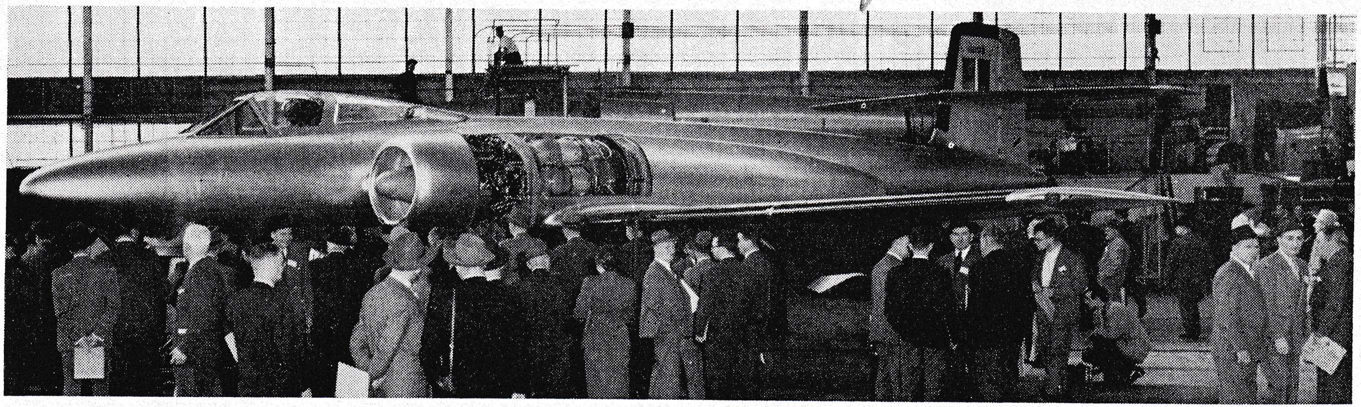
July 1951 RL. 896-1951



ABOVE—The Orenda-powered CF-100 fighter, shown here in the Avro flight hangar, is now flying.

The Orenda Story—

FIRST DETAILS RELEASED ON ORENDA JET ENGINE

By D. W. KNOWLES

Chief Development Engineer
Gas Turbine Engineering Div.
A. V. Roe Canada Ltd.*

THE ORENDA is an axial-flow jet engine having 10 compressor stages, six combustion chambers, a single-stage turbine and an exhaust cone. Under sea-level static conditions the version now in production has a thrust in excess of 6,000 lb., and a specific fuel consumption of about 1.00 lb. per hour per pound of thrust. The dry weight is about 2,500 lb. The nominal diameter is 42 inches and the overall length is very close to 10 ft.

Two mounting arrangements are possible. The first is a four point suspension with two trunnions on the turbine nozzle box and two mounting pads on the centre casting. The second is a three point pick-up having two trunnions on the centre casting and an adjustable strut on the backbone casting. A diagrammatic section of the engine is shown in Fig. 1.

Compressor—The compressor intake is a magnesium alloy casting having an annular air entry around a housing which contains the drive gear box for the engine auxiliaries and the compressor front bearing. The housing is supported by six struts which contain the auxiliary drive shafts, lubrication lines, thermocouple leads, and starter cables. The electric starting motor is mounted on the housing and is covered by the entry bullet.

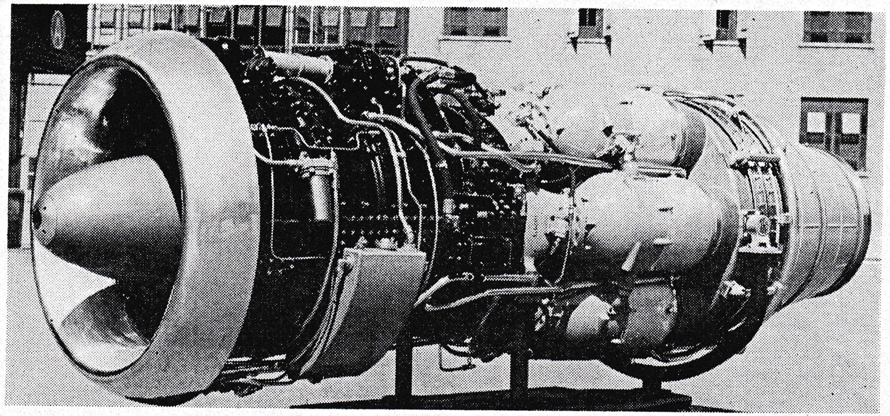
The rotor is composed of discs mounted on an internal drum. The first nine stages have aluminum discs while the 10th disc is steel. A stepped sealing ring projects from the rear of the 10th stage disc into a gland mounted on the centre casting. A small flow of air is permitted to escape past this seal and is used for cooling the rear face of the turbine disc. The blades are retained in the discs by a form of "fir tree" fixing for the first three stages and dovetails for the remaining ones. The first, second, third, and 10th rotor blades are steel. The rest are an aluminum alloy. Rotor and starter blades are unshrouded. The rotor is supported on a bearing in the intake casting and on the centre bearing in the centre casting.

The compressor stator casings are of magnesium alloy. The stationary blades are mounted by dovetails in rings which are retained in place by lips on interstage spacers which in turn are bolted to the stator casing. Provision is made for bleeding air for engine and aircraft purposes at the second, fifth, and eighth stages.

Centre Section and Backbone—The centre section is an aluminum alloy casting containing the diffusing ducts leading from the compressor to the combustion chambers. The centre bearing assembly is mounted inside the centre section. The rotor is retained axially and the rotor thrust absorbed at this point. The centre bearing assembly consists of two bearings with accurately-ground spacer rings between them which permit the bearings to share the thrust load. The bearing housing is spherically ground on its outer diameter to allow the bearing to accommodate angular misalignment of the main shaft due to aircraft manoeuvres. The bearing housing is spring loaded against a composite rubber thrust ring which deforms slightly with angular mis-

AUTHOR—D. W. Knowles, chief development engineer, gas turbine division, A. V. Roe Canada Ltd., author of the accompanying article which is first of a series.

**This article and subsequent installments are based on a paper presented by the author at the semi-annual meeting of the American Society of Mechanical Engineers in Toronto recently.*



The Orenda is 10 ft. long, weighs 2,500 lb dry, has a diameter of 42 inches, develops more than 6,000-lb Static Thrust.

alignment but maintains the axial location of the rotor assembly.

The backbone is a casting of light alloy joining the centre section and the turbine nozzle box. The turbine bearing is mounted on an internal flange at the rear of the backbone.

Combustion Chambers — The six combustion chambers are bolted to the centre casting at the front and are a sliding fit in the nozzle box at the rear. They are arranged around the backbone. Interconnector tubes are provided between chambers to allow crossfiring on light-up. Torch igniters are mounted on two interconnectors for ignition puposes. These consist of a small fuel atomizing nozzle and a spark plug. The combustion chamber consists of a cast aluminum expansion section and a mild steel outer casing with a high temperature alloy flame tube mounted within. The atomizing burners are mounted on pads on the diffuser ducts and project into the combustion chamber.

Nozzle Box—This assembly consists of a welded structure of steel castings and pressings. The turbine nozzle blades are mounted into it as well as the transition ducts which lead the products of combustion from each chamber to the nozzle annulus. The shroud ring which surrounds the turbine rotor blades is attached to the nozzle box.

Turbine and Drive Shaft—The turbine consists of an austenitic steel disc with an integral stub shaft. The blades of nickel-chromium alloy are mounted on its periphery by "fir tree" fixings. The turbine bearing is mounted on a sleeve on the stub shaft section. The stub shaft is attached to the main shaft which drives the compressor through a splined coupling near the centre bearing. The front face and rear faces of the turbine disc are cooled by fifth stage air and tenth stage air respectively. The turbine bearing is cooled by second stage air.

Tail Cone—This assembly is fabricated largely from stainless steel sheet. It consists of an outer cone and an inner bullet supported front and rear by four tubular struts covered by a fairing. Tenth stage air is conducted through the front struts and forward to the front of the bullet. From here it flows outward between the face of the bullet and the turbine disc escaping into the gas stream at the disc periphery. The outer surface of the tail cone is insulated by a fibre glass and foil blanket protected by aluminum covers.

Fuel System—The fuel system is the means of controlling engine output. The pilot's throttle is connected to an altitude-sensitive scheduling-type flow control unit which varies the delivery of two engine-driven pumps through a servo-system to maintain engine speed constant for any throttle setting irrespective of altitude. The pumps have integral overspeed governors. The remaining fuel system components are:

One solenoid-operated reducing valve to supply fuel to the torch igniters; one flow distributor to meter the flow to the burners; six double-orifice burners arranged to allow good atomization over a wide flow range; one dump valve.

A high pressure shut-off cock for the pilot and a low pressure filter are incorporated in the flow control unit.

Lubrication System—The lubricant is supplied by the oil pump to the rotor bearings, gearboxes, front bearing seal and drive shaft flexible coupling through a ring main. Pressure is kept constant in the main by a pressure control valve which returns excess oil to the reservoir. Separate scavenge pump elements are used to pump lubricant from the following sumps: 1. Rear bearing; 2. Centre bearing; 3. Front oil drains; 4. Flexible coupling.

These discharge into the oil reservoir which is a tank of 13 Imperial pints capacity. The lubricant returned from the rear and centre bearings is cooled by a heat exchanger which uses incoming fuel as a coolant. The ring main system operates at 15-18 psi. The engine oil consumption is about one pint per hour.

Cooling Air System—Air is bled from the compressor at the second, fifth and 10th stages and used for cooling as follows:

1. Second Stage Air: (a) backbone cavity; (b) turbine bearing; (c) nozzle box.

(Continued on page 46)

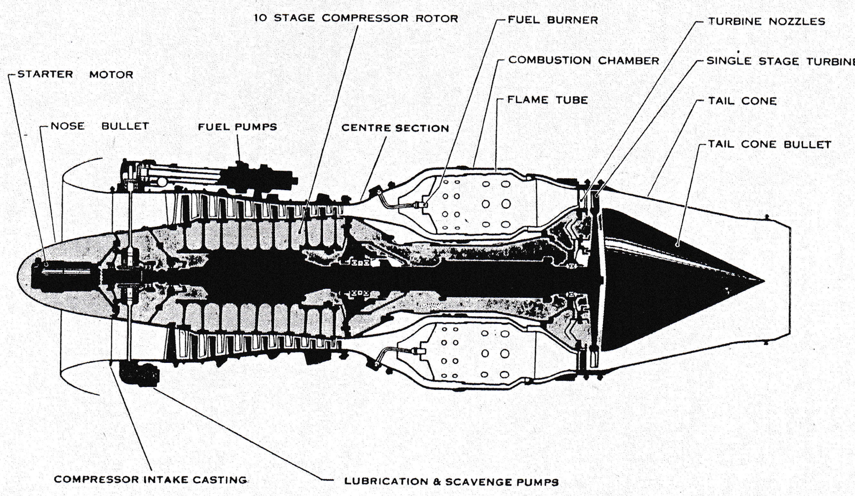


FIG. 1 DIAGRAMATIC SECTION OF ORENDA ENGINE

rop's F-89 Scorpion, where it is used to control automatic selection of fuel tanks, according to the manufacturer.

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Other applications of Meletron Model 431 include installation across fuel filters to control alcohol deicer pump; to control fuel tank pressurization; and in jet engine fuel control systems.

PLAN DEVELOPMENT AIR RESEARCH

(Continued from page 40)

Research Board, who is also the scientific adviser to the Chiefs of the Air Staff; the Air Member for Technical Services of the RCAF, and the chief aeronautical engineer of the Department of Transport.

Correspondence should be addressed to the Director, National Aeronautical Establishment, Montreal Road, Ottawa.

ORENDA JET ENGINE FIRST DETAILS

(Continued from page 22)

2. Fifth Stage Air: (a) centre bearing; (b) front face of turbine disc.

3. Tenth Stage Air: rear face of turbine disc.

Starting—Starting is effected by a 32-volt electric motor housed in the nose bullet. An over-riding clutch disengages the starter motor when the engine reaches self-sustaining speed. The rest of the starting system consists of the booster coils for the torch igniter spark plugs and the control circuit for the torch igniter reducing valve. An external sequence control is necessary to ensure that starting current, fuel for the torch igniters, and power for the torch igniter spark plug are provided at the correct times to permit clean starts.

Historical Highlights

Layout commenced ... Sept. 3, 1946
Layout design finalized & detailing commenced Dec. 6, 1946
Detail drawing issue commenced .... May 1, 1947
Detail drawing issue completed Jan.15, 1948
First engine delivered to Test House .... Feb. 8, 1949
First run .... Feb. 10, 1949
100 hrs. running completed .... Apr. 4, 1949
Engine first ran at design take-off speed May 3, 1949
Engine first delivered design performance .. May 10, 1949
500 hrs. running completed .... July 21, 1949
1,000 hrs. running completed .... Sept. 23, 1949
2,000 hrs. running completed .... Feb. 10, 1950
First official flight clearance at design rating . Mar. 2, 1950
First flight (in Lancaster flying test bed) ..... July 13, 1950
First flight in service type aircraft .... Oct. 5, 1950
First 100 hours flying .. Oct. 20, 1950
5,000 hrs. running completed .... Feb. 5, 1951

Background — The beginnings of the Avro Orenda extend much further back in history than the discussions which produced the first design layout. To appreciate the project fully it is necessary to start in 1942 when reports about the Whittle jet-propulsion engine began to reach Canada.

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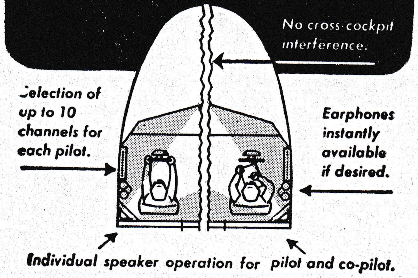

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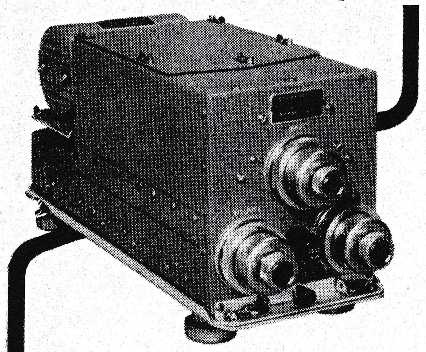

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the heavy wartime cloak of security seemed to indicate that the new engine was light, of great power, easy to design and simple to manufacture. In fact it appeared to offer the possibility of establishing a Canadian engine industry without the costly delay which would have been required to set up an internationally competitive piston engine enterprise.

Late in 1942 senior officers of the Royal Canadian Air Force investigated the situation and as a result a technical mission was sent to Great Britain early in 1943 to study the new development. Some of the enthusiastic reports proved to be groundless. However, the group recommended that Canada could make an important contribution to the British program by establishing a cold weather experimental station to test jet engines under temperature conditions which prevail at altitude or even at sea level in the Arctic.

The project was assigned to the National Research Council of Canada.

The mission also suggested the creation of a gas turbine research establishment with the thought of setting up a development and manufacturing organization at a later date.

The former step was taken in 1944 when the Government set up a crown company Turbo Research Limited to carry out all Canadian research work on gas turbine engines. The company took over the National Research Council's cold-weather testing activities and began to recruit a research and design staff.

This team was selected and trained, some being sent to England for further training. Plans for a research establishment were started. But before they were complete the scope of the activity was broadened to include actual engine design. A provisional engine specification was agreed upon with the Royal Canadian Air Force and design work started. At the same time tentative layouts of a development and manufacturing plant were done.

This phase continued until the spring of 1946. At that time the Government, in furtherance of its policy of turning over a large number of government-controlled enterprises to private industry, assigned the task of design, manufacture and development to A. V. Roe Canada. The allied fundamental research work was turned over to the National Research Council to whom the cold test facilities reverted.

Background—At the time the Turbo Research Limited project was trans-

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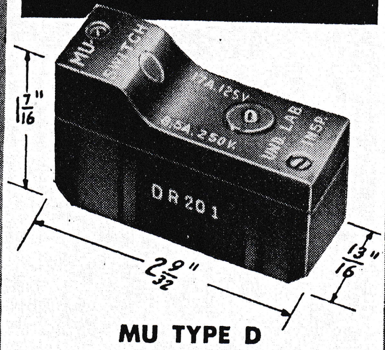

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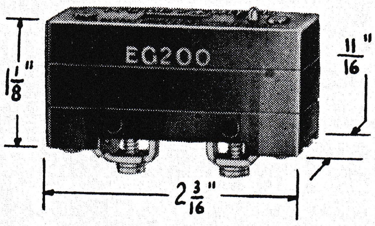

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ferred to A. V. Roe Canada Limited a small engine, the "Chinook," was in an advanced state of design. To confirm design assumptions, establish manufacturing techniques, get development experience, and educate subcontractors a decision was made to build this engine on a development basis.

The work slowly gained momentum as precision machinery became available, manufacturing techniques were worked out, and foundries overcame their initial difficulties with complicated castings. At the same time laboratory space was allotted, test houses designed and the power plant of a wartime explosives plant at Nobel, Ont., was acquired for use as the nucleus of a full-scale test plant for compressors, combustors and turbines.

Much of the test equipment designed by Turbo Research Limited was manufactured in the Avro shops and installed in the experimental laboratories. This work culminated in the first running of the Chinook Engine on March 17, 1948. In the ensuing 20 months over 1,000 hours were logged on Chinook engines and the thrust was increased from the original design value of 2,600 lb. to a figure well over 3,000 lb.

History — In the late summer of 1946, 20 months before the Chinook first ran, the design group were presented with a problem which made the current manufacturing and organizational difficulties seem insignificant. The Royal Canadian Air Force requested Avro to develop an engine for the twin-engined long-range fighter being designed by the Aircraft Division of the company. The specification called for an engine of a thrust equal to that of the largest engines on the drawing boards of British and American companies.

With the Chinook a decision was made to name engines after Indian spirits. Following this tradition the new project was christened the "Orenda" — an Iroquois spirit whose presence in an object or person confers power.

Design studies were started in September, 1946, and finalized at the end of the year when detailing was commenced. Drawings began to appear in the shops in May, 1947, but the drawing issue was not complete until January, 1848.

There were two reasons for this seemingly long time required to issue the design. The first was a policy decision to do the detail design extremely carefully in order that a

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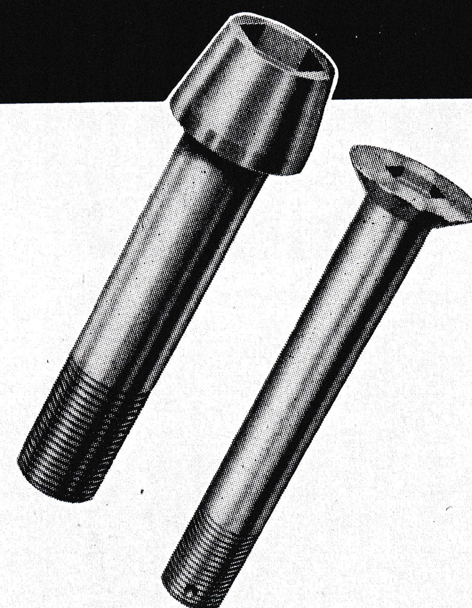

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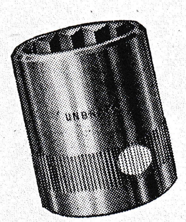

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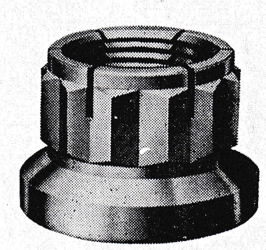

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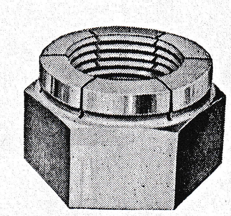

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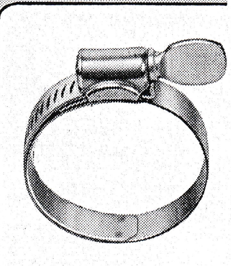

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minimum of development difficulties would be built into the prototype.

The second was the result of a crisis which arose in the summer of 1947 when development work at the English firm commissioned to design the combustion equipment, indicated that a longer combustor would be necessary to assure reasonable performance. This discovery had a substantial effect on design progress as it necessitated a complete redesign of the backbone casting, shafting and turbine bearing to accommodate the lengthened combustion chamber.

The first engine was assembled and delivered to the test house on February 8, 1949. Two days later after preliminary motoring trials, the first attempted start was successful. In the ensuing weeks the wisdom of the careful design policy was proven for there were no immediate operating problems, in fact the engine logged its first 100 hours in eight weeks' time and accumulated almost 1,000 hours of running with only minor rebuilds in eight months. The engine as it is now being produced does not incorporate any basic differences from the original design.

(To Be Continued)

STORY OF THE McKEE TROPHY

(Continued from page 28)

development of cockpit instruments and controls for new aircraft; surveying of new routes in respect to airports; navigational facilities; and the maintenance of close liaison with the Dept. of Transport in the development of radio and visual aids for air navigation. During the 20 years, prior to the award, Mr. Rawson had flown approximately 12,000 hours and 1,500,000 miles. He was issued Transport Pilot's Certificate No. 119, dated July 6, 1938, superseding his U. S. Pilot's Certificate.

"Barney" Rawson continues to be associated with Trans-Canada Air Lines in Montreal, where their offices were moved in October, 1949, from Winnipeg, and carries on his duties as Director of Flight Development.

1948—F/O. R. B. West— While employed on East Coast Operations with No. 103 Search and Rescue Flight, RCAF Station, Greenwood, N.S., F/O. Roland B. West, D.F.C., A.F.C., was awarded the Trans-Canada Trophy.

F/O West enlisted in the RCAF in August, 1941, and was trained as

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