Commonwealth – ARL

ARL Annual Report 1962-63. p 13 (a) Vampire. Flight tests for strains and loading conditions to define programmed loads. Results have produced a safe life and life for wings with a suggested mod. Proposed boom replacement for doubling safe life. List of reports pp 39-41.

> SM.275 – Flight Tests of Vampire Mk.35
>
> SM.116 – CA Patching and JY Mann. A review of Australian investigation on aeronautical fatigue during the period May 1961 to March 1963. [*I could not find this online.*]

ARL Annual Report 1963-64. p 15 (a) Vampire. Completed tests of wings with replaced spar booms – programmed load testing phase concluded. Next: testing under random loads.

p 16 Flight Loads – data collection includes Vampire.

[*No papers of note for Vampire.*]

ARL Annual Report 1965-66. p 15 (a) Vampire Wings. Residual strength tests have been conducted.

Investigations for RAAF. The comprehensive fatigue investigations on Vampire wings has been completed. To extend the safe fatigue life of the structure – main spar to be removed and inspected and replaced if necessary. Inspection technique has been developed for HdH. [p 16 not included in copy; p 15 text may continue!]

p 32. Goblin engine ad hoc investigation due to increasing incidence of abnormal noises and vibrations. Results so far have provided justifications for the RAAF to continue flying ops. With figure.

ARL Annual Report 1967-68. p 15 Other work for the RAAF. Draft report has been completed for estimated safe life for the Vampire.

p 29. Goblin engine investigations. Short service life of flame tubes. p 30 possible inlet flow maldistribution. An air intake and duct system from a Vampire is tested. With figure.

ARL Annual Report 1968-69. p 51 Goblin engine investigation. Noise and vibration. With figure.

ARL Annual Reports

Hardcopy: G.9

Softcopy:

..\Technical Documents - Vampire\Masters Vampire Manuals\ARL Annual Report Extracts 1962 - 1969 OCR.pdf

been started on a priority basis:

(a) Vampire:— After flight tests to determine the strains in various critical components under different loading conditions and gust and manoeuvre load measurements, the wing fatigue of Vampire has been examined under programmed load. The results have produced a safe life for the present wings, a life limit for the wings after a suggested modification, and a proposal for a replacement of the spar boom which would double the safe life. One interesting aspect of this work has been the identification of fatigue markings on the fracture faces with load programmes which has been used in determining the time of initiation of the fatigue cracks (see Fig. 7).

(b) Winjeel:— A.R.L. has been directing the study of fatigue in Winjeel, the computations for which have been carried out by the manufacturers, Commonwealth Aircraft Corporation. The results have shown that the wing, apart from one or two small areas, is safe in fatigue but that the safe life of the fin is too low. A laboratory fatigue test on the fin will be required.

(c) Cessna:— The R.A.A.F., which operates Cessna aircraft on behalf of the Australian Army, has requested A.R.L. to investigate the fatigue of Cessna. The Department of Civil Aviation is also interested in the fatigue of Cessna as being typical of light aircraft in Australia. The load history has been obtained and a flight test programme has been undertaken to determine strains. A test rig for laboratory tests on wings is being designed by the De Havilland Aircraft Co. in conjunction with A.R.L.

Background research on the fatigue properties of "Mustang" wings has continued with the determination of the effect of asymetric loads on fatigue life. The results have been used to check four different life estimation or cumulative damage hypotheses that have been proposed.

In addition to the work on Cessna for Department of Civil Aviation mentioned above, fatigue testing of "Dove" wings has continued and has enabled the safe fatigue lives of further components of the wing to be determined. Eight centre section tension booms fitted to this wing have ultimately developed fatigue cracks, and will be tested to determine their residual strength.

Crack Propagation

The solution of certain "ad hoc" life assessment problems has necessitated a study of crack propagation from the theoretical viewpoint and also by microscopic examination of fractured surfaces. The theoretical study has led to a reconciliation of apparently contradictory hypotheses of Frost and Phillips, who predict $\frac{dl}{dN} = kl$, and Weibull who predicts $\frac{dN}{dl}$ = constant, when l is the crack length and N the number of load cycles. The study of crack propagation by fractographic examination has been most fruitful as noted above. Vampire tests all show regularly spaced bands or rings clearly visible under a low power microscope. When submitting a specimen to lengthened and shortened programmes at regular intervals it was found that the ring spacing was similarly varied thus supporting the view that each ring corresponded to one upward and downward load programme (see Fig. 7). Counts of rings showed that in one case the fatigue crack was present within one or two programmes of the commencement of a test which lasted for 95 programmes. Measurements on 6 fractures for crack sizes greater than 0.05 in. showed close agreement with the expression for propagation rate $\frac{dR}{dP} = ke^{AR}$ where R = crack radius, P = number of programmes and k and A are constants. Study with modified programmes showed that these influenced the subsequent crack propagation rate, so offering a useful experimental technique for a study of cumulative damage.

Fatigue of Materials

The estimation of the life of specimens under a complex load sequence, which is being attempted for several aluminium alloys that have been tested under the same random loads as those applied in the different series of Mustang fatigue tests mentioned above, requires basic fatigue data for the alloys in the form of S-N curves at various mean stresses. Such data is being obtained for the aluminium alloys 7178-T6, 7079-T6, 2024-T4, 2L65, DTD683A and DTD363A. Over the past twelve months tests on 7178-T6 and 2L65 have been carried out. Because of the difficulty in interpretating families of S-N curves at different mean stresses, a mathematical "least squares" method of fitting curves to such data is being developed and is being applied firstly to the data on 7178-T6 and 2024-T4 alloys.

Investigations have continued on the fracture characteristics in fatigue of high strength aluminium alloy extrusions. Rotating cantilever tests at 100 and 1000 c.p.m. on alloy 2024 have given S-N curves with a similar "hump" to that obtained at 12,000 c.p.m. although the "cup and cone" fractures obtained at the latter testing frequency were not found in the former two.

A study of the variation in fatigue properties between three batches of DTD363A aluminium alloy of widely different ultimate tensile strengths has shown that the fatigue strength of unnotched specimens at 10^8 cycles is about one third of the U.T.S. in each case, whereas, for a particular notch, the fatigue strengths are the same irrespective of the U.T.S. of the batch.

Scatter in the "fatigue limit" of SAE4140 steel (U.T.S. 90,000 p.s.i.) was investigated by testing 132 specimens. The statistical distribution in stress about the fatigue limit, whether normal or otherwise, is not yet clear.

Measurement of Operational Loads

One of the most important aspects of the determination of safe fatigue lives of aircraft is the investigation of flight loads due to gusts, manoeuvres,

Appendix III.

UNCLASSIFIED PUBLICATIONS ISSUED DURING THE YEAR

Aerodynamics Notes.

A.201—G. W. F. Pike.
On the use of the Saha Equation.

A.202—A. E. Hodges.
An oil burning smoke producer for flow visualisation in Wind Tunnels.

A.204—R. E. Center.
The interaction of a reflected shock wave with the laminar boundary layer in a shock tube.

A.209—N. Ruglen and R. A. Wallis.
Acceptance trials of a Twin 169 inch Axial flow fan installation for AW.84 Airway Mount Isa Mines Ltd.

A.214—M. D. Frost and P. L. Smith.
A low speed wind tunnel determination of dynamic lateral stability derivatives for a 30° Delta wing Aircraft.

Aerodynamics Technical Memoranda.

A.173—G. R. Kittson.
Measurements of normal force and pitching moment on a body of revolutions (RM-10) at transonic Mach numbers.

A.174—G. Sunderland and A. Chilten.
The manufacture of laminated wooden fans.

A.175—W. S. Howitt and W. N. Hurst.
Survey of the possibilities of using operational research in Qantas.

A.177—W. W. Woods.
Estimation of Wing loads on a Sabre flying in the wake of a Canberra.

A.178—L. T. Banner.
A stagnation temperature probe for use in Hypersonic Flow.

A.179—C. E. Kerr and J. B. Willis.
Proposal for a supersonic development wind tunnel in Australia.

A.180—M. J. Williams.
Hypersonic wind tunnel tests on 1/6 scale model Delta wing test head.

A.181—J. H. Duke.
Wind force measurements on window shade screens.

A.182—W. H. Melbourne and T. H. Trimble.
Performance of the first eight bladed fibreglass fan installed in the 9' x 7' low speed wind tunnel.

Mechanical Engineering Reports.

ME.105—D. R. Warren.
The A.R.L. Flight Memory Project — A brief description of the present system for pre production assessment.

Mechanical Engineering Notes.

ME.251—L. G. Randall.
An experimental self temperature compensated strain gauge system.

ME.252—W. J. Morley and J. C. Wisdom.
Some observations on the gas-turbo supercharged steam boiler.

ME.254—W. J. Morley and J. C. Wisdom.
Investigations of initial brown coal ash deposition reactions on turbine blades.

ME.255—P. A. Salter.
Further boundary layer tests in the Vortex wind tunnel.

ME.257—S. A. Fisher.
The proposed supersonic propulsion test facility at A.R.L.

Mechanical Engineering Technical Memoranda.

ME.230—A. S. Finlay.
Preliminary trial of multiple-jet cooling of ducts.

ME.231—L. A. McGee and S. G. Kerr.
Doxford Marine Engine 67LBD5 Vibration investigation.

ME.232—B. J. Poppleton.
Kinetic of the potassium chloride catalysed oxidation of acetaldehyde.

ME.233—S. A. Fisher.
Attenuation of pressure pulsations in compressor delivery pipe-work at G.F.C. Morwell works.

ME.234—D. C. Gibson.
Preliminary tests on a Mach 3.0 spill diffusion rig with 50% spill factor.

ME.235—P. N. Doogood.
The performance of a simple air to air heat exchanger.

ME.236—R. E. Pavia.
Tests of respirators and air supply system for grain elevator terminal, Geelong.

ME.238—John H. Purdy.
Development of Kodak R.P.12 Print-out recording paper.

ME.239—R. E. Broughton.
Erosion and ash deposition tests on a cascade of turbine blades.

ME.240—D. R. Warren.
Flight Memory Project, Part 7. A Comparison of the flight memory system with current Australian requirements.

ME.241—D. R. Warren.
Flight Memory Project, Part 8. Comparison of the Flight Memory system with the tentative U.K. requirements for Civil Aircraft Recorders.

Structures and Materials Reports:

SM.290—J. P. O. Silberstein.
Static Loading and free vibrations of plates.

SM.291—D. G. Ford.
Some secondary stress diffusion effects in cut-outs.

SM.292—J. Y. Mann.
An introduction of the fatigue of materials for Engineers.

Structures and Materials Notes.

SM.275—J. M. H. Barnard and S. Gee.
Flight tests of Vampire Mk35 Trainer Aircraft.

SM.276—A. K. Patterson, M. J. G. Higgs and F. H. Hooke.
A study of the variability of fatigue meters with reference to results from Fokker Friendship Aircraft.

SM.277—A. K. Patterson.
Further note on flight loads on a Beaver Aircraft on agricultural operations.

SM.278—R. A. Fell.
Investigations on car seat belts and manual exertion for operation.

SM.279—Katarine Muir and I. G. Scott.
Resistance changes in gauges during stabilization and attachment.

SM.280—B. C. Hoskin.
A note on modification in redundant structures.

SM.281—D. D. McConville and I. G. Scott.
Examination of a constant stress cantilever.

Structures & Materials Technical Memoranda.

SM.113—C. Torkington.
Examination of outer wing of Fokker Friendship VH-CAT damaged by excessive pressurisation during refuelling.

SM.114—F. H. Hooke and S. R. Perry.
Acceleration measurements on ship at sea.

SM.115—C. Torkington.
A proposal for comparative tests of webs under combined loading.

SM.116—C. A. Patching and J. Y. Mann.
A review of Australian investigation on aeronautical fatigue during the period May 1961 to March 1963.

SM.118—R. B. Douglas and J. Y. Mann.
The behaviour of internal coatings of integral fuel tanks under fatigue loadings.

Bibliography.

SM.4 —Katarine Muir, R. N. Robinson and I. G. Scott.
Bibliography on electrical resistance strain gauges.

Metallurgy Reports.

Met.42—L. Wilson.
Spectrophotometric estimation of titanium in chromium and its alloys.

Met.46—L. Wilson.
The determination of silver in aluminium alloys by atomic absorption spectroscopy.

Met.47—F. G. Lewis.
The corrosion of the high strength aluminium alloys.

Met.48—I. J. Polmear, I. F. Bainbridge and D. W. Glanville.
Cavity formation during metal fatigue.

Met.49—J. F. Vietz and I. J. Polmear.
The influence of small additions of silver on the ageing of aluminium: Further observations of Al-Zn-Mg Alloys.

Met.50—N. E. Ryan.
An appraisal of possible scavenger elements for chromium and chromium alloys.

Met.51—C. S. Landau.
Analysis of creep data of chromium and certain chromium alloys.

Metallurgy Notes.

Met.14—S. T. M. Johnstone.
The production and welding of refractory sheet metal including proposals for chromium alloys.

Met.17—L. Wilson.
The determination of the solubility of zinc oxide in various solutions by atomic absorption spectroscopy.

Metallurgy Technical Memoranda.

Met.231—D. W. Glanville.
Metallurgical examination of failed and cracked propellers.

Met.232—D. W. Glanville.
Metallurgical examination of cracked main landing gear spring legs from a Cessna 180 A/C, VH-TSB.

Flight Notes.

F.33—R. V. Pavia and D. H. Edwards.
A precision jet pipe temperature indicator for flight use.

Instrumentation Note.

I.62—R. C. Tobin.
Increasing the stability of a series tube regulated D.C. power supply employing a cascade shunt amplifier.

Instrumentation Technical Memoranda.

I.43—K. F. Fraser and J. F. Harvey.
R.A.A.F. Inverter investigation.

Human Engineering Reports.

HE.2—J. R. Baxter and J. D. Workman.

Review of projected displays of flight information and recommendations for further developments.

Human Engineering Notes.

HE.13—C. Cameron and R. W. Cumming.

User opinions of optical and non-optical rifle sights.

HE.14—A projected symbolic display for general aircraft.

Human Engineering Technical Memoranda.

HE.7—J. R. Baxter.

The projected symbolic display — Its application to all weather landing.

Appendix IV.

EXTERNAL PUBLICATIONS

Fatigue.

J. M. Finney and J. Y. Mann. Fatigue behaviour of notched aluminium alloy specimens under simulated random gust loading with and without ground-to-air cycles of Loading. Pages 151 to 177 "Fatigue of Aircraft Structures". Pergamon Press, 1963.

D. G. Ford, D. G. Graf and A. O. Payne. Some statistical aspects of fatigue life variation. Pages 179-208. "Fatigue of Aircraft Structures". Pergamon Press, 1963.

C. S. Landau. Low Frequency Fatigue — A Rheological Approach. The Engineer, **213,** 911, 1962.

I. J. Polmear, I. F. Bainbridge and D. W. Glanville. Cavity Formation during Metal Fatigue. J.Aust. Inst.Metals, **7,** 222, 1962.

W. A. Wood, S.McK. Cousland and K. R. Sargant. Metal Fatigue at Small Amplitudes, Illustrated by Copper and Brass under Alternating Torsion. J. Inst.Metals, **91,** 304, 1963.

Materials.

F. P. Bullen and M. M. Hutchison. Solution Hardening in Some Copper-Base Alloys. J. Aust. Inst. Metals, **8,** 33, 1963.

F. P. Bullen and M. M. Hutchison. The Temperature Dependence of Strain-hardening in Polycrystalline Copper. Phil. Mag., **8,** 461, 1963.

A. R. Edwards. The Thermoelectric Anomaly at 35°C. in Chromium. Phil. Mag., **8,** 311, 1963.

A. R. Edwards. The Influence of Grain Size on the Annealing Behaviour of Chromium. J. Less-Common Metals, **5,** 197 (1963).

L. M. Gillin, M. M. Hutchison and N. P. Louat. Solute Locking and the Mechanical Equation of State. Phil. Mag., **7,** 2087, 1962.

M. M. Hutchison. The Temperature Dependence of the Yield Stress of Polycrystalline Iron. Phil. Mag., **8,** 121, 1963.

M. M. Hutchison and F. P. Bullen. Solute-Dislocation Interaction in Copper-Antimony Solid Solutions. Phil. Mag., **7,** 1535, 1962.

S. T. M. Johnstone. Metallurgical Aspects of Future Space Missions. J. Aust. Inst. Metals, **7,** 202, 1962.

H. L. Wain, S. T. M. Johnstone and F. Henderson. The Effect of Rolling Temperature, Pre-Strain and Strain Rate on the Ductility of Chromium. J. Inst. Metals, **91,** 41, 1962.

Miscellaneous.

R. I. Garrod and M. R. Kindermann. Improvements to a Magnetic Vacuum Valve. Vacuum, **12,** 225, 1962.

R. I. Garrod. Ultra-High Vacuum Techniques. Aust. J. Instrument Technology, **19,** 47, 1963.

J. F. Nankivell. The Theory of Electron Stereomicroscopy. Optik, **20,** 171, 1963.

W. W. Wood. The fall of a towed wire. Proc. Roy. Soc. A269, 205 (1962).

D. E. Hooper (Melbourne University) and A. R. T. Turnbull (A.R.L.). Applications of the charge control concept to transistor characterization. Proc. I.R.E. (Aust.), March 1962.

W. J. Morley and J. C. Wisdom. Save on Fuel costs. Australian Mechanical Engineer, November 1962.

I. G. Scott. Some temperature effects on resistance strain gauges. Chapter in book "Semiconductor and conventional strain gauges", edited by Mills Dean 111. Academic Press Inc., N.Y.

STRUCTURES

FATIGUE RESEARCH

Aircraft Structures

Fatigue life assessments of military and civil aircraft claimed increasing effort during the year.

The following structures are under current study:

(a) Vampire:—With the completion of tests to determine the fatigue life of wings with replaced spar booms, the programmed load fatigue testing phase has been concluded. The next aspect of the investigation involves testing under random loads.

(b) Winjeel:—Further calculations, specified by A.R.L., on the fatigue of wings, tailplane, and fin have been carried out by Commonwealth Aircraft Corporation. These results have enabled the safe life to be assessed more accurately.

(c) Cessna:—The analysis of flight tests has been completed and the information necessary for the fatigue tests has been obtained. With the strain gauges used in flight tests still attached, the wing has been removed from the aircraft and is now being fatigue tested under programmed loading in the laboratory.

(d) Dove:—Using dummy centre sections, spar booms were fatigue tested and the first failure occurred at an equivalent life of 6,600 hours. The residual strength of six Dove spar booms containing fatigue cracks was determined experimentally. In two tests, high speed camera recording of crack propagation was successful.

(e) Mustang:—A detailed analysis of the fatigue lives of Mustang wings under programmed, random, random plus ground to air cycle and manoeuvre loading is in progress.

Crack Propagation

The fractographic study of fatigue crack propagation has continued during the year. Electron microscopy is being used to study the damage sustained at different stress levels (Fig. 10). Part of this work was reported at the ANZAAS Congress in Canberra.

Programmed load tests on a few specimens of 2024 aluminium alloy extrusions containing a grooved hole have been carried out. Their purpose was to relate the markings on the fracture surface to the load programme. The results of these tests were inconclusive. Similar preliminary tests have been performed on steel specimens using the Losenhausen pulsator.

In the study of the residual strength of cracked sheet, a review of the application of elasticity theory in the fracture of a tension panel containing a central crack has been completed; a parallel study of the application of plasticity theory in the same problem is in progress. Static testing of aluminium alloy panels with simulated oblique cracks is almost completed.

Fatigue of Materials

The determination of basic fatigue data, necessary to estimate the cumulative damage to aluminium alloys due to complex load sequences, was carried out on aluminium alloys 7178-T6, DTD 363 A, 2 L 65 and 24 S-T. S-N curves were determined, using a mathematical technique, from the results of axial load fatigue tests. Life calculations for simple specimens made of 7178-T6 and of 2L65 have been made.

In the study of the fatigue properties of current aluminium alloys, S-N curves for unnotched specimens of 2L65 aluminium alloy at mean loads of zero and 50% U.T.S. have been obtained thus completing the programme for unnotched specimens. The results show higher fatigue strengths than have been reported elsewhere. As the tests were conducted on a Vibrophore machine, an investigation is being made of the possibility of a "machine effect" on these results. The test programme will now be extended to notched specimens.

The investigation of the variation of fatigue properties of different batches of DTD 363A aluminium alloy has led to the following conclusions:

(i) For materials with U.T.S. between 78,000 and 92,000 p.s.i., the ratio

$$\frac{\text{unnotched fatigue strength at } 10^8 \text{ cycles}}{\text{U.T.S.}}$$

is approximately constant at 0.34;

(ii) For notched specimens within the above range of U.T.S., the fatigue strengths for notches of a given stress concentration factor K_t, are approximately equal at 10^8 cycles;

(iii) Discontinuities have been found in the S-N curves for notched specimens of $K_t = 4.95$.

A study of corrosion fatigue and the effect of protective coatings has commenced with the setting up of a corrosion rack to establish the corrosive effect of the local atmosphere.

The following projects were also completed this year:

(i) The depth of cut of machining unnotched specimens of 2024 and DTD 683 aluminium alloy specimens was shown to have little effect on the fatigue strength;

(ii) Fretting fatigue tests were carried out on DTD 683 using bolted joints;

(iii) Rotating cantilever tests were made on SAE 4130 steel specimens having a circular hole or V-notch;

(iv) Literature surveys on the fatigue properties of welded SAE 4130 chrome-molybdenum steel tubing and of 24 S-T alclad sheet have been completed.

Flight Loads in Aircraft Structures

A joint project for the investigation of high altitude clear air turbulence has been initiated.

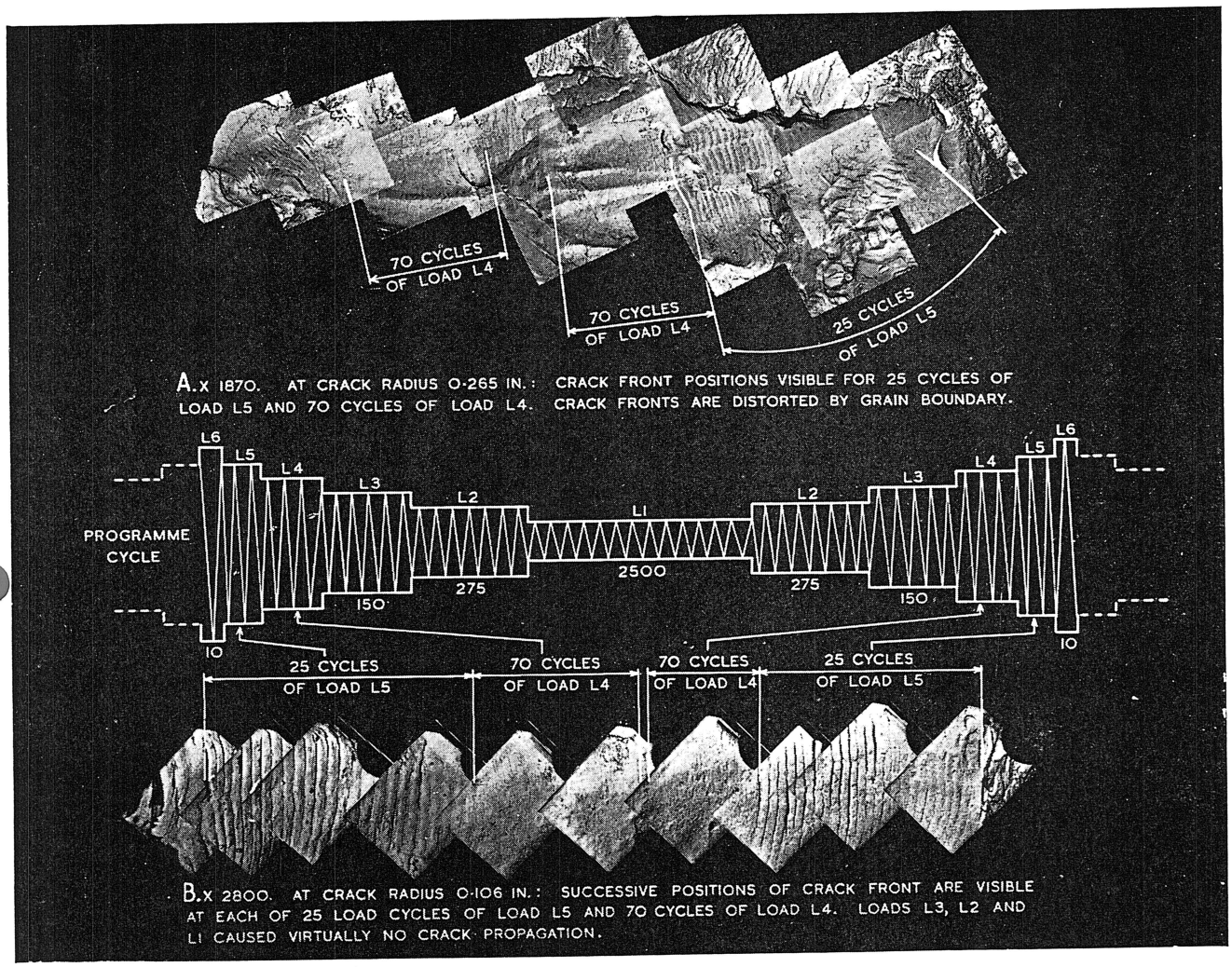

Fig. 10. Electron microscope replicas of fracture surface of fatigue-cracked spar boom loaded in programmed loading.

Planned jointly by R.A.E. (U.K.), A.R.L., W.R.E., University of Melbourne and C.S.I.R.O. Division of Meteorology, it aims at investigating turbulence and its effects in or near the tropopause in the vicinity of Salisbury, Sth. Australia. The flight test programme has been completed and the data obtained are being analysed using the W.R.E. computer.

The collection of flight load data on Neptune, Hercules, Metropolitan, Vampire and Sabre aircraft continued throughout the year. The analysis of data from Viscount aircraft progressed considerably and variation in the spectra with routes and times of the year are being studied.

Investigations on agricultural aircraft were carried out on a Cropmaster aircraft and gust load, gust velocity and manoeuvre load spectra have been calculated for each flight. Further flight tests are being conducted using an instrumented EP 9 Prospector aircraft.

VIBRATIONS AND AEROELASTICITY

Gust Response Analysis

Considerable progress has been made in the theoretical treatment of flexible aircraft response to gusts. A computer programme has been prepared based on the assumption that Küssner lift lag is operative, but Wagner lag is not. An application to an operational transport aircraft is in progress.

Whirl Type Flutter

A digital analysis of a six degree-of-freedom representation of a propeller-engine-nacelle combination has been made for comparison with analogue computer solutions and for the extension of the range of the results. Constant flutter speed contours in the pitch stiffness — yaw stiffness plane for a propeller-nacelle whirl flutter problem have been computed. The representation adopted for analysis is more general than that used hitherto.

Ground Resonance Testing

Research on ground resonance testing using multi-point excitation has proceeded both theoretically and experimentally. In order to derive the natural frequencies and vibration modes of a structure, a new procedure has been devised for the processing of resonance test influence coefficients. The calculations use experimentally determined influence coefficients with associated force and displacement vectors of Venbeke's characteristic phase lag theory. On the

Appendix III.

UNCLASSIFIED PUBLICATIONS ISSUED DURING THE YEAR

Aerodynamics Reports

A.124—A survey of compressible flow boundary layers—Theory and experiment.

H. G. Hornung.

A.125—Evaluation of molecular integrals.

G. W. F. Pike (University of Sydney).

Aerodynamics Notes

A.215—Boundary layer measurements in the A.R.L. hypersonic conic nozzle.

L. T. Banner and M. J. Williams.

A.223—Transonic wind tunnel measurements of the performance of a hemispherical head-incidence-meter.

D. A. Secombe.

A.224—Aerodynamic investigation of the wind loads on a cylindrical lighthouse.

W. H. Melbourne.

A.225—The interaction of an oblique shock wave with an expansion fan.

C. E. Ellen (University of Sydney).

A.226—Oblique shock reflection from a two-dimensional elastic surface.

C. E. Ellen (University of Sydney).

A.227—Hole size effect on measured pressure distribution on a hemisphere cylinder in hypersonic flow.

M. J. Williams.

Aerodynamics Technical Memoranda

A.183—Control surface actuation and direct plotting of hinge moments on models in the 9′ x 7′ low speed wind tunnel.

W. H. Melbourne and A. J. Hooper.

A.185—A dry air supply system for a Mach number 7 wind tunnel.

K. G. Conolan.

Structures and Materials Reports

SM.294—Application of elasticity theory in fracture studies of cracked sheet.

B. C. Hoskin.

SM.295—The fatigue of 24 S-T aluminium alloy wings under random manoeuvre loading.

G. S. Jost.

SM.296—Fitting families of polynomial S-N curves to fatigue data.

D. G. Ford and Jeanette A. Lewis.

SM.297—Some effects of thermoelasticity on the theory of ground resonance testing.

N. B. Joyce.

Structures and Materials Notes

SM.282—The fatigue properties of two casting aluminium alloys containing microporosity.

J. M. Finney.

SM.283—Stress level at the crack front on unnotched rotating cantilever fatigue specimens.

J. M. Finney.

SM.284—A survey of fatigue data on precipitation—hardenable stainless steels.

R. Simpson.

SM.285—Dove wing fatigue test. Interim report No. 3.

D. G. Graff and E. Sipos.

SM.286—Vibration investigation of "Cape" ships.
G. Long, C. M. Bailey, V. Karpowski and B. J. O'Donoghue.

SM.287—A review of the maraging steels.

R. Simpson.

SM.288—Safe life assessment for privately operated Mustang aircraft.

D. G. Graff.

Structures and Materials Technical Memoranda

SM.119—An experimental semi-automatic jig for winding strain gauges.

S. W. Gee.

SM.120—Static and fatigue tests on welded 'deformed' reinforcing bar.

R. B. Douglas, R. A. Fell and R. Simpson.

SM.123—Fracture study as an aid to fatigue evaluation.

J. M. H. Barnard and F. H. Hooke.

SM.125—Static and fatigue tests on prestressing steel bars and couplings.

R. W. Rowan, R. C. Beckett and R. Simpson.

SM.127—Interim report on the fatigue properties of a high tensile notch tough steel.

R. W. Rowan and R. Simpson.

SM.128—A review of the safe life of the De Havilland "Beaver" wing strut attachment.

G. P. Bruce.

SM.129—Proof load tests on glider wing for Beaufort gliding club.

D. G. Graff.

Metallurgy Reports

Met.52—A composite scheme for the analysis of aluminium alloys by atomic absorption spectroscopy.

L. Wilson.

Met.53—Modern concepts of the mechanism of chromium deposition. (A Review.)

N. E. Ryan.

Metallurgy Notes

Met.18—Preliminary observations of the effects of silver additions on the welding of aluminium-magnesium alloys.

J. T. Vietz.

Met.19—The rates of solution of cuprous and cupric oxides.

L. Wilson.

Met.20—Internal nitride precipitation on chromium tantalum alloys during creep.

N. E. Ryan.

Mechanical Engineering Reports

M.E.111—The running of an open cycle gas turbine burning pulverized brown coal with an ash separator.

E. P. Lhuede and M. L. Atkin.

M.E.112—Supersonic intake instability — further investigation on intakes of 25° cone semi-angle at Mach numbers up to 2.14 with and without boundary layer bleed.

D. G. Stewart.

M.E.113—A protracted trial of a coal burning gas turbine with ash separation.

M. L. Atkin and E. P. Lhuede.

M.E.114—The design of a high temperature rig turbine.

L. A. McGee and A. S. Finlay.

Mechanical Engineering Notes

M.E.258—An experimental investigation of a cascade designed for boundary layer suction.

M. Culley.

M.E.259—The stress analysis of a radial flow impellor.

N. S. Swansson.

M.E.261—Gas turbine rotor blade stresses under eroding conditions of operation.

E. P. Lhuede.

Mechanical Engineering Technical Memoranda.

M.E.242—Doxford marine engine vibration investigation M.V. Mittagong and M.V. Wollongong.

L. A. McGee.

M.E.243—Tests of oil buffers for a lift car or counterweight.

E. C. Tremayne.

M.E.244—The thermodynamics design of turbo-blower units for a cold air plant.

L. A. McGee.

M.E.246—A miniature strain gauge force transducer.

E. Raines.

M.E.247—A preliminary assessment of the comparative resistance of chromium and nickel based gas turbine blade alloys to corrosive attack by vanadium.

O. Wilson.

M.E.250—Sulzer marine oil engine 7RD76, No. 40 vibration measurements.

S. G. Kerr and R. W. Jackson.

M.E.251—Determination of the compressor characteristics of a Perkins turbo-super-charger Type T.I. Mk IID.

D. E. Glenny.

M.E.252—Preliminary examination of dust samples from gas turbine pulverized brown coal with an ash separator.

A. R. Nicholas.

M.E.253—Head transfer by impinging jets in a steam condenser tube.

T. S. Keeble and R. G. Hume.

M.E.254—Feasibility study of a vane-type rotary engine.

M. Zockel.

Human Engineering Report

H.E. 3—A study of three pilot operation of a jet transport aircraft.

J. R. Baxter, R. W. Cumming, R. H. Day and N. T. Feather.

Human Engineering Notes

H.E.15—Airline pilot's eye movements during take-off and landing in visual meteorological conditions.

D. Lennox.

H.E.17—Low visibility simulation for pilot training.

J. R. Baxter and R. W. Cumming.

Instrumentation Note

I.63—Sine and cosine function generators for an analogue computer.

K. F. Fraser.

Translation

Trans. 21—Error theory in matrix algebra, by J. M. Souriau and R. Bonnard.

Translated by M. G. Chandivert.

STRUCTURES

RESEARCH IN FATIGUE

Aircraft Structures

The main work in fatigue of structures is still concentrated on investigations for the R.A.A.F. and the Department of Civil Aviation, but a small effort is being devoted to the application of reliability theory to the study of the behaviour of aircraft structures under various operating conditions. In this work, a theory relating the form of the probability distribution of fatigue life under random loading to that under cyclic loading has been developed and is being tested in two ways. The first is by obtaining information on fatigue life reliability from a survey of fatigue data, from both local and overseas sources, on aluminium alloy structures and notched specimens. Analysis of notched specimen data is not yet complete but the results from the structural data are as follows:

(i) For the different load spectra investigated the value of standard deviation is relatively constant ranging from 0.08 to 0.16 for the logarithm of the life.

(ii) The variances in fatigue life for both programmed and random load sequences are similar.

(iii) The variability in life for service failure appears rather less than in laboratory tests but the data are too few for the result to be conclusive.

The second test of the theory is by a programme of experiments, under both cyclic and random loading, on notched aluminium alloy specimens. The random noise testing machine for this latter work, which has been developed at A.R.L., is operating but no results have yet been obtained.

Another aspect of the application of reliability theory follows Freudenthal's (Columbia University) proposal that the acceptable life under fatigue loading can be defined as the life at which the risk of fatigue failure has become equal to the risk of ultimate load failure. This is a quantitative criterion which embraces both fail-safe and safe-life philosophies and is capable of extension to other mechanisms of progressive deterioration such as creep. This approach requires the risk of failure to be predicted as a function of life and a preliminary investigation has been made which indicates that a calculation of the risk of fatigue failure may be possible using representative data on service loads and the residual strengths of structures. Residual strength tests which will contribute to this investigation have been carried out as follows:

(a) **Vampire wings:—**

Residual strength tests have been conducted on four Vampire wings all of which had the same amount of prior damage to fatigue failure of the main spar boom at the second rib from the wing root. The redistribution of tensile load round the failure involved multiple redundancies and it is therefore hoped that the data is reasonably representative of the highly redundant type of structure. The coefficient of variation of the static failing load is 4.2% which is consistent with the representative value of 4.6% established for ultimate strength of undamaged structures in a recent analysis.

(b) **Cracked spar booms:—**

A number of tension booms from the centre-sections of Dove wings have been cracked to varying extents in a vibration fatigue testing rig. Eleven specimens were loaded to failure to provide data showing the variation in strength with the percentage of cracked area. A method for predicting the failed area of the boom from a knowledge of the cracked area was developed and showed good agreement with the test data.

Investigations for R.A.A.F.

A.R.L. continues to be responsible for advice on the fatigue life of a number of aircraft operated by the R.A.A.F., including Neptune, Hercules, Sabre, Winjeel, Vampire, Mirage and Cessna. Work on the Neptune and Hercules is proceeding slowly. It has been found that the safe life of the fuselage of the Australian Sabre aircraft is not covered by the safe life used by the United States Air Force and a more comprehensive investigation of the Australian fuselage has been proposed.

A full-scale fatigue test of the Winjeel wing is under consideration following a preliminary analysis which indicated that the structure may be fatigue critical. Based on a previously published spectrum, a six-load level programme has been designed which includes the landing load to be applied through the fixed undercarriage legs. Flight tests are currently in progress to evaluate strain in fatigue critical areas of the wing, strain at more than thirty stations being recorded.

A hydraulic loading rig has been developed to carry out a fatigue test on the Winjeel fin, which a fatigue investigation indicated could be critical. The fin has been strengthened and a modified fin equipped with strain gauges has been calibrated in the rig before having been fitted to a Winjeel for flight tests by A.R.D.U. The results of these flight tests indicate that the modification may have eliminated the fatigue danger. A fatigue analysis is now being carried out on these data by C.A.C. to check whether the fatigue test is still necessary in view of the modification.

The comprehensive fatigue investigation on Vampire wings has been completed. The safe life of the structure has been established from tests on 16 wings under programmed loading and on two wings under random loading, the two series giving closely comparable results. To extend the safe fatigue life of the structure it has been suggested that the main spar in some aircraft be removed for inspection and replacement if necessary. An inspection technique has been developed for Hawker de Havilland, who

Three aspects have been considered during the year:

(1) A description of the Innisfail Area in Northern Queensland has been produced in conjunction with the Soil Mechanics Section, C.S.I.R.O., and the Army Design Establishment. This area is considered to be similar to certain areas in S.E. Asia, and the description was primarily concerned with physiographic and mobility aspects.

(2) Increasing emphasis is being placed on the mobility of ground forces; it is desirable to be able to predict the performance of vehicles in operational areas, including those which are inaccessible to ground reconnaissance. In addition, a knowledge of the properties and distribution of the various land types would facilitate the design of vehicles having optimum performance in this area. Soil Mechanics Section, C.S.I.R.O., are currently developing a terrain classification system, based on the proposition that the world surface may be described by a limited number of physiographic units which re-occur in similar areas. From a knowledge of the properties of units which are accessible for measurement, predictions may be made of the properties of similar units in inaccessible regions. To date, this work has been concerned primarily with engineering resources; this must now be extended to cover mobility aspects. At A.R.L. an examination has been made of the means by which this can be accomplished, and two aspects are at the reporting stage:

   (a) A review of terrain factors and vehicle characteristics, and their interactions as they effect the perfcrmance of a vehicle in natural terrain.

   (b) A discussion of the way in which these mobility aspects may be incorporated into the terrain classification system.

(3) An operational research study is being considered, whose aim is to determine the requirements for ground vehicles in the future.

AD HOC INVESTIGATIONS

Goblin Engine Investigation

Following an increasing incidence of reports of abnormal noises and vibrations originating from the Goblin engine in Vampire aircraft, an extensive investigation of the characteristics of this jet engine was undertaken at the request of the R.A.A.F. Comprehensive measurements were made both in flight and on the ground of engine and airframe vibrations, pressure fluctuations in the gas stream, and noise level in the cockpit. At the same time, an analysis of the mechanical and thermodynamic operation of the engine was made to assist in interpreting the measured results, and in determining the cause of the various engine vibrations. It was shown that the overall level of vibration is quite low and is not likely to lead to mechanical failure of the engine or accessories. While a satisfactory explanation of the nature and source of excitation of all vibrations present was not found, the results so far have provided justification for the R.A.A.F. to continue flying operations under certain conditions.

Further detailed work is proceeding in order to locate the origin of the unexplained disturbing noises.

A major effort was devoted to a determination of the causes of high failure rates of the combustion system. Initially, these failures were attributed to excessive flame tube temperatures, and a combustion rig was set up to measure temperatures under accurately simulated operating conditions. These measurements, and the results of metallographic examination of sections of a damaged flame tube, have shown that metal fatigue and not excessive temperature, is the prime cause of failure. The cause of fatigue was traced to a high level of pressure pulsation in the airflow reaching the combustion chambers; the frequency of the pulsations of the 17th order harmonic of engine speed.

A freely mounted flame tube, when mechanically shaken, exhibited resonant vibration in modes likely to cause failures of the observed type, at frequencies corresponding to engine speeds within the service operating range. The combustion rig has therefore been modified by the addition of a motor driven pulsation wheel (Fig. 23) which produces pressure pulsations of the required amplitude, at closely-controlled frequencies, in the airstream entering the combustor. Using a vibration probe at critical areas of the flame tube, the vibration characteristics have been determined over the complete range of engine operating speeds; several speeds giving resonant excitation of the tube have been found. Prolonged running at one such speed has produced typical crack damage in several sections of the tube. Present work is concerned with the efficacy of certain techniques of flame tube mounting; tests are to be made of various methods of stiffening to modify the resonant vibrations.

Bird Strikes on Aircraft Engines

The incidence of bird strikes in R.A.A.F. engines is currently causing concern, and a limited survey of existing and possible methods of engine protection was conducted; some earlier A.R.L. work on intake debris guards showing promise of a particular solution to the problem was published.

Underground Tunnels

Problems of communication, detection and ventilation of typical tunnels have been examined, and some experimental equipment has been designed and tested for the Army.

Rabbit Extermination

At the request of the Victorian Department of Lands an afterburner has been developed for fitting to diesel tractors to render the exhaust sufficiently toxic for rabbit fumigation. The burner had to meet a number of unconventional design criteria, including operation with varying degrees of oxygen vitiation, a wide range of inlet temperatures up to 600° C., an over-rich mixture throughout, the ab-

sence of any "cooling" air, and a simplicity of operation and ruggedness appropriate to all-weather farm usage.

At first the unit was designed to utilise the diesel fuel conveniently available in the tractor. This gave adequate toxicity, but when applied to the "Rabication" method of foam fumigation the surfactant action of unburnt fuel traces lowered the stability of the foam. Hence the burner was re-designed to use a separate small supply of alcohol as fuel. Field trials using the afterburner and alcohol as fuel were conducted by the Department of Lands; these proved most satisfactory, no rabbits surviving in the very large warren treated.

TEST FACILITIES

Supersonic Propulsion Facilities

A preliminary calibration of the Mach 1.6 Propulsion Tunnel has been carried out. Although flow uniformity in the working section is quite good (the maximum velocity deviation is 1%), some flow unsteadiness, excessive pressure loss and lack of temperature uniformity have necessitated careful examination of the airflow between compressor and tunnel. Beneficial modifications have already been made and a full calibration will be carried out when these are complete.

Construction of the new Supersonic Propulsion Test Facility (No. 6 Engine Test House) has commenced and tenders have been called for the high pressure storage system. Thermodynamic design of the pebble bed heater system has been completed and detailed design of this and of other equipment is in hand. In the course of this work some general data on the design of pebble bed heaters has been consolidated.

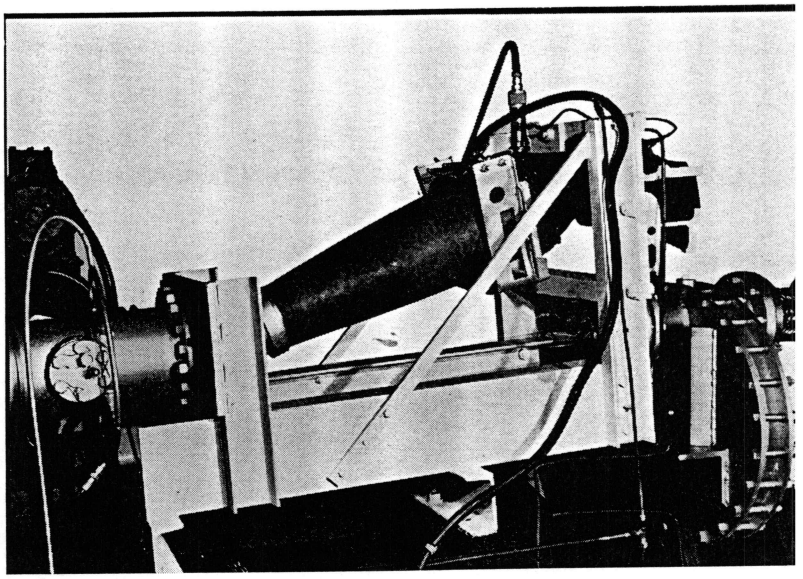

Fig. 23. Goblin flame tube vibration rig showing pulsation disc in air supply line.

Impeller Spin Test Rig

In support of a theoretical investigation of the elastic stresses in unsymmetrical impeller discs, an 80,000 r.p.m. spin test rig, for the mechanical testing of discs and impellers has been built, and preliminary tests conducted.

Cold Air Plant

The first stage air cooling unit for the cold air plant has been assembled (Fig. 4) and has undergone initial tests. Some errors in manufacture led to a cooling performance somewhat less than the design values; redesign of bearings and air seals has also been found necessary. Major components of the plant, including drier shells, piping and valves have been ordered.

Appendix III.

UNCLASSIFIED PUBLICATIONS ISSUED DURING THE YEAR

Aerodynamics Reports

A.126—D. A. Lemaire, Some Observations of the Low-speed Flow over a Sharp-edged Delta of Unit Aspect Ratio, January 1965.

Aerodynamics Notes

A.233—A. E. Hodges and T. N. Pound, Further Development of a Smoke Producer using Vapourised Oil, November 1964.

A.235—W. H. Melbourne, Low Speed Wind Tunnel Tests on the Victa Aircruiser 180, January 1965.

A.238—T. H. Trimble, A Wind Tunnel Investigation of the Airflow around a Tall City Building, January 1965.

A.240—W. W. Wood, Some Linear Equations in Infinitely Many Variables, February 1965.

A.242—G. W. F. Pike, Number Density in a Populated System, Part II: The Helium Plasma, May 1965.

A.243—G. F. W. Pike, Thermodynamics and Aero-Physical Properties of High Temperature Mixtures of Reacting Gases, Part I; A General Theory, Part II: The Helium Plasma, May 1965.

Structures and Materials Reports

SM.299—R. W. Traill-Nash and M.C. Chandivert, A Method for the Estimation of Gust Loads in a Flexible Aircraft, January 1965.

SM.303—R. W. Traill-Nash, C. M. Bailey and G. Long, An Experimental Determination of the Complete Dynamical Properties of a Two - Degree - of - Freedom Model having Nearly Coincident Natural Frequencies, July 1965.

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SM.292—B. P. Holownia, Buckling of Cylindrical Shells under Wind Loading, August 1964.

SM.295—R. B. Douglas and R. Simpson, Fatigue Tests on Vapour Blasted and Grit Blasted 2L-65 Aluminium Alloy, December 1964.

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MET.23—T. Mills and T. G. Hill, Effect of Air Exposure at Temperatures up to 1400°C. on Chromium Base Alloys, December 1964.

MET.25—L. Wilson, The Determination of the Solubility of Magnesium Oxide in various Solutions by Atomic Absorption Spectroscopy, April 1965.

MET.26—J. F. Nankivell, Determination of Directed Distances in Objects Examined in the Electron Microscope, July 1965.

MET.27—I. J. Polmear, The Development of an Aluminium-Magnesium Casting Alloy containing Small additions of Silver, July 1965.

MET.28—N. E. Ryan, The Formation Stability and Influence of Carbide Dispersion in Chromium, October 1965.

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M.E.262—D. R. Warren and M. Zockel, Australian Interest in the Future of the Small Prime Mover, August 1964.

M.E.264—D. G. Stewart and Belinda Harrison, Interference Effects on Multi-engine Supersonic Aircraft, November 1964.

M.E.265—R. Licciardo, A Debris Guard for Turbine Engines, February 1965.

M.E.266—G. F. Pearce and O. Wilson, Flow Investigation of Two Dimensional Baffle Systems for Combustors, April 1965.

M.E.267—D. G. Stewart and S. A. Fisher, Some Observations of Boundary Layer Transition on Curves at Subsonic and Supersonic Speeds, May 1965.

M.E.268—A. R. Oliver, Voriticity Distribution in a Laminar Boundary Layer, August 1965.

M.E.270—W. J. Morley, Pressurised Combustion Pot Tests of High Volatile Bituminous Coal, July 1965.

Flight Notes

F.37—R. S. Trayford and E. C. Tremayne, Spanwise Pressure Loading on the Cessna 180 Aircraft, August 1965.

Appendix IV.

EXTERNAL PUBLICATIONS

J. H. Auld, J. T. Vietz and I. J. Polmear, T-phase Precipitation induced by the addition of silver to an Aluminium-Copper-Magnesium Alloy, Nature **209**, 703, 1966.

C. Baker, L. M. Gillin and A. Kelly, Twinning in Graphite, Proc. 2nd International Conference on Industrial Carbon and Graphite, Society of Chem. Industry, London, 1966.

Burns, A.,* Rider, C. K., Project Topcat — power spectral measurements of clear air turbulence associated with jet streams. R.A.E. Technical Report No. 65210, Sept. 1965.

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Dalton**-Morgan, T., and Rider, C. K., Report on the conduct of clear air turbulence trials in Australia, July-October 1963, W.R.E. Report TRD 18, Jan. 1966.

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G. A. Hawkes, The Effect of Microstresses on the Stress-Corrosion Properties of the Aluminium Alloy D.T.D. 5044, Brit. Corrosion Journal **1**, 244, 1966.

E. L. Hilgendorf, Information input and response time, Ergonomics, Vol. 9 No. 1 January 1966.

F. G. Lewis, The Corrosion of the High-Strength Aluminium Alloys, Aust. Aeronautical Research Committee Report ACA-65, 1965.

F. G. Lewis and D. W. Glanvill, Corrosion and Protection of Aircraft Structures made from High-Strength Aluminium Alloys, Australasian Corrosion Engineering, **9**, Nov. 1965.

K. F. Lorking, Inhibition of Corrosion of Copper in Chromic Acid, Nature **208**, 778, 1965.

K. F. Lorking, The Effect of Alloying Elements on the Corrosion of Aluminium, Australasian Corrosion Engineering **9**, Oct. 1965.

K. F. Lorking and J. E. O. Mayne,*** The Corrosion of Aluminium in Solutions of Sodium Fluoride and Sodium Chloride, Brit. Corrosion Journal **1**, 181, 1966.

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Wendy McGill, Population Expectancies and Traffic System Design. Australian Road Research Vol. 2 No. 7 March 1966.

J. F. Nankivell, Determination of Directed Distances in Objects Examined in the Electron Microscope, Optik, **23**, 505, 1966.

A. O. Payne, Reliability approach to structural airworthiness, Aircraft **45**, p. 16 (Oct. 1965).

I. J. Polmear, Tensile Properties of Modified Aluminium-Zinc-Magnesium Alloys containing Silver, J. Inst. Metals **94**, 36, 1966.

I. G. Scott, A course in resistance strain gauging Australian Journal of Intrument Technology (Nov. 1965-Aug. 1966).

A. P. Vulcan, To Soften Impact, letter to the Editor — Chartered Engineer, p. 24 (Feb. 1966).

A. P. Vulcan, Motor Vehicle Seat Belts — A review of the relative merits of the various types, Journal of the Australian Road Research Board (June 1966).

R. A. Wallis and N. Ruglen — On the aerodynamics of Hangar type engine test facilities. J.Roy.Aero.Soc., February 1966.

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L. Wilson, "The Determination of Cadmium in Stainless Steel by Atomic Absorption Spectroscopy", Anal. Chimica Acta **35**, 123, 1966.

* Royal Aircraft Establishment, Farnborough, U.K.

** Weapons Research Establishment, Salisbury, S.A.

*** Cambridge University, U.K.

Appendix V.

LECTURES GIVEN DURING THE YEAR

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D. W. Glanvill, Design and Construction of Ultrasonic Probes, D.C.A. Course on Ultrasonic Flaw Detection, June 1966.

W. N. Hurst, The Mathematician in Operational Research, Education Students, Monash University, August 1965.

D. Lennox, The pilots task while low flying. Second Australasian Ergonomics Conference, Monash University, September 1965.

F. G. Lewis, Corrosion of High-Strength Aluminium Alloys, Royal Aeronautical Society, Melbourne Branch, August 1965.

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Three unusual factors had to be taken into account during the strain gauging of the wing; (a) some strain gauge positions were inside the fuel tanks so that the gauges had to be protected from kerosene, (b) the structure is subject to aerodynamic heating, and finally, (c) many of the gauges had to be attached before final assembly of the major components.

Besides strain, the instrumentation had to measure and record temperature, deflection, pressure and acceleration, with a total of 101 transducers. In the first stage there were 42 flights.

The fatigue lives of other parts of the aircraft remain to be found and additional data for these will be collected in the second stage of flight testing, which will include a gust probe, (see atmospheric turbulence). In this second stage the number of transducers has been increased to 126, the output of which will be recorded on a newly developed magnetic tape system in the aircraft. This analogue system incorporates a six-track six-pass multiplexer with photoelectric switching which is coupled to timing, encoding and control circuitry. For reproduction a synchronous pulse detector is connected to an analogue-digital converter which will be on-line to the digital computer.

The data reduction programme includes automatic calibration of strain gauges by standard signals applied during flight and the monitoring of system performance. A "quick-look" facility is being developed to demultiplex analogue readings and allow qualitative inspection of selected channels.

A very interesting sidelight of the project was the satisfactory use of photo drawing techniques to produce assembly drawings for inspection authorities. Photographs were taken stage by stage in the assembly of the hardware, they were then reproduced on a drawing format and the necessary notes and instructions added. By using this system, drawings of a complex instrument pack were completed in one week. By using normal drawing methods the time involved would probably have exceeded four weeks.

Other Work for the R.A.A.F.

In the light of improved load spectra and a joint test, Winjeel fatigue life estimates for different areas were reviewed and safe lives were increased. Some over-age and damaged wings were stripped and inspected and there was no visible fatigue damage. Our report on a programme test of an outboard wing joint is ready for publication. Draft reports have also been completed detailing estimated safe lives for Vampire and Cessna 180. Three other aircraft investigated were the Canberra, Sabre and Hercules. Analysis of gust data for the first is almost complete while Commonwealth Aircraft Corporation is estimating lives for the others.

Material Fatigue

A report giving the alternating-stress mean-stress diagram for Cr-Mo welded steel tube is in press; it shows that the fatigue strength is very low even when compared with that of other welded specimens. Tests to determine the residual strengths of cracked tubes are in progress.

During an investigation into the effects of specimen thickness on crack propagation when the specimen is subjected to periodic high loads, we found that the delay in propagation was dependent upon the continuity of the periodic loading — an unexpected result. The usual effect is that when a reduced alternating load immediately follows a high load there is a delay in crack propagation. However, when we stopped the test overnight and restarted the following day at the same alternating load, propagation continued almost immediately. Further tests are at present in progress to determine whether this immediately continued propagation is the result of time lapse or intermediate unloading.

Other investigations into the fatigue of materials have included a survey of the relation between fatigue and ageing behaviour of aluminium alloys, rotating cantilever tests on the effect of initial rate of loading on endurance and the effect of shapes of stress concentration on the fatigue properties of SAE 4130 steel. We have also determined the fatigue properties, of notched specimens of the standard aircraft alloys 2L65 and 7178 under axial load, and cast aluminium alloys with silver additions. Some tests were also carried out on $1\frac{3}{4}$ inch thick welded steel plates.

Cumulative Damage and Life Distribution

The current survey of cumulative damage theories and extensions to these have highlighted three main facts:

(a) Many of the theories advanced are disguised forms of the well known "linear" rule suggested by Palmgren and later extended by both Langer and Miner.

(b) Other theories are unusable without supporting variable-amplitude tests so that they are not genuinely predictive.

(c) Most theories can also be cast in the Bastenaire differential form, indicating that the majority are based on one-parameter damage.

Following earlier work on reliability, a numerical method has been obtained for evaluating the risk function in fatigue. Parameters for crack growth and residual strength are used in a form derivable from results of full scale tests. The method will be tested in cases for which data are available.

Some years ago we embarked on a programme to furnish information about the probability distributions of fatigue lives under random loading, particularly at the lower tail of the distribution, and to study the prediction of life distribution from distributions of lives under loading of constant amplitude. For these purposes a random noise fatigue machine was constructed which could also apply constant loads. This has now been dynamically calibrated and automatic control equipment has been installed to allow overnight running. Establishment of the constant amplitude S-N curves is still proceeding but there is some evidence that the life distributions of the aluminium alloy selected for the work are bimodal. More tests have been planned to investigate this effect.

novel combustion problems associated with this concept, and on methods of obtaining high efficiencies from the turbine under fluctuating flow conditions.

Goblin Engine Investigations

The examination of certain problems encountered in the Goblin Mk 35 engine fitted to the Vampire Aircraft, and outlined in the last annual report, has continued during the year.

The investigation of the reasons for an unacceptably short service life of the flame tubes has now been concluded. Early work showed that this was the result of very severe fatigue conditions due to large pressure pulsations in the airflow leaving the compressor impeller. The pulsation was the 17th order harmonic of engine speed, due to 17 impeller vanes, the frequency being 3045 Hz at take-off rating. Extensive combustion rig tests, in which these pulsations were reproduced, showed that the flame tubes had multiple resonant modes of vibration at the pulsation frequencies generated in the normal engine operating speed range. Each nominally similar flame tube tested had differing response characteristics, some having negligible response in the speed range above and including maximum continuous speed, while others had several severe resonances leading to rapid failure in the same speed range. Resonance testing on a shaking table, using an extremely resonant flame tube, and one with negligible response showed generally similar resonance characteristics in the various sections of both flame tubes. The difference in overall response was probably due to variations in the mode of coupling the component resonances, which varied the energy dissipation between modes.

Rig tests were made with experimental builds intended to modify the resonance pattern, including sprung mountings and shot filled damper pouches welded to the flame tube head. The most satisfactory modification was the fitting of a simple conical outer skin over the conical head skin of the flame tube, with plug welds at frequent intervals; this removed all resonances in the flame tube head and the primary zone wall. The modified flame tube is shown in Figure 23, while the resonance characteristics before and after modification are shown in Figure 24.

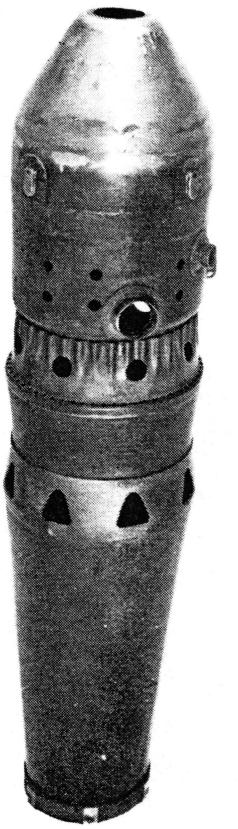

Fig. 23 Goblin flame tube with stiffened head section.

The disturbing medium frequency noise (about 95

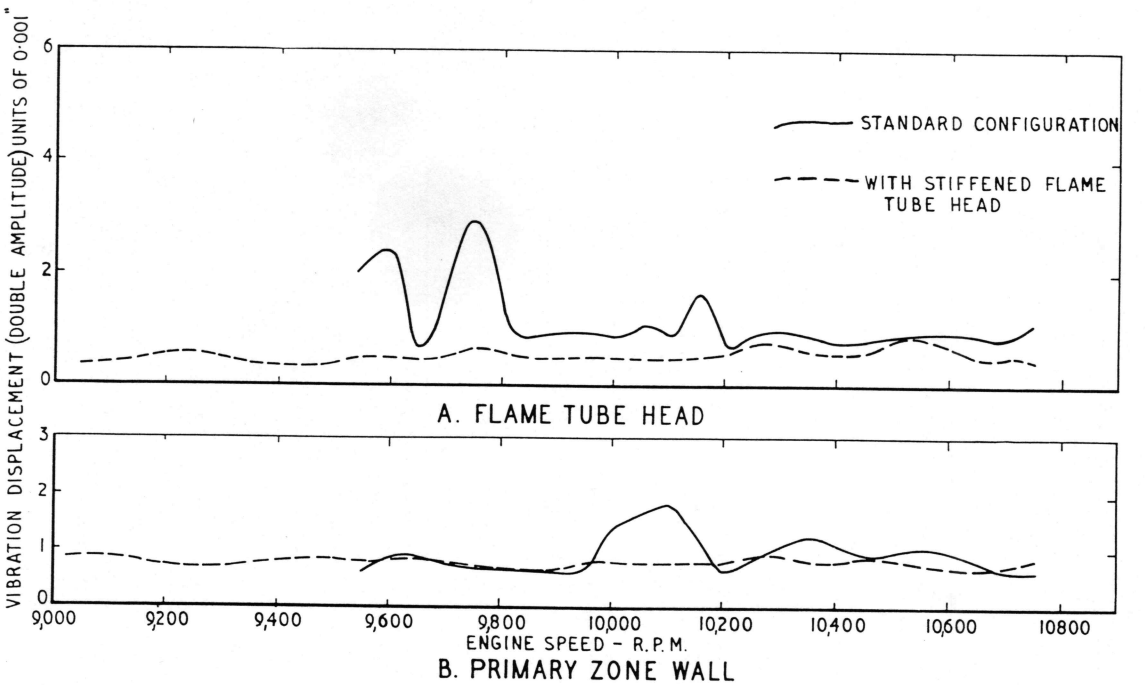

Fig. 24 Goblin engine flame tube-vibration resonance characteristics before and after modification.

Hz) which has appeared in many overhauled engines was, at an early stage, thought to be combustion rumble, since combustion rig tests had shown a considerable tendency to combustion instability at altitude conditions. However, when a full set of modified combustors, previously shown to be free of this instability, were fitted to a "noisy" engine, there was no apparent improvement. Extensive flight testing with pressure measurement in combustors and in the compressor diffuser passages has shown that an extensive flow instability in the diffuser passages sets in when the engine exceeds a certain corrected speed at altitude. This instability commences almost simultaneously in two diffuser passages on opposite sides of the engine, and quickly develops to form an ordered disturbance travelling around the engine in a direction opposite to engine rotation. The frequency appears to be the natural "organ-pipe" frequency of the diffuser-combustor combination from diffuser inlet to choked nozzle guide vanes. The cause of the instability is not yet understood but it may be due either to inlet flow maldistribution, or mismatch of the diffuser vanes to the airflow angle in the vaneless space.

The two diffuser areas in which the disturbance originates appear to be related to the two-lobed air flow distribution through the engine, which results from the bifurcated intake. An air intake and duct system from a Vampire aircraft has been mounted in an open jet wind tunnel (Fig. 25) to investigate the engine inlet flow distribution, using flow visualisation techniques and the direct measurement of velocity. Preliminary results show some surface flow separation in the duct, and vortex type disturbances extending to the impeller face. It is hoped that the stability may be restored by modifications to improve the uniformity of the inlet flow distribution.

In parallel with this, preparations have been made to measure directly the angle of air flow in the compressor vaneless space, to determine whether the diffuser vane angles are matched to the air flow direction.

Combustion of Residual Fuel

The study of the combustion of residual fuels has continued, partly in view of their possible use in industrial and marine gas turbines, but also to gain experience in view of a possible trend to the aeronautical use of heavier grade fuels. The field of application of the combustion systems developed in these Laboratories has been extended to a preliminary investigation of their use in a standard test rig for the evaluation of boiler fuel additives. Boiler tube fireside deposits from residual fuel are a constant problem to the Royal Australian Navy and other marine operators; this investigation may lead to a standard test for anti-fouling additives and may also indicate a way to combustion improvements in service through introduction of more modern combustion systems.

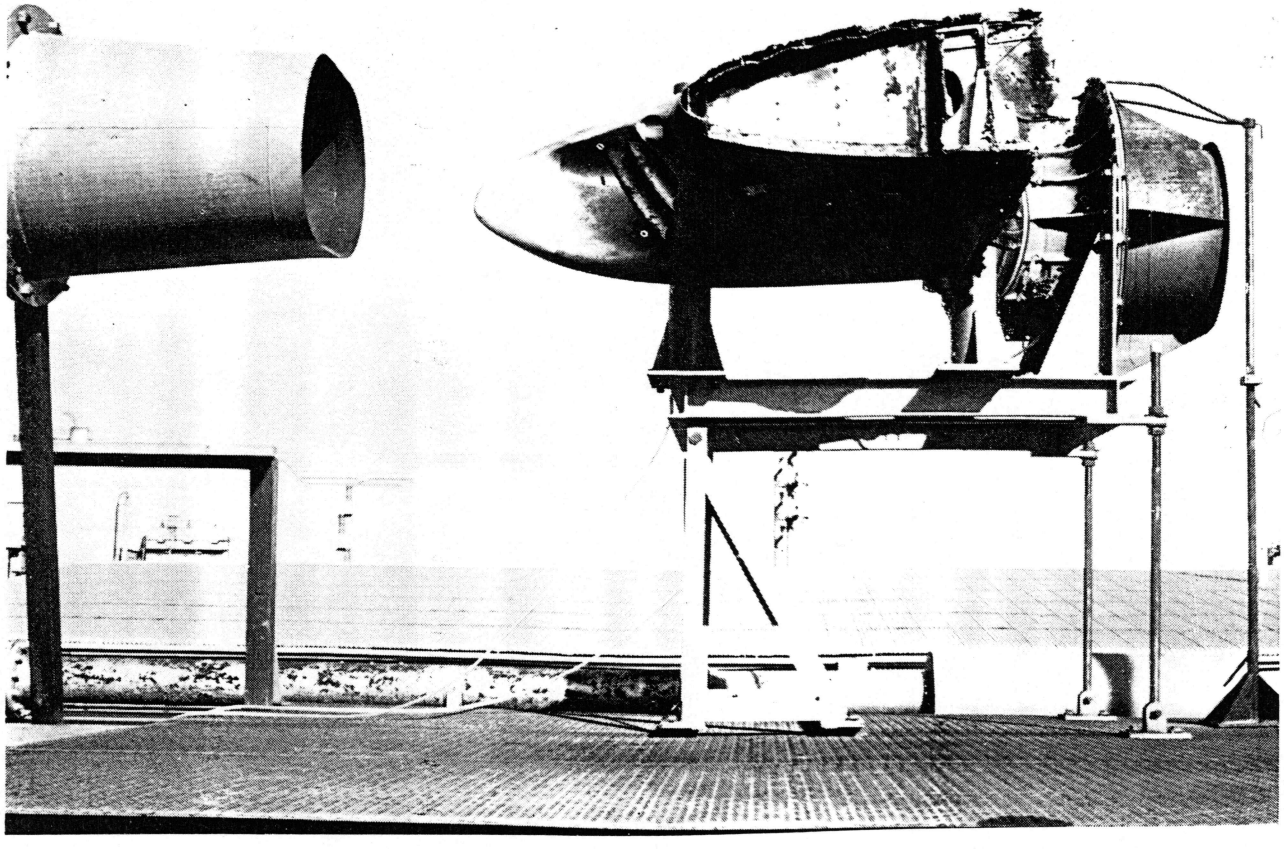

Fig. 25 Aerodynamic test rig for investigation of the flow of air through the intake to a Goblin engine.

Crash and Defect Investigation

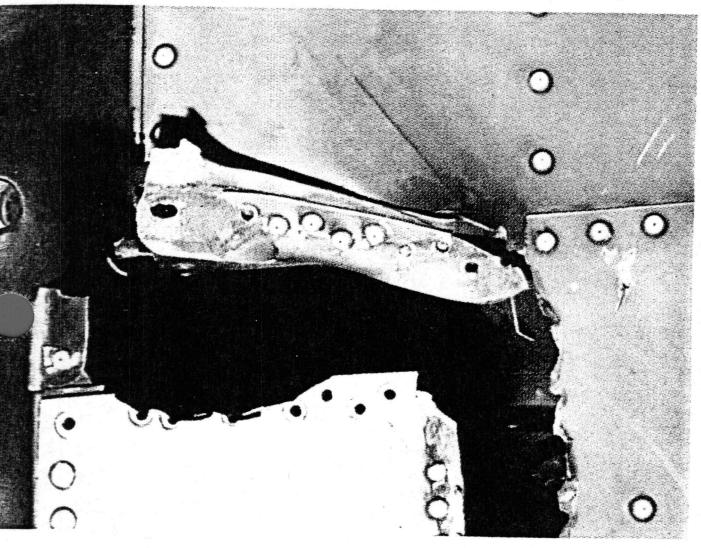

Fig. 26 Fatigue failure of aircraft sheet metal assembly.

A.R.L. Accident Investigation Panel

The A.R.L. Accident Investigation Panel was formed eleven years ago and currently consists of six officers. The panel may be requested by the Department of Civil Aviation or one of the Services to act as consultants and/or make investigations on matters which call for the special facilities or skills of A.R.L.

During the year a fatal accident to the service aircraft, Winjeel A85-416 was investigated. The wing of this aircraft failed in flight and was brought here for examination; the weather conditions, which contributed to the accident, were analysed in detail. An incident involving another service Winjeel, A85-426, is currently being investigated.

Defect Investigations

A very large number of metallurgical investigations on components and materials from service and civil aircraft were undertaken during the year, including work connected with seven incidents and accidents. The major fields of activity on service aircraft concerned corrosion and stress-corrosion damage to skin panels, spar booms and other structural members, and the wide application of ultrasonic testing. We developed an ultrasonic technique for the detection of cracking in compressor blade roots without removal of the blades from the discs. This gave a major saving in inspection costs and has been adopted as a standard factory procedure.

Most of the failures we investigated in non-service aircraft resulted from fatigue in such items as airscrew components, landing wheels, skin panels (Fig. 26) and various auxiliary fittings. However, corrosion damage was well in evidence, ranging from exfoliation in wing structures to stress-corrosion in stainless steel hydraulic lines and extruded light-alloy sections.

We gave training courses, mainly on techniques of non-destructive testing, to technical personnel at various R.A.A.F. stations throughout Australia.

Crash Safety

In aircraft or ground vehicle crashes, deceleration forces on the occupants can be attenuated by energy absorbing restraints. For the design of restraint systems a mathematical model has been developed which uses optimum decelerations compatible with structural strength and human tolerance. A report has been issued on the attenuation of vertical forces and work has proceeded on restraint systems for attenuating longitudinal acceleration. An energy absorbing device which could be incorporated in such a system was developed during the year.

The design requirements on crash helmets are being studied theoretically with support from a literature survey. Crash helmets can give considerable head protection but to offer optimum performance the design must be compatible with head tolerance. The present study will be followed by tests and it is hoped that more rational specifications can be found.

Appendix II
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A.259 P. G. Baines, Iteration of Oseen's Equation for a Circular Cylinder, January 1966.

A.262 G. W. F. Pike, Some Elastic Collision Processes Involving Excited s-State Atoms, March 1966.

A.263 P. G. Baines, Inviscid Fluid Motion Inside a Rotating Circular Cylinder, April 1966.

A.264 L. F. O'Brien, Force Measurements on the Short Span Jindivik Target Aircraft Fitted with Mk. VI Pod, April 1966.

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A.268 D. C. Collis and M. J. Williams, The Effects of Aspect Ratio on Convective Heat Transfer from Fine Wires, May 1966.

A.270 R. J. Griss and A. W. Scott, Wind Pressure Measurements on a Model of the Proposed Adelaide Festival Hall, June 1966.

A.272 A. S. Bennett, Transonic Wind Tunnel Tests of a Model 1000 lb. C7 Bomb, May 1966.

A.284 T. H. Trimble, Some Measurements of the Effect of Mounting Configurations on the Lift and Pitching Moment Measured on an Aeroplane Model in a Subsonic Wind Tunnel, February 1967.

A.285 R. W. Thompson, A Versatile Pressure Recording System, February 1967.

A.287 H. G. Hornung, Hypersonic Flow over Power-Law Bodies in the Newtonian Limit, March 1967.

A.288 H. G. Hornung, Inviscid Hypersonic Flow over Axisymmetric Power-Law Bodies, May 1967.

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SM.312 M. G. Chandivert, Some Considerations on Unconventional Flight Techniques using Small Aspect-Ratio Wings, March 1966.

SM.314 J. M. Finney, A Review of the Discontinuity or Hump Phenomenon in Fatigue S/N Curves: Theories and Further Results, March 1967.

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Met.61 S. McK. Cousland, A Study of Strain Hardening in Copper Single Crystals, September 1966.

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Met.48 K. F. Lorking, The Effect of the Anion and Solution pH on Anodic Processes and Corrosion of Iron, October 1966.

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M.E.288 A. Runacres and D. G. Stewart, The A.R.L. Supersonic Propulsion Test Facility — Thermodynamic Design of Regenerative Heat Exchanger, March 1967.

M.E.289 M. J. McIntosh, Erosion of Particle Impact — A Literature Survey of some Experiments and Theories, August 1967.

M.E.290 Clare Burrage, A Computer Programme for the Thermodynamic Design of Regenerative Pebble Bed Heat Exchangers, December 1967.

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F.41 R. S. Trayford, Flight Load Spectra and Strain Prediction Equations for Ceres Aircraft, March 1967.

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I.64 K. F. Fraser, Electronic Aspects of a Four Channel Tape Recorder for use in Missile Data Acquisition, April 1966.

I.68 J. F. Harvey, Printed Wiring Using the Xerographic Method, February 1967.

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H.E.6 B. H. Tritt, Simulation of Low Visual Ranges in Flight, March 1967.

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H.E.19 E. Linden Hilgendorf, Information Processing, Practice and 'Spare Capacity', May 1966.

H.E.23 W. P. Austin, C. Cameron, R. W. Cumming, D. Lennox and Constance Moffitt, Aircrew Fatigue in International Jet Transport Operations, January 1968.

H.E.24 C. Cameron, A Questionnaire Study of Fatigue in Civil Aircrew, January 1968.

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24 Patricia Callaghan, edited by M. Culley, Wind Tunnel Tests of the Intake of Mirage Determination of Engine Matching Law, January 1966.

25 SM N. B. Joyce, Enclosure Theorems for the Eigenvectors of Normal Matrix-Pairs, (by S. Falk), March 1966.

26 SM M. G. Chandivert, The Principles of Structural Global Vibration Tests, (by Gerhard de Vries), October 1966.

27 SM M. G. Chandivert, Experimental Procedures for the Global Vibration Test of a Structure (by Christian Beatrix), December 1966.

28 SM M. G. Chandivert, The Analysis of the Responses of a Mechanical Structure in Global Vibration Tests (by G. de Vries), October 1967.

the shell analysis, and the dynamic equations can finally be solved by programming a computer.
Supporting the theoretical analysis, we are making experimental vibration measurements on a compressor blade; the object is to investigate the effects of pin clearance, centrifugal stiffening, and change in the aerofoil profile of the blade resulting from rework. A pulsed air exciter is used and centrifugal loads are simulated by tensioning the blade. Natural frequencies are determined by strain gauges fixed to the blade, and corresponding mode shapes observed by a novel application of the shadow moiré fringe technique.

GOBLIN ENGINE INVESTIGATION The investigation of medium frequency noise and vibration in overhauled Goblin Mk35 engines, which we reported last year, has been completed. the earlier diagnosis of flow instability in the compressor has been confirmed by in-flight measurement of velocity profile and pulsation phasing in diffuser passages, (Fig. 31) and of the angle of flow approaching the diffuser lips (using a cylindrical two-hole yaw probe in the vaneless diffuser space). This proved that the diffuser lips were receiving flow at the correct angle and that the pulsation did not originate in the diffuser passages. Technical literature in recent years has contained limited reference to rotating instability in the vaneless space of centrifugal compressors, particularly where the ratio of radial to tangential velocity is low (as in the Goblin compressor) and the radial width of the vaneless space large. It appears therefore that the instability occurring in certain overhauled Goblin engines has been the result of modification during overhaul of the diffuser and impeller, leading to increased radial width of the vaneless space.
The observed initiation of the instability on two opposite sides of the compressor is probably due to the two lobed air distribution from the bifurcated air intake. An intake test rig was used to develop a system of vortex generators in the intake duct to control flow separation and reduce the inlet of flow maldistribution, but the arrangement was less effective in flight, and limited flight tests did not show reduced compressor instability.

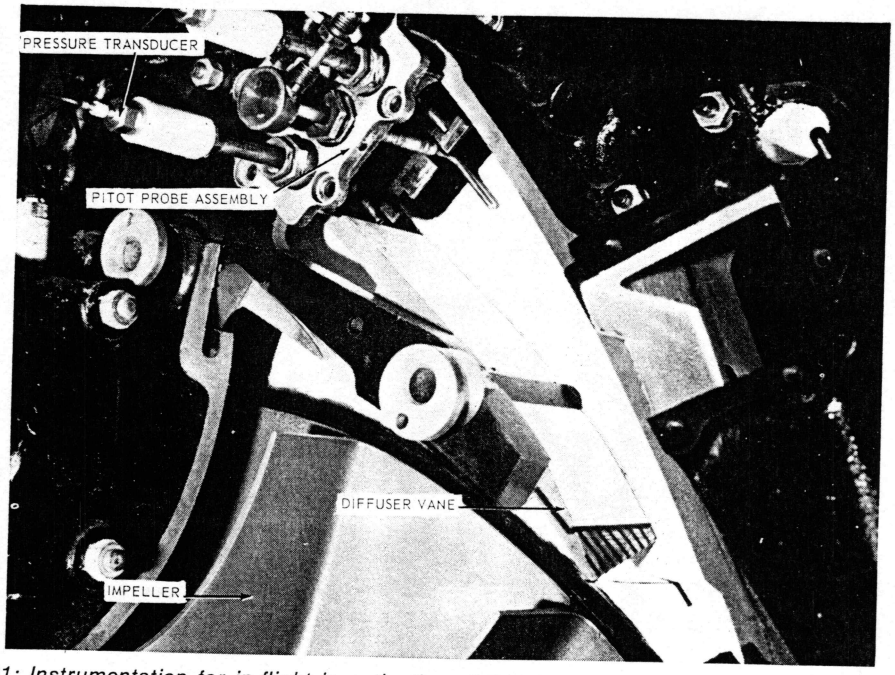

Fig. 31: Instrumentation for in-flight investigation of flow in Goblin engine diffuser passages. (Mounted in display engine.)

Appendix II

UNCLASSIFIED PUBLICATIONS ISSUED DURING THE YEAR

AERODYNAMIC REPORTS:

A.130 *H. G. Hornung* and *I. A. Campbell,* An Experimental and Numerical Study of Hypersonic Flow over Power-Law Bodies, March, 1968.

A.131 * *L. E. Reece,* A Comparison of Pressure Fields Generated by Continuous and Discontinuous Bodies in Supersonic Flow, August, 1968.

A.132 *D. A. Secomb,* Comparison of Bomb Stability Data at Transonic Speeds from Several Wind Tunnels and Free Flight, September, 1968.

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A.289 *K. A. O'Dwyer,* Low Speed Wind Tunnel Tests to Investigate Power Plant Intake Performance and Static Longitudinal Characteristics of the G.A.F. Project F.2., June, 1967.

A.294 *M. J. Walker,* Aircraft and Support Budget Allocation and Optimization, January, 1968.

A.297 *S. Pelczynski,* An Extension of Koenigsberg's Cyclic Queues, April, 1968.

A.298 *A. D. McEwan,* Shock Wave Intensification through a Shaped Contraction, April, 1968.

A.299 *M. J. Williams,* Static Pressure Hole Errors on Four Simple Shapes in Hypersonic Flow, May, 1968.

A.300 *N. Pollock,* The Behaviour at Subsonic Speeds of a Mirage III 0 Pitot-Static Probe Mounted Close to a Hyperbolic Headed Gust Probe, May, 1968.

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SM.318 *M. B. Benoy, F. E. Verinder* and *T. S. Maddock,* Fatigue Tests on the Cessna 180 Wing and Strut, October, 1967.

SM.320 *A. K. Patterson,* A Statistical Study of Flight Loads on a Cropmaster Agricultural Aircraft, January, 1968.

SM.321 *S. R. Sarraihle,* Padding Materials for Head Impact Protection, July, 1968.

SM.322 *M. J. O'Neill,* A Two-Phase Damage Theory for Life Distribution Prediction, October, 1968.

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SM.321 *J. Y. Mann* and *A. Vann,* Variations in Fatigue Properties between Batches of DRD.363A Aluminium Alloy, December, 1967.

SM.322 *J. M. Finney, J. Y. Mann* and *R. Simpson,* The Effect of Depth of Machining Cut on the Fatigue Properties of Unnotched Aluminium Alloy Specimens, December, 1967.

SM.323 *R. P. Carey,* Residual Strength Tests on "Drover" Centre Section Spar Tension Booms, January, 1968.

SM.324 *S. R. Sarraihle,* An Energy Absorber for Crash Protective Restraint Systems, April, 1968.

SM.325 *I. G. Scott,* Creep Resistance Strain Gauges at Elevated Temperatures, May, 1968.

SM.326 *A. Vann,* The Effect of 0.3 per cent by weight of Silver on the Fatigue Behaviour of Two-Aluminium - Zinc - Magnesium - Copper Plate Alloys, May, 1968.

SM.327 *I. G. Scott,* Pre-Attachment Matching of Resistance Strain Gauges on a Temperature Coefficient Basis, June, 1968.

SM.328 *P. J. Foden* and *R. Rowan,* Interim Report on the Fatigue Test of a Winjeel Wing Joint Test Specimen, July, 1968.

SM.329 *G. P. Bruce,* Seasonal Variations and the Effect of Mode of Operation on Flight Loads on D.C.3 Aircraft, July, 1968.

SM.331 *R. C. Beckett,* The Effect of the Initial Rate of Loading on Fatigue Life, October, 1968.

SM.332 *M. B. Benoy* and *J. M. Grandage,* An Analogue Solution for Transient Temperatures in a Skin/Shear Web Structure, November, 1968.

SM.334 *R. C. Beckett,* The Effects of Some Specimen Storage and Cleaning Techniques on the Fatigue Life of DTD 683 Aluminium Alloy, December, 1968.

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Met.79 *A. Ball* and *M. M. Hutchison,* The Superplastic Behaviour of the Aluminium-Zinc Eutectoid, December, 1967.

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Met.49 *K. F. Lorking,* The Effect of Solution Composition on Anodic Processes and Corrosion of Iron, March, 1967.

Met.53 *L. M. Gillin,* Kink Bands on Deformed Graphite Crystals, April, 1968.

Met.54 *S. McK. Cousland,* A Study of the Unloading Yield Point in Copper Single Crystals, May, 1968.

Met.55 *J. N. King,* The Temperature of Substrates Used in the Preparation of Thin Films by Vapour Depositions, June, 1968.

Met.56 *A. Ball, F. P. Bullen* and *H. L. Wain,* The Ductile/Brittle Transition for Chromium Pressurized at 10-25 K Bars, July, 1968.

Met.57 *J. N. King,* The Application of Double Diffraction to the Measurement of Elastic Strain in thin Films by Electron Diffraction, August, 1968.

Met.58 *I. G. Scott,* Use of the Complex Impedance Diagram in Eddy Current Testing, October, 1968.

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M.E.291 *K. F. Fraser,* Microphone Preamplifier for use in Data Acquisition System, February, 1968.

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M.E.295 *G. G. Holt,* Thermal Fatigue Testing of Chromium Alloy Guide Vanes, May, 1968.

M.E.296 *S. G. Kerr,* An Automatic Multipoint Temperature Recorder, May, 1968.

M.E.297 *G. A. Duke,* Erosion Tests on a Modified Rover Gas Turbine Engine, June, 1968.

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M.E.299 *M. J. McIntosh,* Erosion by Particle Impact — Some Preliminary Experiments, August, 1968.

M.E.300 *W. J. Morley* and *W. H. Clements,* Flow and Dust Separation Efficiency in Two Inertial Separators, August, 1968.

M.E.301 *G. F. Pearce,* The Goblin Mk 35 Engine Flame Tube Wall Temperature Measurements and Preliminary Evaluation of a Flame Tube with improved Cooling, September, 1968.

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Sys.4 *G. A. Butler,* A Parametric Study of Simple Anti-tank Engagement, February, 1968.

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