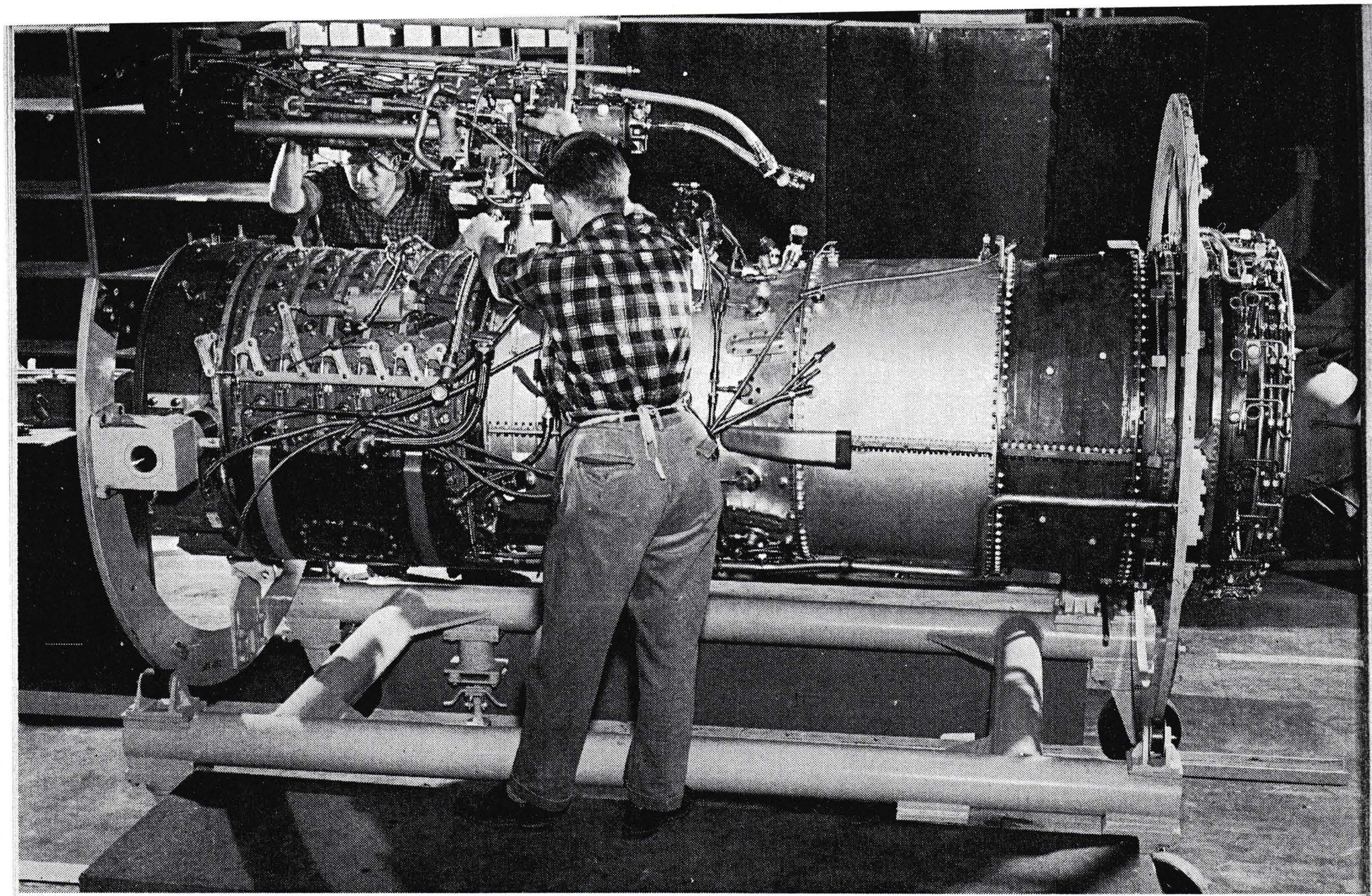


ORENDA-BUILT J79-7 in the final stages of assembly, with the gear box assembly being lowered into position on the engine.

RL. 896-1961

Orenda J-79-7 Program

Planning the power

Deliveries of the Orenda-built J79-7 engine powering the CF104's for the RCAF are being made well on schedule. The first production engine to leave the line at Orenda Engines' Malton plant was despatched to Lockheed Aircraft Corporation for installation in the first of 14 104 trainer airframes being supplied to the RCAF by the U.S. company.

Later models went to Canadair Ltd., in Montreal, and will power the first Canadian-built CF-104's during flight testing and acceptance trials.

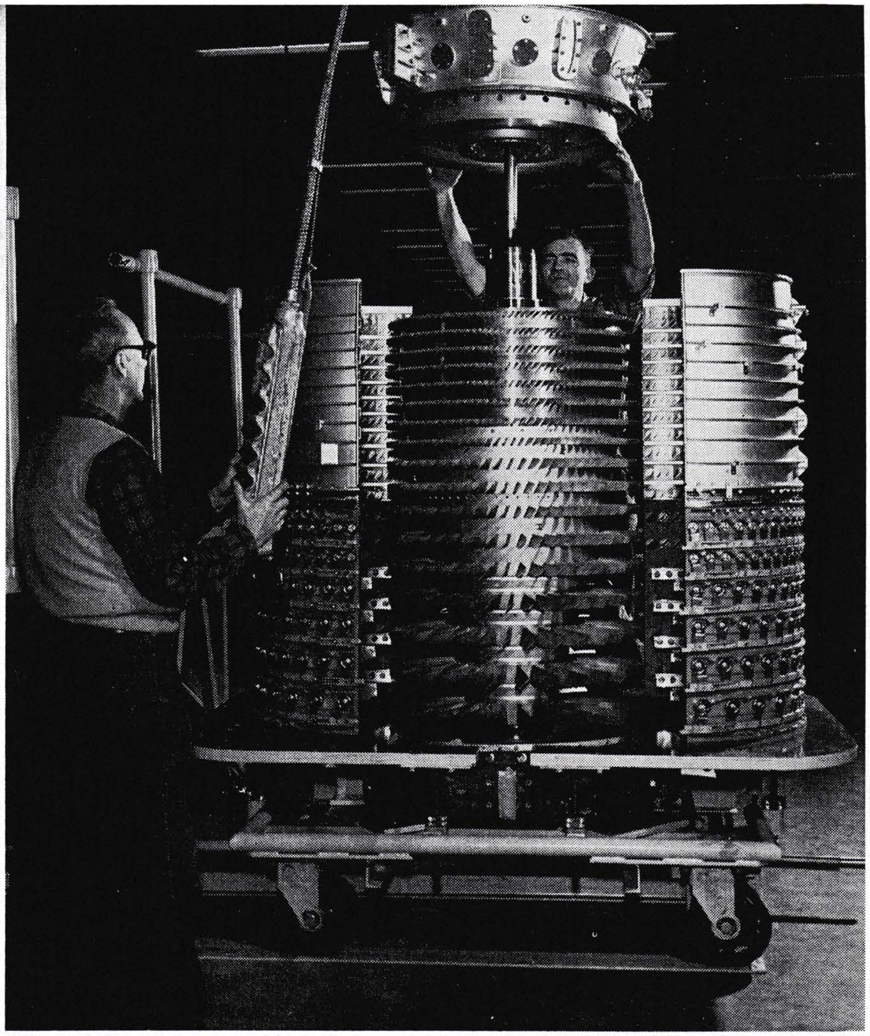
The manufacture and testing of this Canadian version of the General Electric-designed J79-7 engine is the result of negotiations between the Canadian and U.S. governments, the Canadian General Electric Company and its U.S. parent company, and Orenda Engines Ltd. Orenda is building the J79 to technical data supplied by the General Electric Company through an agreement with the Department of Defence Production, under a licence arrangement between DDP and the Canadian GE, and between CGE and its parent company.

The technical data received by Orenda (on October 26th 1959) included all engine and tool drawings, specifications, planning sheets, etc. This data was reviewed and released within Orenda so that engineering, procurement and manufacturing activities could commence simultaneously.

The editors of Canadian Aviation gratefully acknowledge the assistance of D. H. Parker, GE J79 Project Engineer for Orenda Engines Ltd., in the preparation of this article.

It was necessary to review all of the engine drawings and specifications so that Orenda engineers would be fully cognizant of the design and testing requirements of the complete engine and its accessories. The drawing review was straightforward because the Canadian manufacture of the J79 engine was to be a direct copy of the design currently under manufacture in the U.S.A. Specification reviews, however, required additional work.

This entailed a compilation, from GE information, of special instructions applicable to either the engine testing facilities at Orenda or to the testing and qualification requirements



ASSEMBLY of compressor casing, front frame, rear compressor frame, compressor.

for the CF-104

of the various Canadian subcontractors providing materials and accessories for the program. For example, such items as fuel pumps, fuel controls and nozzle area controls, which are just a few of the main accessories, are now being manufactured in Canada by Canadian companies under license from their original American designers.

This meant that adequate testing requirements had to be set up to qualify each of these manufacturers to the satisfaction of Orenda and the R.C.A.F. Review of material specifications peculiar to this program meant a familiarization with the item concerned, plus a review of Canadian facilities in the light of any special processes associated with these new specifications. Finally, through the engineering department, technical liaison arrangements were set up between Orenda and the GE plant at Cincinnati, whereby all kinds of technical and manufacturing questions were resolved.

Tooling and Planning

The manufacturing department at Orenda was faced with the task of reviewing not only the engine drawings, but also all of the tooling and planning information, to determine which parts could best be manufactured at Orenda, or which could, with advantage, and with the advice of procurement information, be produced by other Canadian companies. Examination of the tooling and planning information required examination of the applicability of this data to Orenda's equipment. In reviewing the tool drawings it was found that all required modification to varying degrees. Parts not manufactured by GE in the U.S. required the design and development by Orenda of new Canadian tooling as tooling data on such parts was not available.

Parallel with these activities, Orenda undertook procurement activity to place orders for long lead-time items. Canadian suppliers of forgings, castings, accessories, etc., were used to the maximum extent providing delivery arrangements were satisfactory and the vendors' equipment was suitable. In some cases it was necessary to obtain small quantities from American sources until such time as Canadian industry was able to take over the supply of these items.

The J79 engine being manufactured by Orenda started out as a direct copy of the J79-7 model in order to keep costs and development to a minimum.

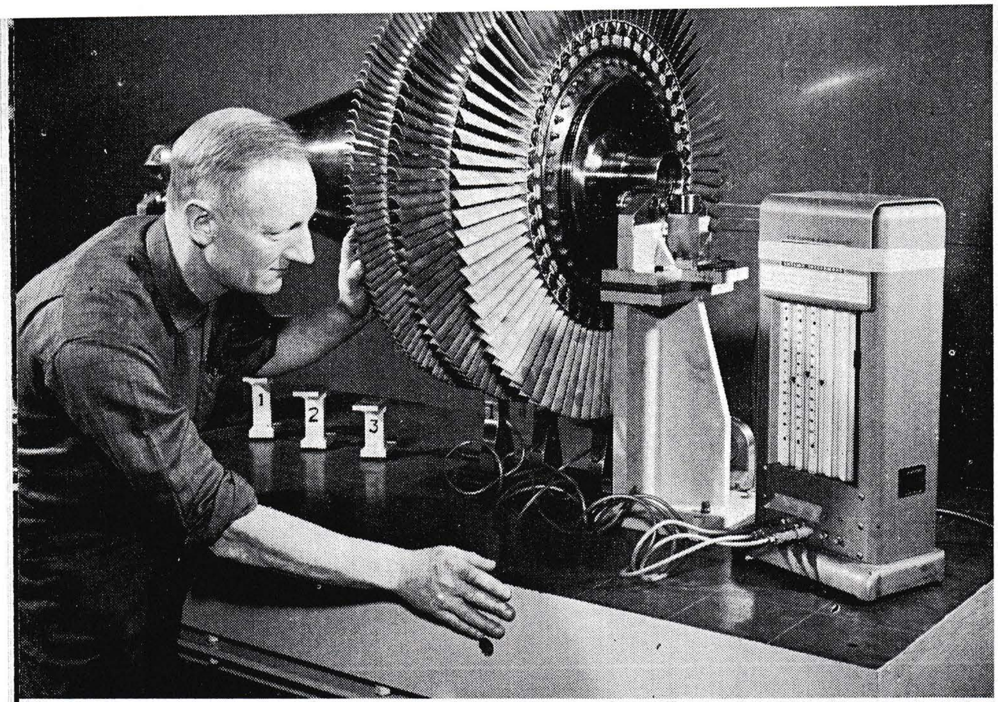
Some Changes Made

Some changes were made, however, so that the engine is not now a direct copy of the original -7 model but incorporates modifications included in the -11 and -11A versions of the J79. These changes have come about through the service experience of the U.S.A.F. and GE and any further development carried out by GE and through changes introduced by Orenda to facilitate Canadian manufacture.

The J79 is an axial flow reheat turbojet engine. It consists of a front frame, 17 stage compressor, rear compressor frame, "cannular" type combustor, 3 stage turbine, afterburner manifold and spray bar assembly, a tailpipe and variable exhaust nozzle, 3 gearboxes and various accessories mounted on the external portion of the engine.

The front frame assembly consists of a four strut magnesium casting and variable incidence inlet guide vanes. The hub of the casting provides support for the number one bearing and also houses the front gearbox. The four struts contain passages for lubrication and thermal anti-icing services. Three of the struts and the variable guide vanes are deiced by 17th stage bleed air. The vertical and bottom strut is de-iced by virtue of warm oil return and also provides for a vertical power take-off to the transfer gearbox for the accessories. The front frame also makes provision for engine mounting at the top and two sides of the front frame casting.

The compressor casing consists of



TURBINE ROTOR gets a tip radius check, using an air gauge. Clearance between blade tips and air jet nozzles is registered by the three pointers on gauge (right).

three portions, the front casing, incorporating six stages of variable incidence stator blades, an intermediate casing to provide a compensating joint for thermal expansion between the front and rear portions of the compressor casing and the rear casing containing fixed stator vanes. The front casing is a magnesium thorium casting split into two halves. The six variable stages of stator vanes are rotated through a series of individual bell cranks and ring assemblies. The first four stator stages are shrouded.

Operation of the variable incidence inlet guide vanes in the front frame and the six stages of compressor stators is in response to fuel control signals. The intermediate casing is an A286 fabrication and provides mounting for the 7th stage stator vanes. The compressor rear casing is a chromoloy fabrication and contains stator stages eight to seventeen.

Seventeen Stages

The compressor rotor consists of seventeen discs, front and rear stub shafts, blades, spacers and torque cones. The front stub shaft is supported on the number one bearing in the front frame and is splined to provide a power take-off to the front gearbox. The rear stub shaft is supported by the main thrust bearing in the compressor rear frame. The compressor blades are held in the discs by dovetail slots. The function of the torque cones is to transmit power from the rear stub shaft through the latter stages of the rotor forward to the eleventh disc. Power to the remaining stages of compressor rotor is transmitted through the spacer rings between the discs.

The compressor rear frame is a welded assembly and consists of outer and inner shells connected by ten equally-spaced hollow struts. These struts provide passages for various lubrication and air services. From these struts and openings in the compressor casing, bleed air is extracted from the engine at the 9th and 17th stages for thermal anti-icing, cooling air, sump pressurization and airplane services. The compressor rear frame also provides mounting bosses for ten fuel burners which are inserted through the casing into the head end of the ten combustion liners.

Sheet Metal Used

The combustion section is completly fabricated and consists of an outer and inner shell with the annular space between occupied by ten combustion liners. The combustion liners consist of three parts, an inner and outer liner and a rear liner. The dome portion of the combustion liner is so shaped that a uniform flow of compressor discharge air is conducted into the liners for cooling and combustion.

The first version of combusion inner liners is of ceramic coated L605 material, but subsequent production will exclude the ceramic coating and change the material to Hastelloy X. The rear end of the complete combustion assembly incorporates the first stage of the hollow sheet metal turbine nozzles.

The turbine casing is a split fabrication assembly incorporating the 2nd and 3rd stages of turbine nozzles and honeycomb seals for the 2nd and 3rd stages of turbine blades. All stages of turbine nozzles are shrouded. The turbine rotor assembly consists of a conical rotor shaft, three turbine wheels, two inter spacers and three stages of turbine blades. The turbine blades are fixed to the wheels by multiple fang dovetails with the blade roots being so designed that blades are assembled in pairs. That is, one side only of the blade root is serrated, the opposite side being flat to mate with the next blade.

Discs Air-Cooled

The 3rd stage turbine wheel incorporates a stub shaft which is supported in the number three bearing mounted in the turbine frame. Cooling air is directed over the turbine discs by baffle type fans mounted between the discs and is also provided for the first two stages of the hollow nozzles. Suitable inter-stage sealing arrangements also protect the discs from excessive gas temperatures.

The turbine frame consists of a welded and riveted assembly which provides support in its hub for the number three bearing and scavenge pumps and on its outer shell for the rear engine mounts. The afterburner manifold and spray bar assembly and rear inner cone are mounted respectively on its outer and inner rear flanges. The afterburner manifold and spray bar assembly consist of four sectors to provide sector afterburning as regulated by the afterburner fuel control system. The rear inner cone, in turn, supports, by a series of struts, the three ring afterburner flame holder.

The tailpipe and variable exhaust nozzle are cantilevered from the rear flange of the spray bar assembly. The tailpipe consists of outer and inner shells. The inner shell is a ceramic coated fabrication with an annular space between it and the outer shell, providing a passage for relatively cool turbine discharge air during afterburner operation. A pylon-mounted pilot burner is located at the bottom forward end of the tailpipe to provide for afterburner ignition.

The variable exhaust nozzle consists of an internal primary nozzle of twenty-four flaps and an external secondary nozzle of twenty-four flaps. The primary nozzle flaps are hinged to the rear tailpipe and the secondary nozzle flaps to the rear of an outer fixed shroud. The nozzle area is controlled by four hydraulically-operated synchronized jacks. These are controlled in response to temperature, throttle and speed signals, thereby regulating nozzle area.

The transfer and rear gear boxes are mounted on the bottom portion of the engine, the transfer gearbox being supported by the front frame and rear gearbox on the rear compressor casing. The gearboxes supply mounting flanges for and power to operate the engine fuel and afterburner pumps, lubrication pumps, fuel controls and when installed in the aircraft, for aircraft hydraulic pumps and generators.

The fuel system consists of a main gear-type fuel pump, a fuel control, compressor inlet temperature sensor, main oil cooler, a pressurizing and drain valve and fuel nozzles. Also included in the main fuel system, although assembled as an aircraft part, is a fuel flowmeter which is incorporated between the fuel control and the final nozzles.

The main fuel control is a hydromechanical computer which maintains engine speed at selected values. It controls fuel during starting and acceleration, limits engine speed relative to inlet temperature and compressor discharge pressures and controls the operation of the variable guide vanes and stators relative to engine speed and inlet air temperature.

Afterburner Operation

Associated with the main fuel system is the afterburner fuel pump and control. The signal to operate the afterburner is obtained by advancing the throttle through a given position. Fuel from the afterburner fuel pump passes through the afterburner fuel contol which controls fuel flow as a function of throttle angle and compressor discharge pressure. It passes through an oil cooler and finally through the flow divider and selector valve into the afterburner manifold and spray bar assembly. The flow divider controls the fuel flow for sector burning of the afterburner.

There are two ignition systems on the engine, one for main engine ignition consisting of two separate main ignition units and two spark plugs and one for the afterburner consisting of an ignition unit and spark plug mounted in the pilot burner.

The variable exhaust nozzle system controls the nozzle area to ensure that the engine is operating within safe limits at all times. The system combines temperature, speed, fuel pressure, throttle position and nozzle area signals to regulate the output of the nozzle hydraulic pump to position the nozzle. The control systems are interconnected with various flexible and solid control linkages. During engine assembly, these must be rigged to provide for the proper relationship of guide vanes, compressor stators, throttle angle, nozzle area etc.

Spray Lubricant

The engine lubrication system is a closed dry-sump spray type system. It can be divided into three sections, namely, supply section, scavenge section and pressurizing section. The supply section delivers oil through suitable filters to the main engine bearings and to the gearboxes. The scavenge system returns the oil from the bearing sumps, gearboxes and hydraulic system to the oil tank. The hydraulic system is supplied from the same source as are the bearings, etc. The pressurizing section vents sumps, gearboxes and oil tank to atmosphere, thereby controlling system air pressures.

All of the pumps and other oil system components are mounted on the gearboxes on the external portion of the engine with the exception of the number three bearing scavenge pump which is mounted within the hub of the rear turbine frame. All pumps are the vane type. Filter protection is provided in both scavenge and pressure sides of the system.

The first problem encountered was that of correct interpretation and understanding of the data supplied. Through the offices of the GE representative at Orenda and the Orenda engineering representative at General Electric, correspondence and discussions have been exchanged to resolve questions on interpretation of specifications and drawings, document handling, manufacturing methods, etc., These have been augmented by the attendance of Orenda engineering and manufacturing personnel at formal training courses at the GE Evandale plant.

Another problem encountered was that of welding. The J79 engine incorporates a considerable number of fabricated assemblies. In fact, with the exception of the front compressor casing and the various machined elements constituting the rotating parts, the remainder of the engine consists of sheet metal fabrications. This necessitated a considerable expansion of Orenda's welding facilities.

All of the materials had been welded previously at the Malton plant with the exception of Chromolloy. The required increase in the welding facilities not only included the acquisition and qualification of the necessary equipment, but also the hiring and training of operators. Orenda set up a welding training school and this proved very successful. Operators are trained to become proficient in the welding of all types of materials and joint configurations.

In order to meet Canadian content requirements, the maximum amount of raw materials has been procured from Canadian sources.

This posed a significant problem, that of qualifying, in the short time available, not only the initial material from these sources, but

(Continued on page 40)

COMBUSTION LINERS being fitted, showing the annular intake and the inner connecting pads for mounting the inner connectors between each of the liners.

Orenda J79-7

(Continued from page 15)

the larger production quantities following immediately after the prototype samples. This has been overcome by the build-up of laboratory staff and the continued checking of test data to maintain minimum testing consistent with quality.

Facilities were available for engine testing, but modifications were required to adapt them to the J79 engine. Test cells which had been modified for the Iroquois operation were changed to fit the J79 requirements. This involved installation of the required instrumentation and some minor modifications of existing water supplies for cell cooling during afterburner operation.

With the completion of tooling and the acquisition of raw materials and accessories from various suppliers, part manufacture proceeded at an ever-increasing rate. No undue problems were encountered in engine assembly and testing results have been very satisfactory. Some of the assembly operations are shown in the photographs on earlier pages.

The rotor assembly is built up on a rotating table, starting with the front stub shaft. Blades complete with discs and their respective stator rings, torque cones, etc., are assembled stage by stage with concentricity checks being taken after each stage. Following assembly of the compressor casing, front frame, rear compressor frame and compressor rotor, the compressor rotor is positioned in the front frame with the rear frame lowered into position. The two compressor halves are moved horizontally and bolted around the compressor rotor and to the flanges of the front frame and rear compressor frame.

Pit Assembly System

Following the assembly of the compressor rear frame comes the installation of the cannular combustion chamber and the 1st stage nozzle guide vanes. Having assembled the engine up to the compressor rear frame, the complete unit is then mounted in a pit which permits the engine to be lowered below floor level for easier installation of the combustion section to the compressor rear frame. The outer shell of the combustion chamber has still to be installed.

Coincident with the build up of the compressor rotor, the turbine rotor is assembled for run-out and tip radius check using air gauging. The turbine rotor is then assembled into and supported by the turbine frame. It, plus the nozzle guide vane assembly is then assembled as a complete unit into the engine, the spline shaft of the turbine rotor being locked to the rear stub shaft of the compressor rotor.

After the assembly of the turbine frame and rotor to the engine in the vertical pit, the engine is transferred to a horizontal roll-over stand, and the transfer and rear gearbox assembly is attached. The front ring of the roll-over stand is bolted in place, thereby permitting the engine to be rotated for the assembly of the various accessories, piping, hoses, etc.

Finally, the tailpipe and final nozzle are assembled and this in turn, is transferred from the vertical stand to a horizontal stand and brought forward to be assembled to the engine in its roll-over stand.

The Orenda J79-7 program has proceeded remarkably smoothly reflecting credit upon the Malton company and its many suppliers and subcontractors. The delivery of the first engine to Lockheed's on January 19th 1961, represents a period of only 15½ months from receipt of the drawings at Orenda to delivery of the finished product.