Quality in Engineering

By GROUP CAPTAIN H. R. FOOTTIT

"Quality in engineering is one of the manifestations of what I call the Second Industrial Revolution."
—*Val Cronstedt**

IN THE MID-THIRTIES, the Western World was enduring an uneasy peace. Already the tramp of German and Italian boots, and the thunderous cries of "Heil Hitler" and "Duce", were raising the black clouds of war on the horizon. In the dying over the face of Europe and Western Civilization. If war came, in which camp would Russia's armies stack their rifles?

In musty diplomatic offices a quiet campaign was being blueprinted to induce Russia to the side of the West. Part of this plan was to give technical aid to Stalin's current "Five Year Plan." As the plot blossomed into actuality, teams of Russian engineers coursed through major industrial layouts in Europe and North America. Faltering question followed faltering question around the conference table. Slowly the Russians eked out the information they required. And in many cases a licensing agreement followed.

A Lesson Learned: In one instance the old Vultee Aircraft Corporation sold a license to Russia to build the Vultee V-11 attack bomber. But once the engineering drawings and reports were shipped behind the Russian frontier, trouble started. For the V-11 was a relatively new airplane and the engineering had been done by a small group in a hurry. Between Russia's lack of skilled tradesmen with production know-how, and the poor quality of the engineering, the great Moscow plant came to a slow halt. A U.S. engineering-production team, seconded to Russia, solved the problem. But the Russians had learned that, like all things under the sun, there is a certain "quality" to engineering.

Quality, as applied to engineering, is perhaps too broad a term. But here high quality engineering means not only technical superiority, but engineering which has the stamp of lucid accuracy on it so that it reflects clearly the engineering department's intentions. Thus it flows smoothly through the records office, the loft, production planning, tooling, purchasing and all the multitude of control points that make up a modern industrial complex. Finally, of course, the mechanic in the shop makes up the part with ease and fits it perfectly into the airplane.

High quality engineering is the sought-after goal of every industrial organization. It is probably never attained in an absolute sense. But the up-hill fight goes on from the time the first line is put on a drawing, until the last product rolls out of the shop. For the closer a company can come to this engineering perfection, the better and cheaper is the product it can turn out.

The Engineering Team: R. D. Hiscocks, design engineer for de Havilland Canada, pointed out when he accepted the McCurdy Trophy at the Canadian Aeronautical Institute's dinner last May, that aeronautical engineering today is a teamwork proposition. Here is the root of the difficulty. To collect together the technically superior engineers and draftsmen, and then weld them into a team is a job in itself. To keep this team technically on its toes, in the rapidly changing field of aeronautics, and to keep their thoughts flowing accurately and clearly from mind to paper, day in and day out, is impossible of human attainment. But to continually strive for this ideal, is to continually strive for the pay-off of high quality engineering.

With the "big stick" of air power a vital factor in this warmongering world, we are more apt to associate quality in engineering with the ability of the engineers and draftsmen to design parts that can be readily turned out on a quantity production basis. This producibility facet of engineering quality is certainly an important one. Production records sifted from statis-

Quality in engineering (top) simplifies the production workers' job (below). High standards in engineering means production can be carried out by workers of comparatively low skills, without any sacrifice of quality in the finished product.

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AIRCRAFT - NOV/54 134

tics of World War II show that this feature, and the skill of the management, were the two factors that determined the time a company took to tool up and produce a modern war plane.

What engineering has achieved along this line, is what Val Cronstedt, Director of Engineering for Avro Canada's Gas Turbine Division, calls the Second Industrial Revolution. Out of several hundred Pratt & Whitney engines built during four years of the last war, over two-thirds were manufactured by unskilled licensees, without any previous aircraft experience.

This fact adds weight to Val Cronstedt's words: "During the last war such complicated products as aircraft engines were made, not by skilled workmen, but by laundresses, waitresses, housewives, street sweepers, and cooks. They did this after only a few days instruction on the part each had to play in their industrial role. To accept this hard fact, is to accept the equally true one that the quality in engineering in all its phases—drawings, specifications, assembly and test instructions, etc.,—had reached a high degree of development."

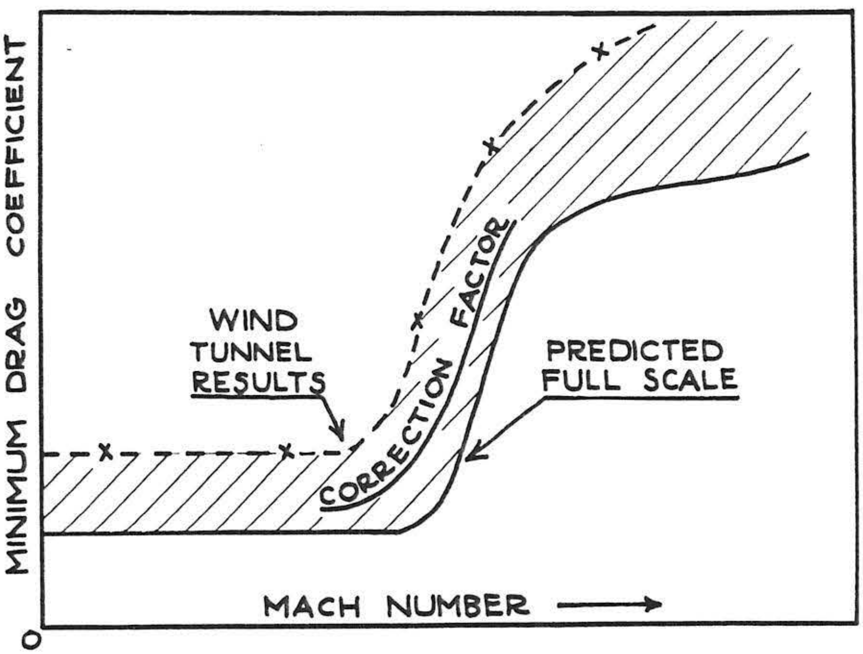

FIGURE 1
LOW QUALITY TEST RESULTS

Precision in Production: There is an important side to this producibility that must not be forgotten. This is precision. And as the performance of military and commercial aircraft rise with the rapid pace of technology, the number of precision parts will increase, making this factor of even greater importance. Yet the tighter the tolerance on parts, the more difficult and costly they are to make. Drawings that call for excessively close tolerances, also call for wasting man-hours and money.

Jarry Hydraulics of Montreal, a Canadian contractor with a wide reputation for high quality workmanship in the aircraft hydraulics and landing gear field, has had considerable experience on precision manufacture.

Says John W. Truran, an executive of Jarry, "Basically, in aircraft hydraulics, the secret of quality in engineering lies in knowing where to apply high precision and where not to. There have been many examples in our manufacturing experience where drawings called for extremely close tolerances, simply because the designer has assumed that all hydraulic components must be kept to such tight dimensions. Our own service experience has shown that in many such cases normal shop limits would suffice. On the other hand, we sometimes find parts, such as an actuating cylinder, which will call for a relatively rough finish of 32 micro-inches. Jarry's experience on such as this dictates a finer 4-6 micro-inches finish to ensure satisfactory service."

Applying the correct dimensional limits to ensure good service, easy manufacture, and interchangeability, however, is only one of the many sides of quality engineering. But what is the foundation for ensuring high quality engineering? Val Constedt, one of the pioneers in aeronautical engineering, has drawn from his background of over 40 years in the business, and states frankly that quality in engineering springs from the "moral fibre" of the engineering department. If the moral fibre is high, then the quality of the engineering is high.

on record

ONE OF THE building blocks for maintaining a top moral fibre is an engineering records organization. This is the policeman of the engineering department that ensures that the drawings are explicit in their instructions to unskilled workmen, that all parts lists and assembly lists are pristine in their accuracy, and that the engineering change system is maintained and functioning in such a manner that there is never any question of Engineering's intentions and instructions to Production, purchasing, outside vendors, and others.

Under Cronstedt's experienced eye, Avro's Gas Turbine Engineering have built up a recording system that makes extensive use of punch card business machines. According to Avro, and verified by the experience of Pratt & Whitney and Wright Aeronautical Corporation, a mechanical recording system is the only answer to keeping track of the thousands of parts and the thousands of changes that go into a modern aircraft engine.

Business Cards: Punch cards giving the basic drawing data, called the Drawing Title Master, are supplemented with cards for the Numerical Parts List, Alphabetic Parts List, Material Specifications, Inspection and Processing, Weight Analysis, and many others.

Through the use of these cards the Engineering Department can log valuable data, and answer many specific questions in an efficient and speedy manner. For example, the Procurement Department asked for the details on parts for a particular model Orenda engine that were made from aluminum casting, forging, or extrusion, and from magnesium casting. By feeding the cards through the business machine, the answer was completed and printed in less than 3 hours.

In another case, it was decided that all parts finished in black oxide would be changed to a phosphate treatment. By pushing the Inspection and Process cards through a high speed sorting machine, that can handle these at a rate of 600 a minute, the numbers of the drawings requiring this change were sifted out in less than 10 minutes.

Measure of Efficiency: This business-like manner boosts engineering efficiency. The other important building block to keeping the high standard of Cronstedt's engineering team, is to measure this efficiency. This he does by a number of statistical controls, such as comparative cost surveys, and the maintenance of a running curve of engineering changes caused by drawing errors.

With this up-to-date engineering recording and reporting system, and a high quota of top technical personnel, then the last most important factor is the engineering approach to any technical problem, whether it be the design of a new axial compressor blade or merely a revamped fuel line.

Present day aeronautical engineering is in the throes of converting to a quality approach by test. In essence more ground test work is being carried out under conditions which simulate, as closely as possible, actual flight. Even in the case of wind tunnel tests, the quality of the tunnel must eliminate large correction factors that have to be ground into the results to convert them to full scale. For example, if the minimum drag coefficient curve for a fast airplane required a large correction factor in converting from model to full scale, then the quality of the engineering is far from maintaining a peak standard, (Figure 1): too many question marks are inherent in such corrections.

Test by Design: This test approach to engineering is particularly important in the design of a gas turbine engine. A. C. Lovesey, a Fellow of the Royal Aeronautical Society, told that august body, "The design of the testing program for an engine and its components is no less important than the design of the engine itself, and time devoted to careful thought in this direction is well repaid. The design of special equipment or instrumentation should run parallel with the main design so that when the engine or component is built, special test apparatus is available for the first run."

We are apt to think that this period is relatively completed when the engine goes up on the test stand for its official 150 hour qualification run. But such is not the case. Air Commodore F. R. Banks, the well-known British authority on engines has stated that, "An engine that has just passed the type or model test, is still in the early development stage and, therefore, more vulnerable to engineering and material changes."

Val Cronstedt's wide experience confirms this view. He has found that a modern axial flow turbo-jet will have a further one to two years ground running, including some air tests in a flying test bed. All-in-all, the engine will log some 10,000 running hours before it has amassed a high quality technical background that will make it suitable for use in production aircraft. What this extended test period means in terms of dollars and time is shown in a relative manner in Figure 2.

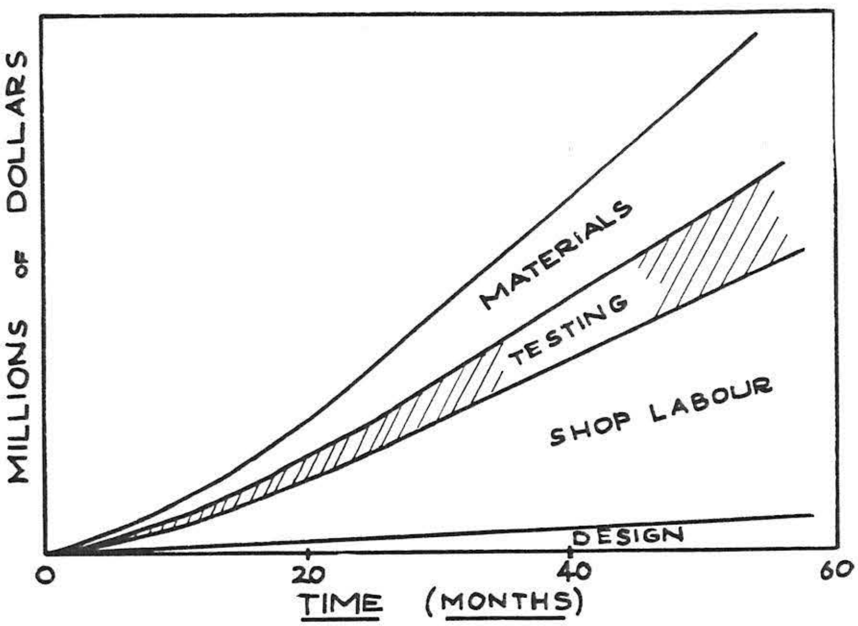

FIGURE 2
JET ENGINE TEST COSTS

Four Times 4,000: As the engine goes through thousands of changes in its life, from birth to obsolescence, this test approach to technical quality in engineering is constantly maintained. The extent of these changes can be be judged from Avro Gas Turbine's experience. They found that even in the development period every part of the engine went through an average of four changes, and each change involved an average of ten drawing changes. With an engine the size of the Orenda, which has about 4,000 parts, the quality of the engineering that is involved with changes alone, literally runs through thousands of drawings.

This same quality concept for a new design of airplane is also in evidence at major airframe plants. At one time the airframe manufacturer did everything to rush through his first design and get the prototype into the air. But airplanes today are costly items. And there are too many parts that may go wrong with fatal results. Hence the modern manufacturer often delays the first flight of his prototype and allows his engineering department to develop quality in the first instance by running as many tests as they can. It is therefore not unusual to see working mock-ups of complete powered control systems, hydraulic systems, fuel systems, and other major intricate parts of a modern airplane. These are instrumented and set up in the shop, and operate as closely as possible to the actual installation, long before the first airplane is wheeled out of the hangar doors.

This test approach to high quality engineering, coupled with a high standard of producibility and technical excellence, and maintained by a rigid reporting and recording system, add up to a top "moral fibre" in any engineering organization. That this is important in this restless decade is echoed

(Continued on page 59)

this continent. You will be hearing more from Avro Canada Gas Turbine Division design and engineering teams before long."

Present with Sir Thomas at the ceremony were: Lady Sopwith; Sir Frank Spriggs, managing director of Hawker Siddeley Group; Sir Roy Dobson, Avro Canada chairman of the board; W. R. McLachlan, vice-president & general manager of Avro Canada's Gas Turbine Division; Crawford Gordon, Jr., Avro Canada president & general manager.

Among the special guests were a number of World War I pilots, all of whom had flown Sopwith aircraft at that time. These included: Air Marshal W. A. Curtis, vice-chairman of the board of Avro Canada; Gerry Nash, who holds the doubtful distinction of having been shot down by von Richtofen while flying a Sopwith Triplane; Mel Alexander, a Toronto executive; A. F. Sandy MacDonald, sales manager for de Havilland; Quinn Shirriff, and Stanley McCrudden. All flew with the Royal Naval Air Service.

QUALITY IN ENGINEERING

(Continued from page 24)

by USAF Secretary Harold E. Talbott, "In the present air atomic age, it is imperative that we maintain at all times qualitative superiority." And qualitative superiority has its roots in top quality engineering.

John W. Truran of Jarry sums it up more simply, "Top quality in engineering, once achieved, gives pride to all the people that have a hand in producing it, and low cost with lasting satisfaction, to the customer."

MENTOR

(Continued from page 19)

clear expect for the odd puff of cumulus. In the air, we encountered practically no turbulence save a mild bumpiness at the 3-4,000 ft. level.

The airplane in which Flight Lieutenant Bill Lawler and I flew was, like the others delivered to the RCAF, almost identical to the USAF version, the only variations being slight ones in cockpit and instrument layout. Actually, this particular machine, which bore the markings "PX 105", was one of the first delivered by Canadian Car & Foundry to the RCAF, and since it was being used for test purposes by CEPE, it was fitted with some special test instrumentation, such as a Potter Flowmeter. It also had a radio compass, which, I understand, is not to be standard equipment in the RCAF version. Seems this equipmen is quite heavy and its weight might cut down performance too much. The Mentor test course will learn to use the radio compass in Harvards (in which they will take a ten-hour course — though to keep them "pure" of Harvard influence, which could prevent a true assessment of the Mentor test, they will not actually take off or land the bigger machine).

Touch of Color: PX 105 featured a natural aluminum finish relieved only by the bright yellow vertical tail surfaces, and the normal RCAF markings. Evidently all the RCAF Mentors are finished in this manner, and do not have the traditional "all yellow" paint job.

Normally, the instructor sits in the rear seat and the pupil in front; after some discussion it was decided that