ORENDA

CHINOOK & ORENDA ENGINES

A Short History

Acting on the recommendations of a government technical mission, the National Research Council of Canada established Turbo Research Limited in 1944 to direct gas turbine research in Canada. Turbo Research built a small design and experimental team and made plans for a substantial test establishment. The fledgling organization was provided with facilities at Research Enterprises Limited, a Crown company located in Leaside, an eastern suburb of Toronto. Turbo-jet engine design concepts evolved by the design people were designated TR1, TR2, etc. A specification for a turbo-jet was drawn up in collaboration with the Royal Canadian Air Force and the design was commenced as the TR4 engine, later to be called the Chinook after the 'Warm Wind' of Western Canada.

In September of 1945, AV Roe Canada Limited, initially wholly owned by the Hawker Siddeley Group of the UK, was formed to provide Canada with a domestic aircraft and engine design and manufacturing facility, particularly with regard to defence requirements. The new company began operations by taking over the assets of Victory Aircraft Limited, located adjacent to the Toronto International Airport at Malton. In the following year, the assets and most of the Turbo Research team moved to Malton and continued with the design of the Chinook engine. More people were hired, manufacturing facilities were increased and test cells were built at the Malton plant. Facilities for compressor, turbine and combustion testing were built at what had been an explosives plant at Nobel near Parry Sound, Ontario, which had a boiler and steam turbine for driving a test compressor and large air compressors to supply air for other tests.

The first Chinook engine ran in March 1948 and had the distinction of being the first gas turbine engine to be completely designed and developed in Canada. Over 1000 hours of test bed running were logged during the ensuing 20 months. Four sets of parts were made and three engines were actually built and tested, each attaining a thrust of 3000 lbs, well in excess of its designed thrust of 2600 lbs.

It was never intended to produce the Chinook in quantity. The program did provide for the development of engineering and manufacturing skills, the establishment of shop facilities and of subcontract sources capable of producing the high quality of workmanship demanded by this new type of engine.

In the late summer of 1946 the RCAF requested what had now become the Gas Turbine Division of AV Roe Canada, to design and develop a turbo-jet engine with a thrust equal to that of the largest engines then on the drawing boards of any British or American companies. This engine, designated TR5, was later to be known as the Orenda, the name of an Indian deity for 'The Source of Power'. A contract for design and manufacture of the Orenda was issued in April 1947 and the first engine ran on the test bed in February 1949, surpassing its design thrust rating of 6,250 lb. The engine incorporated a 10-stage axial compressor driven by a single-stage turbine and six separate combustion chambers. It looked not unlike a large Chinook. As the manufacture of development engines continued, testing experience accumulated rapidly. In July 1950, flight testing was initiated in a Lancaster bomber converted into a flying test bed with an Orenda engine in each of the outboard nacelles. The original Merlin piston engines operated in the two inboard nacelles. Three months later another prototype Orenda was used to power a North American F-86A Sabre aircraft.

The first production model, the Orenda 2, completed its qualification in February 1952 for delivery at a guaranteed thrust rating of 6,076 lb. This model was to be used in the CF-100 all-weather fighter aircraft designed and built by the Aircraft Division of AV Roe Canada. An Orenda-powered CF-100 first flew in June 1951. In January 1953 the Orenda 8 for the CF-100 and the Orenda 10 for Canadair-built Sabre 5 aircraft were qualified at a guaranteed thrust rating of 6,355 lb. The Orenda 9, an unhanded version of the series 8, was qualified at the same rating in April 1953. In January 1954 the two-stage turbine version of the Orenda completed qualification testing at a guaranteed rating of 7,275 lb thrust. This version of the Orenda was produced as the Orenda 11 for the CF-100 and as the Orenda 14 for the Canadair Sabre 6 aircraft. It produced an average realized thrust in service of 7,400 lb.

By 1951, the original nucleus of engineers and technicians had been considerably expanded. The Experimental Manufacturing organization had grown into a pre-production operation as well; and a new, modern production plant was under construction. This plant at Malton was officially opened in September 1952 and less than seventeen months later, 1000 engines had been delivered to the RCAF. During the Korean crisis, the plant produced four engines per day. In 1955 the Gas Turbine Division became Orenda Engines Limited, a subsidiary of AV Roe Canada Limited. Production of the Orenda series continued until July 1958, at which time total production of all models stood at 3,829. Delivered cost of an Orenda was computed to be about 30% lower than the comparable British-built engine and approximately 10% less than its US equivalent. The Orenda engine saw service with the RCAF in Canada and Europe, as well as with the air forces of Belgium, Colombia, Germany, Pakistan and South Africa. Today, more than 26 years after the last Orenda turbo-jet engine was produced, a few are still flying in Sabre aircraft.

CHINOOK

MODEL..........CHINOOK TR4-11

TYPE...........TURBOJET, 9 Stage axial compressor, 6 combustion chambers, 1-stage turbine.

COMPRESSOR.....9-stage axial flow compressor. 2-piece aluminum alloy stator casing, with 1 row of aluminum alloy guide vanes, and 9 rows of aluminum alloy stator blades inserted in aluminum alloy rings. Rotor of aluminum alloy with 2 rows of steel blades and 6 rows of aluminum alloy blades, bolted to 9th-stage steel disc having 1 row of inserted aluminum alloy blades. Front rotor shaft supported in 1 roller bearing, with drive to accessory gearbox. Rear rotor shaft supported in 1 2-row ball bearing. Compression ratio 4.5:1, and air mass flow 42 lb. (19 kg)/sec. at 10,100 r.p.m./sea level, static.

COMBUSTION.....6 interconnected tubular combustion chambers, of straight-through flow type. Front sections of cast aluminum alloy bolted to rear sections of aluminized sheet steel, 1 perforated flame tube of Nimonic 75 alloy inside each combustion chamber. 1 duplex fuel burner in each diffuser connecting combustion chamber to compressor outlet, with downstream injection into flame tube.

TURBINE........1-stage axial flow gas turbine. Fabricated stainless steel casing. Diaphragm with 90 inserted cast Vitallium nozzle guide vanes. Air-cooled rotor disc of Jessop G.18B steel, with integral stub shaft, and 119 inserted Nimonic 80 alloy blades. Rotor shaft supported in 1 roller bearing, and connected by hollow drive shaft and flexible coupling to rear compressor rotor shaft. Gas temperature 1,292°F (700°C) before turbine and 1,202°F. (650°C) after turbine at 10,100 r.p.m.

EXHAUST-
NOZZLE.........Fixed area type. Steel outer casing and stationary inner cone. Heat insulating blanket and aluminum cover.

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FUEL SYSTEM... Dual fuel manifold system. 2 Lucas GA multi-plunger variable stroke fuel pumps with overspeed governors and interconnected servo system, 1,110 lb./sq.in. (77 kg/cm^2), connected in parallel. Lucas CCU flow control unit with integral throttle valve, shut-off valve, and low-pressure filter. Lucas NRV dump valve. Lucas Duplex One burners.

LUBRICATION SYSTEM.........Dry sump system. Plessey pressure pump, 15 lb./sq.in. (1.0 kg/cm^2). Nicholas scavenge pump. Vokes filter. Semi-circular oil tank and cooler around underneath side of compressor casing.

STARTING...... Rotax C03813 electric starter. 2 Lucas flame igniters, and 2 Rotax ignition coils.

Diameter......................	32.0 in.	813 mm
Length........................	125.1 in	3 180 mm
Frontal area..................	5.6 sq. ft.	0,52 m^2
Weight........................	1,250 lbs.	567 kg
Weight/max. thrust............	0.48 lb/lb.t	0.48 kg/kgt
Fuel grade....................	D.Eng.R.D. 2482	Kerosene
Oil Viscosity (at 100°F)......	59 S.U. (AN.0-9 1010)	10,0 cs (at 38°C)
Fuel consumption (cr).........	1.00 lb/lb.t/hr.	1,00 kg/kgt/hr
Oil consumption (cr)..........	2.0 lb./hr.	0,9 kg/hr

Take-off, static..............2,600 lb.t (1 180 kgt)/10,100 rpm/sea level
Normal static.................2,100 lb.t (950 kgt)/9,800 rpm/sea level
Cruising static...............1,900 lb.t (860 kgt)/9,500 rpm/sea level

ORENDA 14

MODEL......... ORENDA 14

TYPE.......... Turbojet, 10-stage axial compressor, 6 combustion chambers, and a 2-stage turbine.

INTAKE........ The magnesium alloy intake casing has six hollow struts carrying oil and electrical lines and the upper and lower vertical driveshafts which power the fuel, oil and hydraulic pumps.

COMPRESSOR.... Ten stage axial flow compressor. Two-piece magnesium alloy stator casing carries 9 rows of aluminum alloy stator vanes and a tenth row of stainless steel vanes. Compressor rotor blades are stainless steel in stages 1,2,3,9 & 10 and aluminum alloy in the remainder. The front stub shaft of the compressor rotor is carried in roller bearings and drives the accessory power takeoff unit. The rear stub shaft is carried in two-row ball bearings. Compression Ratio is 6.1:1, and Air Mass Flow is 110 lbs/sec (50 kg/sec) at 7800 rpm, sea level static.

COMBUSTION... Six tubular combustion chambers, of straight through flow type, are positioned around the backbone casting. One Lucas duplex burner is installed at the inlet of each combustor. Interconnecting tubes between the six chambers provide a flame path during engine starting and ensure a balance of pressure throughout the combustion system.

TURBINE...... A two-stage axial flow turbine is enclosed in a fabricated stainless steel casing. Austenitic steel discs and nickel chrome alloy blades are cooled by air from the compressor 10th stage. The two turbine discs are bolted to a stub shaft which transmits torque via the turbine shaft to the compressor rotor. Maximum temperatures: Turbine Inlet - 917^{o}C (1680^{o}F), Turbine Outlet - 715^{o}C (1320^{o}F).

EXHAUST CONE.........	Fixed area nozzle. Steel outer casing and stationary inner cone. Exhaust cone rear flange has bayonet joint for attachment of aircraft jet pipe. A stainless steel foil blanket encloses the cone, providing heat insulation.
FUEL SYSTEM..	Two Lucas multi-plunger variable stroke fuel pumps, with overspeed governors and an interconnected servo control system, deliver fuel at 1200 psi (85 kg/cm^2) at max. speed. A Lucas proportional flow control, with single lever input, meters fuel for all flight conditions. An emergency flow control unit, connected in parallel, allows direct manual control of the engine in case of failure of the PFCU. A dual fuel manifold system provides primary and main supply to the Lucas duplex burners.
LUBRICATION SYSTEM.......	Oil is supplied to bearings and gearboxes on the 'ring-main' principle. Two Nichols gerotor type pumps circulate the oil through the pressure and scavenge systems - Oil temperature is regulated in a fuel/oil heat exchanger. The oil tank, capacity 2.9 imp. gals. (13 litres), is located in the aircraft.
STARTING.....	A starter-generator, mounted on the forward face of the intake casing, rotates the compressor to start-up speed, powered by an external supply. A Bendix ignition exciter box, mounted on the right-hand side of the compressor casing, is activated during the starting cycle and delivers high-energy pulses to the surface-discharge type igniter plugs located in No. 2 and No. 5 combustion chambers.
TEMPERATURE LIMITING.....	A temperature limiter unit, mounted on the lower left-hand side of the compressor casing, senses excessive exhaust gas temperaure in the tailpipe and emits a signal which reduces the output of the fuel pumps, thereby reducing RPM and EGT.

Diameter (Nominal)............	42.8 in.	1087 mm
Length........................	123.3 in	3132 mm
Frontal area..................	9.98 sq. ft.	0.93 m^2
Weight........................	2430 lb.	1105 kg
Weight/max.thrust.............	0.33 lb/lb.t	0.33 kg/kg.t
Fuel grade....................	JP4	(Kerosene)
Fuel consumption(Max.)........	0.99 lb/lb.t/hr.	0.99 kg/kg.t/hr
Oil consumption (Max.)........	1.5 pints/hr.	0.85 litres/hr

Maximum Rated Thrust..........7275 lb. (3307 kg) at 100% rpm
Military Rated Thrust.........6600 lb. (3000 kg) at 97.5% rpm
Normal Rated Thrust...........5460 lb. (2482 kg) at 93% rpm