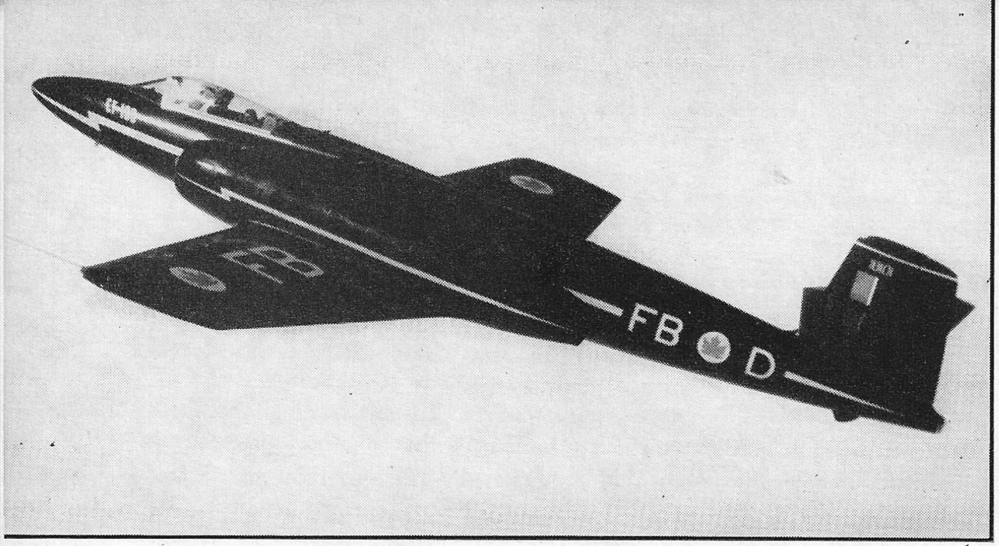
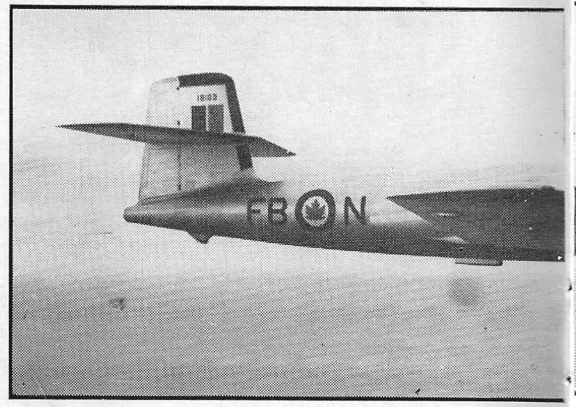




Production of a Fighter

By R. K. ANDERSON

The following article was originally presented as a paper, "Production of an All-Weather Long-Range Jet Fighter," at the first joint meeting of the Canadian Aeronautical Institute and the Institute of Aeronautical Sciences, held last October in Montreal. The author, R. K. Anderson, is Assistant Industrial Engineering Manager for the Aircraft Division of A. V. Roe Canada Limited, now known as Avro Aircraft Limited.

IN CONSIDERING the subject "Production of an All-Weather Long-Range Jet Fighter," it seems logical to consider, briefly, the thinking behind the necessity for producing such an airplane. What are the operational requirements?

I have here a quotation from a standard schoolboy's Atlas: "Canada comprises the whole northern part of North America excepting Alaska. Including the Arctic Archipelago lying between the 60th meridian on the east and the 141st meridian on the west and extending from the northern boundaries of the U.S. to the North Pole, the total area of the country is over three and three-quarter million square miles."

These simple geographic statements when considered from a defence standpoint become facts that stagger the imagination. How can such a vast territory be defended? First of all, it seems logical to assume that the potential threat to this country is by air. Again we ask, "How can Canada be effectively defended against air attack?"

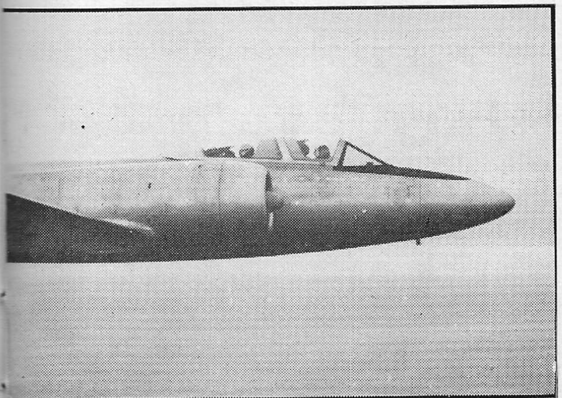
The Oracles: It is fortunate, indeed, that we have people in our Government and in private industry who can see clearly into the future, not in the forecast of actual events but rather in the development of scientific equipment. All of us have rather definite ideas of what to expect of aircraft in the near future. We know that our potential enemies can develop and are developing advanced bombers that are faster, that can attain higher maximum altitudes, and that will carry weapons that are more deadly and more accurate than anything that is in use today. Those things we must assume. Our airforce planners have estimated the probable speed and ceiling of near future bombers.

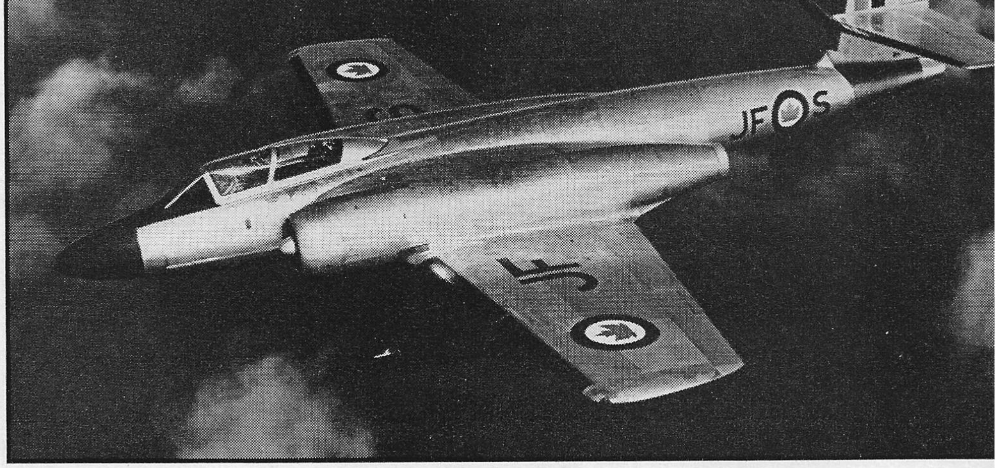
In order to intercept and destroy such potential enemies after detection, we must have an airplane that can fly a long way, engage the enemy and return. This means that a terrific amount of fuel must be carried to feed the best available engines. This interceptor must have great speed to be able to make contact in a very short time and to be able to out-fly the enemy once contact is made. It must carry deadly weapons of the latest types and it must be equipped with the latest electronic devices for detecting and combating the enemy, under possible blind conditions. These basic requirements plus many others are the facts that determine the size and approximate configuration of the required aircraft.

You can see that we are not talking about fighters and interceptors in the class of Spitfire, Hurricane or Mustang, nor are we any longer considering our present best fighters. We are talking about a 15 to 20 ton airplane that will fly in excess of the speed of sound and perhaps attain a ceiling of something over 10 miles. Air Force technicians and analysts who estimate future threats work closely with aircraft design teams in deciding in detail the specifications for the airframe and at the same time, develop such items as armament, radio, radar, pressurization, refrigeration, heating, etc.

Five-Year Lag: At the close of World War II, defence planners accurately estimated the requirements that would be necessary in 1954 and as a result they are getting the CF-100 long range jet interceptor which has the speed, maximum altitude, fuel capacity, radar facilities and fire power to intercept and destroy any known bomber in existence today. The time from conception through design, development and quantity production, though normal for the aircraft industry world wide, was a long five years. We can say accurately that it takes about five years for aircraft manufacturers in any country to produce aircraft in quantity from the beginning of design.

Past practice has been a development production cycle that began with the building of experimental prototypes, flight testing and then tooling for quantity production. The initial stage in this cycle, the hand building of prototypes, required that engineering design releases be only sufficient to enable first class aircraft workers to make parts strictly by hand methods, cutting and fitting on a trial and error basis. This results in an aircraft that may be a thing of beauty and may per-





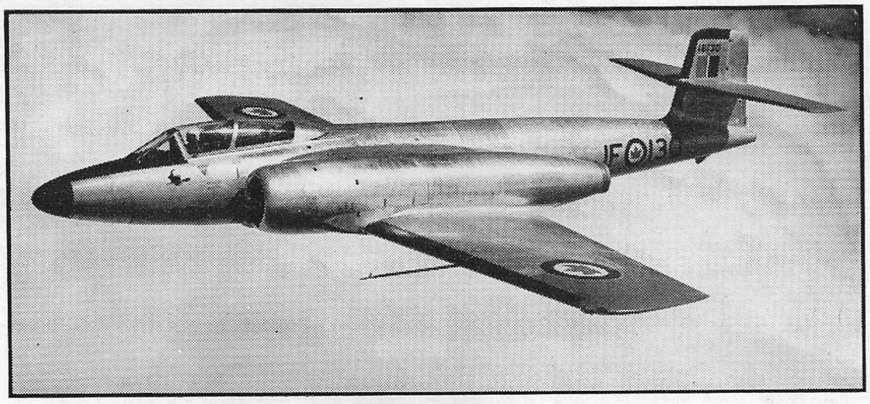
Development pattern of a modern fighter is illustrated by photos of various CF-100 models. Far left is Avon-powered Mk. 1 prototype; next, Mk. 2 Orenda-powered prototype; above, a pre-production Mk. 3.

form remarkably, but one that cannot be duplicated part for part. Further, there will never be a desire to duplicate such an airplane part by part simply because parts were not developed with any thought as to ease of tooling and producing. This results in having to release a complete new set of detailed dimensioned drawings before processing, tool design and tool manufacture can be done. Then it becomes possible to manufacture detail parts in quantity and proceed with the business of making airplanes.

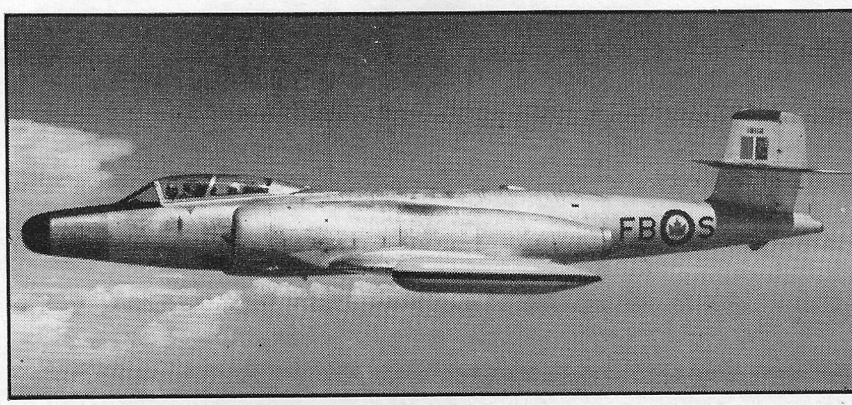
About five years after the original thinking started, usable production aircraft begin to be delivered. By this time the aircraft is obsolete, and so are those that have been planned for the next year and the next. It becomes evident that we must find a way to reduce that five years as much as possible.

Eliminating Steps: After careful study of statistics on the development and manufacture of aircraft over the past 15 years, the following plan has been evolved. It is now thought possible because of our present engineering abilities and research equipment, to design an initial flight article that is extremely close to the specifications developed by wind tunnel work. In other words design engineering will make a complete release the first time with all details fully dimensioned.

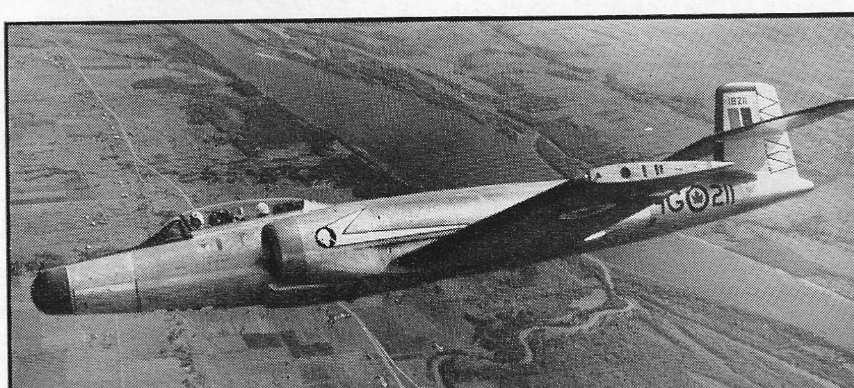
The time lapse for so doing is little greater than would eventually have been necessary for a full production release but saves the time needed for a prototype release. What has been accomplished? All parts and assemblies can be planned for production. Tool designs for production can be started immediately. These are production tools which would have to be made later anyway but can now be ready to



The model above is a production-type Mk. 3, the version which was first to go into widespread service with the RCAF, mainly in operational training.



The prototype Mk. 4 (recently destroyed) was really one of the first dozen CF-100's ordered and was forerunner of production type appearing below.



This is the production version of the Mk. 4, the type which is now in multi-squadron service with the RCAF in both eastern and western Canada.

Mark 4 CF-100's are lined up at the Malton, Ontario, plant of Avro Aircraft Limited, awaiting delivery to the RCAF. In this article, the author describes how a fighter such as CF-100 is produced in quantity.

be used in making the first parts for the prototype. In the past, convenience tools were made by the skilled workers and generally afterwards scrapped.

Assembly jigs can be designed and built that will take no longer than would have been necessary for a prototype but, again, these are production jigs that will not have to be scrapped or rebuilt. Interchangeability media can be incorporated from the beginning. Of course, only one set of tools will be built at this stage. Further, only those tools that are economically feasible for making a few parts will be built. But those parts that are machined by non-production methods will still be made accurately to detailed dimensions. Subassemblies that later will be tooled are now incorporated in main jigs.

Prototypes for Production: It is now possible to make several prototypes that are alike and that are the same as future production models except for those changes that are incorporated as a result of thorough testing. In other words revisions that are a result of research and testing are the only changes necessary and those would have to be made under any system, but those changes that would have occurred due to the difference of method of manufacture are eliminated.

All changes must be carefully recorded in the form of concurrent detail drawings. Tool drawings must be kept abreast of the changes and tools reworked or rebuilt as necessary. The elapsed time will be no longer or very little longer than with the old method, but since all engineering details, all production planning and processing papers, all tool designs and some actual tools have been kept current, production in quantity can start immediately and can accelerate rapidly as the remainder of the tool plus duplicate tooling and convenience tooling are completed. Approximately two years of elapsed time have been saved.

the economics

NOW, LET us consider the cost of such a program. Much to the surprise of most proponents of this theory the saving in cost can be enormous. It should not cost more. It has been determined that except in very unusual cases no greater than 25% scrap loss has occurred in past programs. 25% sounds like a lot but the loss is at a point in production where it is the cheapest.

Sheet metal tools and sheet metal parts are the greatest affected. The cost of these items more than the cost of the same items under the old system is negligible, and the wrong or spoiled parts because of hand methods, are practically eliminated. Further, expensive castings and forgings are not involved since nearly all parts of this nature must necessarily be hogged from raw stock in the beginning. The real saving in cost is in the lower labor cost of producing the first several production models. The cost of the first production aircraft will be reduced to the point where the cost will now be in the general area of 15 to 20 man hours per pound where 25 to 40 is more normal under previous methods. Take this difference over 20 tons of airframe and a considerable saving has resulted.

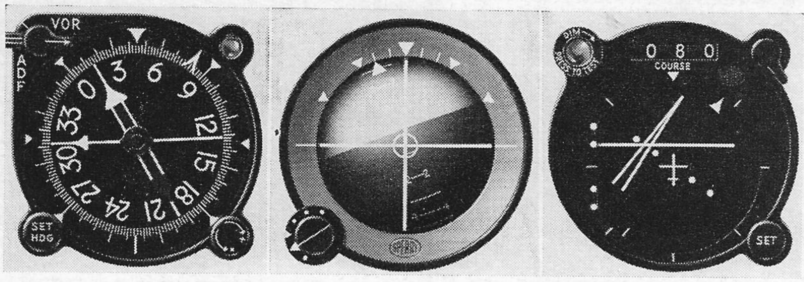
The Learning Curve: The reason for this saving can best be explained by reference to the now common tool of aircraft industrial engineers, the learning of reduction curve. The use of learning curves is a major subject in itself and I shall not go into detail at this time concerning it. It is sufficient to say that learning as applied by the aircraft industry means plant-wide learning rather than the learning of the individual worker on the machine or bench. By that I mean the flow of paper, materials, purchased parts, tools, both production and general, and learning of all the service functions that aid direct labor as well as the direct laborers' learning, all go together to make up a reduction of direct labor cost from one unit of work to succeeding units.

The fact that such reduction occurs is common knowledge, and it is also well known that the high cost of direct labor on the first units produced is caused by the fact that all of these supplementary functions must be perfected as the first units are being produced.

Under this plan most of these functions will have been perfected during the prototype manufacturing and since tools will have been proven and direct labor methods basically unchanged from prototype manufacture to quantity production, the consequent lowering of direct labor cost on the first production units is the inevitable result.

Now let us consider the effect and responsibility on the indirect or service functions of an aircraft plant.

Production Engineering: During the design period Production Engineering people will be working very closely with Engineering in order that, where



Showing the Way

Three new aircraft panel instruments, designed to give pilots additional and more pictorial cockpit information for flying present and future high performance aircraft, were recently announced by Sperry Gyroscope Co. of Canada Ltd.

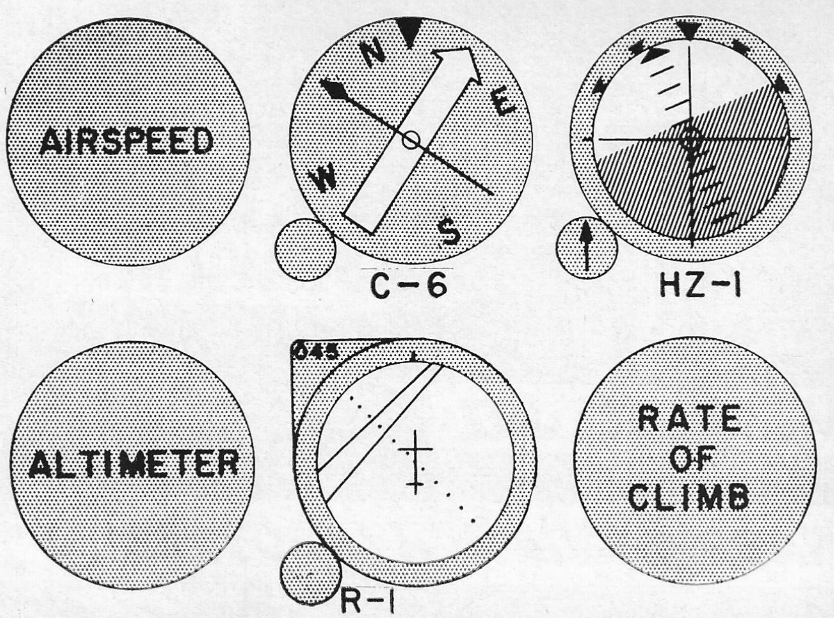
Developed by the Canadian firm's U.S. parent, these instruments — designated the Sperry Integrated Instrument System — provide improved presentation and performance for the gyro-horizon, the direction indicator and the radio deviation indicator. Besides these standard functions, an advanced type Zero Reader flight director and a more realistic presentation of radio beam position are included in logical combination so that no additional instruments are required over the present "basic six".

Combining the flight director and the gyro-horizon in one instrument, the HZ-1 Horizon Flight Director (top centre) not only indicates how to move the controls to seek and follow a desired flight path, but tells the pilot his pitch and roll attitude at all times.

Behind the "fly right or left" and "fly up or down" points of the flight director is a "bar-less" horizon sphere portraying aircraft attitude throughout unlimited maneuvers. Furnishing data to the flight director is a lightweight, tubeless Z-4 Computer designed to provide more stable coupling to ILS beams during manually-controlled approaches.

Directional element of the system introduces an important improvement in RMI performance. This is said to give improved radio cross-bearings directly on a new C-6 Gyrosyn Compass (top left) master dial which is free from repeater errors for greater accuracy on course or for critical approaches in any weather. A settable course marker on the compass dial improves presentation and also serves as the heading selector for the flight director.

Third element of the system gives pictorial representation of the airplane's position and heading relative to radio beams. The R-1 Pictorial Deviation Indicator (top R) portrays the radio beams by means of a narrow converging V-shaped bar that shows at a glance location of the ground transmitter relative to the airplane. The new indicator also incorporates an omni-bearing selector by which any VOR radial bearing can be chosen. Both ILS glide path and localizer deviation are displayed on this instrument as on present deviation indicators. Drawing below shows how the three Integrated Instrument System instruments fit into standard panel of basic flight instruments.



possible, detail parts are designed for ease of production, and Production Engineering can obtain as much advance information as possible. In this manner interchangeability components can be selected and plans made for insuring interchangeability from the first article where possible. Metal and plaster die models can be constructed in advance of manufacture of form dies. These will aid in avoiding countless changes to parts and tooling that are largely trial and error otherwise. In addition, aircraft designers can view their efforts in full scale, three dimensional models so that lines may be altered where it seems advisable.

As fast as detail drawings are released the process planning will be done so that operation sheets can be prepared, tool design orders written, tools designed and tool manufacturing orders prepared. Tool manufacturing orders for those tools deemed necessary for prototype work will be scheduled and released.

Production Engineers, who, of course, are responsible for determining how each part shall be made, can order sooner any expensive machine equipment such as special extra capacity, mills or sheet stretching machines that require many months to obtain.

In short, all tooling activities will be completed before and during the building of the prototype aircraft except for the actual fabrication of those tools not needed for the prototype. As changes occur due to the building and testing of the prototype, all processing papers, tool designs and, of course, those tools in use, will be kept up to date.

Industrial Engineering: As operation sheets are completed by planning, estimators can establish standards. Operations other than machining can be studied as they occur, because now these operations will not change appreciably from the prototype manufacture. Standards having been established, highly accurate manpower figures can be forecast and detailed production schedules can be prepared.

The cost of the impending production program can be estimated accurately, much more accurately than without this information. Later when the production program starts, performance reports can start immediately on a realistic basis. Management reports will be accurate rather than the "seat of the

(Continued on page 65)

suitable for both metal-to-metal and metal-to-honeycomb bonds.

A separate department to handle the metal-bonding process will be established within Canadair. Steam-heated hydraulic platen presses will be used for bonding the flat work and contoured parts will be cured in an autoclave.

Canadair intends to process their parts by alkaline degreasing, sodium-dichromatic-acid etching and air drying. The parts are then spray-coated with the adhesive primer and the tape is immediately attached and force-dried in an air-oven. Bonding of the parts is then carried out in an autoclave or steam-heated platen press.

Canadair comments that at first glance it appears that metal-bonding is more expensive than rivetting or spot welding, but experience in the industry seems to show that where there are more than 20 assemblies, the use of metal-bond adhesive is less expensive.

LETTERS TO THE EDITOR

Antique Aircraft Wanted

Sir:

I am interested in locating any really old aircraft and am willing to make a good cash payment for same. They do not have to be in flyable condition. If you know of any for sale, please get in touch with me . . .

D. B. APPLEGATE

Vancouver.

ED: Mr. Applegate's address is 2306 Macdonald St., Vancouver 8.

Company for the Whooping Crane

Sir:

I would like to tell you the story of an airport—one of the many war surplus ones that stud the Prairie provinces. This particular one was operated by a local flying club. On weekends it buzzed to the sound of the private pilot and his putt-putt. There was a smell of dope and gasoline in the air. Eight small planes were based there.

This fall I called at this same field and could hardly believe my eyes—all was still—the J-3's and the Tiger Moths had all departed; dragged away by their owners to some new residence behind a barn or other exposed tie-down. A look inside the hangar revealed rows of combines instead of airplanes.

What had caused this transformation? . . . The Department of Transport, Civil Aviation Division, had taken over the field. Their hangar rate schedule was in effect. The cost of storing a Cessna was $24.80 a month; a Stinson, $32.85. The cost to a farmer for storage on his combine, $2.50 a month. Thus we have combines instead of airplanes.

Why should a condition like this exist? Granted it costs money to operate airports and they have to be made as self-sustaining as possible. A rate schedule must be drawn up to supply as much of this money as possible. Possibly the DoT schedule is quite all right at some busy eastern airport where the demand for hangar space is high.

I fail to understand why there can't be some logical thinking and flexibility applied to this schedule. If the demand for space at the regular rate is very low or non-existent, why fill the hangars with automobiles and farm implements? If there are breaks to be passed out, why not give them to the private owner? After all, he is already about as near extinct as the whooping crane.

V. E. BARBER

Dauphin, Manitoba.

PRODUCING A FIGHTER

(Continued from page 34)

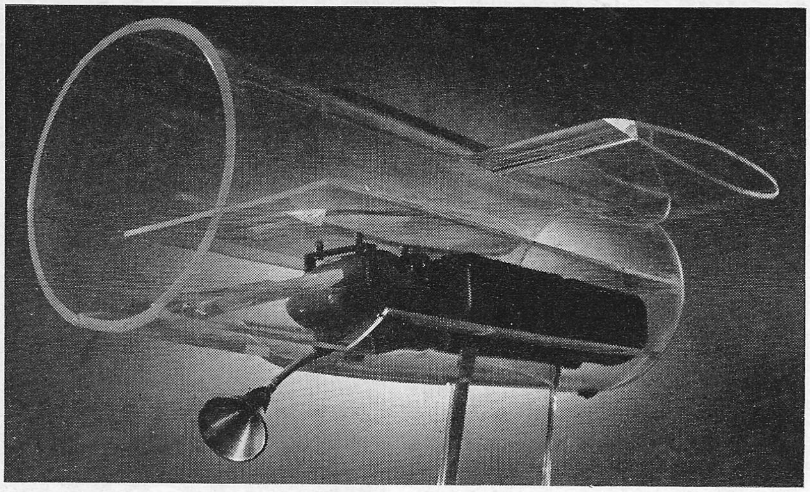
pants" method necessary until later in the program.

Production Control: There are many facets of production control that will benefit from the advance information. The fact that all parts will have been processed by planning and standards applied by Industrial Engineering allows Production Control to determine the load for each type of machine in the machine shop as well as in sheet metal fabrication. Any possible need for future sub-contracting of parts will be apparent.

Since the size and shape of all parts will be known it is now possible to determine the type and size of storage facilities as well as the necessary floor area required for such storage. As I mentioined earlier, the perfection of Production Control systems plays a vital part in reducing the hours of direct labor and reduces immeasurably the lost or idle time of direct workers who are waiting for tools, materials or parts.

Procurement: Since this method calls for detailed drawings, proper material lists can be established much earlier than before. As a consequence materials can be ordered with a much greater degree of accuracy than the bulk type orders necessary in the past. A consequent saving of the material dollar is obvious and the right material is on hand considerably sooner.

Sales & Service: Contract pricing of spares as well as of the complete program is done with a much greater degree of accuracy at the time when that accuracy is needed. Usually pricing of these contracts depends entirely on statistics of past programs with very little knowledge of the current one. Since standards are established before the production program, better pricing results. Sales & Service manuals and



PACKAGE FEEDING: Designed by Flight Refuelling Ltd., Blandford, Dorset, England, this new package-type aerial refueller unit can be installed in an appropriate aircraft in little more than 30 mins. This pack unit is the latest development in the probe and drogue system of flight refuelling. It combines the hose reel from which the drogue is trailed and the fuel supply tanks in a single unit, thus eliminating the need to draw from the tanker's own fuel supply for the refuelling operation. The unit is self-contained, and may be regarded as auxiliary equipment, so no special modifications to aircraft are required for installation.

brochures will be forthcoming sooner, due to the advanced information.

Proper administration of this plan can and will result in a substantial saving in cost, but perhaps more important, it produces aircraft in quantity approximately *two years ahead of other known methods* and thus makes available more nearly up to date equipment in order that we may always stay ahead in the armament race. Variations of this theory are now in use in the United States. An article in "Aviation Week" of April 12, 1954, outlines briefly the current thinking of the United States Air Force along these lines. The article states that the Boeing B-52, the North American F-100, the Convair F-102, McDonnel F-101, Douglas C-133 and Lockheed C-130 are all being produced under modifications of this program.

The content of what I have said is a summary of the thinking that has been taking place at A. V. Roe Canada Ltd. Our reasons for concern in this matter are patriotic as well as selfish. We feel that we have an obligation to Canada and to all free countries, to keep abreast of anything that is possible in other countries, friendly as well as unfriendly, and we are definitely obligated to our Company and to ourselves to produce as economically as possible.

It is indeed unfortunate that so much of our thoughts and efforts must be directed toward protecting ourselves against aggression. It is our fervent prayer that this situation will be changed as soon as possible, and that we can then concentrate on the peacetime development of our country.

SENIOR OFFICER

(Continued from page 29)

World War II present special circumstances and must be considered on their individual merits. Moreover, during the rapid expansion of the RCAF, it has not been possible, in many cases, to give even non-veterans the ideal training and employment specified by the plan. Nonetheless, it is intended that, when the approved manning ceiling is reached, the plan will be followed.

Promotion: The general principles of the RCAF's promotion policy are designed to ensure that:

- Only those officers who are suitable in all respects are promoted to higher rank.
- Officers of outstanding ability are granted due recognition by being promoted ahead of officers more senior but with significantly less ability and potential.
- The opportunity to progress at a reasonable rate to a reasonable level is given to the great body of average officers—on whom, of course, the general efficiency of the Service is largely dependent.

With the above principles in mind, a Central Promotion Board, consisting of the Senior Personnel Staff Officers of all Commands, convenes semi-annually with personnel officers at AFHQ to consider the promotion all officers eligible by virtue of minimum seniority. This Board reviews the officers' confidential files, which contain confidential personal assessments, promotion narratives, course reports, qualifying examination reports, and recapitulation of Service experience. The limitations of each of these sources of information are generally appreciated, but they are being reduced by constant research and, more important, by education of officers with respect to their responsibility in assessing and counselling officers under their commond.

The Central Promotion Board reviews the reports of Unit Promotion Boards' and Command Headquarters' remarks. These, taken in conjunction with the file study, are used to categorize officers finally recommended for promotion as "Very Suitable" or "Suitable." Candidates within each group are then listed in order to relative seniority, and are recommended for promotion to a Senior AFHQ Board, composed of officers whose rank is at least two levels above that of the officers being considered.

LIGHTWEIGHT FIGHTER

(Continued from page 26)

comparison if we are judging lightweights versus heavyweights. And, as we have seen, there is no magic in the comparison. So we can say, with one of the fathers of modern science, Rene Descartes, "There is nothing so hidden that we cannot discover it, provided only we abstain from accepting the false for the true, and always preserve in our thoughts the order necessary for the deduction of one truth from another."

TCA VISCOUNT

(Continued from page 21)

a quality necessary for the low temperature operation of turbine engines, would have to be specially refined from imported crude oils. As a result, JP-4 is one to four cents per gallon cheaper than kerosene and will enable the Canadian air line to save some $190,000 yearly in fuel costs in its Viscount operations, as well as avoiding certain low temperature operating problems.