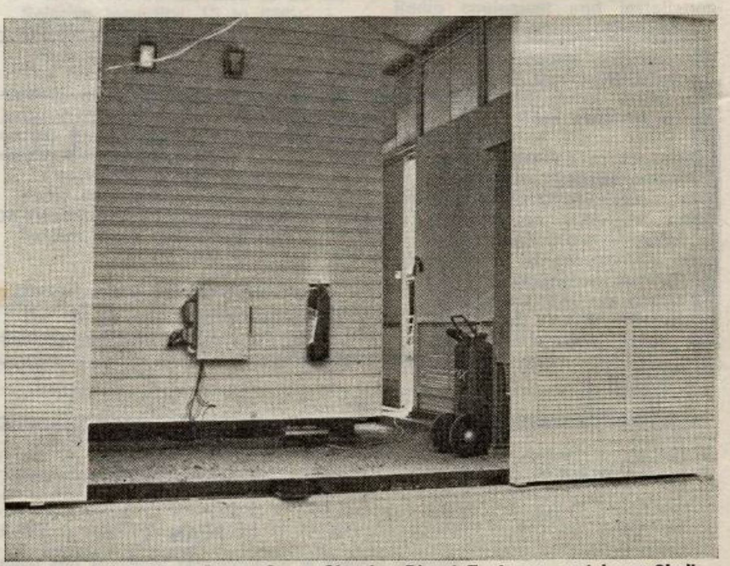

Fig. 5 — End View, Doors Open, Showing Diesel Enclosure and Inner Shell.

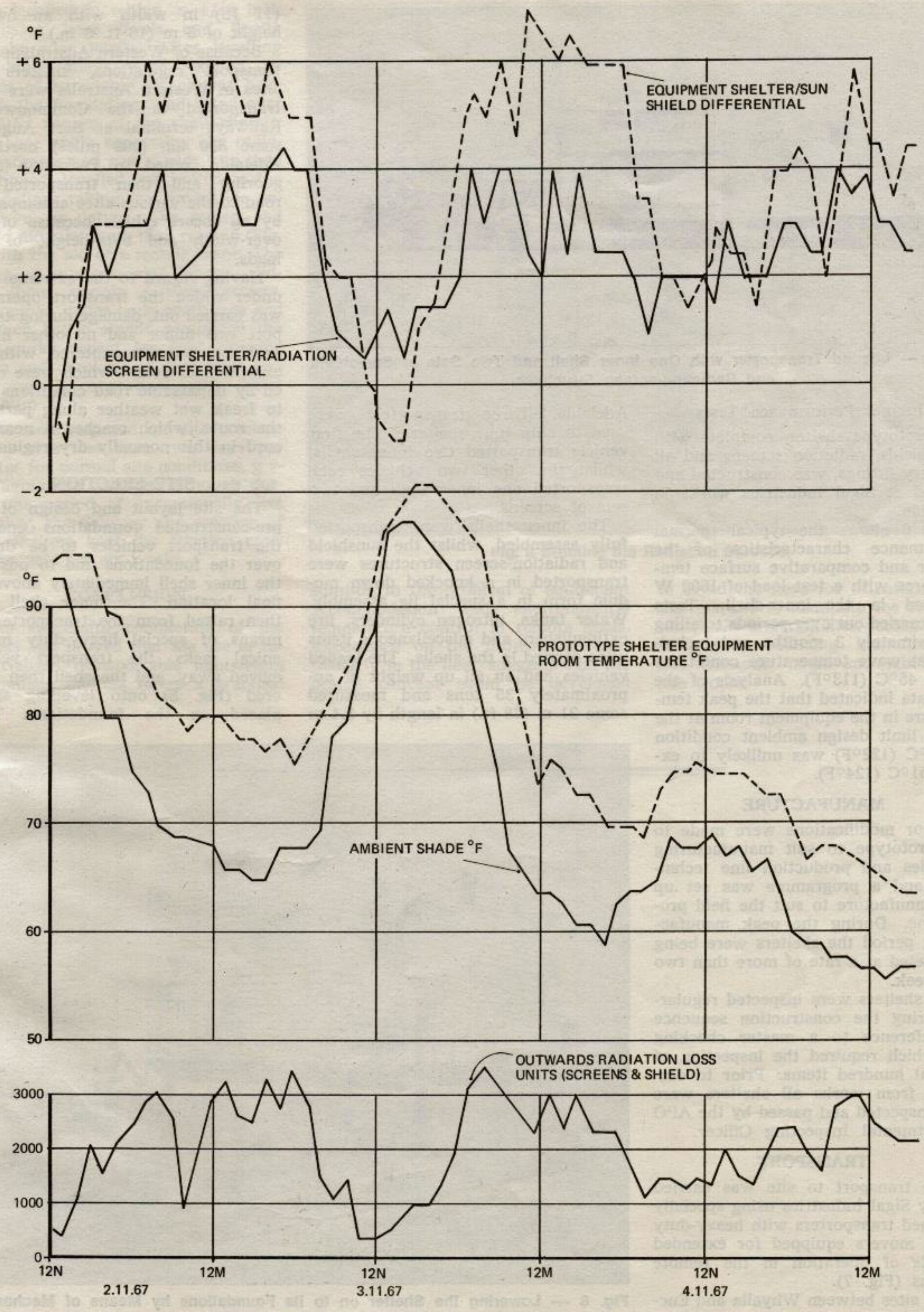

Fig. 6 — Thermal Performance Characteristics.

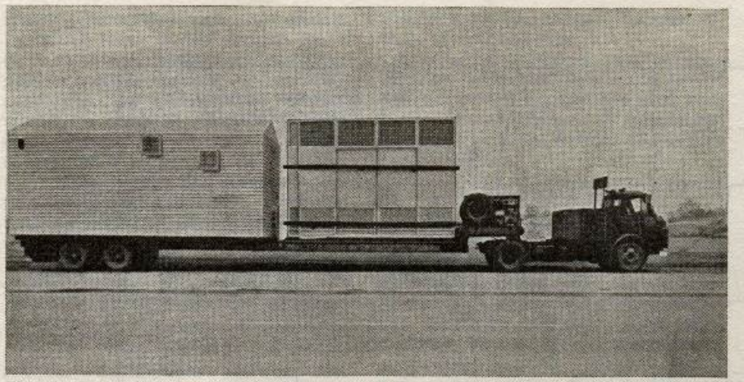

Fig. 7 — Loaded Transporter with One Inner Shell and Two Sets of Sun-shield and Radiation-screen Structures.

Thermal Performance Tests

A prototype shelter, complete with sun shields, radiation screens and all ancillary fittings, was constructed and erected at Sigal Industries works in Adelaide.

Fig. 6 shows the typical thermal performance characteristics of the shelter and comparative surface temperatures with a test load of 1600 W installed in the inner-shell. Tests were carried out over periods totalling approximately 3 months and included heat wave temperature conditions up to 45°C (113°F). Analysis of the test data indicated that the peak temperature in the equipment room at the upper limit design ambient condition of 50°C (122°F) was unlikely to exceed 51°C (124°F).

MANUFACTURE

Minor modifications were made to the prototype to suit manufacturing facilities and production line techniques and a programme was set up for manufacture to suit the field programme. During the peak manufacturing period the shelters were being completed at a rate of more than two per week.

All shelters were inspected regularly during the construction sequence by reference to a master checking list which required the inspection of several hundred items. Prior to despatch from works all shelters were also inspected and passed by the APO Departmental Inspecting Officer.

TRANSPORT

The transport to site was carried out by Sigal Industries using specially designed transporters with heavy-duty prime movers equipped for extended periods of operation in the remote regions (Fig. 7).

For sites between Whyalla and Eucla, shelters were transported from Adelaide. Three transporters were used to ship four shelters. The first vehicle transported two inner shells, whilst the other two vehicles each transported one inner shell and two sets of screens.

The inner shells were transported fully assembled, whilst the sunshield and radiation-screen structures were transported in a knocked down module form in a special jig assembly. Water tanks, nitrogen cylinders, fire extinguishers and miscellaneous items were carried in the shells. The loaded vehicles had an all up weight of approximately 35 tons and measured some 21 m (68 ft.) in length by 3.4 m (11 ft.) in width with an overall height of 5 m (16 ft. 6 in.).

Because of Western Australian road transport regulations, shelters for sites in Western Australia were road transported to the Commonwealth Railways terminal at Port Augusta, some 320 km (200 miles) north of Adelaide, railed to Parkeston (Kalgoorlie) and then transported by road to the various sites accompanied by an escort vehicle because of the over-width and over-height of the loads.

Having regard to the extreme duty under which the transport operation was carried out, damage during transport was minor and no other major problems were encountered, with the exception of delays which were caused by impassable road conditions due to freak wet weather along parts of the route, which reached a near record in this normally dry region.

SITE ERECTION

The site layout and design of the pre-constructed foundations enabled the transport vehicles to be driven over the foundations and to position the inner shell immediately above its final location. The inner shell was then raised from the transporter by means of special heavy-duty mechanical jacks, the transport vehicle moved away, and the shell then lowered (Fig. 8) onto levelling shims placed on the foundations. They

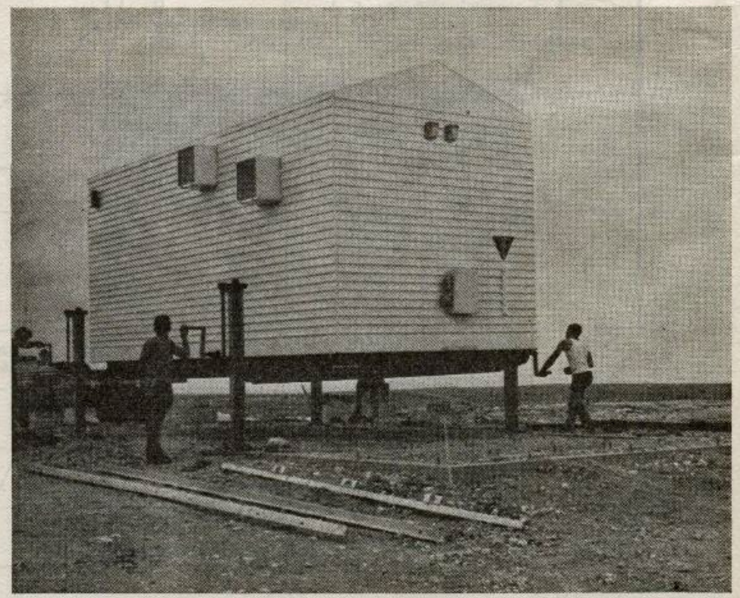

Fig. 8 — Lowering the Shelter on to its Foundations by Means of Mechanical Jacks.

were levelled to within ± 1/16 inch by using hose levels and finally straight edge levels. After levelling the inner shells were secured by means of adjustable toe clamps bolted to the foundations and fitted over the RSJ flanges of the shell chassis. The base angle supporting the radiation screens and sun shields was then positioned, levelled and bolted to the foundations taking the waveguide entry level as datum. The screen and shield modules were then erected (Fig. 9) with the aid of a mobile crane. The fitting of internal wind braces, sliding doors, vermin screens, gutters, downpipes, water tank, earth lugs and nitrogen bottle stands completed the site works except for final cleaning down and checking of door seals and microswitch operation and paint touch-up.

The time required for site erection works was less than two days per shelter for normal site conditions, given favourable weather, although during one period of exceptionally wet weather, the delivery and erection of four shelters kept the erection crew in the field for six weeks.

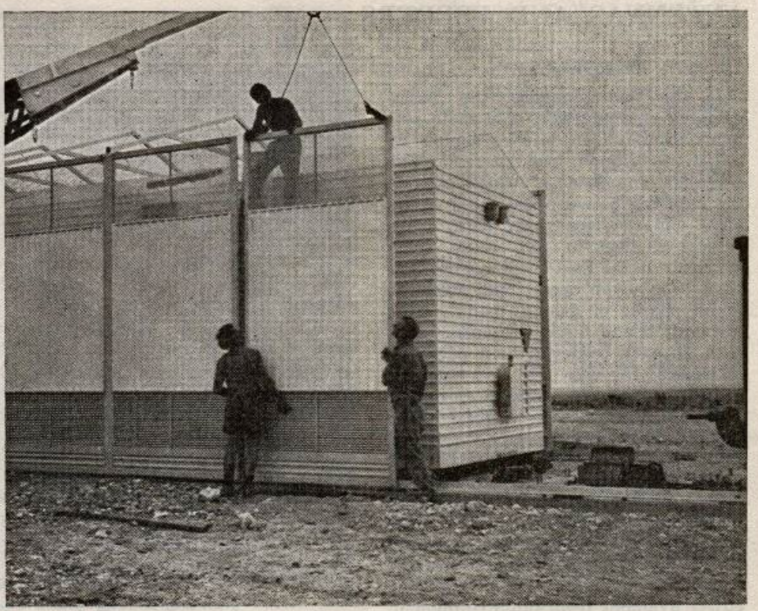

Fig. 9 Erecting the Radiation Screens.

CONCLUSION

The successful completion of the project has proved that the use of industrialised transportable lightweight equipment shelters offers a practical solution to the problem of equipment accommodation and environmental temperature control in remote areas. Experience on the project and particularly in the field, suggests that the design concept could be developed to avoid the need for orientating the shelters and to eliminate the separate sun-shield and radiation-screen structure, thus reducing manufacturing and transport costs and minimising site works.