THE AVRO CANADA Mk. IV CF-100 long-range fighter.

AVRO TOOLS MK. IV CF-100

AS PROTOTYPES of the CF-100 Mk. IV aircraft designed by A. V. Roe Canada, for the RCAF approached the final stages, extensive preparations for production were under way. To increase floor space for manufacture of this 17-ton, long-range, night and day jet fighter, the gas turbine experimental division was moved to another building. While the Avro Canada staff had the knowledge and available facilities for production of the 120 main assembly fixtures, 2,000 sub-assembly fixtures and 26,000 detail tools, outside help was called on to speed up the large program. The story of the extensive tooling subcontract operation, one of Canada biggest such jobs in peacetime, has not till now been fully told, but it shows how a huge project may be distributed over a broad base to help telescope the time factor and yet ensure that a common goal of style and quality be reached.

Seek Canadian Suppliers

Sources of supply in Canada are being used where practicable. The subcontracts organized to supply parts and materials for several thousand Avro Orenda jet engines and their accessories per year have been described by J. F. Taylor in Dec., 1952, CA as resulting in establishment of new plants, extensions of plants and development of manufacturing techniques new to Canada because formerly existing Canadian sources were inadequate. Advances made in casting, forging, gear making, bearing manufacture and machining are a permanent gain to Canadian industry. The CF-100 program likewise is bringing new experiences to our industry.

A. V. Roe have some 30 subcontractors here and in U.S.A. supplying CF-100 tooling. They have favored subcontract sources in the area around Toronto with whom they can work closely to get good tooling as and when they need it.

Supplying Information

The supply of information to the subcontractor is a major problem since it is hard to provide adequate blueprints. In fairness to the outside plant it is vital to supply this information in adequate and understandable form. Mockups, gauges and jig references are supplied by A. V. Roe. Before any job is sublet, the contractors and A. V. Roe have their technical people meet and discuss tools to see that technical and delivery information is complete. A decision is made as to who will supply missing information and a schedule set for when information is to be available.

By Maurice Conklin
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Administration of the program is difficult. Timing of the loan of a master to several users is a special problem. It is preferable to hold jobs as close to home as possible; the diffiiculty of guiding work has been said to vary as the square of the distance to the subcontractors' plant.

All Canopy Tooling From Single Source

Williams Tool Corp. of Brantford, Ont., who have the job of supplying complete tooling for the canopy, have a resident group of four A. V. Roe technical men at their plant. The package type of subcontract, in which all tools for a particular section of the aircraft are made by one supplier rather than having the individual tools quoted on separately, is simpler although there are still co-ordination requirements.

The canopy rim piece required a mockup (model) to be supplied to both Williams Tool Corp. and the casting supplier. At interchangeability points, jigs must tie in with those made by other suppliers. Requirements such as these are met to a great extent by the methods described below.

Start With the Design

Design drawings were made for the aircraft. Based on these full-size drawings (lofts) were produced. The first loft for a section of the plane is the line loft which shows the external shape without indication of skin joints. From this loft a full-size mahogany model of the plane is made. This is a mockup which serves to check the lines of the plane and clearances. The line loft is corrected to match the revised mockup.

Assembly and Detail Lofting

The assembly lofting, which is measured from the line lofting, fills

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General view of lofting section.

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in details. Joints, rivet lines, overlaps, parts inside the craft and a few important dimensions are determined and shown. Carefully measuring from the assembly loft individual components are lofted and lofts photographed to provide information for the shop.

Mockup Uses

The mockup not only provides a check on drawings and a permanent checking reference but is used as a base in production of detail mockups. It also provides categorical locations between stations indicated by contour lines on the lofts. Unusual accuracy is required in manufacture of jet planes because of the thicker skins and heavier sections required for the high power.

The detail mockup surface corresponds to the inside of the skin of the airplane. If skin thickness is to be changed, these mockups are not altered and inside parts require no adjustment. The mockup surface is not stepped because butt-strapped joints are used and the strap is not regarded as part of the skin. The joint lines are marked on the mockup.

When the shape of a piece of skin is to be reproduced, a plaster or a plastic "splash" up is made. To allow for thickness of skin, a sheet of wax of the same thickness is applied to the mockup at the reference area. If curvature is sharp the wax is dipped in hot water before rubbing down into place. Joint lines are scribed on the wax and show on the casting. The splashes are reliable reproductions of the forms required. Plaster of paris is used for large units because of its low cost; glass-fibre-reinforced resolin plastic applied by painting on in layers for taking off smaller areas.

From these splashes detail mockups may be made and to check the detail mockup a casting may be taken from it and tried for fit on the master mockup. Unless a doubly curved form is described by simple arcs a blueprint can only show the shape at isolated sections and intermediate points must be located by interpolation. A detail mockup has all these points and therefore complete data for such a part. It is also a form from which a ready check of tools may be made and a pattern for casting of plastic tools.

Additionally it serves to allow use of a group with manual skill not ordinarily available for tool production. It is a solid drawing prepared for the guidance of the "blueprint-blind."

Mockup of Canopy Glass

Even the match points of the canopy glass were made in the form of a mahogany mockup and from this was made a plastic model of the glass match point to be sent to the glass supplier.

Detail splashes of mockups are used in manufacture of drill jigs, forming dies and router fixtures.

Some skin sections are drilled and routed in the flat but those with deep forming will probably be drilled and routed after forming. Where skin sections overlap, holes are produced before assembly in only the upper layer and the exposed holes are used during assembly as a guide to drill through for riveting.

For a part that is to be drilled flat, holes may be drilled in the template, pins placed in the holes and drill bushings set on the pins. A layer of glass cloth will be placed over the template with holes for the bushings and painted with the self-setting liquid plastic used for splashes and tool. Further layers of glass cloth laminated with plastic are built up to a thickness of about 5/16 in. Locators are kept in place and incorporated during making of the drill jig. The upper and lower layers are woven glass cloth and other layers may be of batting form, a loose felt.

Lightweight Jigs

AN EXTRA COAT of plastic inside and outside after completion provides a glass-smooth surface. The edges may be trimmed quickly by bandsaw. With no further work, a lightweight, accurate, strong jig is provided. Lightening openings may be made. Drawer pulls may be incorporated as handles in these jigs.

Templates which have holes that must match are checked after drilling by stacking and dropping a drill rod through.

For parts that are to be drilled after forming a mockup instead of a template is used to support any needed bushings and locators and to act as a pattern surface on which to make the shell carrying the bushings. This type of jig is known as a drill basket.

Drilling Without Bushings

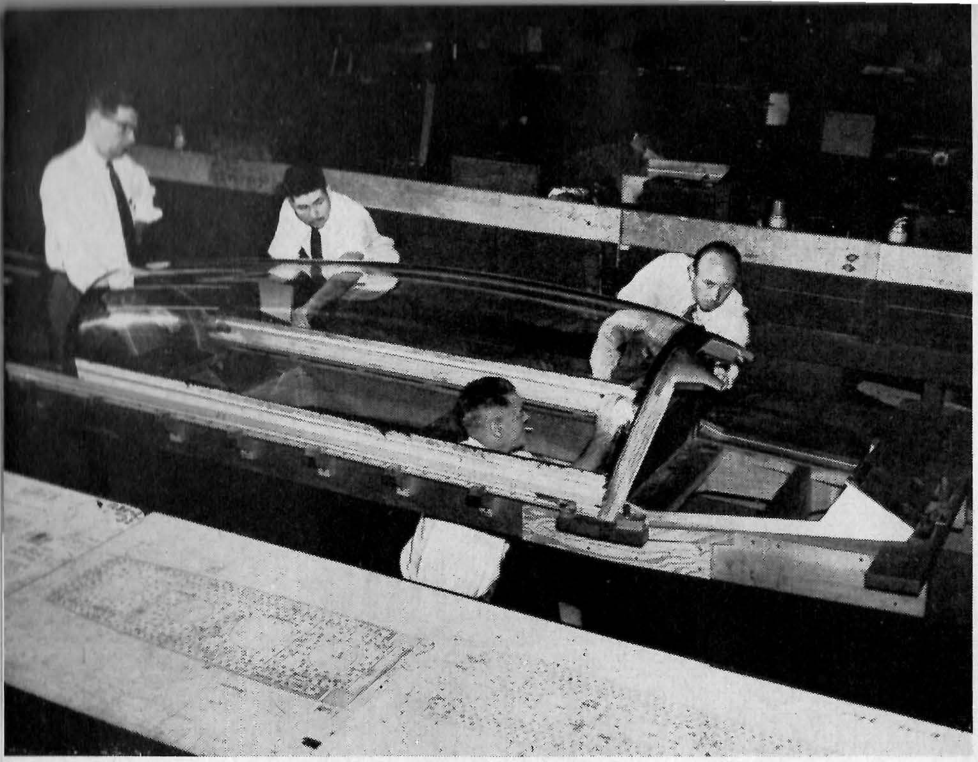
Some jigs are made with countersunk holes and no drill bushings. These are used with a drilling snout, a conical sleeve which locates in the countersink. When the equipment is pushed down a drill protrudes from the centre of the sleeve and makes a hole in proper location. A cylindrical snout to fit bushings may also be used in order to avoid the side thrust of location from being taken by a slender drill.

A basket used for several sizes of holes will have a stripe of color painted along rows of holes of a particular size.

Router Fixtures

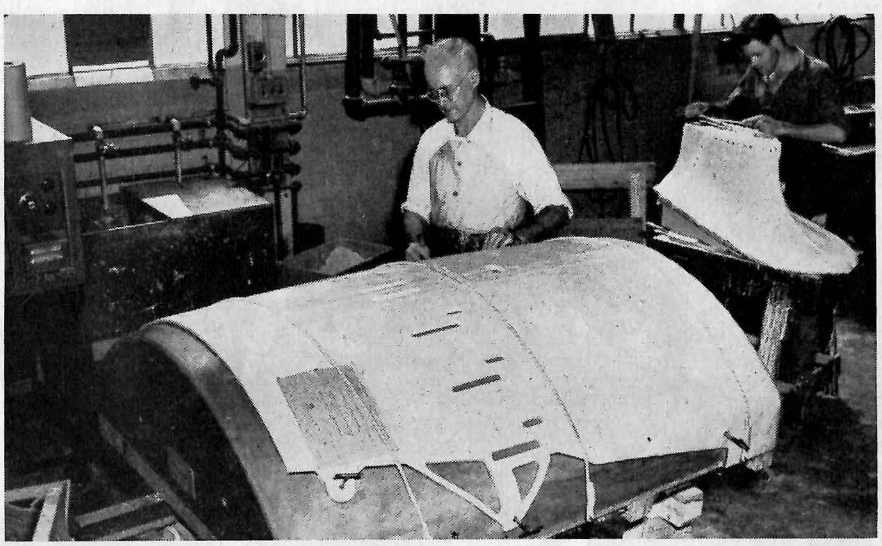
Router fixtures may be made like drill jigs, except that edges are finished to precision according to trim lines. Flat parts are stack-routed—through two or three location holes bolts are passed to assemble a stack of sheets with a plywood sheet underneath and the router form on top. A collar above the routing tool follows the edge of the form to guide the cutter. The sheet of plywood protects the machine table from the cutter.

Parts routed after forming are routed singly, using a pneumatic hand router sitting on a rest with the router form on top of the sheet. Tooling holes for location during routing and drilling are usually punched or pricked-punched during forming. Some parts are held by loose toggle clamps and drilled through bushings in the router form to provide locating holes. The seat for the work during routing may be



Planners checking canopy assembly subcontract unit with jig for trim tolerances.

Plastic drill baskets. Routing fixture for nose wheel door.



Routing fixture for gun package.

made of plastic, using a splash taken from the mock up. Sheets are sheared to size before drilling and routing, and afterward they are deburred by any of several methods before subassembly.

Fewer Rubber Dies

There is a tendency to use more hard dies than formerly, when rubber dies were the rule in the modest quantities required for aircraft. This is particularly the case where blanking and piercing are done in the one die. The pros and cons of quality versus quantity rule in deciding the type of die to use.

Dies of Kirksite mixture are used on stretch forming and press forms. But for simple, more compact forms, plastic dies are cheaper.

Dies are shipped in with trial samples and templates attached as die proof.

Many Avro dies have flame-hardened edges.

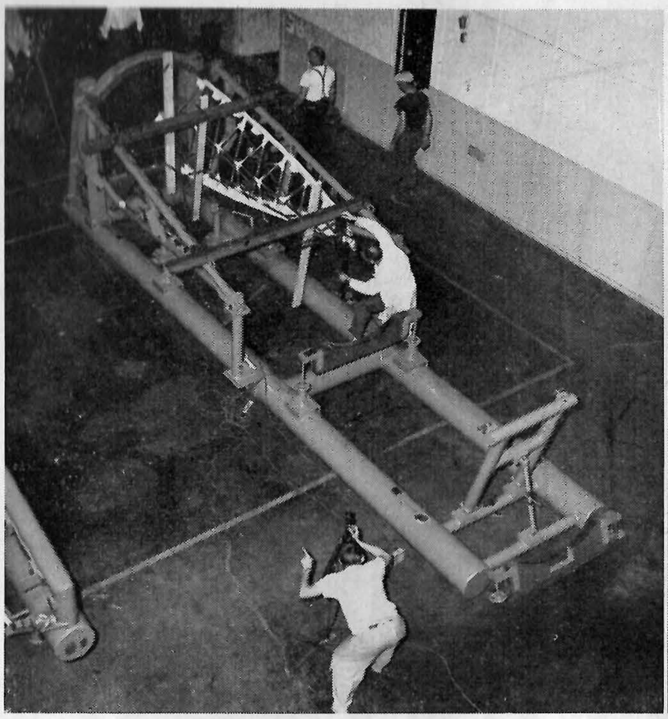
Check for Engineering Changes

The first plane team includes representatives of product design for engineering changes, of production control to look after shortages, of production engineering to check on tool and production problems and of the production department to do the work and learn in detail how the operations are carried out.

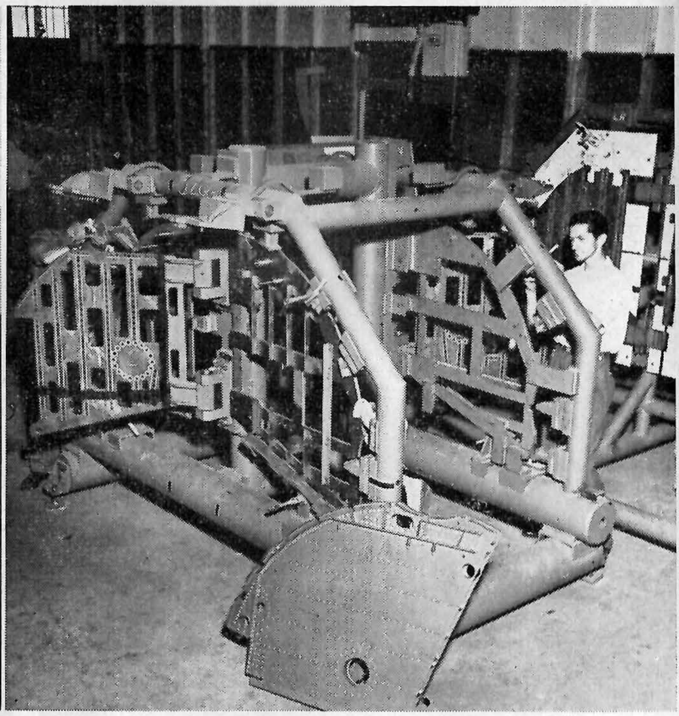
When the tools arrive from subcontractor or from the Avro toolroom they are first checked for recent engineering changes that might affect them and then inspected. If they are approved, a material requisition and a tryout order are issued. Operation sheets checked for up-to-dateness accompany the set of tools. The tryout products are checked with process representatives present. If the tryout is satisfactory a production run follows, otherwise the tryout is repeated.

The plane was initially planned by production engineering to have 32 interchangeability points and to show these a sketch was made up giving an exploded view of the craft divided into various subassemblies, each of which has interchangeable connections to the rest of the assembly. Interchangeability will be increased to some extent by making such parts as panels and doors interchangeable.

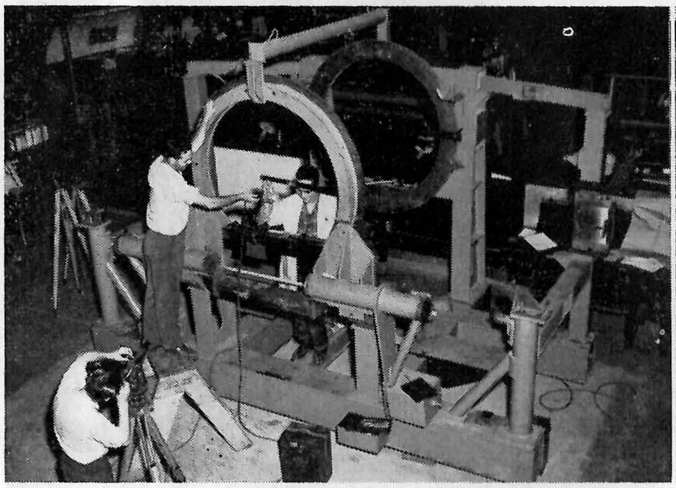
(Additional photographs of Mark II CF-100 tooling are on page 42.)



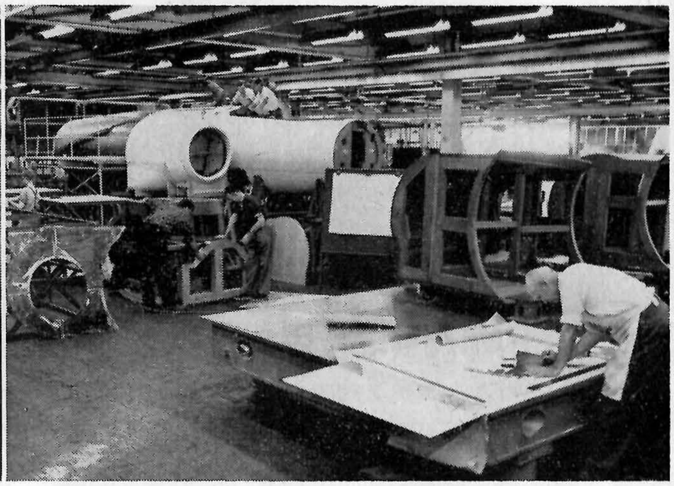
Jig builders setting up master gauge of plastic to co-ordinate fillet trim lines between fuselage and nacelles on rear centre section fuselage.



Nose fuselage details and bulkhead type forming jig. Bushing plate at left with ring of holes prominently marked in white is hinged at centre to drill halves of work symmetrically.

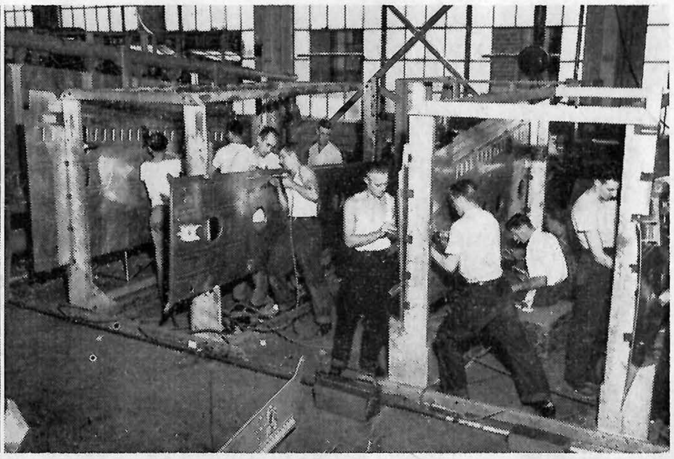


Aligning fore and aft transport joint rings in centre section marry-up.



Full size preshrunk mahogany master mock-up with plaster and plastic models.

Production line final bolt-up of main spar of centre section, shimming root ends.



Outer wing panels supported by wooden structures while stringer riveted.