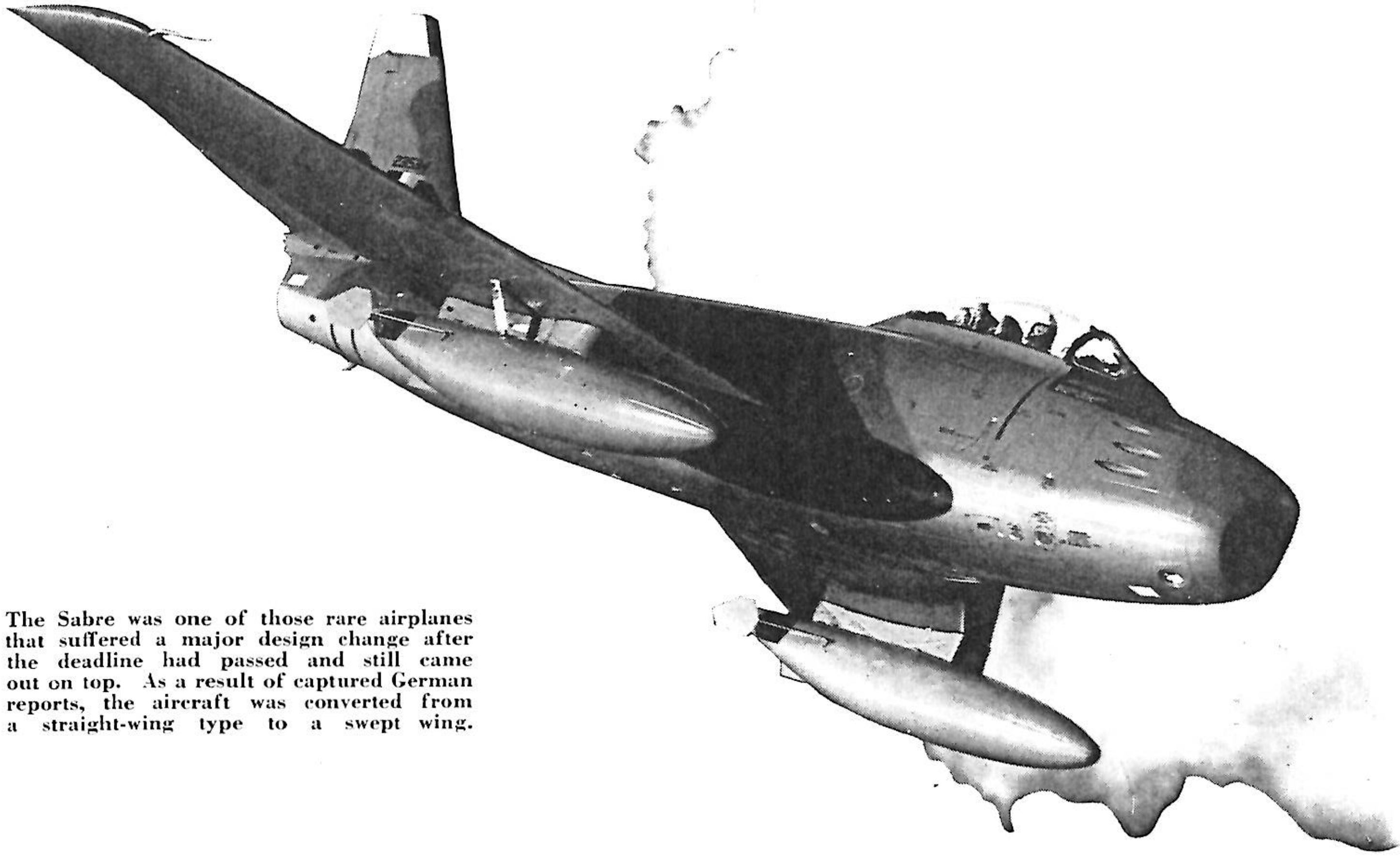


The Sabre was one of those rare airplanes that suffered a major design change after the deadline had passed and still came out on top. As a result of captured German reports, the aircraft was converted from a straight-wing type to a swept wing.

The Design Deadline

By GROUP CAPTAIN H. R. FOOTTIT

"Only with prudence and foresight can we achieve great ends."
—*Napoleon.*

THE TOWERING, snow-capped Alps were beginning to cast frowning shadows towards the town of Nice as Napoleon hunched over his desk scribbling these words. He had just arrived to take over command of the French Army of Italy. He spoke from the heart. For his troops were half naked and half starved. At the age of 27, in this year of 1796, it seemed as though his brilliant career might be broken off before it could begin. As his Army lay poised on the Italian border, Napoleon reached a deadline. With only enough rations for 15 days, the General must decide: on to Italy — and fame — or retreat.

As the annals of the past portray, Napoleon had the prudence and foresight he wrote about. He led his men over the Alps and onto the fertile Italian plains. Victory followed victory. His starving army became the glutted conquerors. And Napoleon marched into history as one of the greatest Captains of all time.

Advance or Retreat: Translated into the aeronautical world of today, Napoleon's deadline for decision — to go forward or retreat — faces every captain of industry, every captain of air transportation, and every captain of the armed services, when he moves into the field of new airplanes, engines or equipment. When a new design first starts there is a period when the customer can change the requirement, or the chief designer can scrap all his drawings and start again. But this period rapidly comes to an end. At some key hour the design must be frozen, if it is to meet its "first run" or "first flight" date. No longer can the customer demand more performance. No longer can the chief designer alter his drawings to incorporate the results of some new and far reaching research. The design must go forward. The design deadline has been reached (Figure 1).

In this day, when the time from first line on paper to the first flight of the first airplane stretches into years, this design deadline has come into the spotline of importance. For there is a long period between the deadline and the physical product when a competitor or potential enemy may dream up a superior specification, or design an advanced airplane. Moreover, there are literally hundreds of companies developing better engines and better equipment. Some of it may come to light after the design is far committed and installation is impossible. Even with development the design may be doomed to obsolescence before the last drawing is taken from the drafting

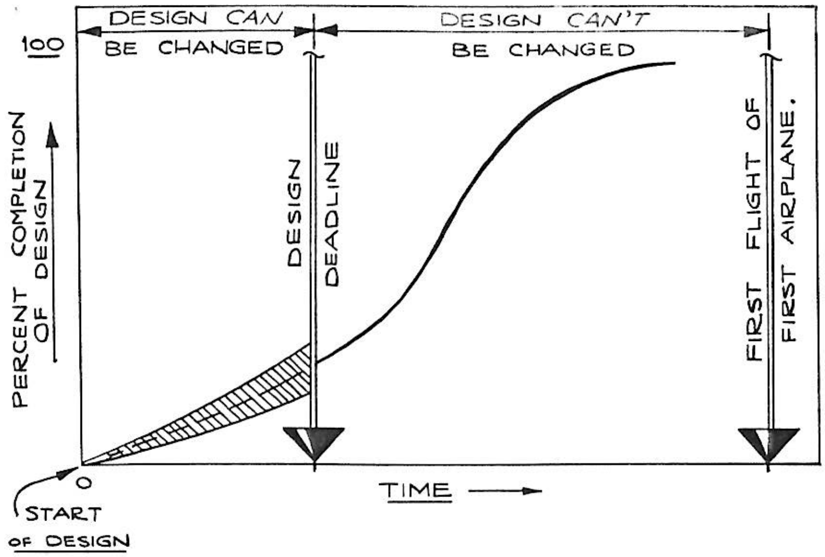


FIGURE 1
AIRPLANE DESIGN DEADLINE

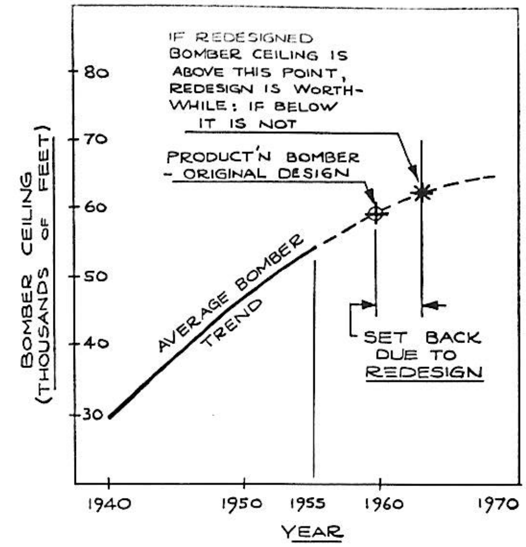


FIGURE 2
ALTITUDE — TIME GRAPH FOR BOMBER

board. On the other hand the designer may have picked up some research results, before the deadline, that his competitors have missed. Then he may have the design that will ultimately corner the civil airline market, or become a leading stalwart in the military stable.

Early this year that remarkable four-engined airliner, the Vicker's Viscount, appeared in Canadian skies under Trans-Canada Air Line's colors. I don't know the full history of the Viscount development. But piecing together the story of the Viscount's Rolls-Royce turboprop engine, the Dart, this apparently is a case where the design deadline played a significant part. It is also a case of remarkable foresight on the part of the Vickers company and their customers, British European Airways.

Dart Development: Rolls-Royce had been wrestling with the design of turboprop engines since 1943. About the end of the last war they plunged deep into the design of the Dart. Finally by the spring of 1946 the first Dart was wheeled from the experimental shops to the test stand. By July the engine was set up, the instrumentation checked, and the high pitched whine of the starter motor heralded the first run of the first Dart under its own power.

About the same time the Dart was under design and development, Vickers started work on the Viscount. It is a long pull before a new breed of engine can receive a civil certification since risk must be reduced to a minimum. Moreover, turboprop engines had been giving their designers plenty of headaches, particularly in the propeller control arrangement. Though the Dart had been flying in test aircraft, it was far from being a proven product when Vickers designed it into the Viscount. If the engine failed to meet its civil certification, then the Viscount would probably fall by the wayside.

The prototype Viscount first flew in July, 1948. The Dart came through. A bottle of champagne christened the first production airplane in the summer of 1952. The following spring Viscounts started scheduled service with British European Airways. Trans-Canada, Irish, Capital, and other air lines in 17 different countries climbed on the Vickers bandwagon. The execellent performance and handling qualities of the Viscount, and the power, low noise level, and vibration-less qualities of the Dart paid off. The seemingly dire decision on this engine had been right. Vickers and Rolls-Royce had scooped the rest of the Western World with the first true turboprop transport.

CF-100 Example: Here in Canada we have a similar example in the military field with the Avro CF-100 all-weather fighter. Before the aircraft met the design deadline it was necessary for the RCAF to pin down the exact performance, armament and equipment requirements for the airplane. I had a talk with Air Vice Marshal A. L. James, who is now Vice-President (Engineering) & General Manager for Bristol Aero Engines Ltd. In the early CF-100 days, however, A/V/M James was sitting on the RCAF's Air Council — the board of directors, so to speak — as the technical services representatives. In this position he had a lot to do with setting the technical and operational requirements for this new Canadian venture.

"In retrospect," said A/V/M James, "it all seems so simple. But at the time we were struggling to establish the detail requirements for this airplane, it was far from simple." He then goes on to relate the innumerable discussions that took place, not only in Canada, but also in the U.S. and U.K. Problems of speed, range, crew and armament were tossed back and forward over the conference table. There was a continual groping and guessing on equipment that would be developed and available some five to six years hence when the fighter would be in squadron service.

"There were those, too, "he said, "who were convinced that in five years time automatic navigation, interception, and firing of target seeking weapons would be here and all we needed was a single place airplane. But in spite of the glowing optimism regarding such developments, some of us had our doubts. In the end we were more conservative. We specified a two-man crew, a pilot and radar-navigator. How right we turned out to be!"

As fate would have it, A/V/M James was to have a hand in the use of the final product that he helped to guide in its embryo days. As Air Officer Commanding the RCAF's Air Defence Command, he controlled a number of CF-100 squadrons operating over

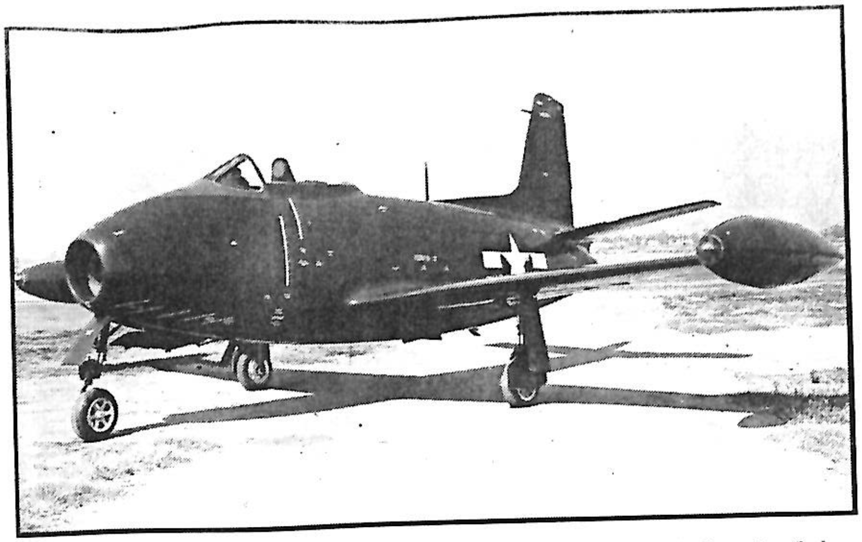
Canada. "It was most interesting," he said, "to finally see that the CF-100 is one of the best, if not the best, all-weather fighter in operation today."

Right at the Start: Continued changes, of course, go on with any airplane after the design deadline has been passed for the prototypes. This is the continued development phase. The CF-100 started with the Mark 1, with Rolls-Royce Avon engines, and progressed through to the present Mark 4, with up-rated Orenda engines. Yet in spite of these development possibilities, the basic design, before it reaches the deadline, must be essentially right. If it isn't the prototypes nearly always end up on the scrap heap, and the project is rolled up for all time. In a few odd cases, a company has embarked on a complete redesign when the initial airplanes have flopped. But this is really a new airplane, no matter what tag they choose to tack on it.

This same deadline applies, too, in the aircraft engine field. The Orenda jet engine, for example, was designed and built by the Gas Turbine Division of A. V. Roe Canada Ltd., (now Orenda Engines Ltd.) for the CF-100 fighter. The basic design, as pinned down before the deadline, finally delivered an engine that was competitive in weight and thrust with other engines in its class, and it was ideally suited to the CF-100 airplane.

At the time the design was fixed, it did not include an afterburner. Suppose, however, that the airframe plus engine combination had been built, and flight tests showed that afterburning was necessary to achieve the specification performance. I asked F. H. Keast, Deputy Chief Engineer for Development at Orenda Engines Ltd., how long, in general, it takes to develop an afterburner. Recognizing that this is a difficult question to answer without going into a specific case, he replied, "I would say that, for a moderate boost afterburner, the development time would be comparable to that of the main engine." He points out, however, that the man-hours involved would be less, since fewer personnel would be engaged on the afterburner as compared to the engine.

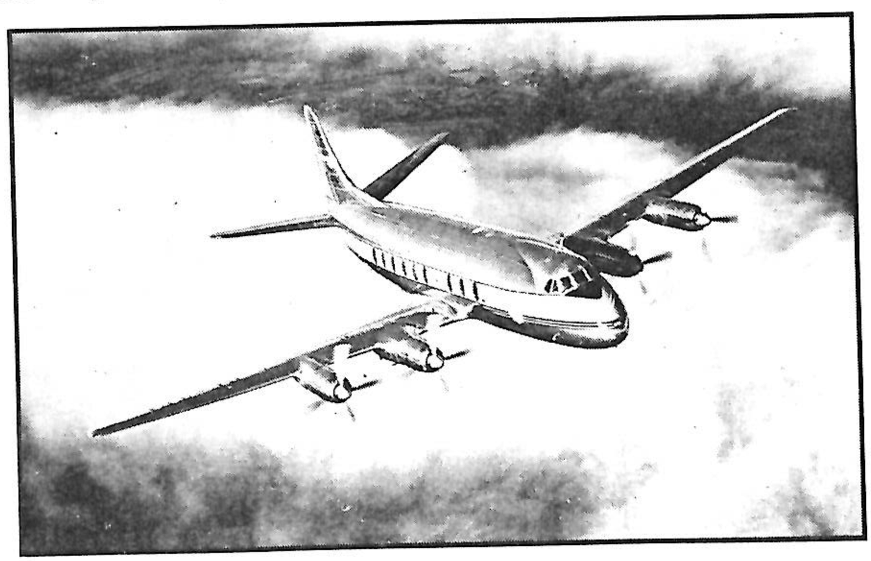
It is apparent, then, that the omission of an afterburner in the initial design, and the extended development time required if it had been necessary to fit one, may well have killed the whole project before it could get past the test bed stage.



This is the prototype of the U.S. Navy's North American XFJ-1 Fury jet fighter, which was later redesigned with swept wings to become the U.S. Air Force's famed F-86 Sabre. The straight-winged Fury flew into oblivion says the author.

photo MISSING.

The CF-100 is one example of an aircraft which successfully met its design deadline. Though the basic design must be essentially right when it reaches the design deadline, there must also be possibilities for further development.



The success of the Vickers Viscount is due in large measure to the success of the Rolls-Royce Darts which power it. Group Captain Foottit notes that this is apparently a case where the design deadline played a significant part.

Back to the Board: While the design deadline on a new airplane or engine may seem like a point of no return, it is not necessarily so. The aircraft designer for example, can always face up to the hard fact that it may be better to start his design again, even though it has passed the deadline, and thus delay the first flight of the first airplane. In essence, then, he establishes a new deadline.

This is a most difficult decision, but it has been successfully accomplished. The North American F-86 Sabre, now being built by Canadair, was one of those rare airplanes that suffered a major design change after the deadline, and still came out on top. Late in the last war North American Aviation Inc. were working on a U.S. Navy contract for a new straight winged jet fighter, the Fury. In the fall of 1944 the U.S. Air Force awarded a contract to the company for two prototypes of a slightly modified version, though essentially both airplanes were the same.

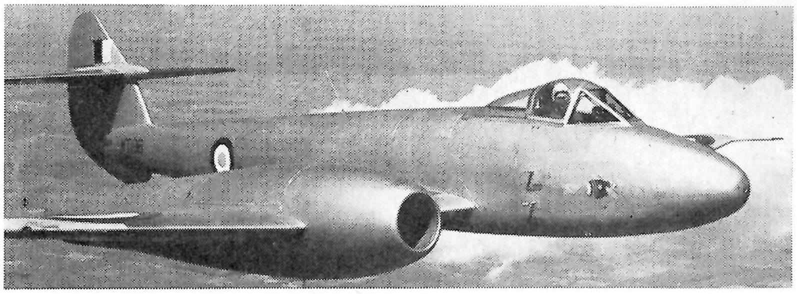
The design of the basic airplane was progressing at an even pace. The design deadline had long past. Then the war ended in Europe. It was not long before the first captured German aeronautical reports came filtering through to the company. Some of them described the advantages of swept wings for high speed airplanes. At almost the same time, the National Advisory Committee for Aeronautics, the U.S. research agency, had been delving into such wing shapes. Some of their early reports were then under study by the U.S. Air Force's technical personnel.

Sweeping Change: Armed with this data from both sources the North American designers put their heads together with the military engineers and a major decision was made. The F-86 would be redesigned for swept wings. Since the original design deadline had passed, this necessitated delaying the first flight of the first airplane for one year.

This was a bold decision. For at that time, and even for some years afterwards, there was really very little detailed design data on swept wings. It was therefore necessary to plunge into exhaustive wind tunnel tests on the new F-86 swept wing plan to ensure that the prophesied gains in performance had a fair chance of realization.

It was not until test pilot George Welch took off from Edwards Air Force

(Continued on page 68)



A Boost from the NAE

For the past four years, Canada's National Aeronautical Establishment has been engaged in the development of an improved system of reheat, or afterburning, and a short time ago a demonstration was held at Ottawa's Uplands Airport to show Canadian newsmen what progress had been made.

The Canadian-developed 230 lb. combustion device is currently fitted to the Rolls-Royce Derwents of a Gloster Meteor F.4 (see photos) which is on loan from the British Ministry of Supply. During the flying demonstration, the increased rate of climb was very noticeable and the pilot, Flyiing Officer Alan Arnold, reported that with the afterburners cut in, the Meteor could climb to 20,000 ft. in three minutes.

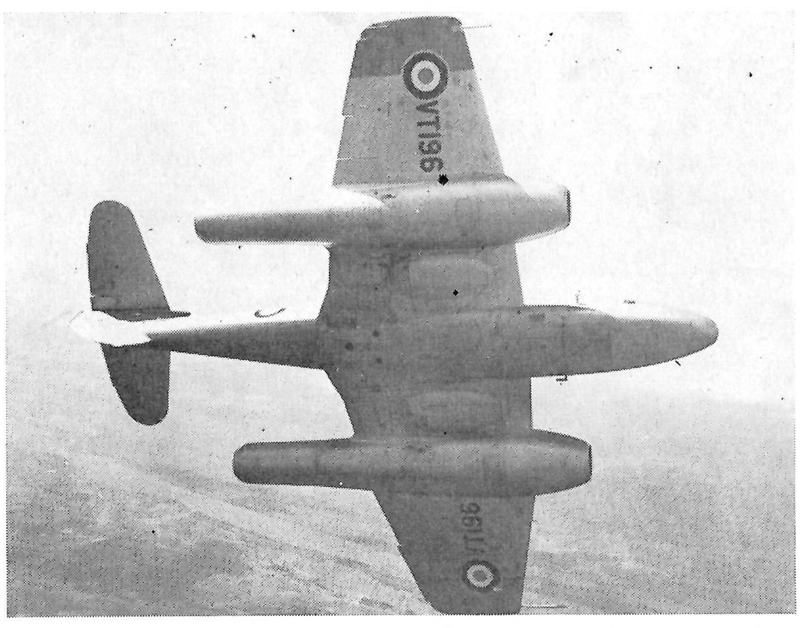
This NAE system of thrust augmentation has been the subject of lengthy investigations which initially included theoretical studies, small scale rig tests, and full scale static engine tests. These were carried out mainly by the Establishment's Engine Laboratory, while the flight tests, which have been under way since January 14, are being conducted by the Flight Research Section at Uplands.

The system under development differs from conventional reheat systems in that the reheat fuel, before being burned, is used to cool the turbine blades, the critical temperature of which normally limits the maximum temperature of the combustion chambers, and hence the rate at which they burn fuel.

Part of the reheat fuel is injected before the turbine, thus cooling the turbine blades as it passes through. This fuel is broken down—"atomized"—by the turbine, but is not ignited until it enters the extended tailpipe. The afterburner adds about four feet to the length of the engine and is somewhat greater in diameter than the normal tailpipe. This increased diameter is calculated to keep low the pressures inside the afterburner tailpipe.

As applied to the Derwents (3,600 lbs./th @ SL), the NAE reheat system boosts thrust by about 25%, while fuel consumption rate per engine goes up to 900 gph. The NAE believes that the system will eventually be developed to provide a 55% increase in thrust, though even the present 25% is sufficient to double the Meteor's normal rate of climb.

The NAE says that bench tests of an Orenda equipped with the system are now in process and such problems as ignition, flame stabilization, and screeching combustion have been studied.



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deeply you gain a thousand feet. But it goes wherever you want it to go with effortless ease. That feeling of limitless power that is typical of the big military jet aircraft is here, too.

Allen took over again to demonstrate the dive brakes to us. These are installed just ahead of the flaps on the upper and lower surfaces of the wing. The upper brake opens aft and the lower opens forward and they are coupled to the same torsion shaft in such a way that they assist each other in opening and closing and thus can be actuated by a low output electric motor. The effect of the brakes when they are opened is quite positive; something like throwing an anchor out of a speeding motorboat. You actually pitch forward in your seat, though the aircraft itself apparently does not alter trim.

That about tied up our ride in the Paris; hardly enough time to get any performance figures, but the Beech boys were anxious to show their bauble to that well-known Canadian store keeper who has made such a good thing out of being a general merchant — John David Eaton. We intend no malice when we say this. One must be realistic about that fact that Canadians with $300,000 or more are something like whooping cranes.

The Paris is an impressive airplane and to ride in it is an unusual and exhilarating experience which we would not like to have missed. Unfortunately its price is also impressive, nay, staggering. While Beech officials are not officially quoting any figures, neither are they doing anything to deny the $300,000 tag that is being bandied around. Let's see, 10% Canadian sales tax on $300,000, that's $30,000. Hm-m-m-m.—R.G.H.

HELICOPTER PILOTS

(Continued from page 30)

Squadron in Northwest Europe. In 1948 he organized the LAS at Rivers (then called 444 AOP Sqn.) and was out of flying from 1950 until 1954 while attending the British Staff College and instructing at their School of Land-Air Warfare. Following his United Kingdom tour of duty Major Reilander returned to Rivers. In recent weeks he has been appointed commanding officer of the 1st Regiment, RCHA. His successor at Rivers has not yet been announced.

Officer commanding the helicopter flight and chief instructor is Flying Officer James Lawrence Jeffs, who has been at Rivers for two years. F/O Jeffs is a wartime instructor on twin-engine aircraft who rejoined the service in 1951. In 1952 he was a member of the search and rescue flight at Trenton, Ont., when he applied for helicopter training. Of his 3,200 hours flying time about 700 has been in helicopters.

DESIGN DEADLINE

(Continued from page 27)

Base, in September, 1947, on the first flight tests, that North American and the USAF knew that they had made the right decision. The U.S. Navy's XFJ-1 straight winged "Fury" had stuck to the original design and the original schedule. It flew into oblivion. The F-86 Sabre, with its swept wing, and its year's delay in design, flew to fame: a fame that is still untarnished in this day, some eight years later.

While it is easy in retrospect to see the advantage of such a drastic change it is usually a most difficult decision at the time. No engineering data, on the frontiers of knowledge, is ever so firm that the designer can be absolutely sure of the real results. There are always facts and counter-facts. And the weighing of these is the thing that brings forth the best design team ahead of the second-best.

Extrapolation: To assess a major change that will increase the airplane's performance, about the only thing the designer can do is to fall back on time estimates and statistical data. Say, for example, he is designing a high altitude bomber. A new aerodynamic theory comes along, after he has passed the design deadline. After careful consideration he concludes that he could increase the airplane's ceiling by redesigning it in line with the theory. He then estimates how long the redesign will set back the production bomber schedule. By plotting this new point on an extrapolated curve of altitude-time statistical data (Figure 2) he will have a rough idea whether the time delay for the redesign is really worthwhile.

We in the military airpower business in Canada are particularly interested in this design deadline with all such ramifications. For, as the Right Honourable C. D. Howe has told Parliament, the RCAF with Avro Aircraft Limited have plunged into the development of a new supersonic delta wing fighter, the CF-105. As the design deadline is spotted on the calendar, we must be sure that every morsel of up-to-date, sound information has been poured into the requirement and the design. If it hasn't, we may defeat ourselves long before the first airplane is wheeled from the hangar.

With advanced supersonic airplanes such as this, it is no mean task. It will take the "prudence and foresight" that Napoleon mentioned, for the achievement of "great ends" is at stake.

FARNBOROUGH

(Continued from page 19)

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turbine. At high supersonic speeds afterburning becomes very efficient by obtaining a high jet velocity from a high-pressure gas stream — the engine is now a turbo-ramjet — and, of course, the turbine is saved from overheating.

Gyron Gen: The shiny paint on the Gyron successfully hid most of the structural details of its 46 inches of diameter and thirteen feet of length. The compressor casing is quartered, which suggests a change to heat-resisting material round the rear stages. The combustion chamber has seventeen fuel injectors, indicating that it is truly annular and not "cannular", and the turbine would appear to have two stages. As illustrated, the Gyron had a markedly convergent test-bed nozzle, but in service it would require a variable convergent/divergent nozzle to maintain high propulsive efficiency at all speeds. The Gyron was a brilliant inspiration of the late Major Frank B. Halford in 1950, when supersonic knowledge was extremely limited, for the 1960-70 fighter power unit requirements.

Although loosely grouped with the Gyron because of its initial rating of 13,000 lbs./st./th., the Rolls-Royce Conway by-pass is an entirely different class of engine. It is offered as *the* turbine for long-range transports. It is simply a two-spool turbojet in which part of the air from the first (L.P.) compressor is by-passed round the engine to rejoin the efflux in the jet pipe. In this way the mass flow is increased and, at the same time, the jet velocity and heat are diminished. This results in a much higher propulsive efficiency at high subsonic cruising speeds. The Rolls-Royce claim is that the overall improvement can be assessed as a 5% increase in range for an Atlantic airliner — which, expressed as payload, means a lot of revenue in a year.

Objections to the by-pass are its weight, the added complication of the by-pass duct and of passing fuel, etc. through it, and a bulky installation. Since the Conway is still partially classified, there is no way of assessing the first two, but accusations of bulk seem to have been unfair. With an intake diameter of 44 in. (only 2.5 in. greater than an Avon) and a length of 129 in. the Conway is not very large for its output. The Conway looks very like an Avon. The intake is surrounded by an air heater, while under the front compressor casing there is a fuel-cooled oil cooler. Aft of the settling duct behind the L.P. compressor (the duct casing carries the mounting trunnions) is the sheet-metal by-pass cover which conceals the second compressor casing, the combustion casing and the turbines. The nipped-in tailpipe is a characteristic of the by-pass.

Pallas Progeny: The Blackburn and General Aircraft series of Turboméca licensed small turbines is based on the 350 lbs./st./th. Pallas turbojet. With this "boiler" a whole range of shaft turbines and the air-bleed Palouste have been developed. The Blackburn engines differ in two major respects from the French originals: the use of Nimonic alloys allows higher, and