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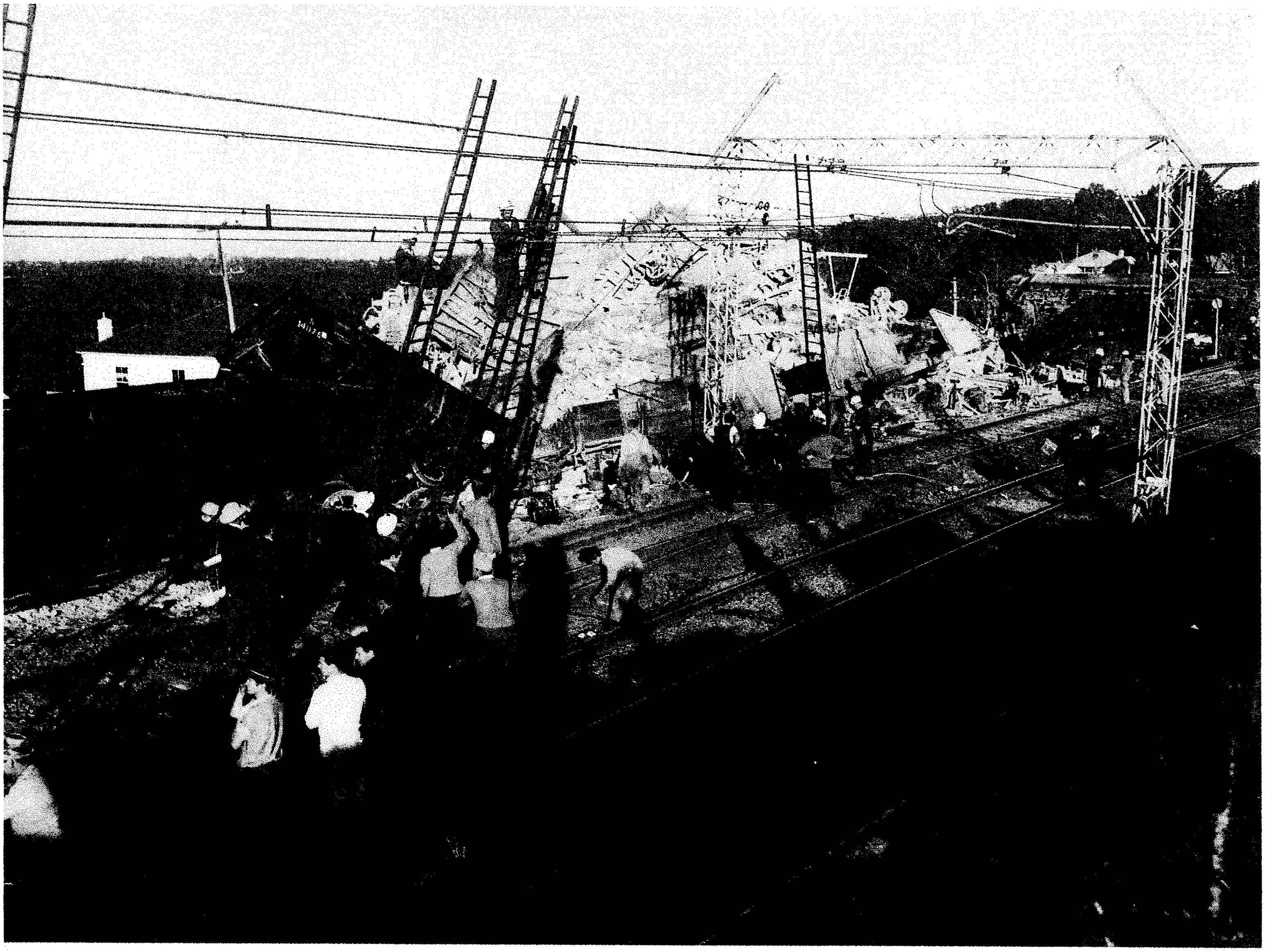

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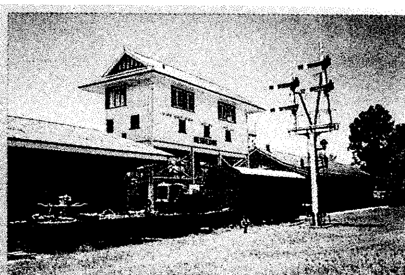
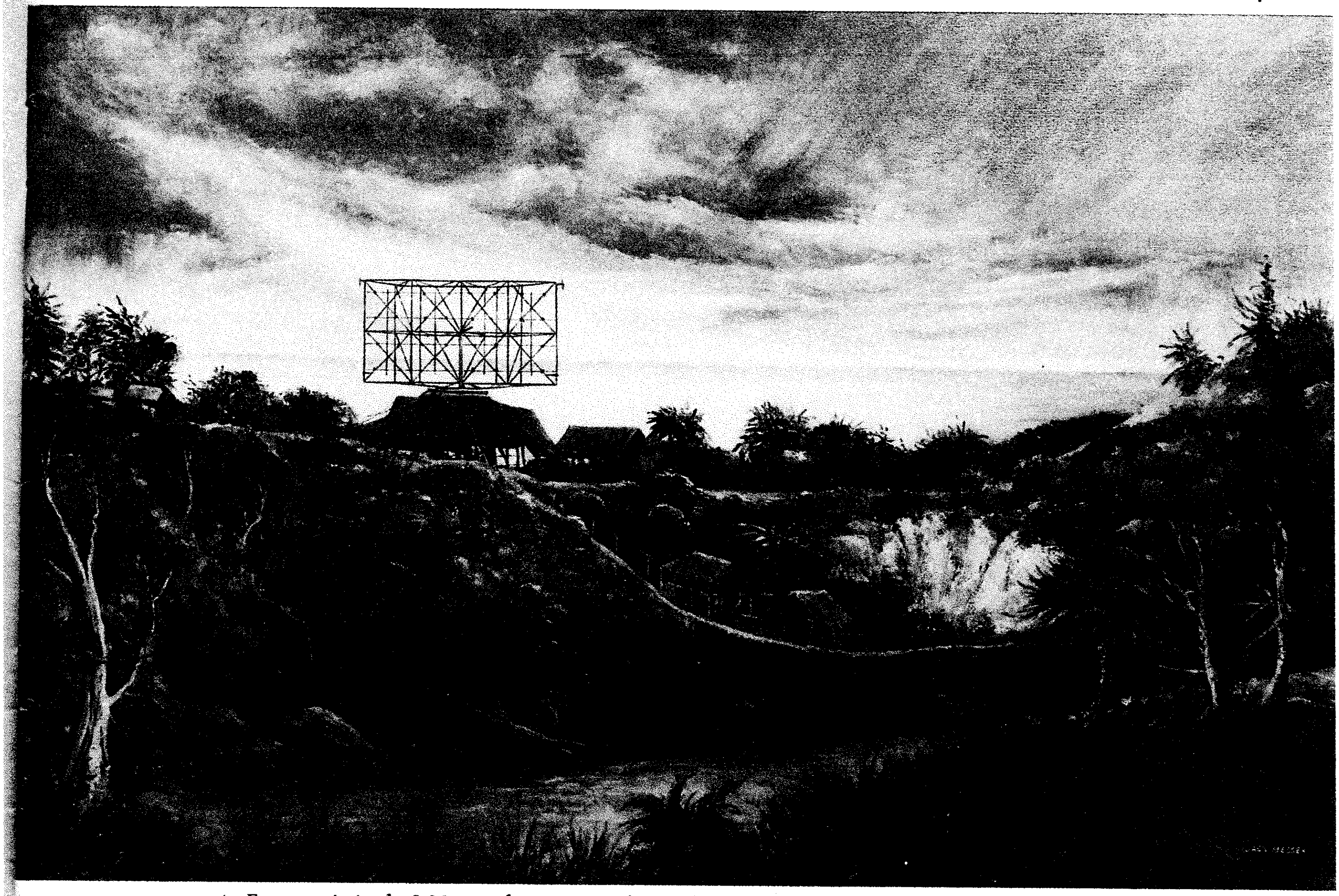


SECRET

DIRECTORATE OF RADAR SERVICES

R.A.A.F. RADAR STATION

PORTABLE TYPE _ L.W. STATION



▲ *From a painting by J. Messer of an LW/AW Mk IA radar unit as in operation at an island site.* E.M. BULLOCK COLLECTION

RADAR MANUFACTURE BY THE NSWGR DURING WORLD WAR II

• BY ERNEST (ERNIE) MARTIN BULLOCK •

Introduction

This article details the events during World War II that resulted in the construction of the Worledge Aerial, as I remember them.

The Japanese Air Force was bombing towns in the Northern Territory. Darwin was bombed for the first time on 19 February 1942, causing the loss of 250 lives and extensive damage to fixed installations.

On 1 July 1942, Wing Commander A. G. Pither wrote unofficially to Mr J. G. Q. Worledge of the NSW Railways enquiring whether he had an opinion on how the problem facing the Royal Australian Air Force at that time might be solved and for him to construct a radar aerial system which, when deployed along with the air warning (AW) equipment, could be loaded into an aeroplane, flown to a new location and re-erected in the shortest possible time, in order to yield warnings of enemy attack. The critical design factor was the aerial system.

The Ministry of Munitions only received responsibility for the supervision of the production of radio, radar and signals equipment in July 1942. The LW/AW tower and antenna was most likely one of its first tasks in the sphere of radar. This is probably why W/Cdr Pither approached Mr Worledge unofficially to find out "how the water lay" before speaking to the Munitions Department.

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Mr Worledge was the Design Engineer responsible for the design of military control equipment and radar stations to be performed by the technical design staff of the NSWGR's Electrical Branch.

As early as December 1941, W/Cdr Pither saw the need for an air-transportable AW set. Also, it was reported to him that mobility was a vital part of AW, particularly where the location was fluid. The idea of using an Air-to-Surface Vessel (ASV) set mounted on a road vehicle to work in remote areas was floated and the Japanese war zone was undeveloped to allow the erection of existing LW/AW SHD radar stations.

Further steps in the development of a lighter aerial were put on the backburner for a few months due to endeavours being focused on establishing radar stations as laid down by the War Cabinet.

W/Cdr Pither, who was regarded as the father of the lightweight Australian radar, appears to have taken a two-pronged attack on the production of an air-transportable AW system. Initially, he approached the NSWGR to manufacture such a unit and secondly he spoke to the Radiophysics Laboratory to look at developing more advanced models for the future.

Mr Worledge was asked to develop a light weight air warning (LW/AW) aerial, weighing 2000–3000 lb., to overcome the problems associated with the British Air Warning Shore Defence (AW/SHD) army type aerial used at Newcastle and Dover Heights, which weighed several tons and required considerable skill to erect.

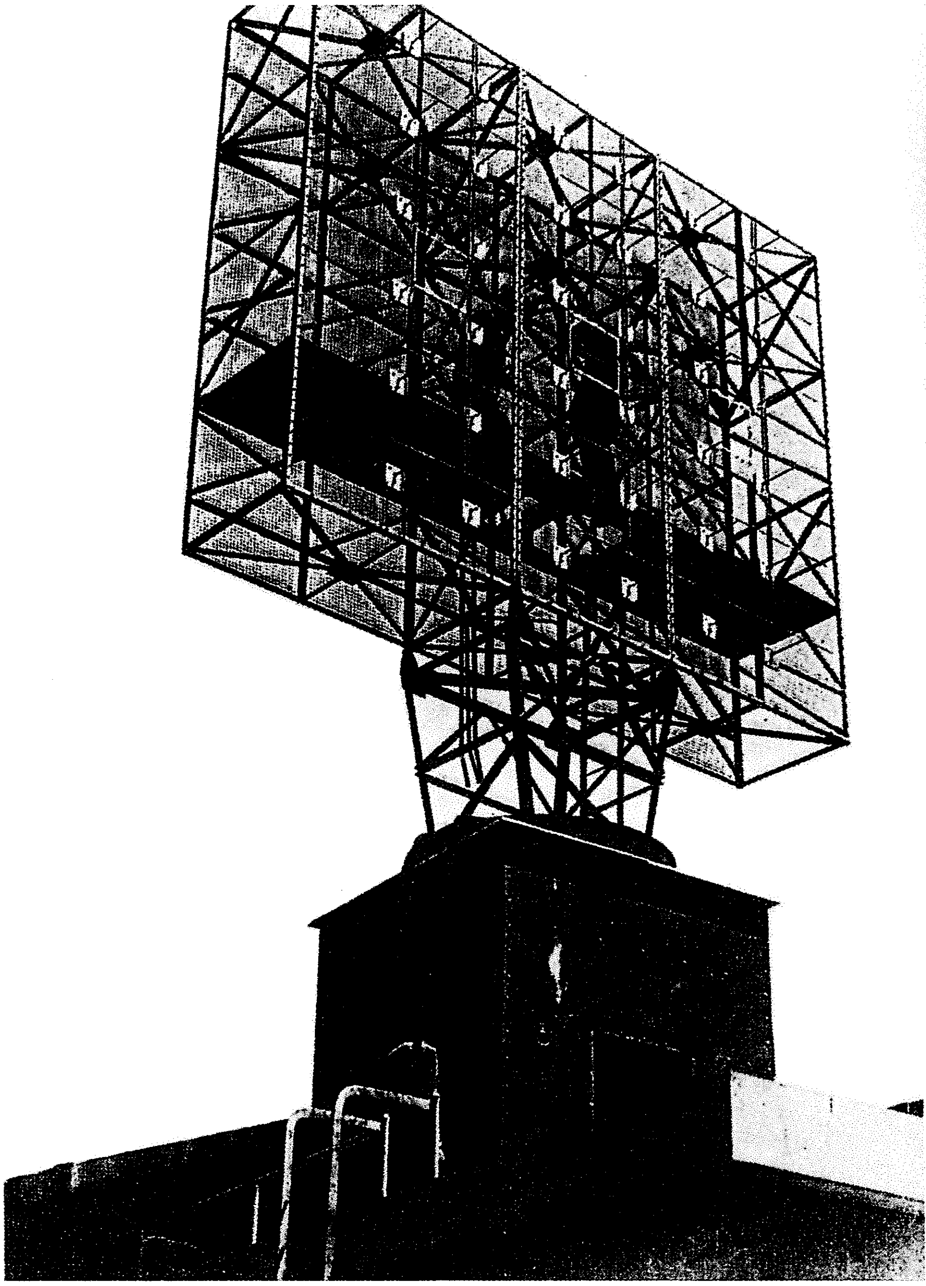
Requirements

The RAAF set the following parameters for the LW aerial:

- Construction to be light in weight.
- It is to be easily divided into small sections,the heaviest being no greater than 80 lb., while the biggest piece was able to pass through the ordinary door of a DC2 aircraft or the blister of a Catalina flyingboat.
- The range of the system was to be a minimum of 80 miles at 15,000 ft.
- Existing AW technical equipment was to be incorporated.
- It had to be easily erected by radar station crew.
- It had to be easily operated.
- The aerial system was to be simple so that the matching and phasing did not require experts.
- It had to be made in Australia from local manufacturing sources.

The RAAF added the following technical specifications:

- The aerial unit was to be a broadside four bay, four stack system deploying open wire feeders similar to the Chain Home Low Flying (CHL) system.
- The AW set was already being made by The Gramophone Company (HMV).
- The power supply to be used was the readily available 240 V Howard twin cylinder air-cooled engine.



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▲ *The British AW/SHD aerial was considered impracticable for Australian conditions.*

The Task

Several RAAF officers visited Mr Worledge. They discussed the need for a LW/AW aerial as the weight of the AW/SHD aerial was several tons and required a lot of labour to erect it and it was difficult to transport. After the departure of the RAAF officers, Mr Worledge explained to me the reason for their visit.

The work was classified by the Ministry of Munitions as top secret and granted absolute priority.

In order to meet these conditions, an annexe was constructed at Wilson Street, Redfern by February 1942. The annexe was required for checking the radar and other equipment as well as packing the equipment for shipping.

The radar transmitter and receiver were the responsibility of the Radiophysics Laboratory. The ancillary electrical equipment was designed by the NSWGR Electrical Branch design staff.

Mr Worledge drew freehand three possible solutions. He asked me to evaluate the three solutions on the basis of weight and draw to scale the three outlines. These results were forwarded to Melbourne for the officers' consideration.

One week later, the officers revisited Mr Worledge to indicate that the diagram which ultimately became the LW/AW Mk I was the preferred design.

When the delivery of a prototype was discussed, Mr Worledge suggested 30 days, a period which was readily accepted by the RAAF officers, although not entirely convinced that it could be achieved. Mr Worledge then gave the task to me, a 1942 graduate in Mechanical and Electrical Engineering from Sydney University. I was assisted by four draughtsmen who produced the detailed drawings of the many structural and mechanical components and two materials chasers who delivered the drawings to manufacturers and located material in short supply.

The prototype Worledge Aerial was duly delivered as promised on the 30th day, to South Head, Dover Heights. The manufacture of the prototype was fast tracked because of the war situation and was made possible because the project was classified "Absolute Priority" over all other defence work.

For example, the 6 in. pipe used for the central mast was obtained from the Shell Oil Company at Rosehill which, at the time, was the only known source of supply.

The manufacturers were required to process the work ahead of all other jobs. Costing and payment procedures were simplified so that their co-operation was excellent.

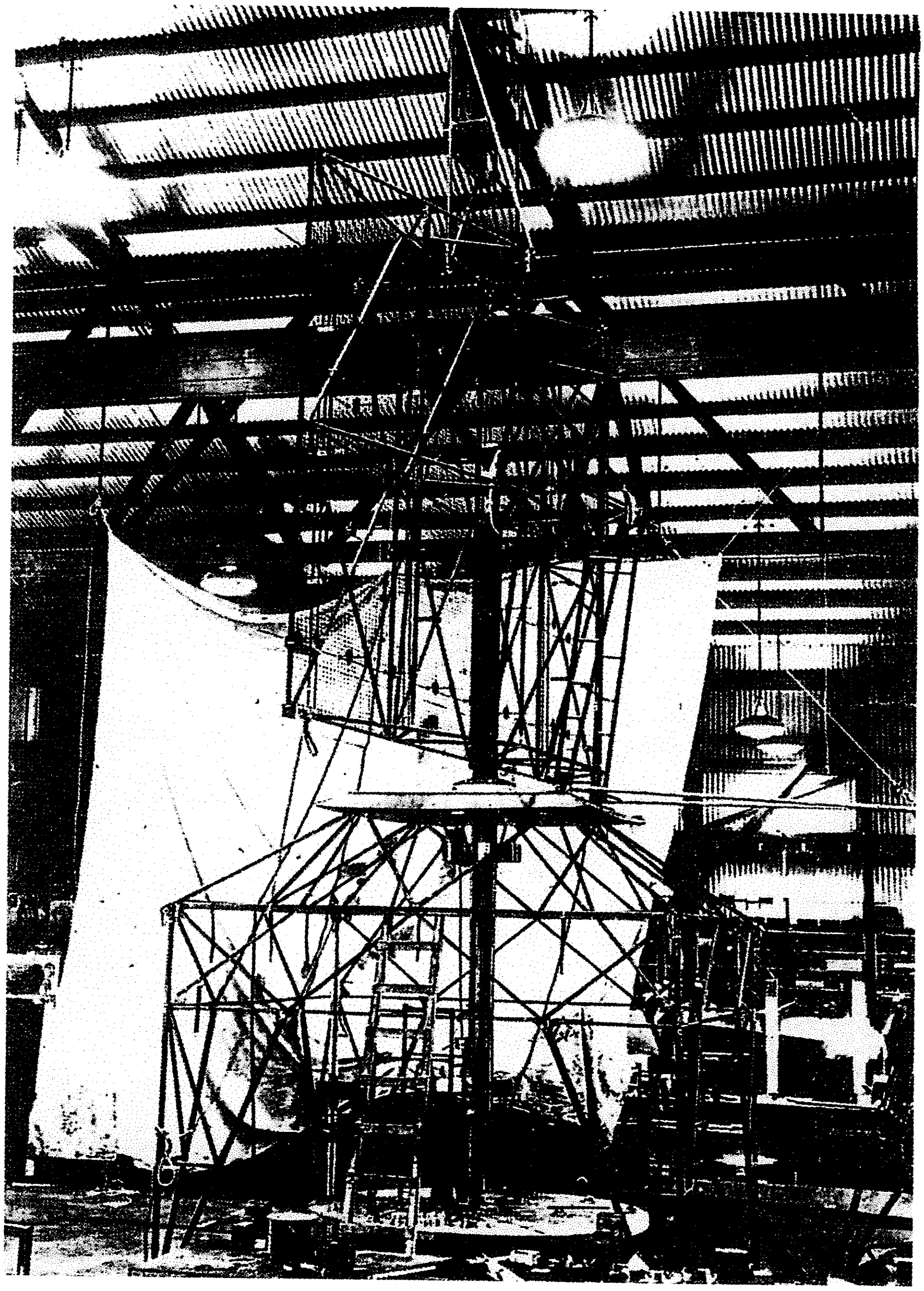
Private companies were used as the Railway Workshops were generally committed to the manufacture of other war equipment such as tanks, aircraft, engines, etc. The tubular steel items were manufactured by Newlands Brothers Pty Ltd, who made tubular steel beds and furniture.

The canvas tents were manufactured in the NSWGR Tarpaulin Shop at Chullora. All tubular steel components were cadmium plated to allow the attachment of bronze items without excessive corrosion occurring due to dissimilar metals.

The prototype was erected at South Head on 13 September 1942.

After testing and adjusting, it was transferred to New Guinea. It proved to be more reliable—operating 23 hours per day and its light weight allowed it to be placed close to enemy lines in undeveloped countries.

Experience in the war zone, with high humidity conditions and poor ventilation, required the structure of the aerial to be modified and provided with more space.



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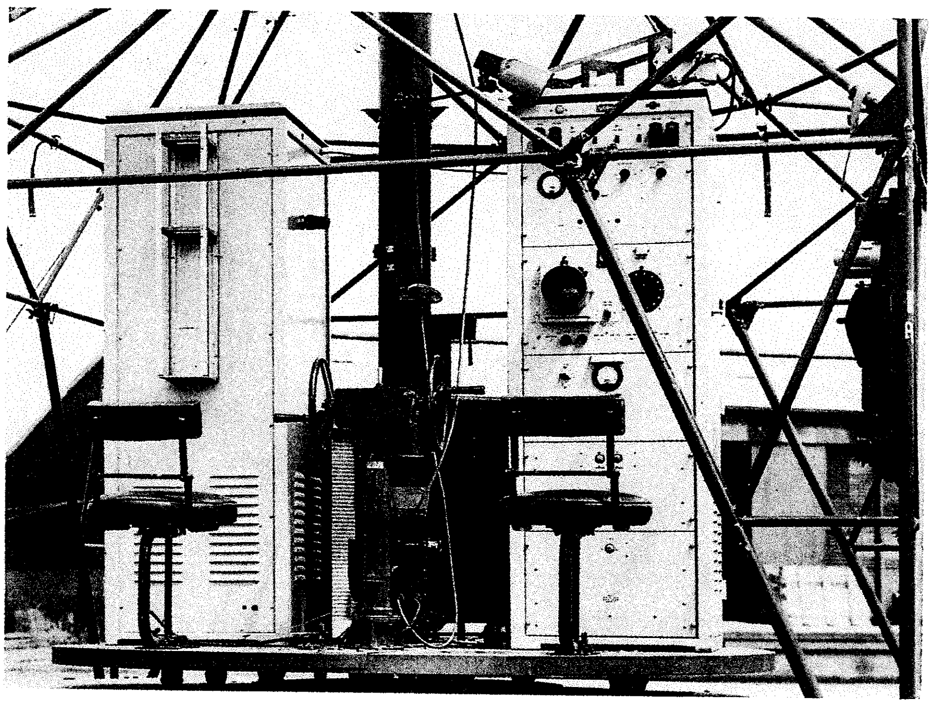
▲ *An aerial being assembled in the Wilson Street Annexe, Redfern.*
▼ *The electronic and control gear for the LW/AW Mk I unit.*



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Hence the LW/AW Mk IA aerial was designed and produced early in 1943.

Mr Worledge had visited the war zone in December 1942 and witnessed firsthand the conditions radar operators experienced when operating the LW/AW Mk I.

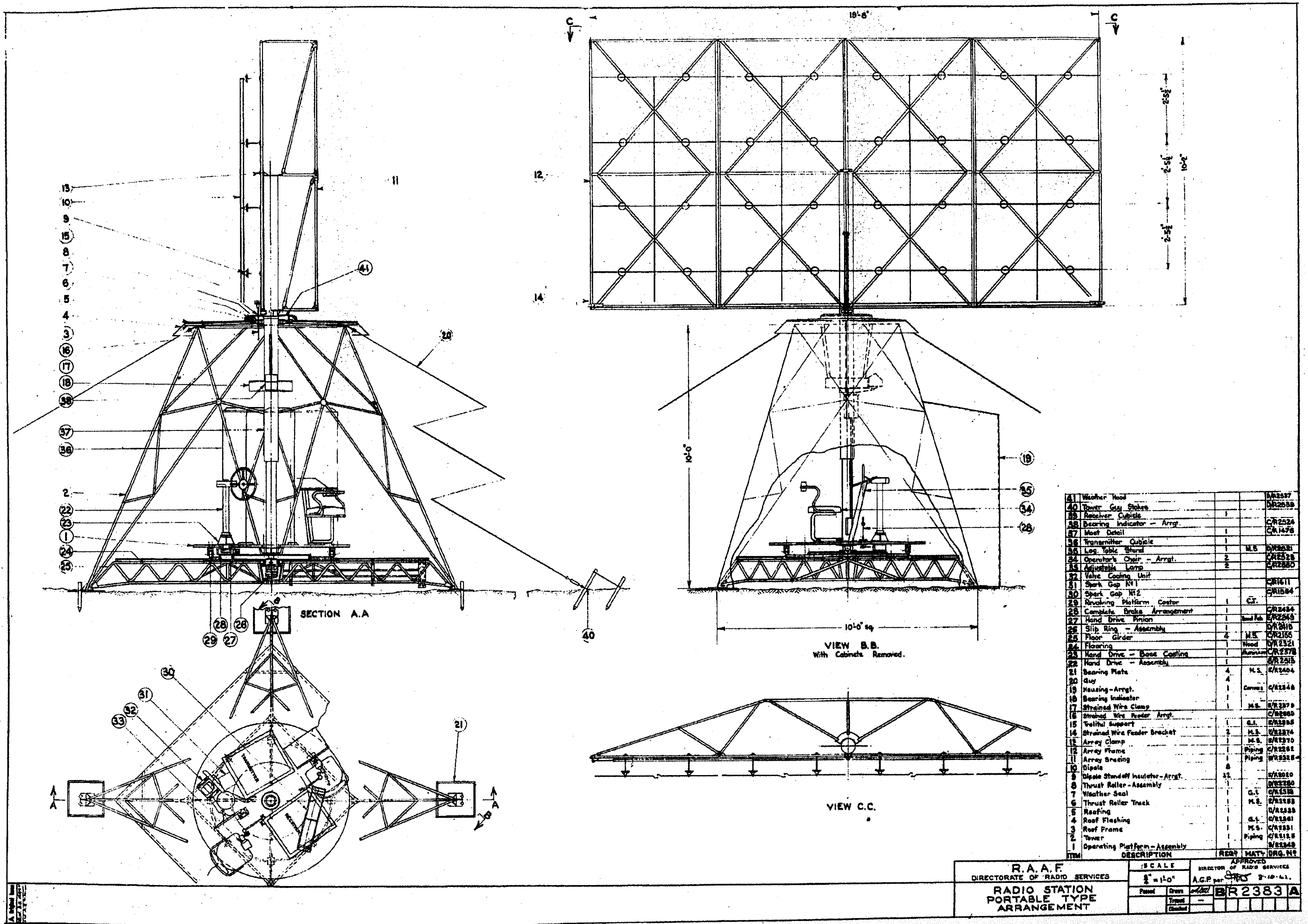
On his return, he required the base structure to be modified, resulting in the production of the aerial LW/AW Mk IA. Once again, I was given the job of designing it.

It had more space within the tented area, while the base was raised off the ground for better ventilation.

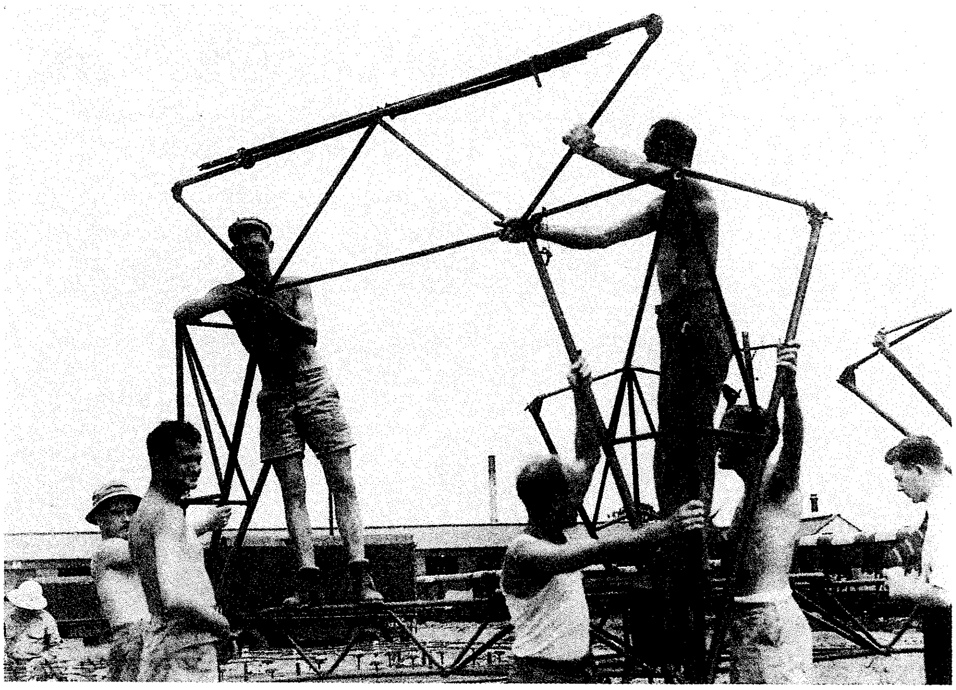
The base structure was also adapted to support a Ground Control Intercept (GCI) array which was designated LW/GCI Mk I. Further, the Army required a gun laying unit using two 4 ft. diameter paraboloid dishes mounted on the base structure.

Identification Friend or Foe (IFF) antenna was also added to the Mk IA.

Wing Commander Pither claimed that



ITEM	DESCRIPTION	REQD	MAT'L	DRG. No
41	Weather Hood			D/R2537
40	Tower Guy Stakes			D/R2539
39	Receiver Cubicle	1		
38	Bearing Indicator – Arrgt.			C/R2524
37	Mast Detail	1		C/R1476
36	Transmitter Cubicle	1		
35	Log Table Stand	1	M.S.	D/R2521
34	Operator's Chair – Arrgt.	2		C/R2528
33	Adjustable Lamp	2		C/R2580
32	Valve Cooling Unit			
31	Spark Gap No 1			C/R1611
30	Spark Gap No 2			C/R1584
29	Revolving Platform Castor	1	C.I.	
28	Complete Brake Arrangement	1		C/R2484
27	Hand Drive Pinion	1	[illegible]	E/R2249
26	Slip Ring – Assembly	1		D/R2416
25	Floor Girder	4	M.S.	C/R2155
24	Flooring	1	Wood	D/R2321
23	Hand Drive – Base Casting	1	Aluminium	C/R2378
22	Hand Drive – Assembly	1		B/R2515
21	Bearing Plate	4	M.S.	E/R2404
20	Guy	4		
19	Housing – Arrgt.	1	Canvas	C/R2348
18	Bearing Indicator	1		
17	Strained Wire Clamp	1	M.S.	E/R2379
16	Strained Wire Feeder Arrgt.			C/R2560
15	Trelitul Support	1	G.I.	E/R2395
14	Strained Wire Feeder Bracket	2	M.S.	E/R2374
13	Array Clamp	1	M.S.	E/R2370
12	Array Frame	1	Piping	C/R2281
11	Array Bracing	1	Piping	B/R2325
10	Dipole	8		
9	Dipole Standoff Insulator – Arrgt.	32		E/R2020
8	Thrust Roller – Assembly	1		D/R2280
7	Weather Seal	1	G.I.	C/R1538
6	Thrust Roller Track	1	M.S.	E/R2183
5	Roofing	1		D/R2533
4	Roof Flashing	1	G.I.	C/R2361
3	Roof Frame	1	M.S.	C/R2331
2	Tower	1	Piping	C/R2125
1	Operating Platform – Assembly	1		B/R2349



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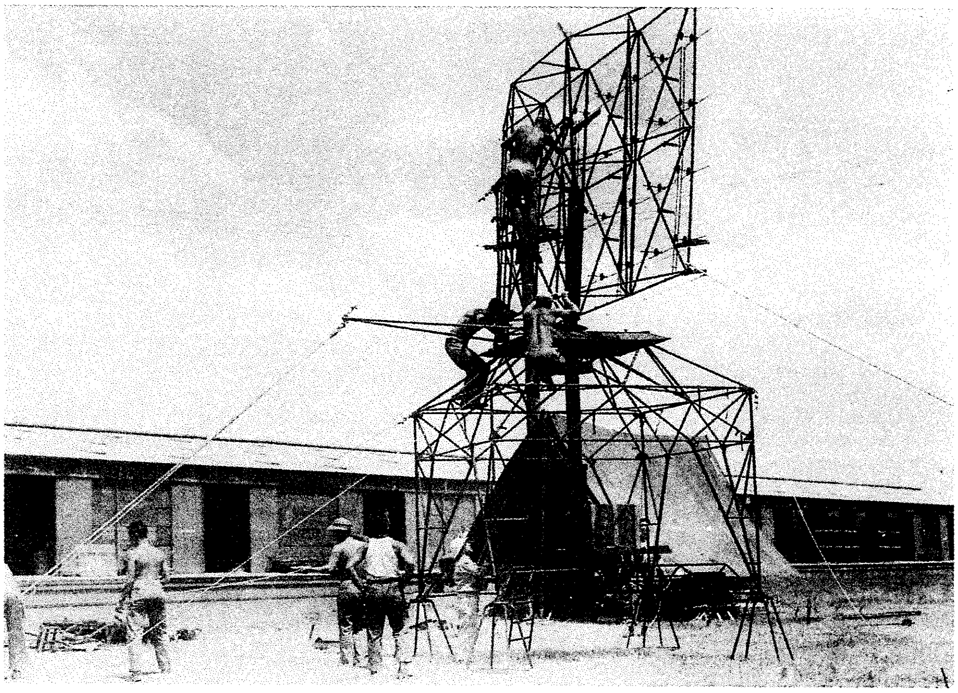
◀ *United States servicemen being trained to erect an LW/AW Mk IA unit at the racecourse opposite their Rosehill N.S.W. Stores Depot. The civilian at the right is the author.*



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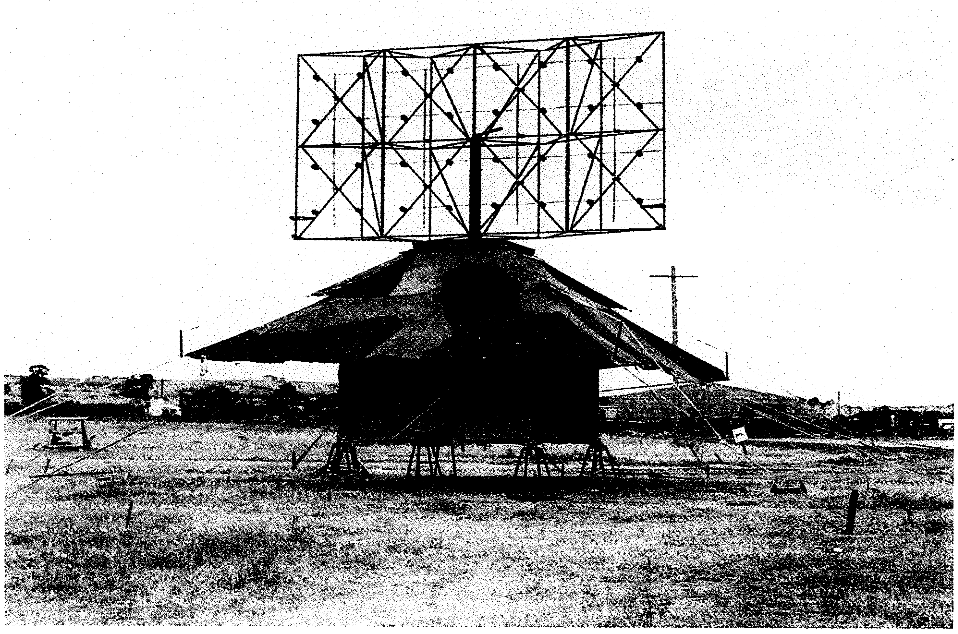
▶ *The framework of the unit is almost complete.*



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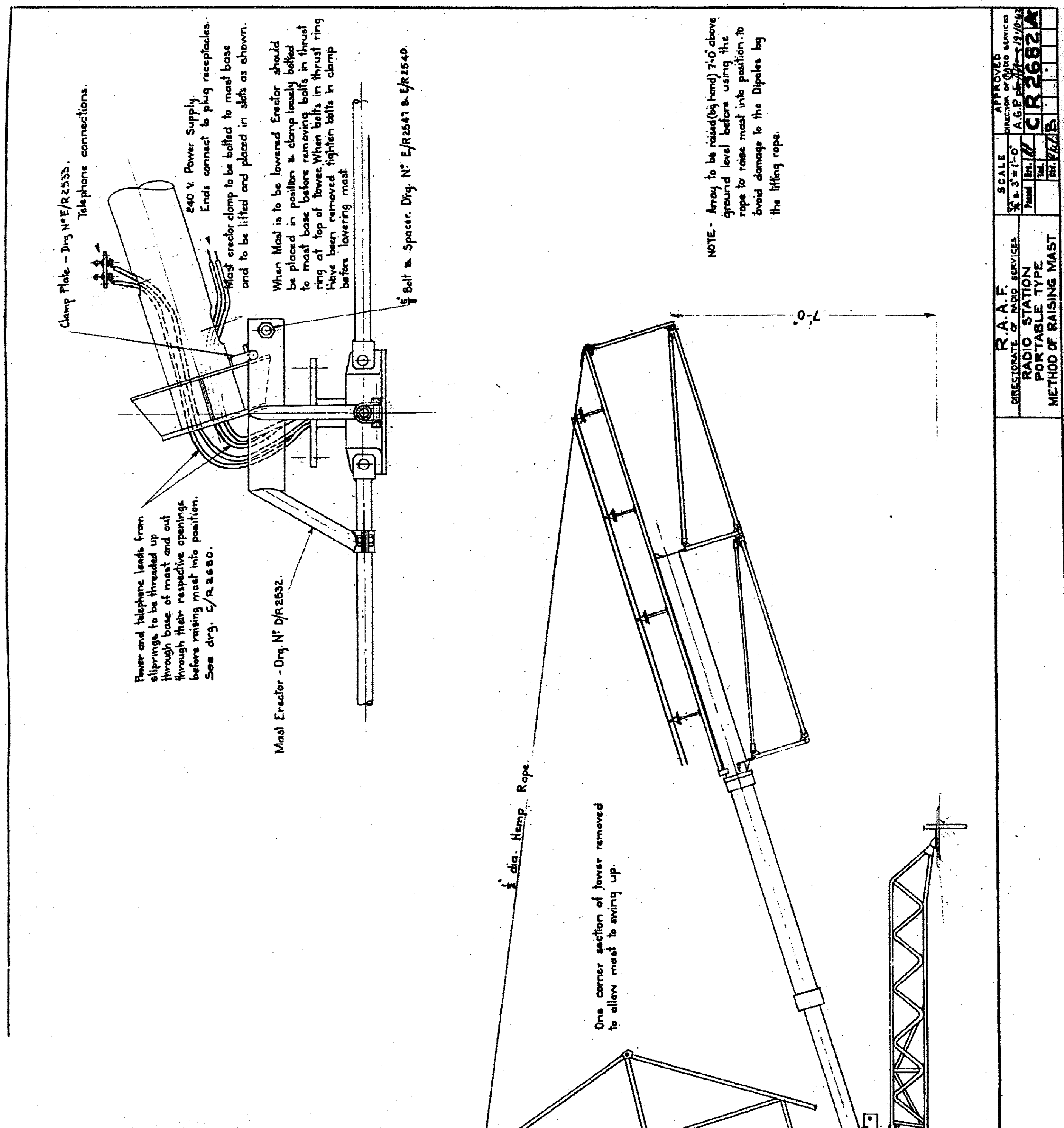
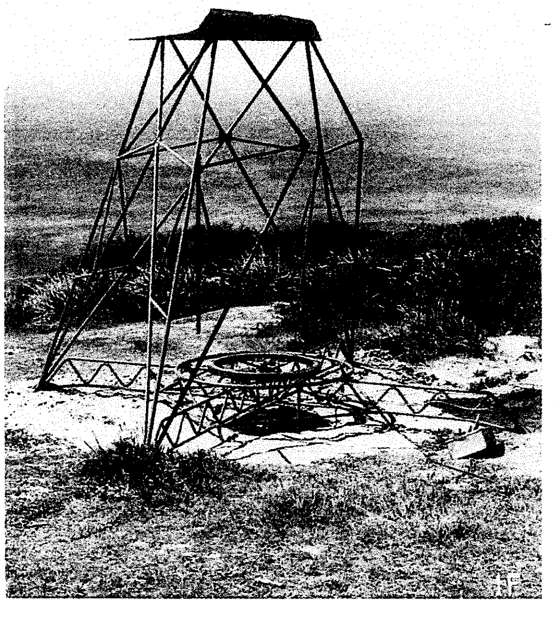
◀ *A completed unit with its canvas tent cover enclosing the operating area.*





First stage of assembly, 3 'A' frame legs, one half roof, floor girder, gear ring and floor track assembled. One 'A' frame leg omitted to enable mast to be erected complete.

without the NSWGR, the RAAF radar programme would have been delayed by at least six months.

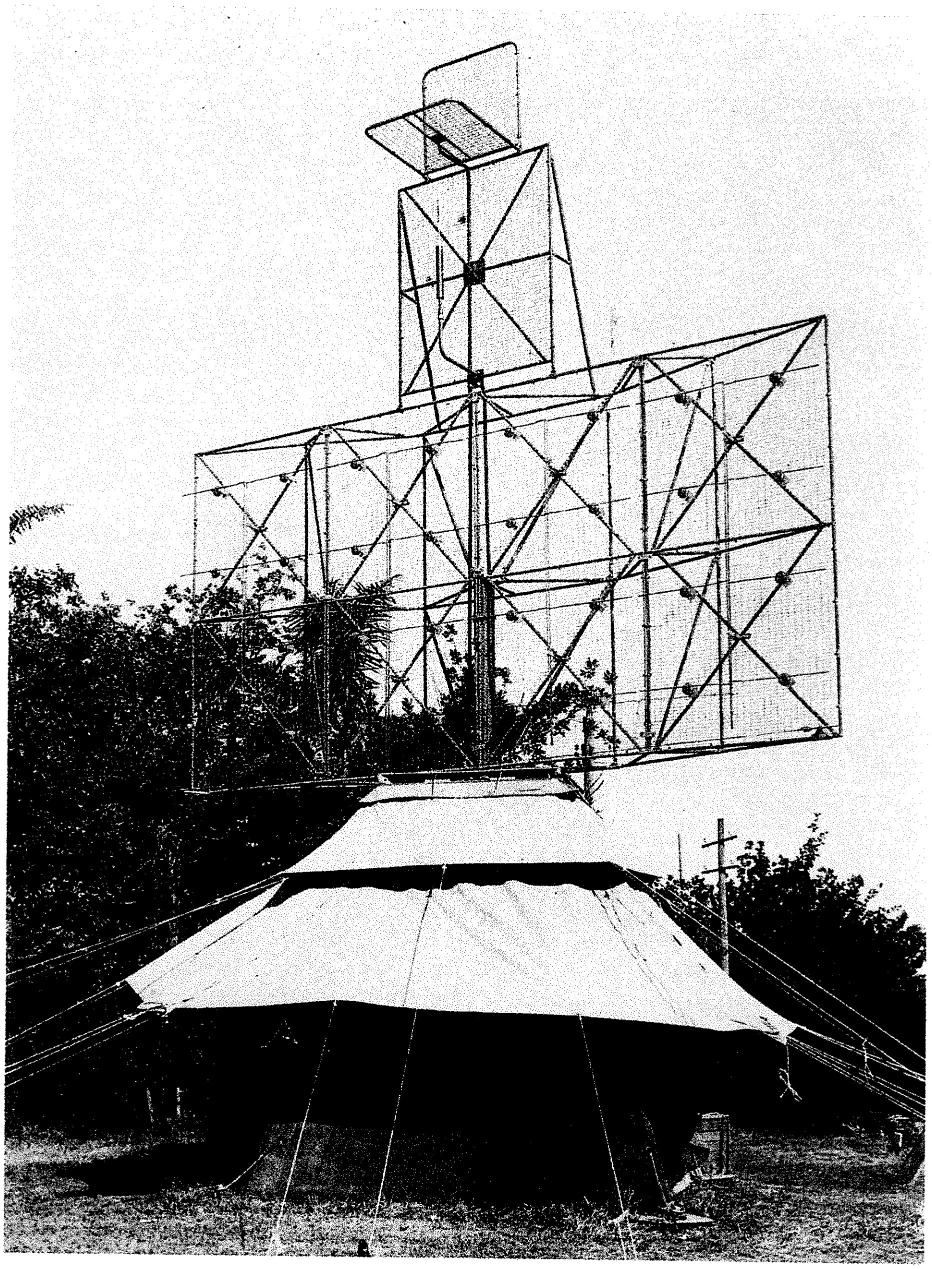
The extent of the Wilson Street Annexe's work was much more than satisfying the needs of the Australian and American services, as can be seen from the following list which only relates to our air warning activities—many more pieces of equipment were supplied to both the Australian and New Zealand Armies and Navies:

For the RAAF

- AW towers and aerials = 13
- AW/CHL towers = 52
- LW/AW Mk I towers and aerials (Worledge) = 75
- LW/AW Mk IA towers and aerials (Worledge) = 24
- LW/GCI Mk I huts, towers and aerials = 3
- LW/GCI Mk II huts, towers and aerials = 11
- LW/PRP plotting rooms = 64
- LW/LFC paraboloid aerials and trailers = 4
- LW/LFC static stations = 3

For the United States

- LW/AW Mk I towers and aerials (Worledge) = 21
- LW/AW Mk IA towers and aerials (Worledge) = 83



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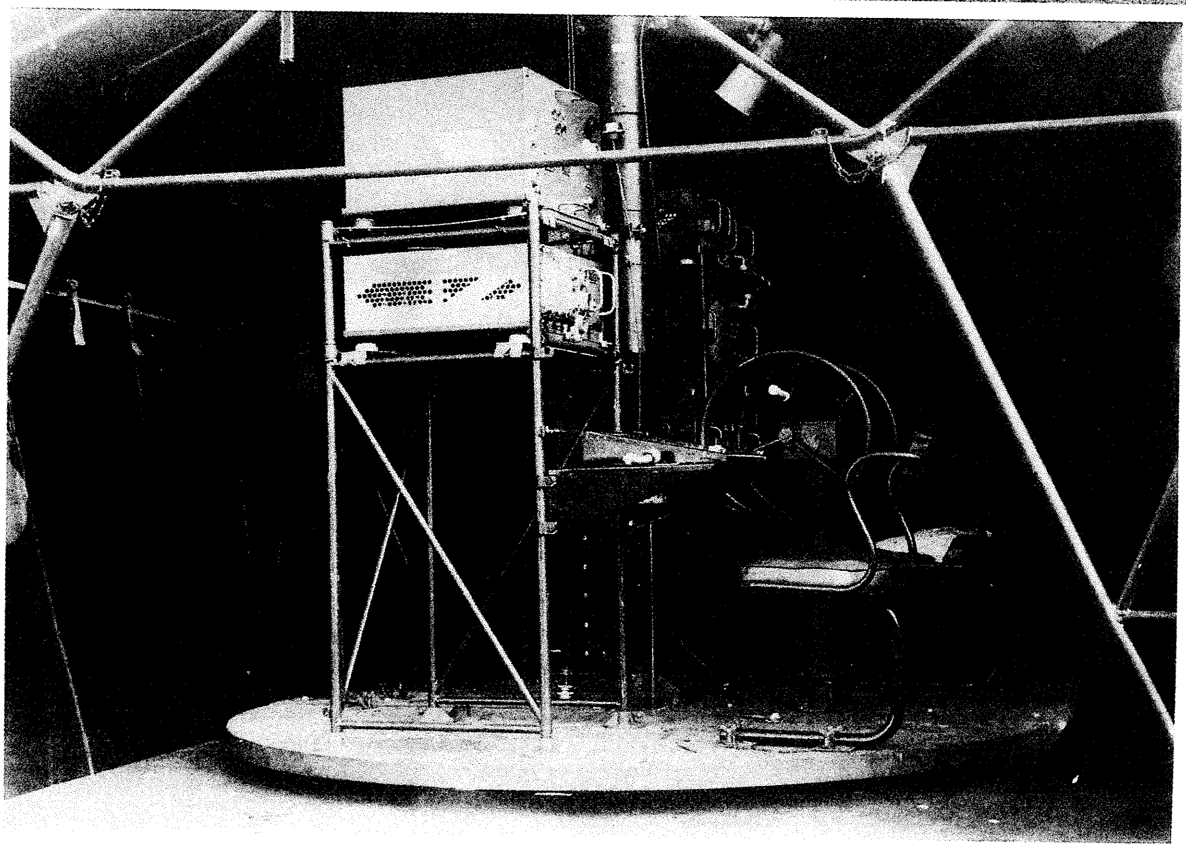
▶ *Completed unit with Interrogator and Response Array mounted above the Air Warning Array.*

▼ *Control area of Ground Control Intercept Array LW/GCI Mark I.*



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• LW/GCI Mk I huts, towers and aerials = 10

For the Royal New Zealand Air Force

• LW/AW Mk I towers and aerials (Worledge) = 4

For the Far East Asia Command

• LW/AW Mk IA towers and aerials (Worledge) = 12

• LW/PRP plotting rooms = 12

Other engineers also involved were J. Mansley, Vic Arnold, Richard Hugo, Frank Garland. There were others but my memory is lacking

Conclusion

The design and manufacture of the LW/AW array and tower by the NSWGR was proclaimed at the time as being one of the outstanding Australian achievements during World War II.

The success also depended on the AW radar equipment developed by the Radiophysics Laboratory.

The only other truly air-transportable system available then was the English LW or AMES Type 6 Mk III. The latter was the English Light Warning equipment with limited range used at beachhead landings.

However, the Australian set had a greater range and the English LW was available to the RAAF before the advent of the LW/AW Mk I.

It was rapidly discovered that the NSWGR-produced LW/AW system was better than any of the older systems, not the least in being a narrower beam and having a longer range.

This narrowing of the beam was due to the fact that the LW/AW Mk I system had a series-parallel four-bay arrangement as distinct from the older English AW's three-bar array.

The first two sets played a significant part in the Buna campaign in Port Moresby following a second flight over the Owen Stanley Range.

Under ideal conditions and with all pieces of the jigsaw puzzle on hand, radar station members could erect a radar station from a pile of parts to the completed task in 3–3.5 hours.

The following example outlines the worth of the LW/AW Mk I unit as a highly transportable piece of equipment:

Enemy reconnaissance aircraft flew over Drysdale Mission in the north of Western Australia early in March 1944, at a height of 30,000 ft. and on a course which avoided the early warning radar situated near Drysdale.

The enemy had to be stopped in order to deny him certain intelligence information. It was decided to move the LW/AW set working at Fenton to the Drysdale airstrip and site it low to give the ability to detect high flying aeroplanes.

At 7.00 p.m. orders were given to the radar station at Fenton, which had been running normal shift hours until that time, to pack and be ready to move by airlift from there at 6 o'clock next morning.

At 7.15 a.m., five C47 transport planes were loaded and took off for Drysdale. They reached there at noon, unpacked and a site selected. It was impossible to work throughout the night because of tiredness and the absence of any lighting but the new station was tested by midday next day. Plots were begun to be outputted to 105FCU at Darwin early that afternoon.

The job of transferring the station and re-erecting it was carried out in its entirety by the usual station staff. This exercise was almost a daily occurrence.

So important was the LW/AW Mk I tower to the operations of the RAAF, that it was officially called the Worledge Array as a sign of appreciation to the man responsible for its design.

Although it only took 30 days to produce the prototype LW/AW array, it took me about 10 months to produce the very comprehensive and "top secret" manual outlining the procedure for RAAF personnel to employ to identify all the pieces of the jigsaw puzzle which arrived in crates and put it together successfully in the minimum of time. This manual is full of diagrams and photographs. The diagrams were very detailed. It was impossible to make a mistake.

So top secret was the operation that many of the personnel involved in the erection of a radar station were not fed, as they did not exist on the base's allotment list.

To show the value to Australia of this top secret equipment and its effectiveness, a few typical examples of units in operation are included.

An LW/AW Mk I was sited at Horn Island, just north of Cape York and picked up an incoming Japanese bombing force at 150 miles.

The course of the raid was continuously plotted and height estimations were made by using the information obtained from successive durations of echoes as the targets flew through the lobe pattern. No fighter force was available at Horn Island but the warning system given was ample to enable the personnel on the Horn Island targets to protect themselves and their vital equipment. As a result, the Japanese force wasted its bomb loads and headed for its base.

The course, speed and height on the homeward run were soon forecast by the LW/AW station and this information was signalled to Fighter Control at Port Moresby.

Shortly afterwards, it was noticed that the range of the homing raiders was not increasing and it was correctly inferred that the enemy was circling in order to render inaccurate any forecasting which may have been made. The range at this period was approximately 100–120 miles. This information was also signalled to Moresby. Consequently, the raiders were finally intercepted by our fighters only a few miles from their home airstrip, when they were practically out of fuel. They were all destroyed.

This operation is a good example not only of the averting of serious damage by enemy bombing but also of how the air warning stations enable the most efficient use to be made of the fighter strength available.

The continuous plotting inwards and outwards of this raid to a range of about 150 miles is only one example of the way in which the LW/AW Mks I, IA and II exceeded in practice their theoretical performance.

Enemy raids on Darwin in January–February 1942 were having a most depressing affect on the morale of the defenders, both air and ground.

The raiders would appear without warning and the available fighters would be scrambled with very little hope of effecting interceptions. The A.A. defences, for similar reasons, operated at an extreme disadvantage.

During this period, six air warning stations, the prototypes of the LW/AW Mk I, were being rushed to completion at the Radiophysics Laboratory.

The first unit, having completed its tests, was flown to Darwin and, after some disappointing experiences due to lack of training and unfamiliarity with the equipment on the part of the operators, commenced to give early warning.

The effect on the whole situation was salutary. On the first occasion the fighters intercepted the enemy some 25 miles from Darwin and completely broke up the raid. The A.A. defence, having had time to organise, also gave an excellent account of itself. Since then, all enemy raiding action against Darwin was quite inaffective.

On one occasion, early in the history of the Guadalcanal campaign, some 20 B24 and B25 aircraft had come in for refuelling to an airstrip.

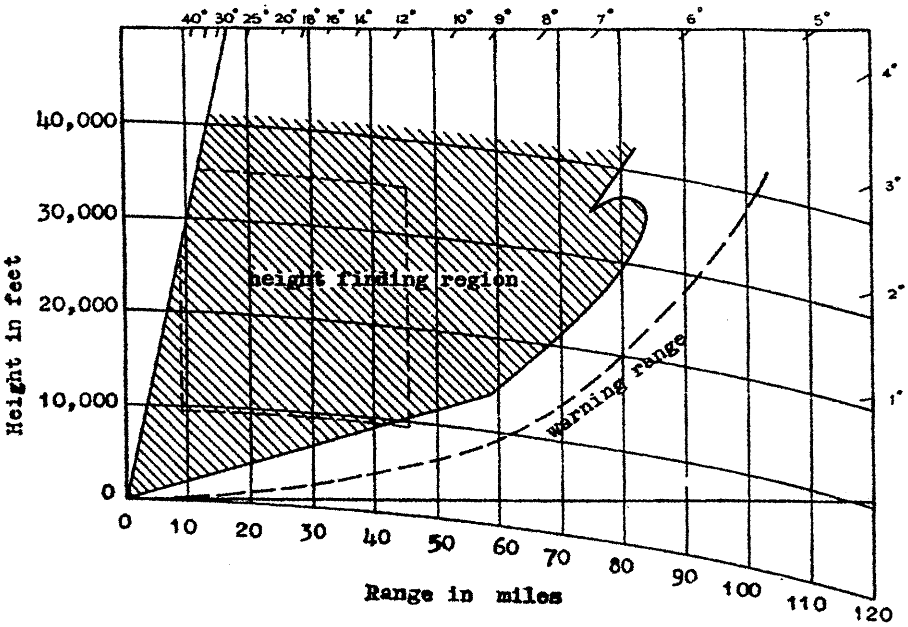
The US forces had by this time set up a fairly complete network of early warning stations, comprising mainly LW/AW Mk II, with one SCR.270 (a heavy, fixed station operating on 100 Mc/s) and a few SCR.602/T6 (a very light equipment, giving warning ranges of up to 40 miles only).

Early warning at approximately 90 miles was given of the approach of a Japanese bomber formation.

This warning enabled the Allied B24s and B25s to get into the air and out of harm's way. The enemy spent his bombs on the empty airstrip, doing minor damage only.

But for the early warning system, it is certain that this raid would have cost the Allied forces some £2,000,000 worth of bombers, of which there were all too few available at that period.

When it is considered how very many times such savings of invaluable equipment and lives have been effected through the light weight early warning stations, it is clear that this "insurance policy" repaid the effort spent in creating and maintaining it.



Polar Diagram of LW/GCI Mk. II.
Lobes left out for clarity.
The Institution of Engineers, Australia.

▼ *Another view of the emergency stanchions using LW/AW technology at Wentworth Falls. These stanchions were manhandled into place without the use of cranes.*

STATE RAIL AUTHORITY OF NSW