ENGINEERS

and aircraft production

By GROUP CAPTAIN H. R. FOOTTIT

"Engineer: One who manages engines, or directs the artillery of an army."

—*Dictionary of the English Language, 1755.*

DR. SAMUEL Johnson penned these words for his famous dictionary. For this was the accepted definition of an engineer in the days when Johnson and his friend James Boswell caroused through the streets of London town in the small hours of the morning. The great era of science, engineering, and production had yet to emerge from the foggy thinking of the alchemists and pseudo-scientists of the Middle Ages.

In fact, some twenty years were to slide by until de Rozier took to the air in the gay Montgolfier Brothers' hot air balloon; over 100 years until Lenoir ran his first crude internal combustion engine, which Sir George Cayley had foreseen some years before and predicted that the "explosion machine" would be used for manned flight; and, of course, some 150 years were to pass before the Wright Brothers soared over the sand dunes of Kitty Hawk.

First Steps: Keeping pace with these advancements in scientific knowledge and engineering know-how were the first crude experiments in mass production techniques. About the time de Rozier was ballooning over France, another Frenchman, LeBlanc, was toying with the idea of mass producing muskets. Thomas Jefferson unearthed LeBlanc and wrote from Paris to John Jay in the U.S. in 1785: "An improvement is made here in the construction of muskets . . . It consists of the making of every part of them so exactly alike, that what belongs to any one, may be used for every other musket in the magazine."

Accuracy, the mother of mass production, had been discovered. And Eli Whitney, some 15 years later, was to light the same torch in the U.S. and see the flame of mechanical duplication spread to clocks, engines, and printing presses. So through the centuries engineering and production have been tightly bonded together. And when considered relative to the modern aircraft industry the bond is longer and tighter.

For aircraft cannot be produced like pots and pans, without the backing of large engineering staffs. This fact is of prime importance to Canada and Canadians. History has shown that Canadian industry has had a great thirst for the production of foreign designs of almost every industrial item. Coupled with this desire has been the vague feeling that engineering staffs are not required. But aircraft production would be crippled without engineers. And the war potential of the Canadian aircraft industry would crumble unless the engineer were there in force to buttress the production line.

The Difference: Before outlining the role played by engineers, it is vital to understand how aircraft production differs generally from other production processing. Everett B. Schaefer, assistant chief engineer of the Canadair Limited, explains it this way: "The use of the term 'production' when applied to aircraft, usually confuses people. It brings to the mind's eye long, mechanical assembly lines, similar to those used in the manufacture of automobiles, radios, and refrigerators. In comparison to these true production lines, the aircraft production line is nothing more than a series of pilot runs that never really get into large scale production."

Coming from an engineering executive of the company that recently turned over to the Hon. Brooke Claxton and Air Marshal C. R. Slemon, RCAF, the 1,000th Sabre fighter, this is an important statement. Of course, it is quite right. This enviable Canadair production run, which stretched over several years, is merely a few days output in the automotive world. Furthermore, the 1,000th Sabre was a Sabre 5; this model being preceded by two other large scale production Sabres,

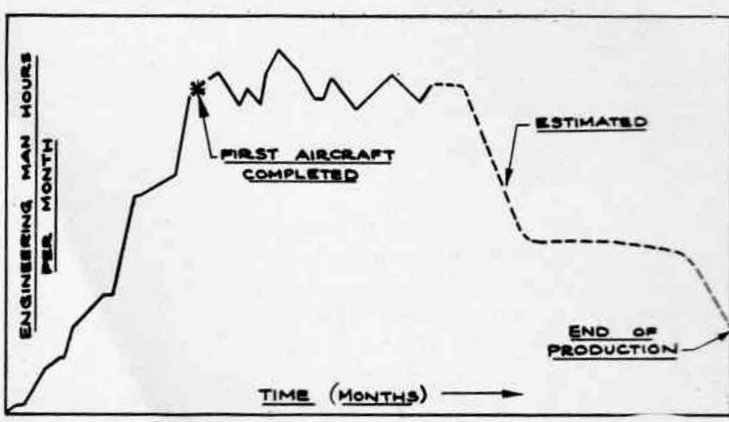

FIGURE 1

T-33 ENGINEERING MAN HOURS

DATA	1952	1953
TOTAL ENGINEERING MAN-HOURS	112,259	157,353
NORTH AMERICAN DESIGN CHANGES REC'D	6,183	5,575
NORTH AMERICAN ENGINEER'G ORDERS REC'D	6,961	6,261
CANADAIR DESIGN CHANGES RELEAS'D	3,489	6,075
CANADAIR MATERIAL SUBSTITUTIONS	289	230

FIGURE 2

SABRE ENGINEERING STATISTICS

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E. B. Schaefer's statement, though made in a time of peace, is just as relatively true in time of war. The production run of airplanes of one type may be longer, but so are the production runs of jeeps and trucks. And the shorter run of aircraft requires a large team of engineers to get the run started, and keep it going with up to the minute fighting aircraft.

Complexity & Change: The two major reasons for the short run military aircraft production, and the engineers required to keep it going, can be summed up in the words "complexity" and "change". The intricate construction and equipment, and the necessity to meet rapidly changing operational demands, has screened out aircraft production from consumer goods production. These two modern factors are the backdrop to the words of J. A. Morley, Sales & Service Director for A. V. Roe Canada; "In 1943 for every specialized radar and electronic job the aircraft manufacturer needed one technician for every 1,000 employees. Today one out of every 24 employees is needed for such a job. At that time one out of 22 employees was an engineering or technically trained man. Today the proportion is one out of eight."

The two basic divisions in an aircraft program which call for a high percentage of engineering talent over a long period of time are: (a) getting a new design, either one's own or one pioneered by another company, into production, and (b) routine and model changes to keep the latest version rolling from the line.

In Canada, the A. V. Roe Company that sprawls on the edge of Malton airport, is the one example of a firm that designed, prototyped, developed, and finally produced in quantity, the all-weather CF-100 with its Orenda engines. It is a well recognized fact in aeronautical engineering circles that the tremendous engineering effort required to get the prototype into large production is usually not much less than the effort required to design and develop the first airplane.

The Hard Way: Avro's Aircraft Division found this out the hard way. To get the CF-100 production moving in the early '50s the same design team was hard at work, often far into the night, trying to productionize the prototype design, correct the stream of operational and flying deficiencies that were spewing from early company and RCAF flight tests, and investigate the advances in fire power that were to eventually result in the present operational version, the Mark 4.

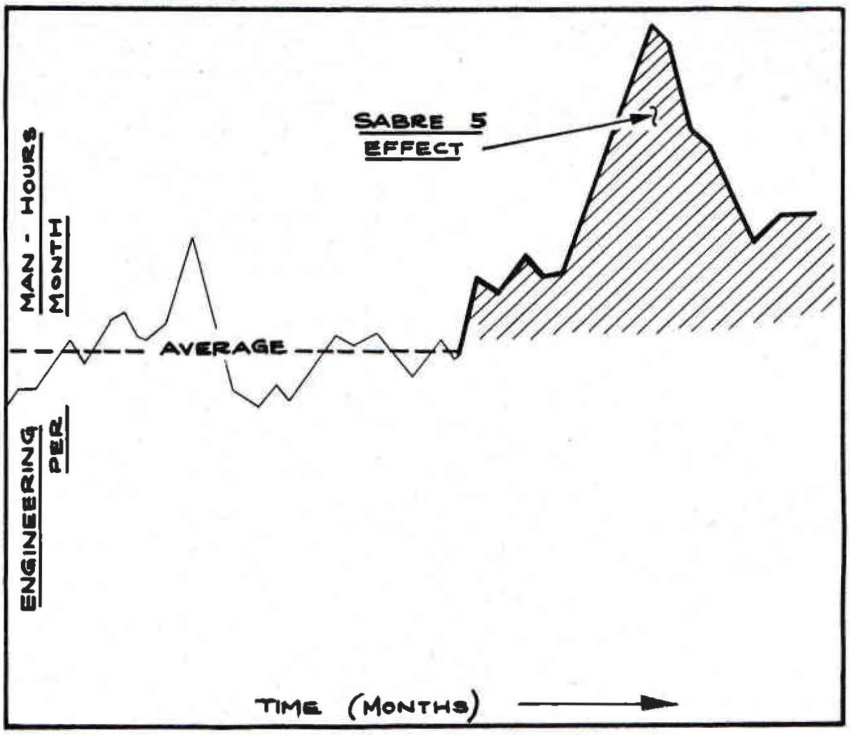

FIGURE 3

SABRE ENGINEERING MAN HOURS

This initial flood of changes, even two years ago, required a 30 to 40 per cent change in what was then considered production tooling: 15,000 templates, 7,000 forming tools and dies, 3,000 machine tools, and 125 major assembly jigs — with many more to follow as production reached a peak. Though engineering has slowed down a lot now, the effort behind the Mark 4 CF-100 program is still a large item on the company's bill for engineering.

The engineering pressure behind getting and keeping a *new design* in production is probably better recognized than the parallel effort that is required to get and keep someone else's d e s i g n in production. Canadair's modern plant on the fringes of Montreal houses one of the world's largest manufacturers that has specialized in this type of aircraft production. And they have achieved world wide recognition for the skill they have shown in doing it.

Silver Star: The latest Canadair production line that was set moving in this fashion was that for the Lockheed-designed "Silver Star" (T-33) jet trainer for the RCAF, with a Rolls-Royce Nene replacing the original Allison engine. The growth of engineering man-hours from the first package of drawings air-mailed from California, to the estimated end of the contract is shown in Fig. 1. A glance at this graph shows that the engineering man-hours reached a peak shortly after the first aircraft moved out of the final assembly hangar. And then the peak steadied into a plateau. Even the estimated monthly man-hours in the future, and within sight of the end of the planned contract, are still about 50% of the peak figures.

What keeps so many engineers busy for so long? Initially every Lockheed T-33 drawing received must be run through the Canadair engineer department. Changes are made as necessary so the drawings fit Canadair's standard procedures and materials, processes and methods of manufacture. Any changes required by the RCAF are also made at this time. To make changes, the Canadair design team must be as thoroughly conversant with these drawings, and the resulting parts, as Lockheed. Consequently, there is a large element of plain study that adds up the hours in this first phase. When the drawings for a fighter run between

1. DESIGN

- (a) Investigation of N.A. changes & release to shop.
- (b) Investigation of service changes & redesign.
- (c) Redesign to overcome manufacturing difficulties.
- (d) Preparation of engineering change proposals.
- (e) Preparation & release of material & equipment changes.

2. LIAISON

- (a) General liaison with manufacturing on specs, etc.
- (b) Salvage of unacceptably manufactured parts.
- (c) Investigation of manufacturing difficulties.
- (d) Representation at sub-contractors plants.

3. FUNCTIONAL PROCEDURES

- (a) Preparation & release of functional test schedules.
- (b) Test equipment difficulties & malfunction of systems.

4. MATERIALS & PROCESSES

- (a) Preparation & maintenance of specifications.
- (b) Technical assistance to shop on materials & processes.
- (c) Operation of materials laboratory.

5. AERODYNAMICS

- (a) Reports on changes affecting aerodynamics.
- (b) Performance estimates — operating data for pilots.

6. STRESS

- (a) Reports on changes affecting strength.
- (b) Check & approval of changed structure drawings.

7. STRUCTURAL TEST

- (a) Operation of test laboratory & conduct of tests.
- (b) Reports on test results.

8. WEIGHT

- (a) Weight & balance estimates on changes.
- (b) Weight check on new and changed drawings.
- (c) Weight & balance check & report on product aircraft.

FIGURE 4

PRODUCTION ENGINEERING FUNCTIONS

10,000 and 15,000, it is not hard to see how the engineering time builds up.

A survey of the engineering record of the F-86 Sabre will answer the question on what keeps the engineers going after production is moving. The first Canadair Sabre flew on August 9, 1950 — just four years ago. In these four years there has been a steady flood of changes: some originating with the original designer, North American, and some originating with Canadair, from both company and RCAF requirements. All in all, in the last three years, these have added up to 50,000 separate engineering change orders. The Sabre engineering man-hours and the log of changes for 1952 and 1953 are shown in Figure 2. This is a staggering record to anyone that thinks that aircraft can be produced without the aid of engineers.

Model Change: Part of this impressive change schedule can be lumped under the heading "model change". In this case the modifications are so extensive, and they affect the operation of the aircraft so much as a whole, that a new designation is tagged on the airplane. A typical case is the Sabre 5. In this case the General Electric J-47 engine of the Sabre 4 was replaced by the Avro Orenda engine to improve the performance of the aircraft to meet a stepped up threat. The new aircraft was labelled the Sabre 5.

This sounds like a simple change. As W. B. Boggs, production engineer for Canadair jokingly tells it, "I well remember the initial discussions on this change. Someone told us that all we had to do was build a large reamer and ream a hole for the larger diameter Orenda engine. But the results were far from this. It ended up with a 50% change in the structural parts of the aircraft!"

The impact of the Sabre 5 on the normal man-hours is shown in Figure 3. In essence, the peak engineering man-hour month, just about doubled the normal production run engineering man-hours previously logged.

Model changes and routine changes, of course, do not occupy the complete time of a production engineering department. Other engineering work filters through the organization. The complete breakdown of work for the Sabre production contract can be summarized as shown in Figure 4. Even a quick scan of this list shows that engineers and aircraft production are welded together into what we now call a "production facility". And this combined operation is a precious link in the defence of Canada.

Vance Report: The Canadian Industrial Preparedness Association has long highlighted the importance of these facilities. Last year they circularized their members with a summary of the U.S. "Vance Report". This report was prepared by a committee headed by Mr. Harold Vance, President of the Studebaker Corporation. The committee's job was to review the defence of the U.S. in relation to its industrial strength. The Preparedness Association reported, "The (Vance) Committee notes that productive capacity is the greatest single deterrent to would-be aggressors, and consequently, any impairment of that deterrent, by neglect or obsolesence, is dangerous."

Engineers, bound as they are to Canadian aircraft productive capacity, are thus as vital to this country as the bricks, mortar, and machine tools of the contractor's plant. Yet we in Canada just do not turn out enough young engineers to meet the demand. The Right Hon. C. D. Howe, Minister of Defence Production, told the students of the University of Toronto two year ago, "I can foresee no possibility of the supply of engineering graduates ever exceeding the demand, in this expanding country of ours."

And A. V. Roe surveyed the aeronautical field early this year and reported that, "only two aeronautical engineers are expected to be graduated in Canada this year, though the nation's aviation industry is operating at a peacetime peak and the demand for scientists is high."

More Engineers: To keep our war-essential aircraft productive capacity going, including its life-blood of engineers, we need to inject more young aeronautical engineers into the stream, and keep them there. The Canadian Industrial Preparedness Association has also worried over this problem. "If our defence production potential is to be as great as is desirable, some careful consideration must

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PROTEUS

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from the engine. The electric starter and starting pump are mounted on the engine gearbox.

Control System: Like all British turboprops, the Proteus has single-lever control. The propeller is automatic, the blades adjusting to take the power being delivered as the engine speed is varied by altering the fuel supply by the single lever.

It is important to appreciate that the pilot controls the "boiler" by varying is fuel supply and from the output of the "boiler" the power turbine extracts the urge to drive the propeller. When the engine is idling, or when it is being started, there is barely enough surplus energy after the compressor turbine to turn the propeller. A feature of the Proteus is that, while the operating rpm of the compressor/turbine are 11,000 to 12,000, the propeller rpm at cruising power are only about 1,000. This low propeller rpm, which is not at all influenced by the compressor/turbine speed, makes the Proteus a very quiet engine. Even at full take-off power the propeller rpm, and therefore the tip speeds, are low and the Britannia, for instance, is very much quieter than any other airplane of its size and power.

The Britannia Accident: The fire that led to the loss of the Bristol Britannia prototype last winter was caused by the failure of a non-standard experimental engine. The sequence of

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be given to building up a pool of skilled tradesmen and technical personnel by building up the industries which can keep them usefully employed and hence up to date in their particular occupation."

This last phrase is particularly important. Once the engineering team is assembled and integrated into our aircraft industry, sufficient contracts must be kept flowing to keep the team on its toes. The CIPA underlines this point: "There is no known way of mothballing technical knowledge and know-how. The provision of these constituents of manufacturing capacity is of equal importance to the provision of machines, buildings, power, and material resources."

Mr. K. Ebel, vice-president, Engineering, for Canadair, holds the same views. "Engineers are a vital part of aircraft production. But as engineering tapers off towards the end of a production contract we must fill in the gap with new engineering work. You can't just keep the men sitting around, since you can't stock-pile engineering talent. It rusts, rots, or runs away unless it is kept busy."

Peace-loving Canadians everywhere can well pay heed to his words. For the defence of the West may hinge heavily on our engineers and the aircraft production lines they help to support.