CHAPTER 18

THE AIRCRAFT INDUSTRY

SOON after the war of 1914-18 a number of small firms, encouraged by the Commonwealth Government, began the construction of wooden, fabric-covered aircraft fitted with imported engines, for use as training machines by the R.A.A.F. Once the demand for training aircraft had been satisfied, the firms had little further scope for activity since there was very little demand for civil aircraft of the type they were making. The inevitable result was that they went out of business.

While on a trip abroad in 1935 Mr Essington Lewis saw in the warlike preparations of Germany and Japan a strong argument for establishing a well-founded aircraft industry in Australia. He believed that because of the peculiar distribution of Australia's population, with large cities along the eastern and southern coasts and hundreds of thousands of square miles to the north and west practically devoid of settlement, aircraft would prove a powerful, and perhaps the main weapon of defence. During his stay in London Lewis was able to gain the support of Sir Harry (later Lord) McGowan of Imperial Chemical Industries, and that of Mr W. S. Robinson[1] of the Zinc Corporation Ltd, but on his return to Australia he found that his ideas were by no means widely accepted. Indeed, had it not been for the strong advocacy of Sir Archdale Parkhill,[2] at that time Minister for Defence in the Lyons Government, and of Mr W. M. Hughes, Lewis's proposals for an aircraft industry might well have been shelved.

In 1936, however, at the suggestion of the Government, three companies with long experience in overcoming problems likely to be met in setting up such an industry banded together and formed a syndicate. They were the Broken Hill Proprietary Company Ltd, Australia's leading industrial organisation; Broken Hill Smelters Pty Ltd, a company that handled almost the entire mining and smelting of non-ferrous metals in Australia; and General Motors-Holden's Ltd, the most powerful member of the automotive industry. The purpose of the syndicate was to discover to what extent it would be practicable to develop a self-sufficient aircraft industry based on Australian raw materials and industrial facilities.

The syndicate formed the opinion that about five years would be required to produce first-line military aircraft, and that before this could be achieved much spade work would have to be done. In the belief that it is better to learn to walk before learning to run, it was decided in the first instance not to attempt to make the most modern, high-performance type of aircraft but to begin with a trainer. In view of criticisms that were later made about the inadequacy of the first Australian-made aircraft as fighter planes, it is important to remember this technical policy.

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[1] W. S. Robinson. Financial Editor, Melbourne *Age*, 1899-1907; Joint Managing Director, Broken Hill Assoc Smelters, 1915-35; Adviser, in London, to Aust Govt in first and second world wars. Of Melbourne and London; b. Hawthorn, Vic, 3 Oct 1876.

[2] Hon Sir Archdale Parkhill, KCMG. MHR 1927-37. PMG 1932-34; Min for Defence 1934-37. B. Paddington, NSW, 27 Aug 1879. Died 3 Oct 1947.

In order to decide the best type of aircraft with which to begin manufacture, the syndicate appointed a mission of three engineering officers of the air force—Messrs Wackett,[3] Harrison[4] and Murphy[5]—and sent them abroad with instructions to visit every country of interest as far as aircraft manufacturing was concerned. They were to study the types of aircraft in production and to be prepared on their return to Australia to recommend an aircraft and an engine suited both to the requirements of the R.A.A.F. and to the stage of industrial development that had been reached in Australia. In the course of their travels the mission visited Italy, France, Germany, Czechoslovakia, Holland, England and the United States.

Among the foremost considerations in the minds of the mission when preparing its report was the desirability of establishing a method of manufacture that would be applicable not to one type of aircraft only, but to a range of types. The design should, moreover, lend itself to making the greatest use of jigs and tools so that in emergency, mass production by semi-skilled labour would be possible. It also took the view that the design should include features likely to become standard practice for some years. Features then regarded as novel but sufficiently important in securing a high performance to be included in the requirements of an aircraft for Australian manufacture were: stressed skin construction; all-metal construction; low-wing monoplane; hydraulically operated, retractable undercarriage landing gear; variable pitch propeller. An air-cooled radial engine was selected as the most suitable type to establish aero-engine production in Australia. The members of the mission were told that, other things being equal, British types of aircraft and aero-engine should be favoured, but that the all-important point was to select types which could be put into production in Australia most easily and rapidly.

Having regard to all these requirements, and to the suitability of the aircraft for the advanced training requirements of the R.A.A.F., the mission unanimously recommended that a licence to manufacture an aircraft known as NA-33 should be secured from North American Aviation Incorporated (California) and that authority to manufacture single-row Wasp engines for installation in the aircraft should be obtained from the Pratt and Whitney Aircraft Division of the United Aircraft Corporation. Choice of this engine was strongly influenced by the fact that many components of the single-row Wasp were common to those used in the twin-row Wasp Pratt and Whitney engine of 1,200 horse power, and that the same techniques and methods of construction were used for both engines. Ability to produce the larger engine would be a great asset if it was decided to build operational aircraft.

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[3] W Cdr Sir Lawrence Wackett, DFC, AFC; BSc. (Served 1st AIF.) RAAF 1919-30; Manager C'wealth Aircraft Corpn. Aircraft engineer (designed the experimental flying boat "Widgeon"). Of Melbourne; b. Townsville, Qld, 2 Jan 1896.

[4] W Cdr H. C. Harrison, OBE. Chief draughtsman in aircraft firm, England, 1916-20. Dir of Tech Services RAAF 1925-27, 1930-35; comd various RDF Stns RAAF 1943-44; Dep Dir Repair and Maintenance RAAF 1944-45. Of Middle Brighton, Vic; b. Norwich, Eng, 22 May 1888.

[5] Air Cmdre A. W. Murphy, DFC, AFC. (Served 1st AIF: 1 Sqn Aust Flying Corps.) Comd 4 Maintenance Gp RAAF, 1942-45. Of Essendon, Vic; b. Kew, Vic, 17 Nov 1891.

The NA-33, a two-seater, single-engine, low-wing, all-metal monoplane had been designed by North American Aviation for simplified, large scale production. Its construction in Australia would provide factory experience in manufacturing techniques likely to form a background for the development of other types of aircraft, ranging from high-speed fighters to bombers. By no means least of the advantages of the NA-33 were the very reasonable terms asked for the licence to manufacture it in Australia. The Air Board accepted all the mission's recommendations. Later the British Air Ministry also adopted the NA-33, under the name of the Harvard trainer.

The original members of the syndicate had now been joined by representatives of I.C.I.A.N.Z. Ltd, the Electrolytic Zinc Company of Australasia Ltd, and the Orient Steam Navigation Company Ltd. Almost immediately after this accession to its membership, the syndicate was registered in Victoria as the Commonwealth Aircraft Corporation Pty Ltd (C.A.C.) in October 1936.[6] This organisation not only pioneered the manufacture of all-metal aircraft in Australia, it also became the leading wartime private manufacturer.

While plans were being prepared for the erection of aircraft and engine factories and an engine test-house at Fishermen's Bend (Victoria), Wackett was sent to Britain and the United States to buy machine-tools and equipment and to arrange the necessary licences. Before the buildings were completed in September 1937, the Commonwealth Government had placed an order for forty NA-33's.

It is an interesting sidelight on the ramifications of the Aluminum Corporation of America that the C.A.C. found it necessary in 1938 to procure from it a licence for making special aluminium alloy castings needed for aircraft parts. A foundry built for this purpose began operations in January 1939 with small and relatively simple castings, but as experience was acquired more and more intricate tasks, such as the cylinder head for the Wasp engine, were undertaken. Casting of magnesium and its alloys, also new to Australia, was begun. By reason of experience gained in foundry work involving light alloys, the C.A.C. became the source of supply of aluminium-magnesium alloy castings not only for its own aircraft and engine projects but for all other members of the wartime aircraft industry. Later, these facilities proved insufficient and an additional foundry was built by the Commonwealth Government at Highett, Victoria, for use by the corporation as a magnesium foundry. This enabled the foundry at Fishermen's Bend to be used exclusively for aluminium and its alloys.

Sheet aluminium for the fabrication of wings and other parts of the Wirraway[7] (as the Australian version of the NA-33 was named) was at first imported. It was not until after war broke out that the works of the Australian Aluminium Company at Granville, New South Wales, were

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[6] H. G. Darling became Chairman of Directors. Board members were: Sir Colin Fraser, Sir Lennon Raws, Messrs E. Lewis, M. L. Baillieu, A. Johnson and L. J. Hartnett. Mr Wackett was appointed manager.

[7] Derived from an aboriginal word meaning challenge.

ready to begin the rolling and extrusion of ingot aluminium. In August 1941 this company began to extrude metal sections for the construction of spars, and wire, rod and bar for rivets, bolts, nuts and engine parts. It also made, to exacting specifications, alloys for the forging of engine pistons, crank cases, landing gear and propeller blades.

The company specialised in the production of "alclad" sheet. The resistance of aluminium to corrosion depended very much on its purity: the higher the purity the more resistant it was. To take advantage of this fact without at the same time sacrificing the greater strength accruing from the alloying of aluminium, the practice had grown up of using composite sheets of metal consisting of a high-strength alloy core (duralumin) sandwiched between thin sheets of the pure metal. The Australian Aluminium Company produced large quantities of "alclad alloy sheet", for making the Beaufort, Beaufighter, Wirraway and Boomerang.

The steel industry gave powerful support to the infant aircraft industry, by providing constructional materials such as high-grade alloy steels and by fabricating these materials. A vital step in the manufacture of the Wasp engine and later the twin Wasp engine, for example, was the production of forgings by Australian Forge and Engineering Pty Ltd of Lidcombe, New South Wales; likewise the production of cylinder blank forgings by Stewarts and Lloyds of Newcastle. Equally essential to the industry were the chrome-molybdenum steel tubing made by British Tube Mills of Adelaide and the undercarriages made by James N. Kirby Pty Ltd of Sydney.

The licence under which the Commonwealth Aircraft Corporation was authorised to manufacture the NA-33 aircraft contained clauses providing that alterations could, if desired, be made in the design and also in the name of the aircraft. Its fuselage was constructed of welded nickel-chrome-molybdenum steel tubing in four sections, all bolted together. The wings were of single-spar structure covered with a stressed metal skin. The Pratt and Whitney single-row, nine-cylinder, 600-horse power, air-cooled, radial Wasp engines built by the C.A.C. were fitted to the aircraft to drive the three-bladed, metal Hamilton Standard type controllable-pitch propellers. Some details of this, the first aircraft to be made wholly in Australia, are set out below.

Wing span	43 ft
Wing area	256 sq ft
Wing loading	21.8 lb per sq ft
Normal gross weight	5,575 lb
Maximum gross weight	6,450 lb
Top speed at critical altitude (8,600 ft) .	220 mph
Operating speeds (2,100 rpm and 28-in manifold pressure):	
at sea level	177 mph
at 9,000 ft	199 mph
at 13,000 ft	209 mph
Landing speed (at normal weight) flaps down	65 mph
Maximum rate of climb	1,950 ft per min

Although a seemingly early start had been made on aircraft manufacture in Australia, it had not been soon enough to allow the development of front-line fighter aircraft in the early years of the war. However it must not be forgotten that trainers such as the Wirraway played a vital role in enabling Australia to meet her extensive commitments under the Empire Air Training Scheme, which were to supply 16,000 fully trained air crew by March 1943, with a further 10,000 each year. In the war Australia produced about 4½ per cent of the British Commonwealth's training aircraft.

The first Wirraway, which was built from imported fabricated aluminium, came off the production line and was flown on 27th March 1939—approximately two years and nine months after work had begun.

While the Commonwealth Aircraft Corporation was engaged on the Wirraway, the De Havilland Company at Bankstown, New South Wales, began work on the Tiger Moth, a trainer powered by Gipsy aero-engines which, in the first instance, it had been intended to import. When the time came, this could not be done and the engines had to be built locally. The detailed story of the De Havilland Company's activities will be taken up later in this chapter. Suffice it to say here that C.A.C. and De Havilland's had, by the outbreak of war, acquired machine tools and built up substantial groups of skilled workers who made possible the rapid expansion of the aircraft industry that took place at the height of the war. In its factories the C.A.C. is said to have possessed at this period the finest assembly of machine tools in the Commonwealth.

Early in 1939 a British Air Mission led by Sir S. Hardman Lever came to Australia to investigate the possibility of manufacturing here a front-line bomber aircraft. The mission made its report to the Commonwealth Government on 18th March 1939 and before the month was out its recommendations had been accepted. In general terms these were that Australia should undertake the manufacture of an operational aircraft, while Britain would supply as much technical assistance as possible and share the output and the costs. The aircraft recommended was the Bristol Aeroplane Company's Beaufort bomber.

As a first step in carrying out the agreement the Commonwealth Government set about establishing two main centres, one at Mascot, New South Wales, and the other at Fishermen's Bend, Victoria, for the final assembly of aircraft. For the purpose of administering these centres it created, in July 1939, the Aircraft Construction Branch within the newly-established Department of Supply and Development. The branch was placed under the direction of Mr Harold Clapp, who had resigned from the chairmanship of the Commissioners of the Victorian Railways to take up his new post.[7]

The general position on the outbreak of war was roughly this. The R.A.A.F., consisting of about 3,500 officers and men, possessed about 250 aircraft of which only two-thirds were suited for military operations,

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[7] Mr F. J. Shea became Chief Engineer, having been released on loan to the Commonwealth from his work as Chief Mechanical Engineer of the South Australian Railways. Mr V. F. Letcher, formerly Manager of the Publicity and Tourist Services in the Victorian Railways, was appointed Superintendent of Administration.

and many of them were already obsolete. About 12 Wirraways had been built; preparations for producing the Tiger Moth were well in hand but the Beaufort organisation was only just beginning to take shape.

With the intention of coordinating the activities of private and government aircraft factories the Federal Government in March 1940 replaced the Aircraft Construction Branch with the Aircraft Production Commission, a statutory body responsible at first to the Minister for Supply and Development and, after June 1940, to the Minister for Munitions.[8] Later events proved that this arrangement was unsatisfactory and the Government was, as will be seen later, obliged to introduce yet another change in the administration of the wartime aircraft industry.

The Beaufort bomber chosen for manufacture in Australia was a versatile aircraft, adaptable for long-range reconnaissance or for use as an ordinary bomber or a torpedo bomber with a range enabling it to operate over wide expanses of land and sea. It appeared to be ideal for the defence of a large continent such as Australia which could be attacked only by forces operating from fairly distant bases. Moreover, it was of a type that lent itself to production under the industrial conditions then prevailing in Australia.

At the time the British mission made its recommendations the Beaufort prototype had just passed its first trials in England. The Beaufort was an all-metal, mid-wing, twin-engine monoplane. Since the manufacture of an aircraft of this kind had never before been attempted in Australia it is of interest to record some of its technical details:

Engine	Pratt and Whitney, 1,200-hp, twin-row Wasp, 14 cylinders, air-cooled radial.
Propellers	3-bladed, 11 ft 6 in diameter, Curtis Electric or Hamilton Standard, constant-speed, fully feathering.
Span	57 ft 10 in.
Length	44 ft 4½ in.
Wing area (gross)	503 sq ft.
Wing area (net)	451 sq ft.
Over-all height (to tip of radio mast) .	14 ft 5 in.
Tare weight	13,000 lb.
Maximum all-up weight	21,500 lb.
Service ceiling	25,000 ft.
Absolute ceiling	26,000 ft.
Maximum rate of climb	1,200 ft per min up to 7,000 ft. 880 „ „ „ „ „ 15,400 ft.
Range	1,600 miles. 1,060 miles.
Speeds (all-up weight 21,000)	
At rated power, at sea level . . .	232 mph
at 8,500 ft . . .	259 mph
at 15,900 ft . . .	267 mph.

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[8] The members of the Commission were: Chairman, H. W. Clapp; Executive Members—J. S. Storey (former Director of Manufacturing, General Motors); R. Lawson (Director-General of Production and Supply, Dept of Air); A. V. Smith (Chairman, Contracts Board, Dept of Supply); E. R. Mitchell (a Sydney chartered accountant) representing the Treasury until Oct 1941 when he was succeeded by W. T. Harris; Secretary, V. F. Letcher.

In addition to a total of 1,000 pounds of bombs in the bomb bay, two 500-pound bombs could be carried under the wings. Alternatively a 2,000-pound torpedo (either English Mark XVIII or American Mark XIII), mine or bomb could be slung in the bomb bay with the doors fixed open. If necessary, an auxiliary fuel tank of 138 gallons' capacity could be carried in the bomb bay instead of bombs.

The arrangement under which torpedo bombers were to be manufactured in Australia was that the Bristol Aeroplane Company should supply all engineering and tooling drawings and all the requisite technical data. Originally the intention had been that most of the difficult components of the aircraft, such as engines, propellers, gun turrets, undercarriages, tail-wheel struts, aircraft instruments, aircraft steels, and light alloy parts, should be manufactured in England, and that little more than assembly of the 39,000 different component parts in each aircraft should be attempted in Australia. This was the plan being carried out in the early days of the war, between September 1939 and the middle of 1940, but at the end of July 1940 a cable was received from the United Kingdom Air Ministry which read:

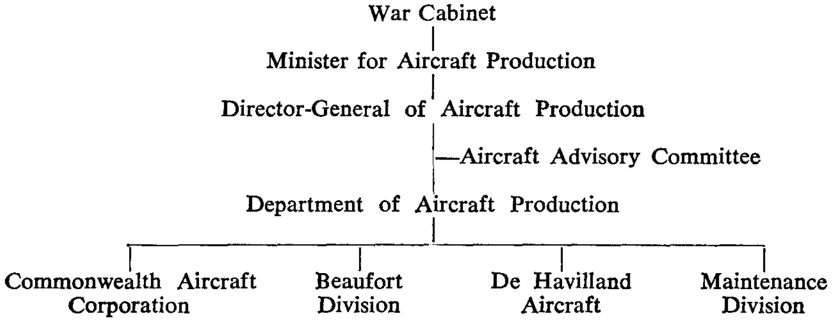
> From this date onwards Australia can rely on England for no further supplies of any aircraft materials or equipment of any kind.

This message caused great consternation among the members of the Aircraft Production Commission, forcing them to make up their minds immediately whether to recommend the Government to proceed with the project or not. It was the death blow to hopes that the first Beauforts would be delivered during 1940 as originally planned. Three months after this embargo had been imposed, it was relaxed sufficiently to permit the Bristol Aeroplane Company to complete its undertaking to supply parts for the first twenty Beauforts; otherwise the whole project might have collapsed.

> Looking back from this point (commented Sir John Storey), I think I can say it was fortunate that we had not the slightest appreciation of the difficulties with which we would be confronted. Had we had any conception of these difficulties I feel we should have recommended the abandonment of the project. As it was, we decided to follow a good old Australian policy and give it a go.

There were to be many periods when failure would threaten the whole venture.

Australia now faced perhaps her biggest and most complex industrial task of the war. An English aeronautical expert at this time expressed the opinion that the building of Beaufort bombers was beyond the capacity of Australia. It meant that, in a short space of time, the country would be compelled to build, from the ground up, a vast organisation for the mass production of an intricate machine that would necessitate the creation not merely of a single industry, but of a large group of related industries. The enlargement of the Government's participation in the industry from merely assembling aircraft from imported components to manufacturing aircraft wholly in Australia called for a radical overhaul of administrative machinery. In the earlier planning insufficient attention had been given to the problem of achieving coordination between government and private industry. The industry now began to assume such proportions that it could no longer be satisfactorily administered as part of the Department of Munitions. In June 1941 the Government created the Department of Aircraft Production and placed it under the direction of Mr Essington Lewis.[9] To assist him it set up the Aircraft Advisory Committee.[1] The organisation for the production of aircraft took the form shown in the accompanying chart.



Late in 1941 the Beaufort Division, which had been placed in charge of Mr Storey, accepted full responsibility for the manufacture of every part of the aircraft, including gun turrets and excluding only armament. This did not mean that every part of the aircraft was manufactured in the Beaufort factory at Fishermen's Bend; engines, propellers, undercarriages and electrical accessories for engines were all made in annexes in different parts of the Commonwealth. At no time was there any question of making these parts in one big central government factory; this would have involved the country in an enormous capital outlay and left it with a largely unwanted plant after the war. Instead, an organisation was required which would be capable of using the facilities of peacetime industry wherever they could be found. This, with variations according to differing circumstances, was the general pattern adopted in manufacturing all the more complex munitions of war: aircraft, tanks, torpedoes and ships. It was a difficult business to build up such an organisation under wartime conditions. Well-defined principles that had been successfully applied in older industrial countries had to be adapted to a country of small population and limited resources, both widely dispersed.

The basic plan, briefly stated, was to spread the manufacture of component parts by sub-contracting among about 600 firms, some of them in

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[9] The Aircraft Production Commission was administered by the Dept of Aircraft Production until Jan 1942, when it went out of existence.

[1] Members of the committee included: Hon D. Cameron (Minister for Aircraft Production); Essington Lewis (Director-General of Aircraft Production), Chairman; D. McVey, V. F. Letcher and W. T. Harris (Dept of Aircraft Production); Air Cmdre E. C. Wackett (RAAF); H. G. Darling (C'wealth Aircraft Corporation); A. Murray Jones (De Havilland Aircraft); J. S. Storey (Beaufort Division); F. J. Shea (Aircraft Maintenance Division); L. P. Coombes (CSIR Division of Aeronautics); E. V. Nixon (Treasury); N. Roberts (Trades Unions); L. J. Wackett, Chief Technical Adviser.

centres more than 1,000 miles apart. Components made by these subcontractors were fed into seven factories, where they were assembled into the main sub-units of the aircraft. Here the workshops of the State Railways of Victoria, New South Wales and South Australia contributed a major share, distributed among them as follows:

Chullora (N.S.W.): front fuselage, stern frame, undercarriage and engine nacelle.
Newport (Vic): rear fuselage and tail assemblies, tail plane, rudder fins and elevator.
Islington (S.A.): centre plane and wings.

The major sub-assemblies were in turn fed into the main assembly workshops at Fishermen's Bend and Mascot, where the final fitting out was undertaken before the aircraft were moved out as complete units ready for flight testing.

The first Beaufort flown in Australia, early in 1941, was an experimental aircraft assembled from parts supplied from the United Kingdom. The first Australian-built[2] Beaufort made its flight in August 1941, within two years and three months of the decision to manufacture.

Although built to the design of the British aircraft, the Australian Beaufort was not an exact copy. It was found as a general rule that minor changes had to be made to meet the requirements of the R.A.A.F. One of the principal reasons for these changes was the fact that aircraft designed for operation in the conditions prevailing in Britain and in the United States were not necessarily suitable for flying in the hot, often humid, tropical areas of Northern Australia and the islands of the South-West Pacific. Some modifications incorporated improved features that had been developed locally; others permitted the substitution of indigenous raw materials, which were seldom identical with those specified.

The most important modification concerned the engine. The original intention, following the recommendations of the United Kingdom Air Mission, was to use British-made 1,000-horse power Taurus engines in Beauforts until they could be made in Australia. The Taurus engine, however, proved a complete failure in Britain and was never produced in quantity there. For this reason the Aircraft Production Commission decided to substitute American twin-row Wasp engines, which could then be imported and for which facilities for local manufacture were being built up.

In order to accommodate the more powerful twin-row Wasp engine (1,200 as against 1,000 horse power) in the airframe designed for the Taurus engine, it was necessary to redesign many parts of the aircraft. The very considerable work involved was rewarded with an aircraft that flew faster than its British counterpart. Among other innovations were the installation of armour plate to protect the pilot from rearward and frontal attacks, and a gun turret with increased rotation (from 180 to 240 degrees). To correct a tendency of the original Beaufort to yaw, the fin

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[2] Except for the engine; the first Australian-built Beaufort engines were not completed until Nov 1941.

was redesigned and its area increased by some 15 per cent. A special "shimmy damping" arrangement designed in Australia by National Motor Springs Ltd, entirely eliminated what was known as tail wheel "shimmy".

The problem of transferring from the United Kingdom to Australia the great mass of technical information embodied in more than 250,000 specifications and accompanying drawings used by aircraft and other manufacturers was a formidable one. To have sent this bulky material by ship would have been much too slow; by air it would have overtaxed the hard-pressed transport facilities. The problem was solved by greatly reducing the volume of the material through the use of microfilm, a procedure first introduced during the Franco-Prussian war.[3] During the siege of Paris several lengthy messages were sent to the outside world by photographing them, greatly reduced in size, on rolls of film sufficiently small to be fastened to the leg of a carrier pigeon. Except for the substitution of aircraft for pigeons essentially the same technique was used in successfully transferring from the United Kingdom and United States much of the technical information needed by Australia in the second world war.

The Beaufort Division could not have achieved what it did without outside help over and above the technical information, drawings and machine tools provided by the Bristol Aeroplane Company. Members of the nucleus technical staff chosen from the State railway engineering workshops and sent for training at the works of the Bristol Company later assumed leading positions in the Beaufort project in Australia and in due course, in the Beaufighter and Lincoln projects. Key men drawn from the company's own experienced engineers included Mr J. A. Latham and Mr J. H. Crovine, who became Chief Engineer and Chief Inspector respectively of the Australian project. Indeed the generous assistance of all kinds received from Britain—from the Air Ministry and the Bristol Aeroplane Company in particular—never ceased. In the darkest days, when she stood alone and was unable to supply all the materials originally intended, Britain continued to give help to Australia even though it meant reducing the slender stocks that were all she had to stave off defeat. "The Australian people can never be grateful enough for the wonderful spirit which was manifested by aircraft authorities and manufacturers in the United Kingdom at that stage and since."[4]

Valuable assistance was also given by the United States, especially through the agency of the Lend-Lease plan; much of this help was due to the generosity of British authorities in sponsoring Australian requests for aircraft materials even when they could only be met at the expense of British orders.[5]

The Beaufort organisation was strengthened by recruiting leading production engineers from Australian industries. Mr E. J. Gibson (Construc-

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[3] K. Burrow and D. P. Mellor, "Microfilms for the Scientist and the Scholar", *Australian Journal of Science*, Vol. 9 (1945), p. 4.

[4] Sir John Storey, *Aircraft Production* (Jul 1945), p. 342.

[5] Supply Liaison Offices were maintained in both Britain and the United States; the former, at Australia House, was in charge of Mr A. E. Hyland; the latter, known as the Aircraft Division, was part of the organisation controlled by the Director-General of Aust War Supplies Procurement at Washington.

tion Engineer for General Motors-Holden's) for example, was responsible for the construction of most of the aircraft factories built in Australia during the years 1939-45; Mr Woodfull[6] was Chief Executive in charge of the Supply organisation; and finally Mr M. D. Penn (Factory Manager for De Havilland), originally in charge of the production of Tiger Moths, supervised the production of wings and centre planes for both Beauforts and Beaufighters.

The transition from building aircraft with imported components to manufacturing them almost wholly in Australia was of course made only gradually. As the war progressed considerable extensions had to be made to existing industrial establishments to enable them to manufacture the more specialised aircraft components. In some instances entirely new manufacturing plants had to be set up. These usually took the form of annexes, originally established by the Commonwealth Government as part of the Beaufort scheme but extended, as the needs of the R.A.A.F. and Allied Air Force operating from Australia grew, to meet the requirements of the aircraft industry as a whole.

A major extension was the engine factory erected at Lidcombe, New South Wales, by the Commonwealth Aircraft Corporation on behalf of the Government for producing twin-row Wasp engines for the Beaufort bomber. The C.A.C. had gained experience of engine manufacture by making the single-row Wasp for the Wirraway.

The Lidcombe factory, which was designed to turn out forty engines a month, produced its first in November 1941; the sixty-sixth engine, the first to be constructed entirely from locally-made parts, passed its test on 2nd June 1942. As an insurance against destruction by enemy action of the only source of twin-row Wasps, plans were made to duplicate this factory at Fishermen's Bend, but because it was impossible to obtain the necessary machine tools from the United States this second factory had to restrict its activities to making engine parts for the Lidcombe factory and was never able to make complete engines. Despite a steady flow of twin-row Wasp engines, the output was sufficient to meet only part of the aircraft industry's needs. As many as 37 Beauforts were delivered in one month, each fitted with two engines. Consequently, although nearly 1,000 twin-row Wasps were made at Lidcombe a much larger number had to be imported from the United States. Had Australia been cut completely off from oversea supplies, the restricted facilities available for making aero-engines would have set severe limits to aircraft production. More engines could have been made if the factory had not accepted orders from the United States Army Air Force for spare parts to the value of about £2,000,000, and had not undertaken the repair and overhaul of large numbers of engines for the R.A.A.F. and American Air Force.

Towards the end of the war the factory turned over to making parts for the Rolls Royce Merlin engines, to be assembled with parts obtained

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[6] M. B. Woodfull. (Served 1st AIF.) Factory Manager, General Motors-Holden's, 1933-39; Supply Manager and Dep Dir, Beaufort Div, Dept of Aircraft Producn, 1939-45; Gen Manager, Govt Aircraft Factories, Vic, since 1948. Of Melbourne; b. Kerang, Vic, 23 Oct 1895.

from Britain into complete engines. This it ultimately did with success, working under licence from Rolls Royce. The Merlin engine was chosen for manufacture because it was required for the Mosquito, Mustang and Lincoln—types of aircraft most used by the R.A.A.F. at that stage of the war. As the factory could not make all the engines required for Mosquitos and Mustangs, some were imported from the United States under Lend-Lease. American authorities, however, refused to sponsor the importation of Merlin engines for use in long-range bombers such as the Lincoln, on the ground that such aircraft could easily be flown out either from Britain or from the United States. The war ended while the initial order for 100 Merlin engines for the Lincoln bomber was being completed.

The manufacture of retractable landing gear, principally for the Beaufort, was undertaken in an annexe operated on behalf of the Government by National Motor Springs Pty Ltd of Alexandria, New South Wales. This company, without the advantage of any data on manufacturing procedure or designs for tools, succeeded in meeting all the requirements of tail-wheel struts and oleo legs for the Beaufort, and later for the Beaufighter and the Lincoln bomber, at a cost of about half the landed cost of the same components from the United States. All the varied electrical accessory equipment for aero engines—starters, generators, voltage regulators, magnetos and many other units—was made in an extension of the factory of Tecnico Ltd at Marrickville, New South Wales.

Aircraft instruments were not made in Australia before the war, and one of the important tasks of the new industry was to provide ample supplies of these instruments. Their manufacture was spread over three firms. At the works of Amalgamated Wireless (Australasia) Ltd a whole factory was devoted to making compasses, the Sperry gyro horizon, Sperry directional gyro, rate-of-climb indicator, pressure gauges and altimeters. Warburton Franki Ltd of Melbourne concentrated on such equipment as ammeters, voltmeters and air temperature indicators, while H. A. Chivers of Melbourne made tachometer generators, tachometer indicators and turn-and-bank indicators.

In selecting the directional gyro for special mention two considerations have been uppermost: it was then the only device affording fixed directional reference in the cockpit of an aircraft in flight; and its manufacture called for considerable skill. The instrument was introduced into the manufacturing program at A.W.A. in January 1942. The greatest care had to be exercised in keeping the premises where it was made free from dust. Traditional watch-making anti-dust practices were not good enough; even the type of clothing worn by the employees concerned was carefully regulated. The gyroscopic movement of the instrument had a speed of 11,500 revolutions per minute (an ordinary electric fan made 2,000 at the most), and being delicately poised could be irreparably damaged if small specks of dust were allowed to enter the pivots or ball races. Operatives were trained to establish by a sense of touch the permissible "play" of 0.0005 of an inch in dynamically balancing the unit. The permissible machining tolerance in making the parts of the gyroscope was one ten-thousandth of an inch. Difficulties caused by the unusual features of its castings held up production for several months, but by September 1942 the target of 30 instruments a week was reached. A.W.A's contract ended in May 1945, by which time more than 2,000 instruments had been made.

Coupled with the directional gyro was the gyro-horizon, a device which created for pilots an artificial horizon so that the orientation of an aircraft with respect to the earth's horizon could be indicated accurately without the earth's horizon being visible. Like the directional gyro it consisted of a spinning wheel (15,000 revolutions a minute) supported by gimbals, but it was also fitted with a pendulum and vanes which automatically corrected any drift error caused by friction in the bearings. More than 2,000 of these instruments were made.

A survey of the facilities for the overhaul and maintenance of instruments disclosed that Australian National Airways Ltd was the only company in the Commonwealth with the equipment and trained staff needed to maintain the Sperry gyroscope instruments. It was therefore invited to operate an instrument maintenance annexe established by the Government for this purpose.

The manufacture of constant-speed propellers for Beaufort, Wirraway and other aircraft was entrusted to De Havilland Aircraft Pty Ltd. To keep pace with the enlarged aircraft program of 1942 an additional propeller factory was built to make full-feathering types of propeller, and this too was operated by De Havilland's. Before the war ended many hundreds of propellers were made, and hundreds more were overhauled and repaired.

Forgings for propeller blades and hubs and for engine crank cases and other heavy types of forging in light alloy materials, were produced in an annexe erected near the works of the Australian Aluminium Company Pty Ltd. Here a 35,000-pound drop hammer, the largest of its kind in Australia, was constantly in operation. This hammer, which was built in the United States, had originally been intended for France and was lying on the docks in New York ready for shipment just as the fall of France was announced; it was promptly diverted to Australia.

Metal propellers were checked for possible failure by means of an electric strain gauge, which when used in conjunction with electronic and film recording devices, permitted the measurement of stresses occurring during flight or ground running. Equipment used for this work was imported from the United States and was widely used to ensure safety in Australian propeller installations.

In anticipation of a world shortage of aluminium De Havilland's undertook the design and manufacture of propeller blades from laminated, compressed, impregnated Australian timbers.[7] Development work carried out along these lines in conjunction with the Division of Forest Products

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[7] Normal seasoned wood had a sponge-like, porous structure into which the small molecules of phenol and formaldehyde readily penetrated. When wood impregnated in this manner was heated, the two chemicals reacted to form a resin (bakelite). If it was then subjected to great pressure, any air that remained was driven out, and the volume might shrink by as much as two thirds. Wood modified in this way, known as compreg, was both dense and strong.

proved that, had the need arisen, Australia could have become independent of imported aluminium for propeller blades. The wooden blades were first fully tested on the Wirraway.

Owing to the difficulty experienced in obtaining aircraft gun-turrets and armament from overseas, a gun-turret annexe under the control of the Beaufort Division was built at Fairfield, Victoria, for the manufacture of these parts. Here other items required for the Beaufort Division—gun mountings, gear for the release of bombs, equipment for remotely controlling the depth setting of torpedoes, etc—were designed, developed and manufactured.

Early in the development of Australia's wartime aircraft industry it was found that the spacious, well-equipped factories and the organising and engineering experience of the staff of General Motors-Holden's Ltd could be used for the production of important aircraft components. At its Woodville, South Australia, factory, the largest motor-body manufacturing plant in the British Commonwealth, techniques that had been used for producing pressed metal parts for motor vehicle bodies were applied to making the 13,600 separate pressed metal items needed for each Beaufort bomber. Altogether some 9,590,000 parts were made at Woodville and supplied as 1,694,000 sub-assemblies and 25,670 main assemblies for the Beaufort. Similar numbers of parts were supplied for the Beaufighter. Thousands of fuel and oil tanks for all kinds of aircraft were made by General Motors. At its Pagewood, New South Wales, works the company made Gipsy Major engines for Tiger Moths, and fuselages and wings for Mosquito aircraft.

Richards Industries Ltd at Mile End, South Australia, did similar work in the field of metal pressed parts. Supplementing its work for the Beaufort Division on Beaufort, Beaufighter and Lincoln aircraft, this company made wings for Wirraways as well as major and minor components for several other types of aircraft.

Without its automotive industry Australia would not have been able to build aircraft on the scale attained at the height of the war. The industry's experience in sub-contracting made it an ideal coordinating contractor, accustomed as it was to bringing parts and sub-assemblies from hundreds of different factories and assembling, testing and delivering to a pre-arranged time-table. The automotive industry was able to inject into aircraft production the experience and training of its executives, production supervisors and foremen. In highly technical matters, aircraft engineers were essential, but for running the factories executives drawn from the automotive industry were the key men. In the opinion of some authorities, one reason why the manufacture of aircraft was more successful than that of tanks in Australia was that the direction of the former industry made greater use of men experienced in production engineering.

While there was no lack of equipment for fabricating light alloys, the same cannot be said about the principal component of the alloys, namely ingot aluminium. Early in 1941 it was the cause of much anxiety: the 1940 quota from the United States had not arrived and prospects of supplies for the next two years grew more and more uncertain. Serious consideration was given to setting up a plant for extracting aluminium in Australia. Efforts to obtain the necessary technical information from America failed. Even if they had been successful it was unlikely that aluminium could have been produced in less than three years from the time construction of a plant was begun. The attempt was therefore postponed. It was not until the threat of Japanese domination of the Pacific had been removed that the authorities responsible for supply breathed more easily. Had supplies of aluminium failed, the aircraft industry could not have carried on. Fortunately for Australia the Canadian Aluminium Company not only managed to supply some 20,000 tons of the ingot metal over the war years, but also supplemented this with a good deal of fabricated metal.

In terms of the numbers of people employed, maintenance, repair and supply of spare parts for aircraft formed a major part of the aircraft industry; at one period of the war more people were employed on maintenance and repair work than on production. Maintenance and repair of aircraft were carried out in the workshops and depots of the R.A.A.F. and the civil airline organisations. For the first two years of the war the R.A.A.F. assumed responsibility for the upkeep of aircraft belonging to the Home Defence Forces; the civil airline operators, working under the control of the Aircraft Production Commission, were responsible for aircraft used in the Empire Air Training Scheme. When Japan entered the war and large numbers of American operational aircraft began to arrive in Australia the existing facilities became quite inadequate and the Government immediately took steps to improve them.

Instead of increasing the repair and overhaul facilities of the R.A.A.F. establishments, the Government decided to improve the facilities of commercial airfields near the mainland capital cities, in the hope that once these additions had served their wartime purpose they would be used for greatly expanded commercial air services after the war. This policy was modified for a brief period, during the critical months of threatened invasion, when plans were made to set up repair and maintenance depots in inland centres, but once the danger of invasion had passed the modified plans were dropped and the original program resumed.[8] In the next two years, and at a cost of approximately £3,000,000, the Government built overhaul workshops, machine shops and hangars covering an area almost ten times that devoted to this kind of work before the war; the number of persons engaged on maintenance and repair work reached a maximum

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[8] The principal civilian aircraft and engine overhaul contractors were: Australian National Airways Ltd (all mainland States); Qantas Empire Airways Ltd (Qld, NSW and WA); General Motors-Holden's Ltd (Qld and WA); Ford Manufacturing Co of Aust Ltd (Qld); Aircrafts Pty Ltd (Qld); Ansett Airways Ltd (NSW and Victoria); Butler Air Transport Pty Ltd (NSW); De Havilland Aircraft Pty Ltd (NSW); Clyde Engineering Co. Ltd (NSW); Newcastle Aero Club (NSW); Commonwealth Aircraft Corporation Pty Ltd (NSW and Vic); Victorian and Interstate Airways Ltd (Vic); Guinea Airways Ltd (SA); MacRobertson Miller Airlines Ltd (WA).

of 12,000 by May 1944. The scope of their activities then covered a growing proportion of R.A.A.F. operational aircraft as well as the United States Army Air Force and to a lesser extent the Netherlands East Indies Forces, the Royal Navy, the Royal Air Force and the Royal New Zealand Air Force. From early 1942 to the end of 1944 Australia was the chief maintenance and supply centre for the United States Army Air Force in the South-West Pacific Area.

Repair and overhaul contractors were also called upon to assemble and carry out modifications to new aircraft, strengthening important components, fitting long-range fuel tanks, installing gun turrets and fitting additional armament. When the war ended the civilian organisations had repaired and overhauled 11,770 engines and 4,155 airframes. Of these, 5,000 engines and 1,500 airframes were overhauled for the United States Army Air Force in the largest individual servicing undertaking set up: an establishment formed by converting the Rocklea Small Arms Ammunition Factory for use by General Motors-Holden's Ltd and the Ford Manufacturing Company of Australia Ltd.

The Maintenance Division of the Department of Aircraft Production played a most useful part in fostering the manufacture of aircraft spare parts in privately-owned workshops. Notable developments were the manufacture of sodium-filled engine valves, copper-lead and silver-lead bearings, light-alloy pistons and aircraft piston rings. Up to August 1945 the total value of spare parts supplied through this division to the R.A.A.F. and U.S.A.A.F. exceeded £30,000,000, the cost of equipment supplied to the latter being charged to Reverse Lend-Lease.

Although the first aircraft manufactured in Australia were entirely of British and American design, the industry was soon beset with many technical problems. The need for research and testing laboratories without which the building of aero-engines and the design and development of new types of aircraft would have been impossible, had been clearly foreseen by the Secondary Industries Testing and Research Committee in 1937.[9] The committee did no more than make tentative recommendations[1] since it was aware of an impending visit by Mr Wimperis,[2] Director of Scientific Research in the British Air Ministry and an outstanding scientist and administrator, whose services had been made available to the Commonwealth Government.

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[9] In this account of the activities of the CSIR Division of Aeronautics, use has been made of two articles by Mr L. P. Coombes, Chief of the Division: "Aeronautical Research in Australia", *Aircraft,* Vol. 24 (Jan 1946), p. 15, and "Ten Years of Aeronautical Research", *Aircraft Engineering,* Vol. 21 (1949), p. 140.

The earliest aeronautical research carried out in Aust was the work of one man, Lawrence Hargrave, records of whose work are to be found in the *Journal of the Royal Society of NSW.* Owing to the disorganised state of the scientific publications on the subject at that time, and owing to the fact that he worked in great isolation from others with the same interest, much of Hargraves' researches consisted of rediscovery. There is no doubt that he was the originator of the box kite and that his writings were studied by the Wright Brothers during the early stages of their work. Santos-Dumont and Voisin were among the pioneers influenced by Hargraves' researches and publications, the last of which ("Rigid Stable Aeroplanes") was read before the Royal Society of NSW in 1909.

[1] *Report of the Secondary Industries Testing and Research Committee,* Appendix IV (1937).

[2] H. E. Wimperis, CB, CBE; MA. Inventor of aircraft instruments; Director of Scientific Research, Air Ministry, 1925-37. B. 27 Aug 1876.

In a report to the Commonwealth Government in December 1937 explaining why an aeronautical research laboratory was necessary and what might be expected of it, Wimperis wrote:

> It is natural that it should be asked whether Australia by reliance on research work done elsewhere, could not obtain all the information it will need. The answer is that it could not. . . . Australia will wish to know the degree to which home-produced products can safely be used in substitution for materials which have to be imported, how far it is safe to adopt novel methods of manufacture which may suit local conditions, and, most important, to learn promptly the cause of any failure during manufacture or use, of any aircraft component, or of the aircraft as a whole.
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> Moreover, if for local reasons any modifications are desired in a given design of aircraft, a study must be made in advance of the effects of such modifications. Sometimes the results can be predicted by calculation and sometimes they can not; in the former case an experimental confirmation is usually found desirable, whilst in the latter, experiment is the only means available of arriving at the answer. Such experimental investigations cannot well be carried out many thousand miles away—despite the readiness, which it is safe to assume, at Teddington or Farnborough to undertake them. They must be made in Australia and be available at once.

Wimperis made three specific recommendations:

(*a*) that an aeronautical research laboratory (costing about £140,000), whose main features he outlined, should be established;
(*b*) that a chair of aeronautics should be created in one of the Australian universities; and
(*c*) that an aeronautical research committee should be formed.

In accepting these recommendations the Government decided that (1) the aeronautical research laboratory should become the responsibility of the C.S.I.R.; (2) the University of Sydney should be asked whether, if financial assistance were provided, it would establish a chair in aeronautical engineering; and (3) the setting up of a research committee should be deferred until the first two recommendations had been fully implemented.

Accordingly construction of the Aeronautical and Engine Testing Research Laboratory at Fishermen's Bend, in close proximity to the Commonwealth Aircraft Corporation's plant and to the site of the proposed government aircraft factory, was begun in August 1939 and though the laboratory as a whole was not completed until about the end of 1941 part of the building was ready for occupancy by April 1940. On its completion the Research Laboratory became the headquarters of the Division of Aeronautics, of which Mr Coombes was appointed Chief.

The division was charged with two main responsibilities: firstly, to assist the R.A.A.F. and industry in problems dealing with the manufacture and operation of aircraft—this was its main function during the war; and secondly to undertake the long-range research on fundamental problems of aeronautics on which future progress of the aircraft industry would depend. In the two years following its establishment, the Division of Aeronautics acquired scientific, technical and administrative staff, purchased or constructed its first items of equipment and trained the staff in their use, and began its scientific and development work. It was organised into four main sections: aerodynamics, structure and materials, engines and fuels, and instruments.

Almost all experimental work in aerodynamics was carried out in wind tunnels. The usefulness of a wind tunnel depended on the principle that the force on a body moving through air was the same as that on a body held at rest in a uniform stream of air of the same speed. A small model of the aircraft being studied was placed in the tunnel and the forces in the model were measured as air, at a known speed, swept past it. In this way it was possible to obtain the general aerodynamic characteristics of the model and to study the performance, controllability and safety of an aircraft. A wind tunnel was therefore one of the first items of equipment to be installed in the new laboratory. It was designed by Dr G. N. Patterson, who came out from the Royal Aircraft Establishment, Farnborough, for this purpose.

Wind tunnels were of two main types: the straight through and the closed return tunnel. An important consideration influencing Patterson's choice of the latter was the great saving in power effected by arranging continuous circulation of air throughout the system. A small scale (one-eighth) model was first constructed and tested at the Engineering School of the University of Melbourne, where it performed satisfactorily. The large-scale tunnel had a working section 9 feet by 7 feet and a maximum air speed of 300 feet per second. The successful manufacture by Kelly and Lewis Pty Ltd of Springvale, Victoria, of the welded steel shell 105 feet long with a maximum cross section 14 feet by 18 feet, and of the wind tunnel balance, was a creditable industrial achievement.

Test runs made towards the end of 1941 bore witness to the excellence of its design. Success in the design and construction of wind tunnels was by no means a foregone conclusion; about this time three large and expensive tunnels built overseas gave a great deal of trouble owing to an unsatisfactory distribution of air flow.

Completion of the tunnel in December 1941 was most opportune, because it made possible the immediate investigation of such aerodynamic problems as were likely to result from modifying the designs of high-speed military aircraft then being manufactured or about to be manufactured in Australia. The C.A.C. made extensive use of it in developing four new designs of aircraft.

At times the wind tunnel was operated 16 hours a day, and it would have been run 24 hours a day if more staff had been available. Numerous investigations, many of them prompted by the thought that Australia might be cut off altogether from outside supplies, were undertaken. Some of the many modifications made to the Beaufort bomber, such as the installation of more powerful gun turrets, were important enough to require checking in the wind tunnel.

Tests were made not only to assist in the design of new aircraft but to solve the problem of how to reduce the loss of speed occasioned by such attachments as jettison fuel tanks and radar aerials. Tests were also made on the stability of rockets, bombs and torpedoes. Supply-dropping parachutes, towed targets, and many other devices, were the subject of wind-tunnel experiments.

Studies made in the course of designing the wind tunnel itself opened up new avenues of investigation in the design of ducts and fans. Thus considerable help was given by the wind-tunnel experts in solving problems related to cooling the completely-enclosed engines of the Australian cruiser tank, and to the flow of air in food dehydration plants. They were also able to help in improving the ventilation in mines and factories.

Towards the end of the war, as the pressure of *ad hoc* investigations eased, the wind tunnel began to be used for fundamental research in the fields of boundary layer, flow compressibility and turbulence, with a view to its application to the higher flight speeds promised by jet aircraft, then in the early stages of their development.

Under the guidance of Dr Woods,[3] the Engines and Fuels Section of the laboratory became the centre for testing internal combustion engines of all types. Performance tests on the engine of a bomber, for example, made it possible to alter the technique of operating the engine in such a way as to increase the range of the aircraft. The formulation of specific instructions for operating engines so as to obtain maximum range for the aircraft was a problem that received much attention from the section.

Early in 1942 the R.A.A.F. became very worried about the excessive wear occurring in aero-engine cylinders, not only in operational areas but also on training airfields. Losses from this source grew to such proportions that it was almost impossible to keep up with replacements. The trouble was discovered to arise mainly from the entrance of dust into the engines. In many areas, especially those inland where there was little or no grass on the airfields and conditions were excessively dry, training aircraft when taking off would raise such clouds of dust, often rising to 2,000 to 3,000 feet, that during their circuits they would scarcely ever leave the dust-laden zones.

The Aeronautical Laboratory approached this problem from several angles. First it looked into the question of speeding the manufacture of cylinders. Ordinarily, fins of air-cooled cylinders were machined out of a solid forging of high-quality steel, and in the course of boring and turning operations about 90 per cent of the metal was cut away. This was not only waste of a valuable material always in short supply, but a time-consuming and expensive process. A method was worked out whereby fins were furnace-brazed with copper on to the steel barrel. By placing the fins much closer together than could be done by machining them, and by making them of a material of high thermal conductivity, a greater output could be obtained from the cylinder. Unfortunately, by the time the new

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[3] M. W. Woods, BE, BSc, DPh. Research Fellow in Engineering, Univ of Melb, to 1940; Officer-in-Charge Engines and Fuels Section, Aeronautical Research Labs, 1940-50. Of Melbourne; b. Hobart, 19 Nov 1911.

technique had been proved, the production of cylinders by the ordinary method had grown to such a scale that it was deemed wiser not to interfere with the manufacturing process. Nevertheless, because of its unusually high capacity for heat dissipation, the composite cylinder had distinct possibilities for high-speed engines and it was with some satisfaction that the division learned later that cylinders of a similar kind had been evolved in the United States.

Another method of coping with the problem of excessive wear was to build up the worn parts of cylinders by electroplating them with chromium. Experience in the United States suggested that if this procedure were adopted it would be necessary to form a porous deposit of chromium to ensure adequate lubrication. Australian tests with hard chromium plating appeared to give equally good results. The Aeronautical Research Laboratory, in collaboration with the Munition Supply Laboratories, improved the technique of chromium plating to the point where the life of a reclaimed cylinder was equal to that of the original cylinder.

Neither of these attacks on the problem could hope to provide more than temporary relief; neither went to the root of the matter, which was to devise some means of preventing dust from entering the engines.

Before this could be done it was necessary to learn something about the dust itself. An officer of the division was sent to a large number of Australian airfields to collect samples, which were brought back and analysed for the distribution of particle size. As a result of these measurements large quantities of an experimental standard dust were made representing the average kind of dust from Australian airfields. This dust was fed to working engines protected with different kinds of filter, and the efficiency of the filters was carefully studied. The work was exceedingly slow and laborious but yielded results of great practical interest and usefulness.

In view of the fact that Australia produced no aluminium—in 1939 there were no facilities even for fabricating ingot aluminium—the Division of Aeronautics, in cooperation with the Division of Forest Products, worked hard (*a*) to discover species of Australian timber suitable for aircraft construction, both in the form of solid timber for spars and booms and as veneers for plywood; and (*b*) to produce design data for aircraft structures of Australian timber and to develop new techniques for fabricating timber. The Wood Technology Division of the New South Wales Forestry Commission also took part in this work, concentrating mainly on a study of the physical properties of coachwood for the Mosquito aircraft.

Most of the available information concerning aircraft designs in timber related to imported materials, so that it was necessary, having discovered the physical properties of Australian timbers, to modify the designs to suit the new materials. In Victoria attention was paid chiefly to the possibility of making in hoop pine and mountain ash the equivalents of major metal components for the aircraft then in production. One of the more conspicuous successes in this work was the redesign in mountain ash of the tail plane of the Beaufort, which proved to be both stronger and lighter than the original tail plane. Another was the production of light-weight panels consisting of a grid of light members as a sandwich between two plywood faces. These, when used in the floors of transport aircraft, led to a useful saving of weight.

Another ingenious use of wood was for special light fuel tanks which could be jettisoned when empty and which helped to increase the range of Kittyhawks, Lightnings and Boomerangs: thin wood veneers bonded with synthetic resin were moulded in an autoclave under heat and pressure. Once the many difficulties encountered in the gluing process had been overcome, their manufacture on a large scale represented a considerable saving of light metal alloys.

The failure of a twin-engined wooden training plane in the air during 1941 led to a thorough examination of the causes of failure in glued joints. In the course of investigations of the strength of aircraft timbers the important discovery was made by the C.S.I.R. Division of Forest Products that at a given moisture content strength decreased very considerably with increase of temperature. This characteristic of timber had not before been recognised.

Apart from these last few examples, only limited use was made of the large amount of investigational work done on the use of wood in aircraft. Its value as an insurance against the loss of supplies of light metal was unquestioned. At one critical period of the war the stocks of aluminium ingot in Australia sank to the alarmingly low figure of 10 days' normal consumption.

For some time after the production of military aircraft had begun in Australia, there was no proper organisation for the conduct of acceptance tests on new types of aircraft. Consultations between the C.S.I.R., the Aircraft Production Commission and the R.A.A.F. led to the Air Board's setting up a flight known as the Special Duties and Performance Flight. Schedules of flight tests drawn up by the Division of Aeronautics were used for trials on the Wackett bomber type CA-4, the Wackett trainer, the Boomerang, the Australian Beaufort, the De Havilland Dragon and the De Havilland troop-carrying glider.

Failure of aircraft in service arose from many causes, prominent among which were fatigue (caused by repeated stressing) and corrosion. Failure due to fatigue of the structure or of smaller components such as airscrew blades or engine parts sometimes caused serious accidents. Instances of this kind of failure were investigated by the laboratory, as also were failures due to corrosion. One of the more difficult problems that came to the laboratory concerned the corrosion of the cooling systems by glycol-water mixtures. At one period, corroded cooling systems led to the grounding of many aircraft. Even in the leading oversea laboratories knowledge of the causes of corrosion from this source was at the lowest empirical level; indeed, Australian investigations revealed that two substances marketed as inhibitors of corrosion were in fact liable to increase it. Some of the corrosive action of these cooling mixtures was traced back to the presence in them of small amounts of dissolved copper.

Testing the strength of aircraft wings and other components, an indispensable activity in any aeronautical research laboratory, called for much mechanical ingenuity and improvisation. This section, which was under the leadership of Mr Wills,[4] devised a method for applying, rapidly and automatically, repeated loads to a large structure, such as the wing. Wings of Australian-built Mosquitos were tested to destruction. This was the first time in any country that such tests had been applied to so large a component. An account of this work was read by Wills at the Anglo-American Aeronautical Conference held in New York in May 1947. Commenting on this and other work done in Australia, the editorial of the British journal *The Aeroplane* stated:

> His (Wills') country has a population which could be housed in London or New York, yet its aeronautical research establishment had made further progress in fatigue testing of complete aircraft wings than either Britain or the United States, an eloquent reminder that achievement comes from selecting the right goal and being single-minded in pursuit of it.

It was very important for a designer to know the distribution of stress in an aircraft, but it was difficult to measure it with mechanical strain gauges. The electric wire resistance gauges which were becoming available from overseas at about this time opened up great possibilities in the study of distribution of stress in complex structures, but needed considerable modification for particular purposes. A great deal of work was done in the Division of Aeronautics to perfect the local manufacture and application of electric strain gauges. Stresses in gun mountings during firing, and in engine mounts, wings and the forces in aircraft controls during flight manoeuvres, were all studied with this type of gauge.

Examination of captured enemy equipment was another of the laboratory's activities. A careful study of the alloys being used by the enemy, for example, indicated that he was seriously short of some alloying elements. It also disclosed that some interesting metallurgical progress had been made. An aluminium alloy containing an unusually large proportion of zinc, taken from Japanese air frames, was found to have a strength-to-weight ratio superior to that of any alloy used by the Allies. Numerous components of enemy aircraft were examined. Special attention was given to the performance of aircraft engines. This work was a great help to Allied intelligence services since it avoided the delay of shipping the equipment to Britain or the United States for examination. The American Air Force in particular made extensive use of the wide range of facilities provided by the Division of Aeronautics.

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[4] H. A. Wills. Research Officer, then Deputy Chief Superintendent, Division of Aeronautics and Aeronautical Research Labs. Of Melbourne; b. Boulder City, WA, 16 May 1906.

The great speeds at which the crankshafts and propellers of aircraft rotated, and the high loads and temperatures which occurred in the main bearings and piston rings, necessitated the development of special alloys for bearings and the expenditure of much effort on research into the origin of friction between sliding surfaces. The development and selection of a bearing metal with the correct mechanical, physical and frictional properties was a highly technical matter and one upon which much care had to be lavished, since small variations in the composition and structure of the bearing alloy could have a profound effect upon its performance. The correct procedure in making a bearing was also of first importance.

Initially all major aircraft bearings were imported, but as time went on supplies from overseas became so uncertain that the aircraft industry was obliged to undertake their local manufacture. Fortunately for industry, the C.S.I.R. had established a section for the purpose of studying problems associated with friction, wear, lubricants and bearings.[5] It so happened that just before the outbreak of war, Dr Bowden, an Australian physicist working at Cambridge, widely known for his work on friction and lubrication, was on a short visit to Australia, and the opportunity was taken of enlisting his services in the establishment of the new section. Bowden quickly got together a team of physicists, chemists and engineers, and using the experience he had gained in England directed the construction of equipment for use in studying problems that were likely to arise. In this he was greatly helped by the University of Melbourne, which not only provided accommodation in its Chemistry School but also, through the Engineering School, provided workshop facilities.

The two bearings of greatest interest to the Australian aircraft industry during the war were the silver-lead-indium bearing used in the Wasp engine, and the copper-lead bearing used in the Rolls Royce Merlin engine.

For some months the first stage in the manufacture of the silver-lead-indium bearing seemed to be beyond the capacity of the local manufacturers. The section immediately came to their aid by working out a technique of centrifugal casting, full details of which were communicated to the manufacturers, A. Wassilief Pty Ltd. It went further and constructed the complete bearing, electroplating on the layer of silver a film of lead and finally a film of indium. This, the first aircraft bearing to be made in Australia, went into service in a Wirraway shortly after it had passed its engine tests.

The work on bearings soon assumed such importance that a Bearing Control Committee was formed, comprising representatives of the R.A.A.F., the Department of Aircraft Production and the C.S.I.R., under the chairmanship of Group Captain Armstrong.[6] Its function was to coordinate all work on bearings and to provide liaison between the research laboratory and industry. As an additional link in this chain, the Department of Aircraft Production set up a Pilot Bearing Annexe to work in

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[5] The decision to establish the section was taken in Nov 1939; work began in Jan 1940.

[6] Air Cmdre W. S. Armstrong, CBE, BSc. Director of Production, RAAF, 1937-43; Director of Tech Services 1943-47. Of Camberwell, Vic; b. Melbourne, 4 Jan 1904.

close association with the C.S.I.R. The general procedure was to make a prototype bearing in the C.S.I.R. laboratories, to try out the method of making it on a larger scale in the Pilot Bearing Annexe, and when it was known to be successful to hand over the technique to the local bearing manufacturers.

In this way all the main bearings required in the wartime aircraft industry were pioneered. Bowden and his colleagues found time, especially towards the end of the war, to investigate the theory of the action of bearing metals, and through a study of different bearings, especially the copper-lead bearing of the Rolls Royce Merlin engine, they were able to make important scientific contributions to the subject.[7]

In pioneering a field of research new to Australia, the Lubricants and Bearings Section provided an excellent example of the mutual fructification of theory and practice. A practical instance of their work was the ingenious method developed for studying the lubrication between the piston ring and cylinder wall of a running engine and of the lubrication in a journal bearing. It depended essentially on measuring the electrical resistance of the film of lubricating oil while the engine was in motion; for full fluid lubrication the resistance was high, but if the film was reduced in thickness to molecular dimensions (thus giving rise to boundary lubrication) or broke down altogether,[8] a pronounced drop in electrical resistance took place. One of the most striking results that emerged from this investigation was the discovery that direct metallic contact between cylinder wall and piston ring could not be completely eliminated. Even with the best lubricants intermittent rupture of the lubricant film occurred, with consequent metallic seizure and wear. Many other results of theoretical interest as well as of practical importance were obtained by using this technique, but too late to have any bearing on wartime manufacture of aero-engines.

The second of Wimperis's recommendations was put into effect just before the war, with the setting up of a Department of Aeronautical Engineering at the University of Sydney under Professor Stephens,[9] who was appointed to the chair in 1939.[1] A four-year course in aeronautical engineering was established and the first students were enrolled in 1940. The object of the course was to provide a general education in the fundamental principles of engineering with as much specialisation in aeronautical subjects as the university was able to provide. As the department was part of a Commonwealth scheme, arrangements were made to allow students who had completed the first two years of a recognised engineering

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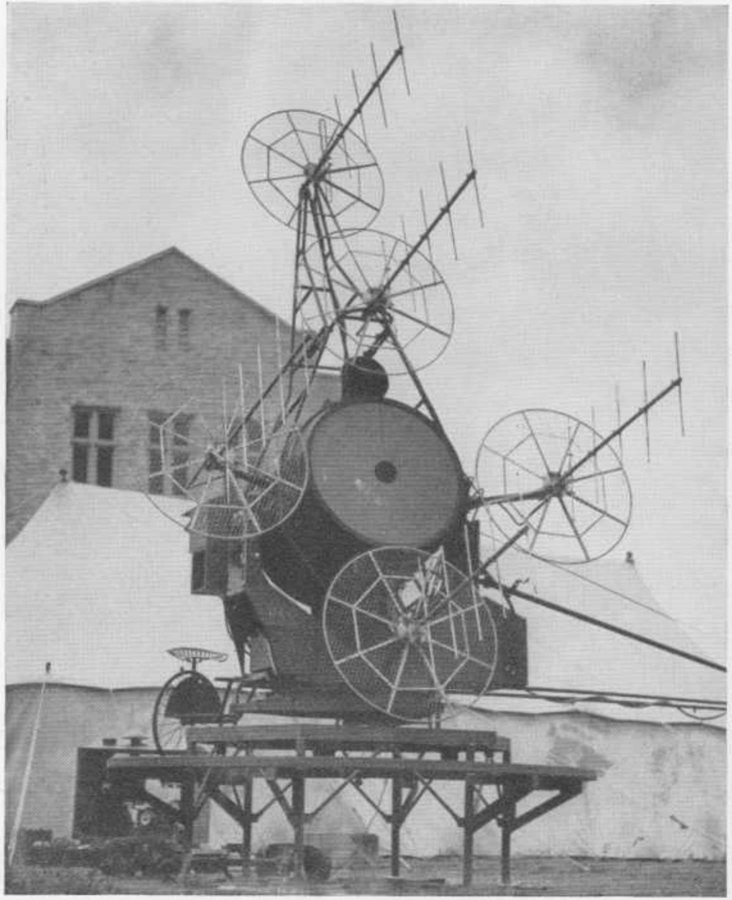
[7] F. P. Bowden, "The Physics of Rubbing Surfaces", *Journal and Proceedings of the Royal Society of NSW*, Vol. 78 (1944), p. 189.

[8] The technique could not enable a distinction to be drawn between these two conditions; that is, the resistance was low in both circumstances.

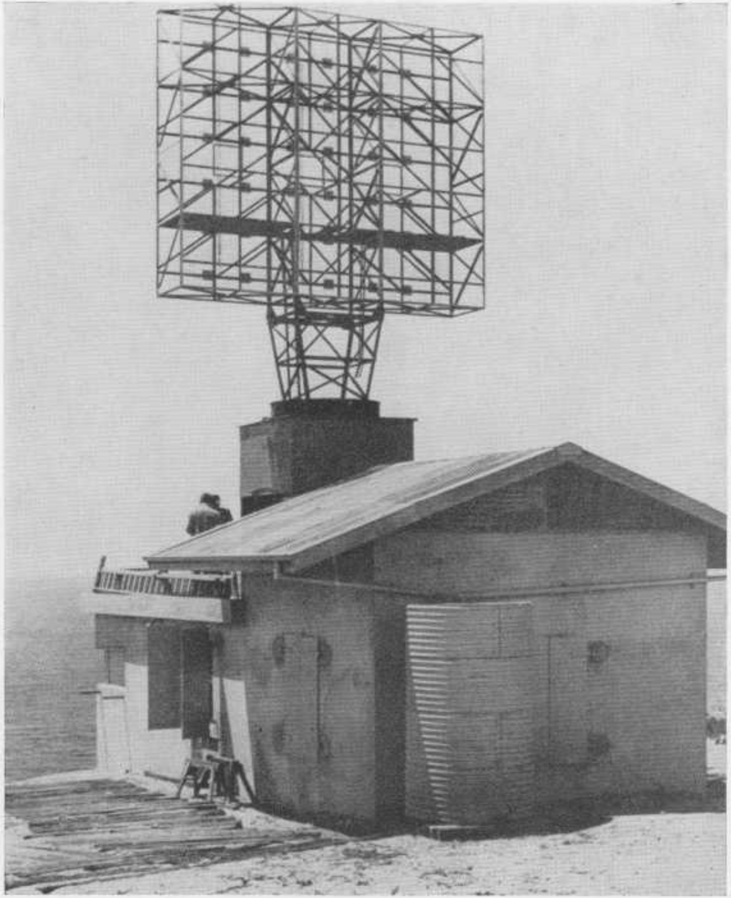
[9] A. V. Stephens, MA. Scientific officer, Royal Aircraft Establishment, Farnborough, Eng, 1930-34; Fellow St John's College, Cambridge, 1934-39; Prof of Aeronautics, Univ of Sydney, since 1939. B. Epsom, Surrey, Eng, 9 Jul 1908.

[1] Some instruction in aeronautical subjects had been given in the Univs of Melbourne and Sydney before this, but this was the first chair of aeronautics to be established in an Aust university.



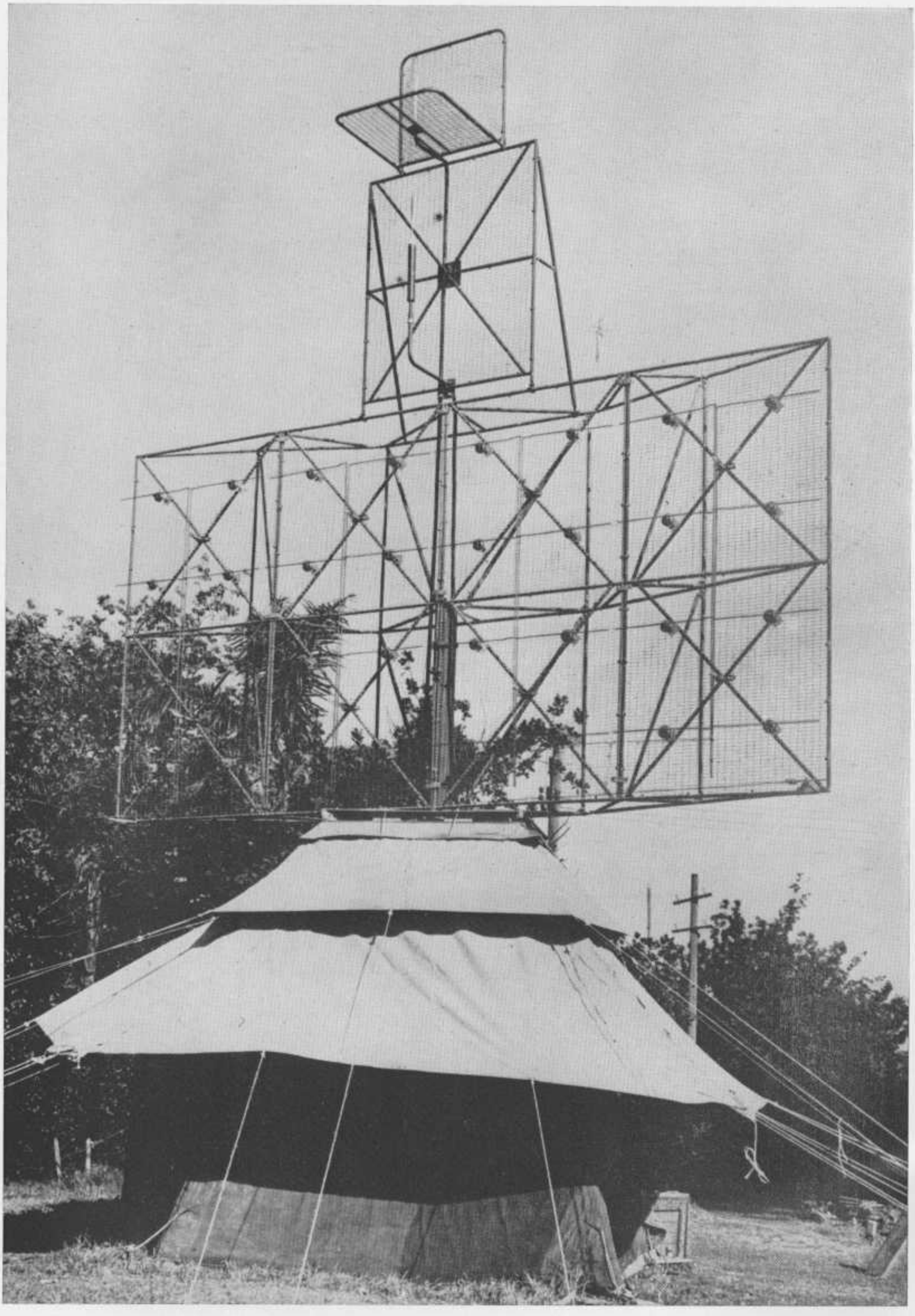
(*Radiophysics Laboratory*)

Searchlight control equipment.



(*Radiophysics Laboratory*)

Shore-defence radar equipment at Dover Heights, near Sydney.



(Radiophysics Laboratory)

Light-weight air-warning equipment.

course in any other Australian university to enter the third year at Sydney and to proceed to the degree of Bachelor of Engineering in aeronautics. In the first years of its existence the department's research concentrated mainly on aerodynamics and its application to problems of design, together with the more general aspects of aeronautical engineering. A modern type of wind tunnel 7 feet by 5 feet was installed and was used in the development of a troop-carrying glider for the De Havilland Aircraft Company.

The third of Wimperis's recommendations, namely the formation of a body to advise on aeronautical research in Australia, was not put into effect until some progress had been made with the first two. Towards the end of 1941 a stage had been reached that warranted taking the third step, and the Prime Minister accordingly established the Australian Council for Aeronautics.[2]

The Australian council advised the Government on scientific and technical matters relating to the development of the aircraft industry; it advised the C.S.I.R. on the investigations it considered should be initiated, and the universities and technical colleges on matters relating to education in aeronautics. It also rendered a valuable service in collecting and disseminating information from overseas and publishing reports on work done at the University of Sydney and at Fishermen's Bend.[3]

When a pilot made a sharp turn at a high speed, momentary "blackout" might occur. The pilot would experience unusual visual disturbances such as a blue haze followed rapidly by a sensation of intense blackness which ended in a momentary loss of consciousness. These visual effects were correlated with the marked centrifugal force developed during high-speed turns. As the maximum speed of aircraft continued to increase, instances of blackout became more numerous and they were recognised as a major hazard in high speed flying. Individuals varied in the acceleration they could withstand before blacking out. Briefly, it was generally believed to be due to the fact that centrifugal force drove the blood from the higher to the lower regions of the body, especially to the abdominal area, with the result that insufficient blood reached the brain. Nerve cells thus deprived of oxygen no longer responded to the stimulus of light.

One of the first Australian scientists to become interested in this phenomenon was Professor Cotton.[4] His attention was drawn to it almost accidentally by a reference in an evening newspaper. Some years earlier he had made an extensive study of the location of the centre of gravity in the human body and had for long been deeply interested in the circulation of the blood. Quite early he formed the opinion that any device likely

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[2] The members of the council were: Sir George Julius (Chairman), Gp Capt W. S. Armstrong, W. E. Bassett, A. G. Berg, I. H. Boas, L. P. Coombes, N. A. Esserman, A. Murray Jones, J. T. McCormick, F. J. Shea, Prof A. V. Stephens, J. Storey, Air Cmdre E. C. Wackett, L. J. Wackett, H. A. Wills, and B. McA. Foster (Secretary).

[3] The Australian Aeronautical Council series, beginning with *The Inauguration of the A.C.A.* (1944).

[4] F. S. Cotton, DSc. Lecturer in Physiology, Univ of Sydney, 1913; Senior Research Fellow of National Health and Medical Research Council 1939-45; Research Prof of Physiology, Univ of Sydney, 1941-55. B. Sydney, 30 Apr 1890. Died 23 Aug 1955.

to counteract blackout would have to depend for its success on maintaining blood circulation throughout the body. More specifically, a successful device would have to ensure maintenance of the blood return from the lower portions of the body to the heart. Cotton believed that once it was returned to the heart, that organ would have sufficient margin of power to pump the blood to the brain against the centrifugal force.

Cotton's solution to the problem of maintaining the circulation of the blood was the "aerodynamic anti-G suit".[5] This consisted of a series of overlapping rubber sacs incorporated in two separate leggings and a pair of shorts.[6] The leggings extended from the soles (or from the ankles in some modifications) nearly up to the top of the thigh. The thigh portions of the shorts were arranged to overlap the leggings. Each legging contained four rubber sacs; the shorts contained two, the lower one covering the lower part of the abdomen and the upper one extending to the lower borders of the ribs. Each rubber sac was so arranged that when inflated an inextensible fabric in its outer wall prevented it from expanding outwards, while the rubber coating on its inner wall allowed it to expand and press smoothly against the skin. The rubber sacs did not inflate until the body was subjected to moderate accelerations, and then the pressure was so regulated that it increased in proportion to the acceleration. This automatic regulation of pressure was attained by means of a valve. In the design and fabrication of the rubber portions of the suit Cotton received much help from Dunlop Rubber Australia Ltd.

To determine the efficacy of the suit in the laboratory, it was necessary to devise some way of exposing a test subject to high accelerations, that is to high values of G.[7] This was most readily, if not most comfortably, done by whirling the subject in a centrifuge—an ordeal from which even experienced pilots were known to shrink.[8] Funds for building the machine were provided by the R.A.A.F. Flying Personnel Research Committee and the National Health and Medical Research Council of Australia.

From the middle of 1941 onwards a considerable body of data gained by experiments on pilots and trainees made it possible to assess fairly accurately the amount of protection afforded by the suit against increasing accelerations.[9] It was found that the suit increased a pilot's tolerance to high accelerations by about 30 per cent; in other words, if without a suit the maximum acceleration that could be tolerated by a pilot without loss of vision was 6 G., with the suit he could tolerate 8 G. The average pilot "blacked out" for several seconds when exposed to about 5 G. or 6 G. In a test carried out just before he left on a mission to Canada and the

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[5] F. S. Cotton, "An Aerodynamic Suit for the Protection of Pilots against Blackout", *Aust Journal of Science,* Vol. 7 (1945), p. 161.

[6] Originally it was intended to make the suit in one piece, but the problem of making it to fit pilots of different sizes and builds was considered too difficult of solution at that stage.

[7] 1G is the acceleration due to the earth's gravitational field. Other accelerations are measured in terms of it.

[8] Sqn Ldr K. V. Robertson, chief test pilot for this work, played the part of guinea pig most successfully and patiently, both in the air and in the centrifuge.

[9] Mr C. W. W. Prescott was chiefly responsible for the design of the centrifuge, which was constructed by White Elevators of Sydney under the general supervision of the University Engineer, Mr T. Wilkins.

United States, Cotton was, while clad in the anti-G suit, exposed to about 9 G. (7 G. at the head and 11 G. at the feet) for 35 seconds, without blacking out. He was able to report this successful test in Canada and America and to convince the authorities there of the value of his aerodynamic suit.

By the time Cotton reached Canada, Wing Commander R. Franks of the Banting Institute of Toronto had reached an advanced stage with his independently conceived solution to the blackout problem. Franks' hydrostatic suit, so called because pressure on the pilot's limbs was exerted by water-filled sacs, was the first suit devised that afforded protection against blackout. Cotton freely communicated his ideas and experimental results to Americans working on the subject, and from then on the suit was developed rapidly, though not without a great deal of additional experimental work. The Americans quickly realised its potentialities and explored them with great thoroughness.

While the suit was being developed in the United States, further work was being done on it in Australia. Improvements were made in the local suit, especially to the valve regulating the air pressure. The valve as designed by Cotton worked easily and accurately enough, but required more compressed air than could be conveniently carried in an aircraft. A more economical, and very ingenious valve was subsequently invented by Dr Myers of the National Standards Laboratory. To comply with air force requirements the suit had to be easily donned and doffed, reasonably comfortable to wear, light and lasting, and as nearly fireproof as possible.[1] Once it met these requirements the suit was officially adopted and a wing of the R.A.A.F., under the command of Group Captain Caldwell,[2] was trained in its use. The wing was based on Darwin, but to the disappointment of the pilots they were unable to meet the enemy in combat, for at this very juncture the Japanese attacks on Australia ceased.

In the meantime large centrifuges were built in the United States, and from the information obtained with their aid the United States Navy and Army had devised, by 1944, an anti-blackout suit, provided with a series of bladders inflated to appropriate pressures by a valve operated automatically (as in the Australian types) by gravity and the centrifugal force at the moment.

Suits of this type were worn in ten major engagements from Palau to the Philippines, when 243 aircraft were destroyed and 75,000 tons of Japanese shipping were sunk.

At the time of the Japanese attack on Pearl Harbour the first Beaufort bombers were coming off the production line; the Wirraway and Tiger

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[1] F-Lt G. C. Ellis did much to solve the problems of installation in the aircraft. Messrs A. Martin and E. Smith, technicians in the Dept of Physiology, also made useful contributions to the work of developing the suit.

[2] Gp Capt C. R. Caldwell, DSO, DFC. Successively bank officer, jackeroo, and motor trader 1928-40; served RAF and RAAF 1940-46; notable fighter pilot whose record earned him title of "Killer"; Managing Director, Falkiner, Caldwell Pty Ltd Sydney, since 1946. B. Sydney, 28 Jul 1910.

Moth and Wackett trainers were being made in substantial numbers but no attempt had been made to manufacture fighter aircraft of any kind. With the new turn of the war the question of future aircraft production was thoroughly discussed at a meeting between representatives of the Department of Air, the Department of Aircraft Production and the Commonwealth Aircraft Corporation. The Deputy Chief of the Air Staff made it clear that fighter aircraft capable of intercepting bombers launched from any Japanese aircraft carriers that might attack Australian capital cities and other industrial centres, were urgently needed. He strongly advocated that every effort should be made to procure P-40 (Kittyhawk) fighters from the United States and that at the same time an attempt should be made to manufacture a fighter locally as an insurance against the non-arrival of the Kittyhawks.

The C.A.C. had already considered an aircraft of this type, and had in fact designed one which it believed would have the high rate of climb and easy manoeuvrability needed for an effective interceptor fighter. The aircraft under consideration, a low-wing monoplane which subsequently became known as the Boomerang, was essentially an adaptation of the Wirraway.[3] Indeed Wirraway parts constituted about 65 per cent of the aircraft. With wind tunnel tests as a guide the Chief of the C.S.I.R. Division of Aeronautics formed the opinion that the adaptation proposed by the C.A.C. was an excellent method of building, in a reasonable time, a substantial number of high-performance aircraft. After some further improvements had been made to the design there seemed every prospect of attaining a maximum speed of 300 miles an hour at 15,000 feet, with a rate of climb of 2,560 feet per minute.

Acting on the joint recommendation of the Minister for Air and the Minister for Aircraft Production, the War Cabinet decided on 2nd February 1942 to place an order for 105 Boomerangs, although not even a prototype had been built. Since it had been decided to cease making Wirraways for the time being, there would be ample facilities for the new project. In fact the C.A.C. was faced with the alternatives of making the new fighter or of continuing with making the Wirraway beyond the real needs for this aircraft, or of dismissing 2,000 experienced aircraft workmen with little prospect of securing their services again when they were wanted.

Since the forecast performance of the Boomerang was only about that of the Buffalo (an American aircraft equipped with the same class of engine), which had not achieved much success against Japanese Zeros in Malaya, there was naturally some hesitation on the part of the Government about going on with the Boomerangs while there was still the possibility of importing more modern fighters. These prospects became so un-

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[3] Some of the important characteristics of the Boomerang were as follows:

Wing area	225 sq ft	Diving speed (max) .	410 mph
Wing span	36 ft	Rate of climb . . .	2,500 ft per min
Top speed (at 15,000 ft) .	300 mph	Range on 180 gal of fuel	500 miles

The aircraft was fitted with a Pratt and Whitney twin-row Wasp engine of 1,200 h.p., equipped with a 2-speed supercharger.

certain that the Boomerang was put into production and the first was flown on 29th May 1942.

The Department of Air arranged for comparative trials, taking the form of mock combats, to be carried out between the first Boomerang and the Kittyhawk and Airacobra. Comparative figures for the performance of the aircraft are shown in the accompanying table.

	Boomerang	Kittyhawk	Airacobra
Altitude	Performance in level speed (m.p.h.)		
G.L. . .	260	280	315
5,000 . .	280	300	340
10,000 . .	295	320	360
15,000 . .	295	315	360
20,000 . .	300	310	330
25,000 . .	285	295	325
30,000 . .	260	275	310
	Performance in climb, ft per min.		
G.L. . .	2,500	1,850	2,000
5,000 . .	2,500	1,850	2,000
10,000 . .	2,300	1,850	2,000
15,000 . .	2,080	1,400	1,550
20,000 . .	1,550	1,000	1,100
25,000 . .	1,050	550	650
30,000 . .	500	150	200
Service ceiling	34,000	30,500	31,500

In a report on the trials it was stated:

> At 10,000 feet
>
> The Boomerang is more manoeuvrable than the Kittyhawk and can turn inside it. The Kittyhawk's speed advantage is not sufficient for it to dictate the type of combat and, although it gains more in the dive, the Boomerang's greater manoeuvrability with pull out and superior climb finds it level with the Kittyhawk at the top of the ensuing zoom. The Kittyhawk's only manoeuvre is to dive through a great height and break off the combat; the speed advantage is not sufficient for it to fly away at the same height without becoming vulnerable once combat is joined with the Boomerang.
>
> The Airacobra has a greater speed advantage over the Boomerang than has the Kittyhawk but is outmanoeuvred at the same height in concentric attack (turning circles). When first attempted the Airacobra was able to dictate terms of combat to the Boomerang by its superiority in dive and zoom which allowed it to gain the extra height necessary to deliver an attack from above. Later this advantage was not so apparent and this was thought to be due to the pilot becoming more familiar with the Boomerang.

When the C.A.C's attempt to build a dive bomber of its own design became involved in unforeseen difficulties[4] and the making of Wirraways was suspended, it was decided to concentrate efforts on the Boomerang and the order was increased to 250. The production schedule of the Wirraway, the Wackett Trainer and the Boomerang is shown in the accompanying table.

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[4] There was little scope for such a bomber in New Guinea and the islands: it was hard enough to find the enemy in the jungles and mountains, let alone dive-bomb him.

		Wirraways		Wackett Trainers	
		Per month	Cumulative	Per month	Cumulative
1939	Jul	2	2		
	Aug	4	6		
	Sep	6	12		
	Oct	7	19		
	Nov	6	25		
	Dec	8	33		
1940	Jan	5	38		
	Feb	8	46		
	Mar	5	51		
	Apr	6	57		
	May	11	68		
	Jun	7	75		
	Jul	8	83		
	Aug	16	99		
	Sep	15	114		
	Oct	33	147		
	Nov	34	181		
	Dec	23	204		
1941	Jan	5	209		
	Feb	9	218		
	Mar	21	239	1	1
	Apr	22	261		
	May	19	280	3	4
	Jun	20	300	9	13
	Jul	5	305	7	20
	Aug	26	331	13	33
	Sep	36	367	23	56
	Oct	45	412	14	70
	Nov	37	449	10	80
	Dec	42	491	16	96
1942	Jan	25	516	22	118
	Feb	22	538	35	153
	Mar	29	567	29	182
	Apr	26	593	18	200
	May	18	611		
	Jun	9	620	Boomerangs	
	Jul				
	Aug			1	1
	Sep			3	4
	Oct			5	9
	Nov			4	13
	Dec			11	24
1943	Jan			3	27
	Feb			13	40
	Mar			21	61
	Apr			18	79
	May			16	95
	Jun			10	105
	Jul			4	109
	Aug			22	131
	Sep			14	145
	Oct			7	152

		Wirraways		Boomerangs	
		Per month	Cumulative	Per month	Cumulative
1943	Nov	5	625	9	161
	Dec	5	630	8	169
1944	Jan	—	630	4	173
	Feb	—	630	5	178
	Mar	4	634	6	184
	Apr	5	639	12	196
	May	8	647	5	201
	Jun	3	650	5	206
	Jul	1	651	6	212
	Aug	4	655	5	217
	Sep	6	661	2	219
	Oct	8	669	4	223
	Nov	9	678	5	228
	Dec	8	686	7	235
1945	Jan	2	688	13	248
	Feb	7	695		
	Mar	2	697		
	Apr	6	703		
	May	4	707		
	Jun	3	710		
	Jul	5	715		
	Aug	2	717		
	Sep	5	722		
	Oct	2	724		
	Nov	5	729		
	Dec	4	733		
1946	Jan	3	736		
	Feb	3	739		
	Mar	5	744		
	Apr	1	745		
	May	7	752		
	Jun	2	754		
	Jul	1	755		

Boomerang aircraft performed valuable service with forward operational units of the R.A.A.F. in New Guinea and in the Solomons, where they were used for such varied army cooperation work as marking targets for fast bombers, dropping mail and supplies to troops, dive-bombing targets inaccessible to other aircraft, and also for mapping and photographic reconnaissance flights.

The Commonwealth Aircraft Corporation was the only section of the Australian aircraft industry that undertook original development work during the war. Its design section worked on several new types of aircraft besides the Boomerang. In June 1940 the War Cabinet voted the corporation a sum of £50,000 for the construction of a prototype light bomber-reconnaissance aircraft. The resulting aircraft, known as the Wackett bomber, was completed in 1941.

Only after intensive performance tests and modifications had been made did the War Cabinet, early in 1942, authorise the production of 105 of these aircraft. Even then further modifications to the prototype were made before the design was approved for production, by which time the order had been reduced to 20. The design of the aircraft called for as much in the way of imported materials as did the Beaufort. Furthermore, no engine then being made or even planned for manufacture in Australia was suited to it. In these circumstances it probably came as no surprise to the industry that after the first two bombers had been delivered, in September 1944, the whole project was closed down and the staff transferred to making the Mustang.

The War Cabinet also gave approval for the development of a new type of fighter aircraft (the CA-15 Fighter) designed for medium altitude operation and to be complementary to the Mustang, which operated at high altitudes. When the prototype was tested, its performance proved in many ways superior to that of the Mustang. The CA-15 was, in fact, a much greater technical achievement than the Boomerang, but by the time it had passed through the long period of experiment and development the war had ended and there was no need for it.

A proposal to manufacture the Beaufighter, the fastest low-altitude, twin-engined, long-range fighter aircraft that Britain had produced, was first made in 1941 by Storey soon after he had returned from three months' visit to England. The Beaufighter was suitable either for concurrent manufacture with the Beaufort bomber, or as its successor, since about 75 per cent of the components and manufacturing techniques were common to both aircraft. For several reasons the proposal to manufacture the Beaufighter was temporarily abandoned and not revived until November 1942.[5] By then the problem had arisen of what to do with the facilities that would become available once the Beaufort program was complete. As soon as the end of this program was in sight approval was given for manufacture of the Beaufighter to begin.

Designed by the Bristol Aeroplane Company, the Beaufighter was a most versatile aircraft, capable of delivering low-level attack by torpedo, cannon or rocket bomb. It had a maximum speed of 304 miles an hour at 9,500 feet; with an all-up weight of 24,650 pounds the aircraft had a rate of climb of 830 feet per minute from sea level to 7,200 feet and of 540 up to 14,500 feet.[6] Wind tunnel tests carried out by the Division of Aeronautics indicated that it might be necessary to fit a dihedral tail plane in place of the straight tail plane originally fitted. Flight trials verified this prediction; the aircraft was not sufficiently stable, a defect easily remedied by making the modification foreshadowed from the wind-tunnel tests. The other principal alterations made to the British model were in the armaments: two .5-inch Browning guns were introduced in

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[5] One of the reasons was that Britain herself would not be interested in any Beaufighters surplus to Australian requirements since Mosquitos were likely to replace them.

[6] Other characteristics of the aircraft were:

Span	57 ft 10 in
Length	41 ft 4 in
Overall height . . .	15 ft 10 in
Wing area, net . . .	451 sq ft
Carrying 500-lb bombs with flame-damping exhausts fitted and with a normal fuel load of 700 gal, the range was	570 sea miles
Service ceiling . . .	28,900 ft

One 500-lb bomb was carried under each wing; alternatively a 2,000-lb bomb or mine beneath the fuselage; or a 200-gal auxiliary fuel tank.

each wing, replacing .303-inch guns, and a rearward firing gun of greater range was installed.

The deliveries of Beaufighters and of Beaufort bombers are shown in the accompanying table.

		Beauforts		Beaufighters	
		Per month	Cumulative	Per month	Cumulative
1941	Aug	1	1		
	Sep	1	2		
	Oct	3	5		
	Nov	2	7		
	Dec	3	10		
1942	Jan	4	14		
	Feb	6	20		
	Mar	8	28		
	Apr	12	40		
	May	16	56		
	Jun	20	76		
	Jul	13	89		
	Aug	17	106		
	Sep	24	130		
	Oct	29	159		
	Nov	25	184		
	Dec	24	208		
1943	Jan	19	227		
	Feb	27	254		
	Mar	23	277		
	Apr	27	304		
	May	24	328		
	Jun	33	361		
	Jul	33	394		
	Aug	33	427		
	Sep	37	464		
	Oct	34	498		
	Nov	32	530		
	Dec	29	559		
1944	Jan	25	584		
	Feb	26	610		
	Mar	17	627		
	Apr	11	638		
	May	20	658	1	1
	Jun	15	673	2	3
	Jul	15	688	8	11
	Aug	12	700	13	24
	Sep			20	44
	Oct			23	67
	Nov			27	94
	Dec			18	112
1945	Jan			28	140
	Feb			26	166
	Mar			28	194
	Apr			30	224
	May			29	253
	Jun			31	284
	Jul			26	310
	Aug			19	329

Eighteen months after the decision to manufacture it, and 14 months after the receipt of the first batch of drawings, the first Australian Beaufighter was given its flight test. Australian rocket-firing Beaufighters were in service right up to the end of the war from New Guinea north to the Philippines and west to Borneo.

Beginning in 1929 as a sales and service organisation in Melbourne, De Havilland Aircraft Pty Ltd, a branch of the English company, gradually extended the scope of its activities until, in the late thirties—and consequent on a move of the factory to Sydney—it began to undertake the partial manufacture of aircraft, relying on importations for metal fittings and aircraft engines. For example, in 1937 it made a number of DH-83A Fox Moth single-engined cabin biplanes for use as aerial ambulances by the Bush Aid Society and the Darwin Flying Doctor Service.

Two years later the tempo of the company's activities suddenly increased with the receipt of an order from the R.A.A.F. for 20 DH-82A Tiger Moth training aircraft, which were to be fitted with imported Gipsy Major engines. This order was soon followed by others and from May 1940, when the first Moth was delivered, to August 1942 more than 1,000 of these elementary trainers were built. With the exception of the first 200 they were equipped with Gipsy engines made by General Motors-Holden's. Meanwhile, in 1941 the company was asked to design and build a special type of military glider. By 1943 eight prototypes had been delivered. This was the first design project undertaken by the Australian company.

These aircraft were a valuable contribution to the Empire Air Training Scheme. Tiger Moths were made not only for the Australian section of the Empire Air Training Scheme, but also for the South African and Southern Rhodesian sections; they were also exported in limited numbers to New Zealand, India, Burma and Indonesia. Before the last of the Tiger Moths had been delivered a start was made on the manufacture of DH-84 Dragons, twin-engined aircraft for use as wireless and navigational trainers by the R.A.A.F. and also as ambulances and transports. The company made 87 Dragon aircraft, each powered by Australian-made Gipsy Major engines.

From the technical point of view, however, the most interesting achievement of De Havilland Aircraft was the manufacture, towards the end of the war, of the Mosquito bomber. The parent company in England, long experienced in the construction of wooden civil aircraft, decided just before the war to try its hand at designing a military aircraft of the same material. Such an aircraft would, De Havilland's believed, relieve the drain on supplies of light metal which was bound to be serious in wartime. It would, moreover, make possible the use of skilled labour from woodworking trades, on which there would be fewer calls than on the metalworking trades. Certain sections of the British Air Ministry, which was sceptical of the military possibilities of wooden aircraft, opposed De Havilland's proposals. The company nevertheless persisted in its views and eventually produced the Mosquito. The advantages of wooden construction proved, in the event, to be quite considerable.

The knowledge and experience of aircraft manufacturers had for many years been such that a poor aircraft was rarely, if ever, designed and made, but every now and then one was designed that more or less unexpectedly stood out from the rank and file in the excellence of its performance and its versatility. Such an aircraft was the Mosquito which, starting life as an unarmed intruder designed for hit-and-run raids, became successively a fighter, a fighter-bomber and a first-class photographic reconnaissance aircraft, and remained in service in all these roles throughout the war.

Some time before the outbreak of war, the possibility of constructing wooden military aircraft in Australia had been seriously considered.[7] In 1938, at the instigation of the Premier of New South Wales, Mr Stevens,[8] who had invited all government departments to submit suggestions on ways in which the State's resources might be used in the event of war, the State Forestry Commission's Division of Wood Technology began a rapid survey of the properties of timbers in New South Wales with a view to ascertaining their fitness for various defence purposes. Timbers were examined to determine their suitability for rifle furniture, artillery waggons, for aircraft construction, and as substitutes for English and Canadian timbers. In its search for substitutes the Division of Wood Technology co-operated with the Standards Association of Australia,[9] the C.S.I.R. Division of Forest Products, and the Institution of Engineers of Australia. Coachwood (scented satinwood), a tree that grows in the coastal forests of New South Wales and Queensland, showed promise as a material for aircraft plywood.

Before the C.S.I.R. entered the field of wood technology in 1928, Australia had lagged seriously behind other countries of the world in regard to many of the techniques for handling and using timber, such as seasoning, milling, preserving and gluing. In the ten years that followed the setting up of the Division of Forest Products much of this leeway was made up, especially in the development of efficient methods of seasoning timber. Indeed the background of knowledge concerning kiln-seasoning of timber built up by the C.S.I.R. and by the Forestry Commission of New South Wales was of the greatest value during the war in making it possible to meet the demands for seasoned timber. Without the progress in wood technology that took place during these years, the difficulties confronting the manufacturers of wooden aircraft would have proved considerably greater than they were, if not insuperable.

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[7] The Munitions Supply Board had planned to manufacture wooden military aircraft soon after the first world war, and had acquired plant for the purpose. However no orders for such aircraft were forthcoming and the plant was eventually sold.

[8] Hon Sir Bertram Stevens, KCMG. MLA, NSW, 1927-40; Premier and Treasurer of NSW 1932-39; Aust Repve, Eastern Gp Supply Council, India, 1941-42. Consulting accountant. B. Sydney, 2 Jan 1889.

[9] The Standards Association drew up a series of emergency standards for aircraft timbers.

After discussions had taken place between the Department of Aircraft Production and Major Murray Jones,[10] General Manager of De Havilland's, the War Cabinet gave its approval to the manufacture of the Mosquito, but only on condition that it did not involve taking skilled men from other aircraft factories. It agreed that £50,000 should be set aside to enable De Havilland's to discover what would be involved in establishing production. With the department's sanction De Havilland's sent a number of its officers to Britain and the United States and also to Canada, where plans for the manufacture of the Mosquito were well advanced. Arrangements were made for the supply of blueprints, drawings and other technical details.[1] Technical liaison with De Havilland's in Britain was established and certain essential machine tools were secured. The British firm could spare only one of their own engineers, Mr Waghorn,[2] to help in the Australian undertaking.

The difficulty of obtaining skilled manpower had reached its wartime peak by late 1942, when manufacture of the Mosquito was begun. Consequently De Havilland's were compelled to build up an almost entirely new labour force of some 600 men and women, most of whom had never been in an aircraft factory before, at a time when most of the promising recruits to this kind of work had already entered the industry. Subcontractors for manufacture were of necessity engaged in all parts of the Commonwealth, but fortunately most of those concerned with the woodwork of the aircraft were in the Sydney area. Continual shortage of labour dogged the Mosquito undertaking—not so much in the wood-working industries as in the metal trades.

Among the most interesting features of its construction was the plywood and balsa wood sandwich used to cover the fuselage. In the Australian version the plywood consisted of coachwood bonded with phenol formaldehyde resin. The technique of making plywood of this kind had been pioneered some years before by the Sydney firm of Frederick Rose. Though coachwood, the nearest Australian equivalent to Canadian birchwood, was used in the Mosquito, it was inferior to the Canadian timber in some respects, being relatively weak in shear. This necessitated redesigning portions of the Mosquito wing to permit the use of thicker plywood.[3]

The demand for coachwood was so great (it was also being used for rifle furniture) that new forests round Wauchope and Wagga, New South Wales, had to be opened up. All the routine testing of coachwood for the

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[10] Maj A. Murray Jones, MC, DFC. (Served 1st AIF.) General Manager of De Havilland Aircraft Pty Ltd, Sydney, since 1940. Aviator; of Sydney. B. Caulfield, Vic, 25 Feb 1895.

[1] The main features of the Australian Mosquito were:

Over-all length . .	41 ft 2 in	Power plant .	2 Rolls Royce Merlin engines
Wing span . . .	54 ft 2 in	Max speed .	376 mph at 22,000 ft
Wing area . . .	436 sq ft	Range . .	1,260 miles
Wing loading . .	42.5 lb per sq ft		

Some modifications to the design of the British aircraft were necessary because the Rolls Royce engines were of American make and different from those used in Britain.

[2] M. M. Waghorn. Engineer, De Havilland Aircraft Co, England, to 1942; Engineering executive De Havilland Aircraft Pty Ltd, Sydney, since 1942. B. London, 16 Nov 1917.

[3] De Havilland's took over the piano factory of Beale and Co Ltd at Annandale, NSW, and operated it to manufacture fuselages. Sydney furniture firms who made wing components were: Ricketts and Thorp Pty Ltd, front spar; F. Dickin Pty Ltd, rear spar; Bray and Halliday Pty Ltd, wing skins; Reilton and Griffin, tank doors.

Mosquito was done by the Division of Wood Technology of the New South Wales Forestry Commission. As time went on the importation of timber became easier; more and more birchwood ply from Canada was used in place of coachwood owing to its superior shear modulus. Balsa wood, a timber of unusually low density, which formed the middle of the sandwich, stabilised the plywood and prevented it from wrinkling without adding greatly to the weight of the structure. No satisfactory substitute for South American balsa wood could be found among Australian timbers, although one roughly resembling it was found in the stinging tree in New South Wales. In making some of the special joints, for example those carrying bolts, compressed impregnated (compreg) plywoods found important application.

The spars of the wings, in section, resembled a metal constructional beam. The stressed skin of the wings consisted of resin-bonded coachwood ply. All wooden joints were glued and screwed—the screws, in some cases assisted by heavy clasps, serving only to hold the wood in place until the glue had set. Casein glue, being a product in common commercial manufacture in Australia, was used for making joints, in spite of the fact that it was known to be susceptible both to moisture and to bacterial attack. Since the aircraft were likely to find service in the tropics, the manufacturers gave careful consideration to the suitability of such a glue under these conditions. However the outside of the wing and fuselage were so well protected by a water-resisting, doped fabric that no serious trouble ever arose from deterioration of glued joints. Any doubts that might have been entertained on this score were set at rest by a thorough examination of the wings of an aircraft that had seen service in the tropics for some time. It revealed that the glued joints were in remarkably good condition. Nevertheless, as soon as synthetic resin cements (phenol and urea-formaldehyde resin) came on the market through the efforts of Messrs Elliotts and Australian Drug Pty Ltd, a change over to the synthetic cement was promptly made. Besides being much safer in the tropics, synthetic cements accelerated the gluing process because they set more rapidly than casein glue. The chemical firms experienced difficulty occasionally in meeting the specifications for these cements, which were far more exacting than those for cements used in the ordinary woodworking industries.

After De Havilland's had built the first jigs and assembled the first two wings to demonstrate that the tooling was correct, assembly of wings for the Mosquito was undertaken by General Motors-Holden's in their factory at Pagewood, New South Wales. The techniques required for assembling the wooden component structures of the wings were so different from those used in the assembly of motor car bodies that the firm experienced some difficulties in the early stages. Defective glued joints discovered in seventeen of the first wings to be assembled occasioned one of the more serious delays experienced in the manufacture of Mosquitos. The ill wind that brought the defective wings did, however, blow in an unusually bountiful supply of research material for the Division of Aeronautics, where many wings which had been rejected for use on aircraft were most carefully and profitably tested to destruction.

The absolute reliability which was the keynote of all processes and specifications for aircraft materials contributed greatly to their cost. The Aircraft Inspection Directorate maintained a most intricate system of checks and counter-checks designed to ensure dependability of material. Manufacturers of material for aircraft construction always despatched it with an accompanying "release note" signed by one of their technical officers who accepted the responsibility of declaring that the material fully met the specifications. Similarly the aircraft manufacturer was required to be in possession of this release note before he began to use the material. The system was such that should a defect be discovered at any stage, the material in which it occurred could be traced right back through all phases of its manufacture.

Plans were made by the parent company in Britain for Mr John De Havilland to visit Australia for the purpose of flight-testing the first locally made Mosquito, which was delivered on 23rd July 1943. Unfortunately De Havilland was killed in an aircraft accident. In his stead Mr P. Fillingham, chief test pilot at De Havilland's Canadian factory, was sent out and on 11th November 1943 gave the Australian-made Mosquito a flight test.[4]

The next few aircraft came rather haltingly off the assembly line. Their progress was delayed by extensive modifications to the telecommunication equipment called for by the R.A.A.F. By May 1944 the fourth aircraft was completed and De Havilland's could then inform the Department of Aircraft Production that the performance of the Australian-made Mosquito was comparable in every respect with that of the British machine. Before the thirtieth aircraft had been produced (in December 1944) progress was further marred by two fatal accidents during test flights. While experts were of the opinion that the accidents, similar to several that befell Mosquitos in Britain, arose from failure due to high-speed flutter, they could, in the subsequent inquiry into the nature of the accidents, find nothing to substantiate this opinion.

In addition to the fighter-bomber-intruder type, De Havilland's made six photographic reconnaissance Mosquitos which played an important part in the aerial survey that preceded the invasion of the Philippines. Weeks before the Leyte landing, Australian-made Mosquitos in cooperation with American aircraft ranged far and wide over the islands on reconnaissance, bringing back photographic information.

The Mosquito was the first large, wooden, cantilever wing aircraft to be made in Australia. It will probably be the last. The high hopes that De Havilland's once held for the potentialities of wood alone, wood reinforced with plastics, and plastics, were not sustained by the record of experience. In varying degrees, but most of all with plastics, the strength

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[4] Actually the first aircraft was first flown by an Australian pilot, W Cdr H. Gibson Lee, before Fillingham arrived.

of these materials was notch sensitive,[5] a failing to which metals and alloys were not so prone. This makes the record of the Mosquito all the more remarkable. It was the first modern front-line machine of all wood construction to go into service.

By 1942, when the Beaufort, Beaufighter, Boomerang and Mosquito were in production or approved for production, one of the main problems occupying the minds of those directing aircraft industry was that of matching or more than matching improvements in the performance of enemy aircraft. One method of doing this was to try to improve the performance of the four types of aircraft already in production. This proved impracticable. An alternative policy was to select the best of the proven types of aircraft in use or under development by the Allied Nations and try to make them in Australia. This was the course of action finally decided upon, and to give effect to it the Director-General of Aircraft Production and the Chief of the Air Staff recommended to the Prime Minister on 9th October 1942 that a mission representative of the R.A.A.F. and the Department of Aircraft Production should be sent overseas without delay. This proposal was accepted by the War Cabinet on 7th December.[6]

Well briefed on the nature of the aircraft required, the mission left Australia in January 1943 to visit the more important aircraft manufacturing centres in Britain and the United States. On its return, in May 1943, the mission recommended that the Mustang and Lancaster should be manufactured in Australia. As manufactured by North American Aviation Incorporated to British specifications, the Mustang was, in the mission's view, the most suitable type of high-altitude fighter aircraft.

Of the British fighter aircraft studied by the mission the only one considered as likely to compare with the Mustang's performance was the Spitfire Mark VIII. Under some conditions the advantage lay with the Spitfire, under others with the Mustang. What finally decided the mission in favour of the Mustang was its greater potentialities for improvement in performance[7] and the fact that it was relatively easy to import from America supplies of equipment needed for its production.

Beginning with the first delivery in May 1945, the C.A.C. produced 59 Mustangs before the year was out.

The mission had been asked by the Air Board to recommend, if it could, a twin-engined bomber with a range of 2,000 miles while carrying a bomb load of 2,000 pounds. It found, however, that for operations of this type four-engined aircraft were being used in Britain and the United States.

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[5] The tensile strength of a piece of material, in the form of a cylinder for example, is proportional to the area of its cross section. If, when the area of this cross section is reduced by notching the cylinder or boring a hole through it, the tensile strength is reduced by an amount far greater than the proportional reduction of the cross-sectional area, such material is said to be notch sensitive. Wood suffers from this defect but not to such a great extent as plastics.

[6] Members of the mission were: D. McVey (Dept of Aircraft Production), Leader; D. E. Callinan (Beaufort Division engineer); AVM A. T. Cole (RAAF); Gp Capt W. S. Armstrong (RAAF); W Cdr J. P. Ryland (RAAF); and L. J. Wackett (Manager, CAC).

[7] An aircraft has only a limited range of possibilities for modification; there comes a time when it can no longer be modified and improved. The Spitfire, which had reached Mark VIII, was nearing the end of its development. The Mustang, on the other hand, was at the beginning and therefore a better choice because of its potentially longer future.

Of the American four-engined aircraft examined, the type that came nearest to fulfilling Australian requirements was the Liberator or B-24. Better still, however, was the Avro Lancaster bomber developed by A. V. Roe and Company in England, regarded by some authorities as the best four-engined heavy bomber produced in either Britain or the United States. At that time it carried the heaviest bomb load of all Allied aircraft.

While the mission was examining the question of the suitability of this aircraft, the Australian War Cabinet, in pursuance of the arrangement that had been made between the Prime Minister and the Commander-in-Chief of the South-West Pacific Area (General MacArthur) that the nature of the Commonwealth's war effort would be governed primarily by the Commander-in-Chief's plans, submitted for the latter's comment the proposal that Australia should make long-range bombers. In his reply to the Prime Minister (in March 1943) MacArthur adduced reasons for doing nothing of the kind:

> All of the larger types, including transport airplanes, can be flown from the United States and thus require none of the limited shipping space for delivery. Fighter airplanes must be brought in by surface ships, with considerable expenditure of cargo capacity. It is evident therefore that local manufacture of fighter aircraft would not only provide us with airplanes required in this category but would at the same time release worth while cargo ship space which could be used for other requirements. I believe therefore that insofar as the war effort is concerned, the local manufacture of fighter type airplanes would be preferable to attempting the manufacture of a type which can be flown to this theatre.

This definitely ruled out the Liberator, since Australia could hardly expect Lend-Lease support in these circumstances. Commenting later on the specific proposal to make the Lancaster in Australia,[8] MacArthur was no less emphatic: "There has been no new development which would tend to alter my opinion," he said. On the other hand the R.A.A.F. staff were not so easily convinced. It was their view that as a Service the R.A.A.F. was unbalanced, lacking particularly long-range general reconnaissance and heavy bomber aircraft which could be expected to give it a great deal more striking power than it possessed. Moreover, though it lacked aircraft of this type, it did have available large numbers of trained air-crews who had gained a great deal of experience in handling heavy, long-range aircraft in Europe.

Despite the lack of support from MacArthur, the Department of Aircraft Production recommended that the manufacture of the Lancaster should be undertaken. In addition to the arguments advanced by the R.A.A.F., there was the problem of maintaining continuity in the program of the government aircraft factories—the need to have some project to follow the Beaufort and Beaufighter. In the light of these considerations the War Cabinet finally approved of the setting up of facilities for the production of the latest type of Lancaster at a rate of 15 aircraft a month,

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[8] The manufacture of the Lancaster had been first recommended by Storey in July 1941 after his visit to Britain with the Prime Minister, on the advice of the leading British authorities. The Lancaster was only then going into quantity production in England, as a replacement of the Manchester Bomber.

to a total of 50. By the time Australia was in a position to build the Lancaster, so many modifications had been made by its designers in England that it was virtually another aircraft and was in consequence renamed the Lincoln.

Manufacture of the Lincoln was a much bigger undertaking than any before attempted. The Lincoln dwarfed all aircraft previously made in Australia, as the following details will show:

Wing span	120 ft
Length	78 ft 4 in
Height	17 ft 3½ in
All-up weight . . .	82,000 lb
Wing area	1,421 sq ft
Engines	4 Rolls Royce Merlin 85 1,660-h.p., 12-cylinder, ice-type liquid cooled in-line engines. Supplied at first from Britain, Merlin engines were later made in Australia.
Max speed	314 mph at 18,000 ft
Load	A bomb load of 22,000 lb could be carried

Headed by Storey, a team of Beaufort technical executives spent many months at the Avro works in Manchester in 1944 and 1945, and received the greatest help from the A. V. Roe Company.

The first Australian Lincoln was delivered to the R.A.A.F. on 10th May 1946; six others were completed before the year was out. The significance of this achievement lies not only in the size of the aircraft itself but also in the fact that for the first time Australia was able to build an aircraft at the same time as it was being developed in Britain. In the years immediately after the war it was not possible to repeat efforts of this kind. One of the main problems that confronted the industry in Australia then was to avoid manufacturing aircraft that became obsolete during the process.

The establishment of an aircraft industry in Australia would have been difficult enough under normal peacetime conditions. Under the adverse conditions of war, when demands were far in excess of supply not only for manpower and materials but for equipment of all kinds, the difficulties were infinitely greater. Nevertheless the aircraft industry became one of Australia's major undertakings, employing at the height of its activity (in June 1944) some 44,000 men and women. Women did a magnificent job for the industry: they worked lathes and milling machines, presses and drills; they worked as electric welders, riveters, assemblers, laboratory assistants, inspectors and tracers. In some Beaufort plants, for instance, as many as 57 per cent of the workers were women; over the whole organisation they made up about one-third of the total number of employees. More than 80 per cent of the men and women working in the Beaufort organisation had had no previous factory experience; less than 10 per cent of factory employees were skilled men.[9] One factor responsible for much

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[9] These figures are taken from "The Organisation behind Torpedo Bomber Manufacture in Australia", an address delivered to the Institute of Industrial Management by its President, Mr John Storey, on 4 May 1943.

of the success achieved in producing aircraft and other munitions whose manufacture had not previously been attempted here, was the adaptability of Australian workers.

To have produced 3,500 aircraft of nine different types and nearly 3,000 aircraft engines of three types, must notwithstanding the mistakes and miscalculations that occurred, be ranked among the great achievements of Australian industry, especially when it is remembered that the fighter aircraft was one of the most highly complicated examples of precision engineering.

A fairly complete and well-balanced industry had been built up with parallel development of research, with the result that after the war Australia was capable of building aircraft and aero-engines of the most advanced jet-propelled types, such as the Avon-Sabre fighter, the Canberra bomber and the Rolls-Royce Nene engine, thereby establishing herself firmly as a strong link in the chain of air bases protecting the British Commonwealth.