RAF COLLEGE CRANWELL
F Whittle - Jet Pioneer

RAF College Cadet
2 September 1926 - 27 July 1928

In its electronic form, this document contains underlined, hypertext links to additional material, including alternative source data and archived video/audio clips.
[To open these links in a separate browser tab and thus not lose your place in this e-document, press control+click (Windows) or command+click (Apple Mac) on the underlined word or image]

Version 2.0 dated 28 March 2023 IBM Steward 6GE

The College Apprentice & Flight Cadet

F Whittle - Flight Cadet Record

"Robin" Looseleaf Books 138 Sp. 42074
J. W. Ruddock & Sons, Lincoln and London

COLLEGE SEQUENCE NUMBER	CHRISTIAN NAMES	SURNAME
387.	FRANK.	WHITTLE.

	DATE		DATE		DATE
BORN	1/6/07.	NATIONALITY English.		RELIGION Wesleyan.	
JOINED COLLEGE	2/9/26.	ORDER OF MERIT ON JOINING –		NO. IN CLASS ON JOINING 35.	
LEFT COLLEGE	27/7/28.	ORDER OF MERIT ON LEAVING 2.		NO. IN CLASS ON LEAVING 30.	

PROMOTED		JOINED		DROPPED	
CADET CORPORAL		1ST CLASS	3/9/26.	AFTER	TERM
CADET SERGEANT		2ND CLASS	14/1/27.		
UNDER OFFICER		3RD CLASS	2/9/27.	AFTER	TERM
		4TH CLASS	13/1/28.		

COMMISSIONED IN R.A.F.: 28/7/28.

REASON FOR WITHDRAWAL IF COURSE NOT COMPLETED:

NAME OF PARENT OR NEXT OF KIN: S.A. Whittle, Esq.

ADDRESS: 18, Vincent Street, Leamington Spa.

PROFESSION OF PARENT OR NEXT OF KIN: Engineer.

CHANGE OF ADDRESS:

WHERE EDUCATED: Rugby Road Elementary. Leamington College. S. of T.T., Cranwell. (No4 Apprentice Wing) RAF Cranwell

PRIZES, ETC., ON JOINING:

PRIZES, ETC., ON LEAVING: Abdy Gerrard Fellowes Memorial Prize.

REMARKS AND FURTHER HISTORY

Selected Aircraft Apprentice. Posted to No. 111 (F) Squadron w.e.f. 28/7/28, A.M. Posting List No. 148/1928 dated 15/8/28.

Promotions: Flying Officer 28/1/30; Flight Lieutenant 1/2/34. Squadron Leader 1/12/37. T/Wing Commander 1/6/40. T/Group Captain 1/7/43. Wing Commander (WS) 1/1/44. Wing Commander 1/12/43. Group Captain (WS) 1/1/45. Group Captain 1/1/46. T/Air Commodore 1/1/46. Relinquished T/Air Commodore 1/11/47. A/Air Commodore 1/11/47.

Transferred to Technical Branch 24/4/40.

Appointed a COMMANDER of the ORDER OF THE BRITISH EMPIRE - London Gazette No. 36309 dated 1/1/44.

COMMANDER of the LEGION OF MERIT (U.S.A.) 5/11/46.

COLLEGE SEQUENCE NUMBER	CHRISTIAN NAMES	SURNAME
Service No:- 26074 387.	FRANK.	WHITTLE.

P.T.O.

Awarded DANIEL GUGGENHEIM MEDAL for achievement for Aeronautics for 1946 "for pioneering the development of turbo-jet propulsion of aircraft - A.R.8.(a) Air Ministry Officers Records dated 29/11/46 (Branch Folder Pr1(a)/836.

Appointed a COMPANION of the ORDER OF THE BATH (C.B.) - London Gazette dated 1/1/47 (4).

Appointed a KNIGHT COMMANDER of the ORDER OF THE BRITISH EMPIRE (K.B.E.) - London Gazette dated 10/6/48. (Birthday Honours).

Received the honarary degree of DOCTOR of LAWS at Edinburgh University July 6th 1951.

Placed on Retired List w.e.f. 26.8.48 (retains rank of Air Commodore)

F Whittle - The ‘Thwarted’ Applicant

Frank Whittle was born on June 1, 1907 in Earlsdon, Coventry, the eldest son of a machine tool factory foreman.

He spent his early days familiarising himself with the equipment of draughtsmanship. He had already learnt the rudiments of metal work by the age of 10, when his father bought a small engineering business.

At the age of 11, Whittle gained a scholarship to Leamington College. His school work was undistinguished, owing to his "extreme dislike of homework”, but he spent many hours in the Leamington Spa reference library reading up subjects such as astronomy, physiology, engineering (particularly aircraft engineering) and exploring many other fields of knowledge, not catered for in school.

Whittle desperately wanted to fly, and was determined to join the RAF as an apprentice. He first applied in 1922, passing the written examination with flying colours, but he failed the medical examination because, being only five feet tall, he was considered to be undersized. He refused to accept defeat, and by following an exercise regime and diet laid down by an RAF PT instructor who took pity on him, he added three inches to his height and three inches to his chest measurement in six months.

The RAF refused to reconsider his application, in line with policy concerning apprentice applications. Whittle then hit upon the ruse of starting all over again, as if he had never previously applied by using a different first name. He got away with it and so found himself in the Royal Air Force at last, having been accepted under false pretences, as one of 600 apprentices in the September 1923 Entry at Cranwell.

F Whittle - The Apprentice

No 4 APPRENTICE WING ROYAL AIR FORCE CRANWELL JULY 1926

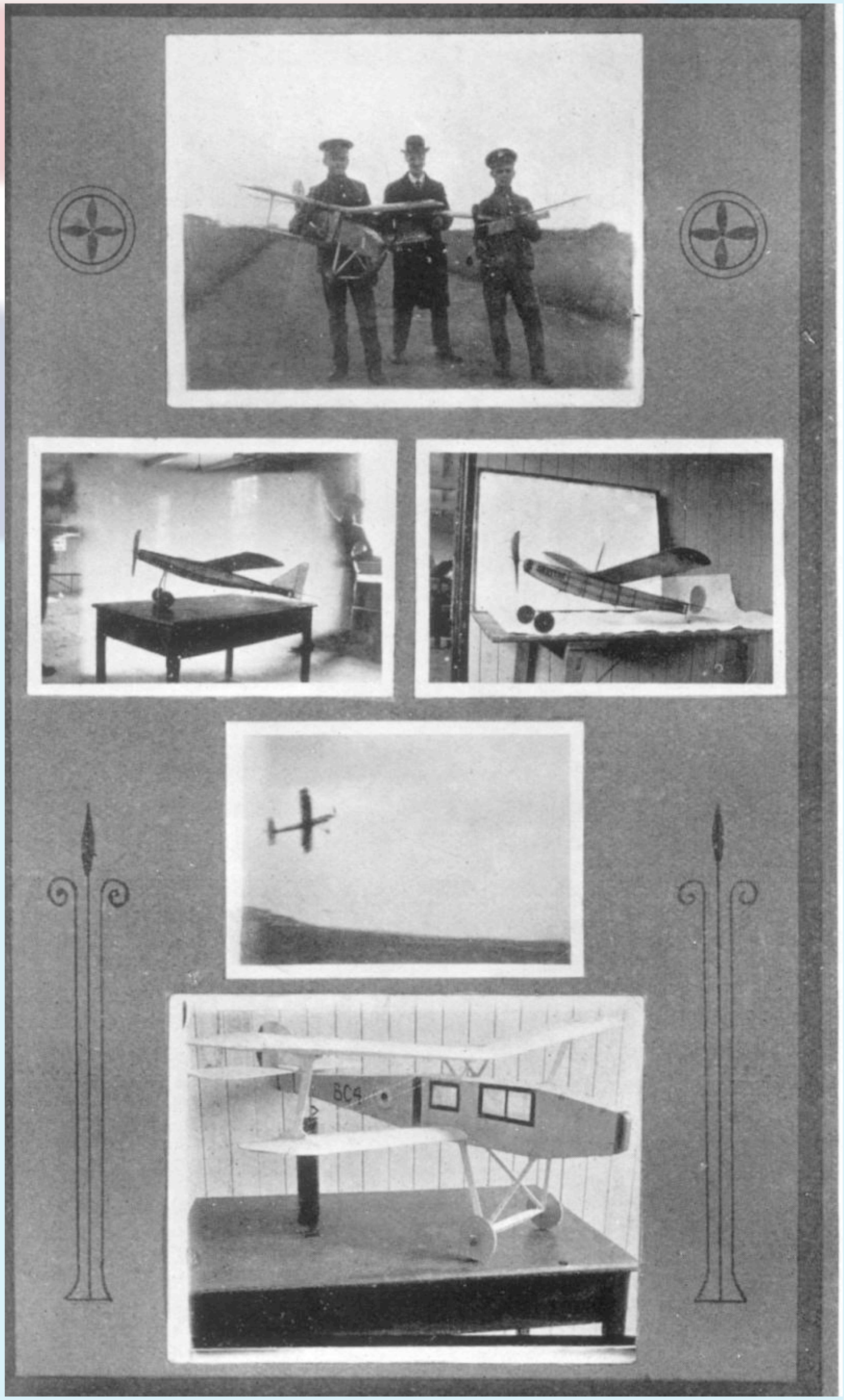
He was accepted to train as a fitter and spent his first five years in the RAF as an Apprentice and then a Flight Cadet.

In days spent pointlessly chipping at chunks of metal, his dream of becoming a pilot faded. His dislike of the strict discipline and barrack room life landed him in much trouble; although many of his misdemeanours remained undetected.

After the first year his training broadened to repair and maintenance of the newly introduced metal airframes.

However, Cranwell life had great benefits. He was very good at his schoolwork, because he could see its practical application; for example, he could see the relevance of mathematics to the kind of engineering he was interested in.

F Whittle - The Aero Model Maker



Another great benefit of Cranwell life, was the Model Aircraft Society. Sir Frank Whittle admitted later that the Society was the main activity which kept him from being completely miserable.

As well as satisfying his deep passion, it was also an activity which the authorities saw as an acceptable alternative to organised games. It was to this Society that Sir Frank later attributed his subsequent award of an RAF College cadetship. Through his work with this Society, he captured the attention of the CO.

Sir Frank was totally dedicated to model making. His dedication culminated with the leadership of a small team to make a model aircraft with a 10ft 6in wingspan, powered by a two-stroke petrol engine. Not only responsible for the drawings, Whittle also made the wooden jigs for the construction of the ribs and other aircraft parts and undertook most of the fabric work.

When officers dropped, in he would inform them of the progress his team had made, demonstrating his depth of engineering knowledge and leadership skills. Despite having a temperament totally unsuited to the harsh discipline and regime at Cranwell, Sir Frank never gave up his dream of becoming a pilot.

F Whittle - Winning a Cadetship

In 1926, Wg Cdr Robert Barton, an instructor at Halton, made a special plea to Lord Trenchard for one of his apprentices to be awarded a cadetship even though he scored poor marks outside the classroom.

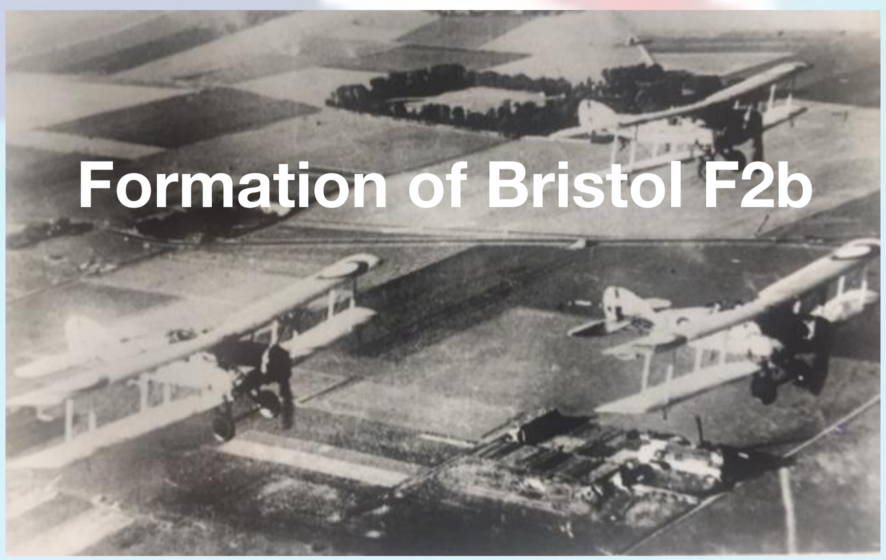
"Having known the boy for three years," Barton recalled, "I was aware that he was no good at games and had a poor personality, but at the same time I realised that we had somebody whose brain was streets above any of the other boys and that if he did nothing else he would develop into a most valuable technical officer."

Unfortunately, the Personnel Branch was unimpressed and refused to make an exception for him. Barton had served with Trenchard in the Royal Scots Fusiliers before the war - he was the reluctant subaltern Trenchard had taught to ride at Londonderry - and so his request for a hearing with the great man was approved. He argued so persuasively on behalf of his student that Trenchard overruled the Personnel Branch and agreed that the boy should be given a cadetship. At the same time, he warned Barton that if he was making a mistake he would not be forgiven.

During the 1920's only five apprentices per year were awarded a Flight Cadetship and Sir Frank, being sixth on the list, benefitted from another apprentice's aircrew medical failure! He was surprised to be recommended for a Cadetship as he had never been a Leading Boy (only those with the rank of Leading Boy had been considered in the past). Thus it was that 19-year-old Frank Whittle, inventor of the jet engine, entered Cranwell and learned to fly.

F Whittle - The Trainee Pilot


AW Siskin 111A


Formation of Bristol F2b


Avro 504Ks of 2 Sqn

During his two years as a Flight Cadet, Sir Frank learnt to fly on aircraft types such as the Armstrong Whitworth Siskin and Bristol Fighter.

After only five and a half hours of dual instruction on an Avro 504K during his first term and just eight hours in his second term, he flew solo - a good performance, particularly as his tuition had been spread over a long period. His piloting skills were much tested when he had an engine failure after only three and a half hours solo. Luckily he was close to Cranwell's North Airfield and landed without damage to the aircraft or himself.

A few weeks later, after becoming lost in poor visibility, he made a forced landing in a field, but instead of leaving the aircraft there, he took off and crashed into a tree, thus writing off the aircraft - a double crime as taking off again was against regulations. Recognising his undoubted potential, the authorities treated him leniently.

On another occasion, during training, he blacked out during a tight loop which made him lose confidence for a while. However, when the Medical Officer assured him that this was normal, he became more confident - even daredevil - but this got him into trouble. On several occasions during his fourth term he was caught low flying over Sleaford in a Bristol Fighter, for which he received 28 days' restrictions.

F Whittle - The Trainee Engineer

Whittle became more engrossed in science and excelled at physics, mathematics and the theory of flight. Prof OS Sinnatt was the principal instructor in these subjects and, recognising his talent, mentored him. Sir Frank's thesis in the first year was entitled 'Chemistry in the service of the RAF', a major proportion of which concerned explosives, incendiaries and gas warfare - topics which took up much of his extra-curricular time.

His fourth term thesis (written in 1928) was entitled 'Future Developments in Aircraft Design'. Professor Sinnatt, on reading it said,

"I couldn't quite follow everything you have written, Whittle. But I can't find anything wrong with it!"

This brought him full marks. His thesis covered the topic of future engines which would perform at great speeds at high altitudes. Prof Sinnatt wrote in Whittle's Flight Cadet character record that he "should ultimately specialise in Engineering".

The previous five years had been a hard path; but Sir Frank was now a pilot, an officer and a gentleman. He had fought his way out of the working class background of his childhood and had proved that he could do better than the vast majority of his public school contemporaries, both in the air and on the ground.

F Whittle - The Graduate

PRIZE WINNERS, R.A.F. CADET COLLEGE, CRANWELL
JULY, 1928
F/C. W. R. Worstall — F/C. F. Whittle — F/C. Sgt. H. J. Pringle
F/C. U/O. N. E. White — F/C. Cpl. G. N. E. Tindal-Carill-Worsley

SENIOR TERM, ROYAL AIR FORCE COLLEGE, CRANWELL
JULY 1928

Sir Frank graduated from Cranwell in July 1928, receiving the Abdy Gerrard Fellowes Memorial Prize for Aeronautical Sciences. He had distinguished himself in everything he tackled - with the exception of field sports. He demonstrated that he was a better leader than follower. He had wanted to win the RM Groves Memorial prize, which was awarded to the Cadet who was the best pilot of his term. To this end, Whittle was one of three pilots chosen to represent B Squadron flying Armstrong Whitworth Siskin fighters during a flying display. Unfortunately, Sir Frank was disqualified for dangerous flying, despite adhering to the aerobatics sequence, worked out with his flight commander.

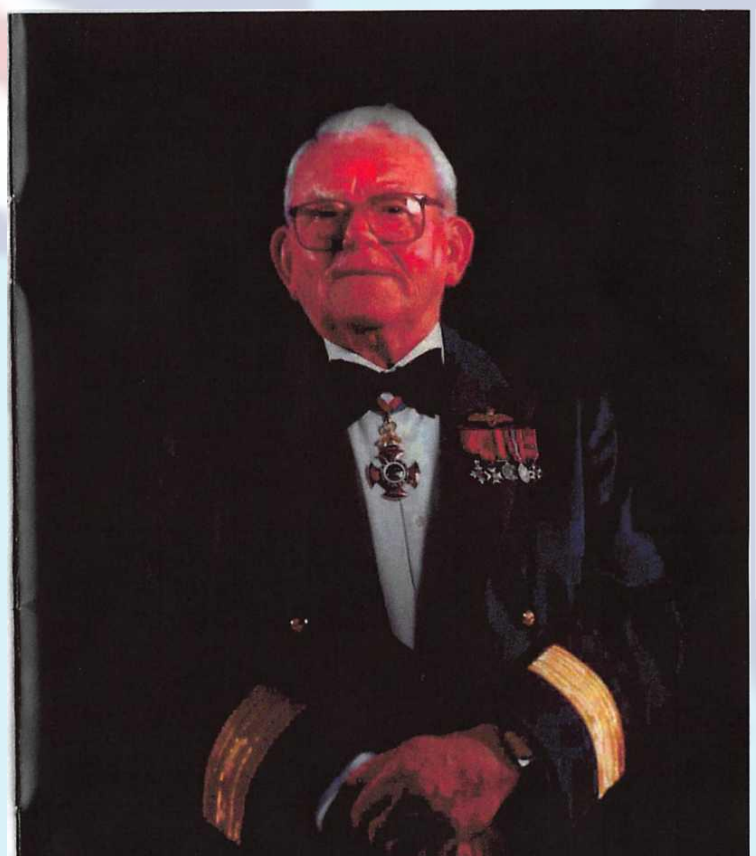
Instructors graded Sir Frank as an "Exceptional pilot" and "above average" on Siskins. However, despite this high proficiency rating and his skill at performing aerobatics, a red insert in his logbook read, *"Over confidence. This is most marked. He gives aerobatics too much value and has neglected accuracy. Inclined to perform to the gallery and flies too low"*.

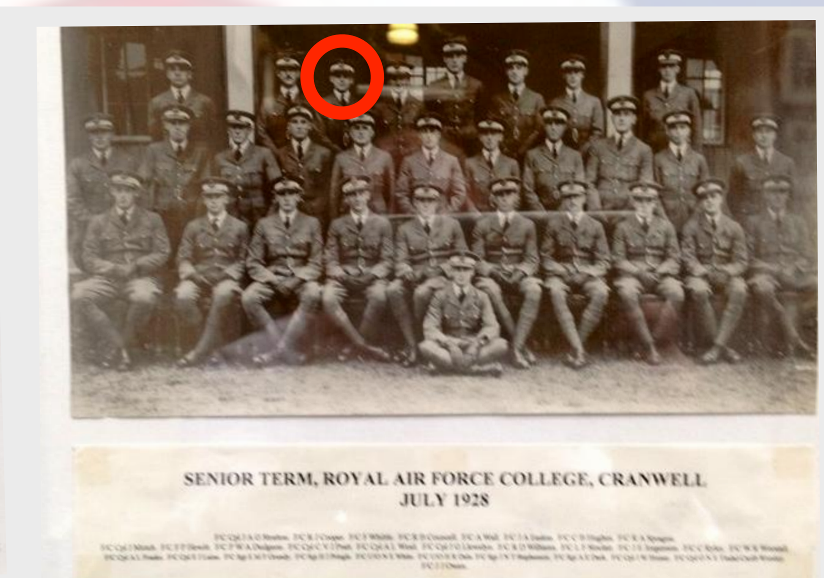
Whittle's Own Account

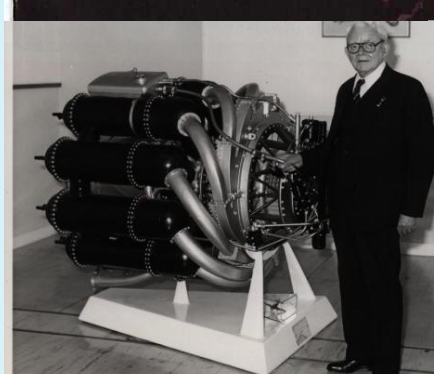
One of our very finest Cadets

Air Commodore **Sir Frank Whittle** OM KBE CB FRS FRAeS
(1 June 1907 – 9 August 1996)

Despite passing the RAF entrance examination with a very high mark, Whittle failed twice to enter the RAF because he was too small, at just 5 feet tall. Undeterred, he applied again under an assumed name, passing the physical and, in September 1923, 364365 Boy Whittle, F started his training as an aircraft mechanic in No. 1 Squadron of No. 4 Apprentices Wing. Recognised by RAF staff as a genius, he developed the jet engine that first flew in a Gloster E28/39 at RAF Cranwell on 15 May 1941, thereby heralding jet flight and revolutionising military and civil transportation worldwide for many years to come.





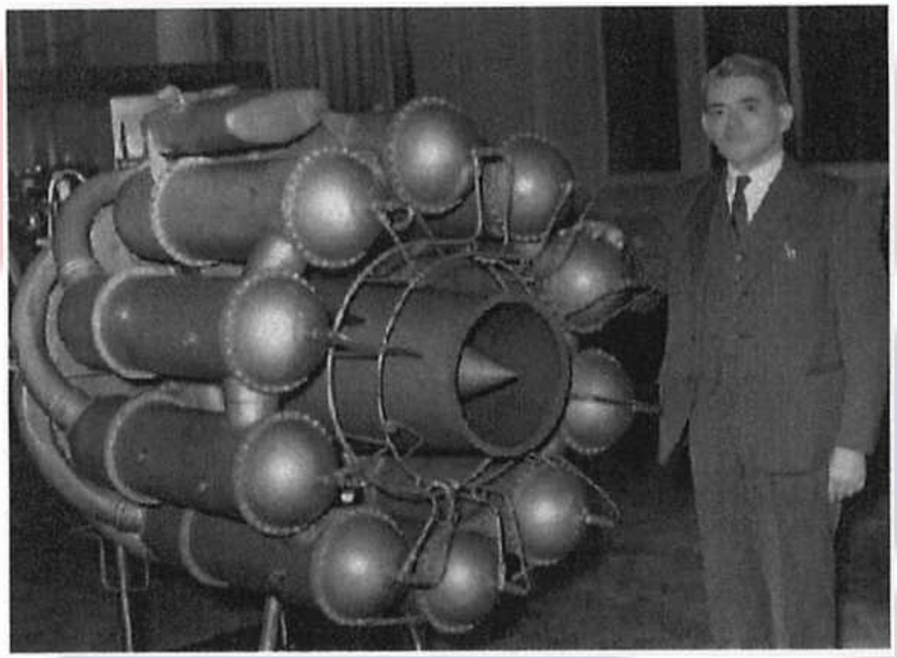


He was accepted to train as a fitter and spent his first five years in the RAF as an Apprentice and then a Flight Cadet.

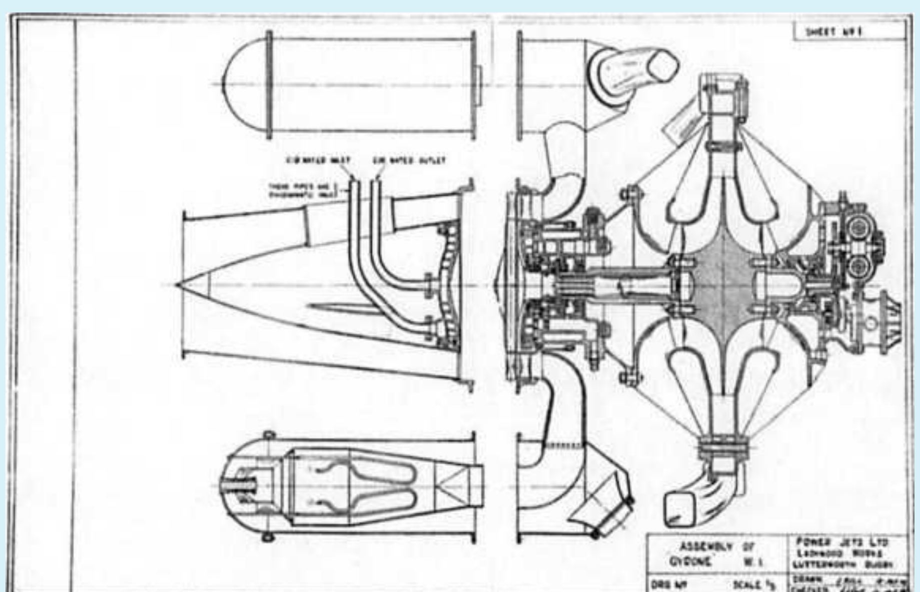
In days spent pointlessly chipping at chunks of metal, his dream of becoming a pilot faded. His dislike of the strict discipline and barrack room life landed him in much trouble; although many of his misdemeanours remained undetected. He nevertheless qualified as a pilot, a very good one, and an outstanding engineer.

The Inventor

F Whittle - The Build Up



Sir Frank Whittle with his engine.



Design drawings of Sir Frank Whittle's experimental engine.

Sir Frank's first posting was to 111 Squadron at Hornchurch on 27^{th} August 1928. During this period the squadron was flying Siskins, and the easy lifestyle was one of the most carefree periods of his life. He continued his passion for pushing the boundaries with his flying; which again was to get him into trouble on a few occasions.

Postings followed thick and fast. In September 1929, he was posted onto 30 Flying Instructor's Course at Wittering; next as an instructor to Digby on promotion to Flying Officer. Here he continued to develop his theories for a gas turbine engine and took out a patent on $16^{,h}$ January 1930.

Continuing his excellent airmanship, he became a winner in the RAF Hendon Annual Display 'crazy flying' competition. Specialist skills were of course a pre-requisite, but there were numerous accidents and Sir Frank wrote off two aircraft in three days. An irate Flight Commander was heard to invite him to

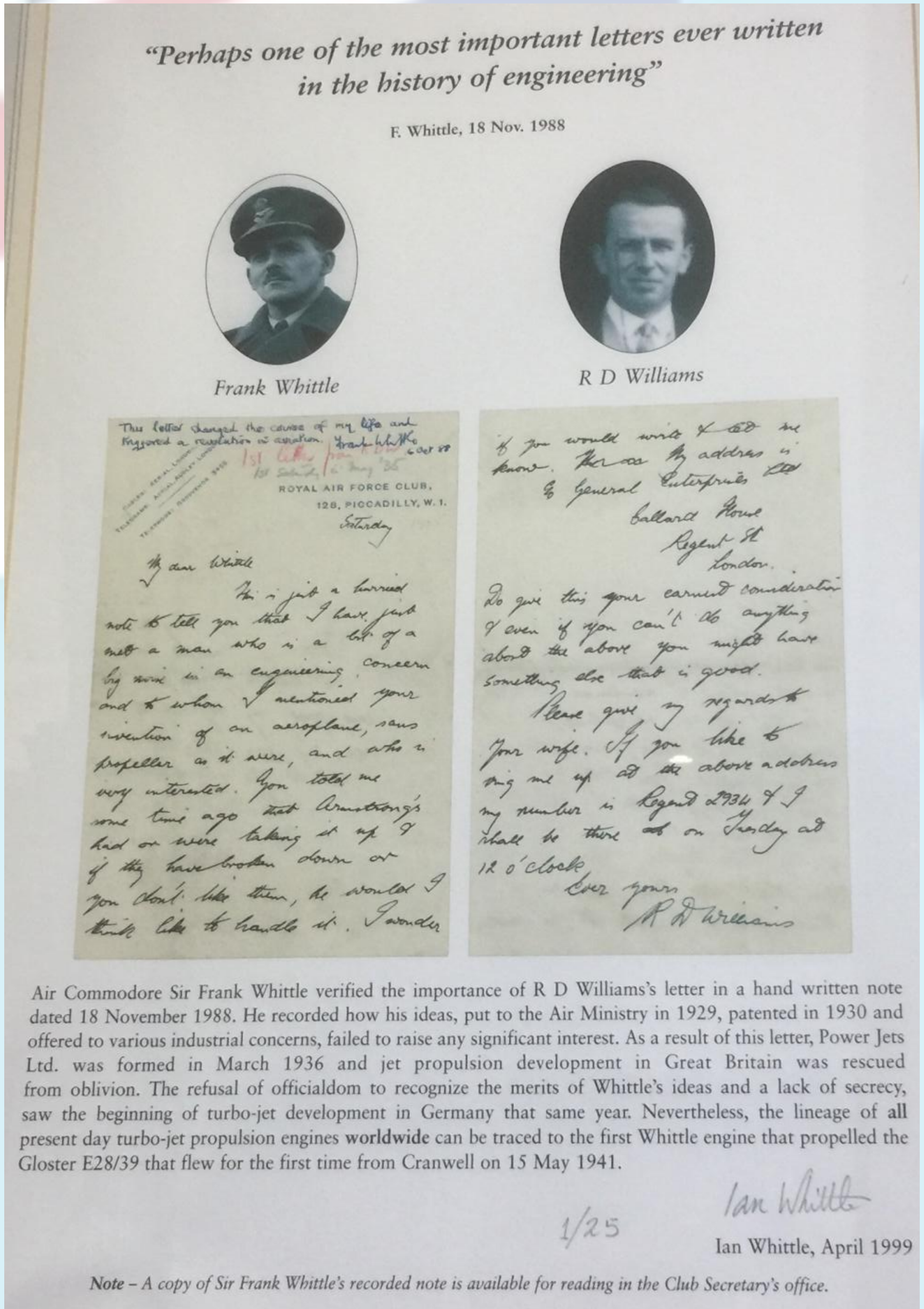
"take all my bloody aeroplanes into the middle of the airfield and set fire to them - it's quicker!"

His next posting was to Felixstowe as a floatplane test pilot.

After four years of holding a permanent commission, every officer had to specialise in engineering, signals, armaments or navigation. Sir Frank chose engineering, and in August 1932 was posted to the Home Aircraft Depot at RAF Henlow.

With an aggregate score of 98% in all subjects in preliminary examinations, he was allowed to take the course in 18 months rather than the usual two years, gaining distinctions in all but one subject. This enabled him to apply to Cambridge University to take the Mechanical Science Tripos.

F Whittle - Looking for a Partner



"Perhaps one of the most important letters ever written in the history of engineering"

F. Whittle, 18 Nov. 1988

Air Commodore Sir Frank Whittle verified the importance of R D Williams's letter in a hand written note dated 18 November 1988. He recorded how his ideas, put to the Air Ministry in 1929, patented in 1930 and offered to various industrial concerns, failed to raise any significant interest. As a result of this letter, Power Jets Ltd. was formed in March 1936 and jet propulsion development in Great Britain was rescued from oblivion. The refusal of officialdom to recognize the merits of Whittle's ideas and a lack of secrecy, saw the beginning of turbo-jet development in Germany that same year. Nevertheless, the lineage of all present day turbo-jet propulsion engines **worldwide** can be traced to the first Whittle engine that propelled the Gloster E28/39 that flew for the first time from Cranwell on 15 May 1941.

1/25

Ian Whittle

Ian Whittle, April 1999

***Note** – A copy of Sir Frank Whittle's recorded note is available for reading in the Club Secretary's office.*

Meantime, work on his jet engine theories continued as he sought, unsuccessfully, to interest firms in his proposals. However, he did meet Fg Off Dudley-Williams (a former Cranwell colleague) who believed that his theories might work.

However, he had become disillusioned with the lack of support for his engineering projects and let his jet engine patent lapse when it became due for renewal in January 1935.

A few months later, however, he received a letter which was to change his life. R Dudley-Williams had now retired from the RAF and therefore, he and his partner (JCB Tinling), believed that they could secure backing for the jet engine project.

The result of this was the formation of the Power Jets Company in January 1936 with interests held by Sir Frank, Dudley-Williams and Tinling. A contract was placed with British Thompson-Houston (BTH) of Rugby for the design drawings of an experimental engine.

The Air Ministry saw his work as a 'spare time' job, but nonetheless gave him a post graduate year for research work upon graduating from Cambridge University with a First Class honours degree in the Mechanical Science Tripos. The Ministry also allowed him to act as Honorary Chief Engineer and Technical Consultant to the company for a period of 5 years.

F Whittle - ‘Result’

The Whittle W.IX engine was installed in WAOA1, which undertook taxi trials at Brockworth airfield, near Gloucester.

The Whittle IV.I engine was then installed and the aircraft was transported by road to RAF Cranwell for its first official flight.

By July 1936, initial stages of manufacture had begun and the first runs took place on 12th April 1937. During the early stages, the engine speed increased so rapidly that the staff had to sprint for cover. This became such an issue that the project had to be relocated to a disused factory at Lutterworth, where the local police suspected the engineers of being IRA terrorists making a bomb! Progress was hampered throughout 1937 and 1938 through lack of funding, which meant that they often had to use old components rather than manufacturing new. As the results of the test improved, so did the Air Ministry's confidence in the project and this brought further Air Ministry funding.

Power Jets' first contract for a flight engine with BHT to power it came in July 1939, with Glosters providing the experimental aircraft; the E28/39. In 1940, the Air Ministry decided that Power Jets would become a research organisation only, with BTH and Rover sharing the engine production costs. The situation worsened for Sir Frank when both companies, eager to obtain an operational jet fighter, ignored him and authorised Glosters to produce the F9/40 which became the Gloster Meteor. They also approved alterations behind his back.

The E28/39 made its maiden flight at Cranwell on 15 May 1941. Fg Off Gerry Sayer flew it to a top speed of 370mph at 25,000ft over the next few days. After this, there was much interest from all of the major aircraft companies, including some in the USA. So much so that six months later they had more jet aircraft than Britain! This American interest led to Sir Frank being sent over there to assist with the development of his engine. The visit was beneficial to both Sir Frank and the UK; as the knowledge that Britain had technology of major significance improved relations between the two countries.

January 1970 - College Journal Article (1)

AIR COMMODORE SIR FRANK WHITTLE

SPECULATION *

By Flight Cadet F. Whittle.

I was once asked by an optimistic sub-editor of this magazine for an account of how I intended to reach the moon. I was naturally a little shaken at first, as I have never contemplated leaving this homely planet, but, thinking that I might write a little light fiction, I promised ; only to find that I cannot rise to the level of Verne or Wells. It, however, caused my thoughts to soar above the tropopauze (for the benefit of those who have never been initiated to the mysteries of meteorology, the tropopauze is that altitude above which the temperature of the atmosphere remains constant), and the following speculation is the result.

The trans-Pacific flight marks the greatest step in aviation to date, yet it is little more than a score of years since the crossing of the Channel by air was acclaimed as a marvellous feat. There is no reason to suppose that this progress is going to cease, and it is my intention to discuss possible lines of future development. We are not yet satisfied. We want greater range, greater speed, better freight-carrying ability, and more economical air travel.

The formula connecting distance which may be flown with the characteristics of an aeroplane using petrol is

$$R = 2800\ \phi\ \psi\ \eta\ \text{Log.} \left[1 + \frac{\omega}{W}\right]$$

where R is the distance in miles which may be travelled in still air, by an aeroplane of weight W lbs. (without fuel) carrying ω lbs of petrol ;
ϕ is the thermal efficiency of the engine ;
ψ is the airscrew efficiency ;
η is the lift drag ratio of the whole aircraft.

It may be seen that R will be decreased by increasing the speed of a given aeroplane beyond that for its incidence of maximum Lift / Drag ratio, as the rapid increase of passive drag would cause a decrease of η.

It may also be seen that as R is in air miles, the actual range depends upon the winds encountered. Now above the tropopauze (about 35,000 feet) such things as depressions do not exist, because this region is isothermal, consequently there are no convection currents. Therefore winds, if any, will be of constant value.

There is another case for high altitude flight. The density of the atmosphere falls off very rapidly with altitude, and for an aeroplane flying at a given incidence (its best) at any altitude, its speed in level flight must be $\sqrt{\frac{\rho_O}{\rho_H}}\ V_O$, where V_O is its speed at ground level for level flight, ρ_O is the ground level density of air, and ρ_H is the density of air at the altitude of flight. As the lift and incidence are the same as for ground level, so also will be the drag. Therefore $HP_H = \sqrt{\frac{\rho_O}{\rho_H}}\ HP_O$, where HP_O and HP_H are the horse power for level flight at ground level, and the power for level flight at that altitude respectively. Similarly, as the air forces on the airscrew will be the same, $N_H = \sqrt{\frac{\rho_O}{\rho_H}}\ N_O$ where N_O and N_H are the rate of rotation

* This article first appeared in the 'RAF Cadet College Magazine,' Autumn 1928.

January 1970 - College Journal Article (2)

of the airscrew at ground level and at that altitude respectively.

The value of $\sqrt{\frac{\rho_o}{\rho_H}}$ is given by the curve (Fig. 1).

This curve clearly shows that the most efficient method of obtaining great speeds is to attain great altitudes, as an increase of speed obtained through altitude does not mean an increase of landing speed.

For example, an aeroplane at 80,000 feet must go five times as fast as at ground level. The HP necessary for level flight must also be five times as great, so also must the airscrew revolutions.

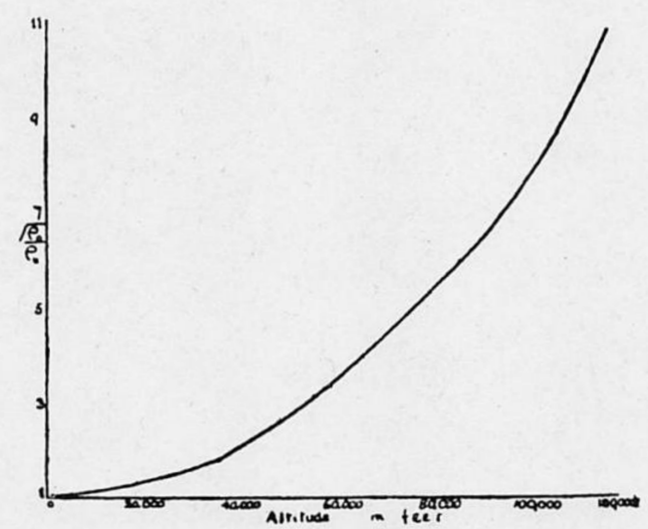


Figure 1

Example :—

Aircraft weight 2,000 lbs fully loaded.
Overall L/D of 10.
Air speed 60 mph at ground level.
Drag will be $\frac{2,000}{10} = 200$ lbs.
Speed is 60 mph = 88 fs.
$\therefore$ HP for level flight $= \frac{88 \times 200}{550} = 32.$

At 80,000 feet this machine would fly at 300 mph for the same incidence and would require 160 HP for level flight.

The reasons why we cannot yet reach these altitudes are :—

(1) The engine speed is limited, and thus the only method of obtaining the extra airscrew speed would be by gears.

(2) The tip speed of an airscrew is given by $\frac{V}{P} \times \pi D$, where V = velocity of aeroplane in ft / sec, P is practical pitch of air-screw in feet, D is airscrew diameter in feet. It has been found by wind channel research that the efficiency of an airscrew falls off as the tip speed approaches 1,100 fs, therefore for great speeds $\frac{P}{D}$ must be greater than one, and efficiency falls off for increasing values of $\frac{P}{D}$.

(3) The present type of aero engine depends for its power on the weight of mixture it takes into its cylinders per unit time, and as practical limitations prevent the increasing of revolutions as the density of the atmosphere decreases, a supercharger must be used which will supercharge the air to ground level density to maintain full power. A supercharger which will cope with the rarified atmosphere of great altitudes without absorbing much power has not yet been devised.

Even if winds do exist at these altitudes, their effect on aircraft would be very much less than at ground level. For instance, a 100 mph wind against a machine travelling at 300 mph at 80,000 feet would have the same effect as a 20 mph wind against the same machine doing 60 mph at ground level.

If such advantages are to be attained by high altitude flight, how are we going to overcome the difficulties which prevent it ? The solution seems to me to be the development of a more suitable power unit.

We have heard much recently about the rocket-driven car, and of proposals for an aeroplane to be driven on the rocket principle. The principle is this :—If gases be ejected from rest, under pressure in a chamber, through a nozzle, there is a reaction equal and opposite to the force giving the gas its kinetic energy in the nozzle. Now suppose W lbs of gas per second pass through nozzle with a final velocity V fs. Then the force exerted on the gas, and therefore the reaction $= \frac{W}{g} V$ lbs. The kinetic energy per second given to gas by heating agent $= \frac{W}{2g} V^2$ ft lbs — ie, power given to gas $= \frac{W}{2g} V^2$ ft lbs / sec. Now if the vehicle being driven in this manner has a velocity v.f.s. in the direction of the reaction, then the power for driving

$= \text{Reaction} \times v$ ft. lbs / sec $= \frac{W}{g} Vv$ ft lbs per sec.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{W}{g} Vv \div \frac{W}{2g} V^2 = \frac{2v}{V}$$

Now suppose we want a thrust of 200 lbs and we can at most pass 1 lb of gas per second through the nozzle.

Then $200 = \frac{W}{g} V = \frac{1}{32} V$

$\therefore$ Velocity of gas = 6,400 fs

and the efficiency of the " engine "

$$= \frac{2v}{6,400} = \frac{v}{3,200}$$

where vfs is the velocity of the object being propelled. Thus in this particular case, we should require 1 lb of rocket mixture for every second of flight, and even if the velocity were as great as 300 mph — ie, 440 fs — efficiency would only be $\frac{440}{3,200} = 13.7\%$.

The rocket principle is obviously impracticable unless one applies it to a rotating nozzle where high linear speeds are possible ; then one is, of course, approaching the principle of the turbine, which I now propose to discuss.

January 1970 - College Journal Article (3)

The steam turbine is the most efficient prime mover in common use. It has a high thermal efficiency compared with the aero engine and is a smoother running machine. Of course, a steam turbine is out of the question for aircraft owing to the enormous weight, but there seems no reason why an air turbine should not be developed, with petrol or crude oil as the heating agent. In the case of an air turbine the heating agent may mix directly with the working agent and thus exhaust via the nozzles. There being no heat wasted in flue gases, an air turbine should have a greater thermal efficiency than a steam turbine.

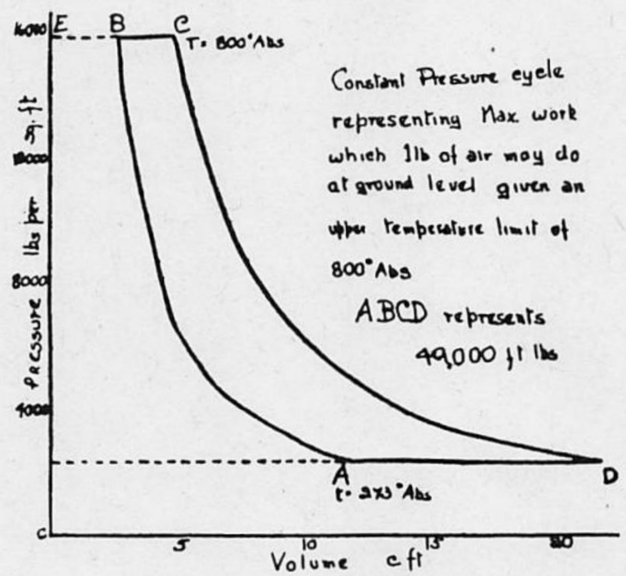


Figure 2

The cycle is shown in the two examples, Figs 2 and 3, which are actual constant pressure cycles for 1 lb of air at ground level (Fig 2) and at 115,000 feet (Fig 3).

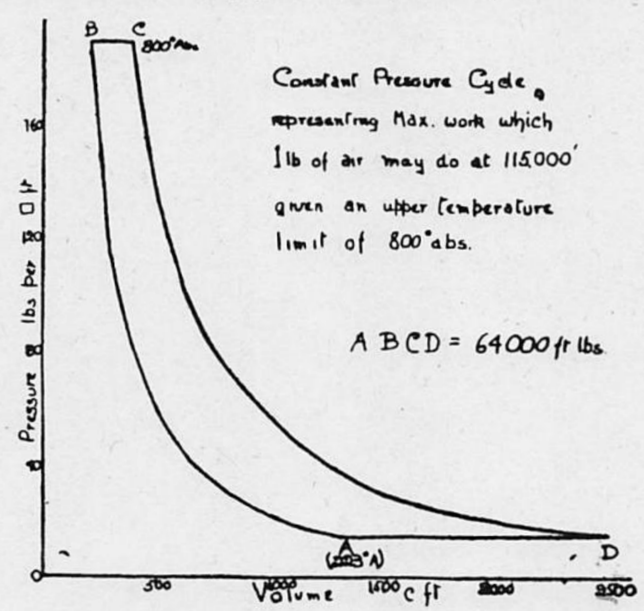


Figure 3

Air is compressed adiabatically AB. It then passes into a heating chamber and is heated at constant pressure BC. It then passes through the nozzles, expanding adiabatically CD, and finally cools at atmospheric pressure outside the engine DA.

The efficiency is given by $\eta = 1 - \frac{1}{R^{\gamma - 1}}$, where R is the compression ratio.

The velocity of the gas at the nozzles, on which depends the most efficient velocity of the turbine rotor [the most efficient velocity of the turbine blades = $\frac{1}{2}$ V cos α, where V is velocity of gas at nozzle, and α is the angle that the axis of the nozzle makes with the rotor] is such that the kinetic energy of the gas equals the area ECDF (Fig. 2) ; thus the power of the turbine is not dependent on the rpm.

The power is given in the particular cases shown by

$$IHP = W \times \text{area ABCD} \div 550,$$

where W is the weight of air undergoing the cycle per second.

The maximum work which 1 lb of air may be made to do is only limited by the maximum temperature which the materials of the heating chamber will stand and the temperature of the atmosphere.

Maximum work = $336 (\sqrt{T} - \sqrt{t})^2$, where T is the maximum temperature (absolute) and t is the atmospheric temperature (absolute).

The idea as a whole is very similar to the steam turbine, the differences being that air is pumped adiabatically into a heating chamber, where it mingles with a burnt petrol-air mixture instead of water being boiled. As far as the nozzles and rotor are concerned, such an engine would be similar to the steam turbine.

The advantages of such a power unit may be stated as follows :—

(1) The only limit to the compression ratio is the maximum temperature which the heating chamber may stand.

(2) Power is not dependent on r.p.m., as in the case of the petrol engine.

(3) The work which may be done by 1 lb of air increases with altitude, and partly compensates for the smaller quantity of air available.

(4) Supercharging does not appear to be necessary.

(5) Rotors of different diameters may be used to act as gearing.

The main disadvantage as far as air work is concerned is the gyroscopic effect of the rotors, but on reviewing the points for and against it seems as though the air turbine is the aero engine of the future.

January 1970 - College Journal Article (4)

COMMENT ON SPECULATIONS OF 1928

by AIR COMMODORE SIR FRANK WHITTLE, KBE, CB, MA, ScD, FRS, C.Eng, RAF (Ret'd)

The Editor has asked me to agree to the re-publication of ' Speculation ' which appeared in the College Magazine for the autumn of 1928 shortly after I had graduated from the College. He also asked me to write a similar article giving my present views about the future. However, I felt obliged to excuse myself from the latter on the ground that, though I have kept in general touch with aeronautical engineering over the past few years, I have been mainly concerned with oil well engineering, and I would need to do a lot of brushing up to attempt such a task. Moreover, the thought was in my mind that one can stick one's neck out a long way as a Flight Cadet aged 21 and get away with it, but I cannot do that today with impunity. Inter alia, there is too big a risk of inadvertently forecasting things which may already be on the drawing board and under security wraps. That could lead to awkward questions as many would assume that I am ' in the know ' when, in fact, I am not. I have run into this difficulty in the past. For example, in 1943 I wrote a paper on probable developments in submarine design which was submitted to the Admiralty. A few years later (long after the war) I requested permission to publish. This permission was granted but only subject to important deletions, because I was rather too close to secret work then in progress. However, I agreed to the re-publication of ' Speculation ' and to write this commentary on it.

I fear it was a very amateur effort, but I suppose it has some historical value because — so far as I recall — it was the first article on a technical subject by me to be published. It was a condensation of part of my fourth term thesis " Future Developments in Aircraft Design."

Unfortunately, it was marred by printing errors to such a degree that it was probably only comprehensible to anyone so familiar with aerodynamic and thermodynamic theory that the mis-prints would have been obvious. The proofs were never submitted to me for correction, so I cannot wholly be blamed for the apparent errors though, undoubtedly, my handwriting was largely at fault. Generally speaking, the errors took the form of the Greek letter ' rho ' appearing as ' P ' ; the Greek letter ' gamma ' appearing as ' Y ' ; indices appearing as coefficients ; + signs instead of the word ' and ' ; 9 for the symbol ' g ' etc. eg

$$\sqrt{\frac{\rho_o}{\rho_H}} \quad \text{appeared as} \quad \frac{\sqrt{Po}}{PH}$$

As may be seen, I looked into the possibilities of rocket propulsion and into propellers powered by internal combustion turbines — it had not then occurred to me that the gas turbine was the best way of producing a propelling jet (for aircraft propulsion at least). The penny dropped just over a year later, by which time I had raised my sights to speeds of the order of 500 mph.

Though I did not know it at the time, the first formula in the article (for range) was a form of the Breguet Equation (the figure 2,800 was the calorific value of petrol in foot pounds per pound divided by 5,280 — to convert feet into miles). It can be applied to jet aircraft by the substitution of the appropriate efficiencies.[1] The formula tends to ignore climb and descent — I probably assumed that the extra fuel required for climb was compensated for by fuel saved on descent. It also requires that the flight condition is at constant lift / drag ratio ie, at constant incidence, which implies a gradual climb as the weight is reduced by fuel consumption. I did not then foresee that traffic control requirements would usually prevent adherence to this optimum flight plan. (With jet aircraft one must fly at a speed somewhat higher than that for maximum L / D because as the thrust of a jet engine varies only slightly with speed at cruising speeds any attempt to fly at maximum L / D — ie, minimum drag — would mean that the slightest deceleration would result in the drag becoming greater than thrust, thus causing further deceleration)[2]

My views about conditions in the stratosphere were distinctly optimistic but I could not know this as no-one had ever been there nor, so far as I knew, had anyone devised any means for regular exploration of the stratosphere. Such things as jet streams had yet to be discovered as also the fact that the tropopause is very much higher in the lower latitudes (I have seen cumulonimbus towering many thousands of feet above when flying across the Caribbean at 35,000 feet).

The discussion of propulsion by rocket leaves a great deal to be desired, but I was, of course, thinking only in terms of aircraft propulsion. (I think I would have been as disbelieving as anyone if someone had suggested that man would set foot on the moon within 31 years). I remember being very uneasy at the expression I derived for the efficiency of rocket propulsion because of the implication that if the flight speed became more than half the jet velocity, the efficiency would exceed 100% which is improbable to say the least of it. However, this condition would have meant flight speeds more than seven times greater than the 300 mph I was considering. I must have decided not to worry about such a seemingly remote possibility. One of the things I did not take into account was the work done in imparting kinetic energy to the vehicle in addition to overcoming drag. A satisfactory definition of the efficiency of rocket propulsion still seems to me to be a somewhat elusive thing.

The discussion of the gas turbine in the latter part of the paper is, I fear, very amateurish. It is evident that I was thinking only in terms of what was then known as the simple impulse turbine of the de Laval type and that I was still far from being familiar with turbine theory. The most serious defect of this section, is that I evidently assumed that the losses in the processes of compression and expansion would be negligible whereas, as I came to realise shortly after, compressor and turbine efficiencies were all important. The low values then usual for rotary machinery of this type was, coupled with the lack of materials capable of withstanding high stresses at high temperatures, the main stumbling block in the several unsuccessful attempts to develop the gas turbine in the early years of the century.

On reflecting on this serious defect in my argument, my embarrassment is somewhat mitigated by the knowledge that I wrote a paper entitled " The Case for the Gas Turbine " while I was a floatplane and catapult experimental test pilot at the Marine Aircraft Experimental Establishment, Felixstowe between January 1931 and July 1932. This paper was never published but, though I had still to receive my engineering training at Henlow and Cambridge, it shows that I

---

1 It is now often written in the form

$R = \frac{V}{f}\frac{L}{D}\text{Log}_e\frac{W_1}{W_2}$ where V is flight speed (mph if R is in miles or knots if R is nautical miles) ; f is specific fuel consumption in lbs / hr / lb of thrust ; W_1 is all up weight at beginning of cruise and W_2 is all up weight at end of cruise.

2 When I embarked on the task of finding a range formula I fully expected to find that great increases of range could be obtained by flight at great altitudes and my disappointment was great when I was forced to accept that maximum still air range was independent of height.

January 1970 - College Journal Article (5)

had greatly advanced in my knowledge of gas turbine theory and had acquired a much more realistic approach and become well aware of the importance of component efficiencies and the need for suitable turbine blade materials. By that time I was, of course, concentrating on the jet engine application of the gas turbine.

The advantages as listed at the end of ' Speculation ' also show that my ideas were still somewhat nebulous. The first would have been better stated as " The limiting pressure ratio is governed by the component efficiencies and the maximum cycle temperature which available materials will permit." Item (2) is wrong. I was evidently thinking of steam turbine characteristics. Even so it should have read " Power is not as dependent on rpm . . . . . ". However, as everyone now knows, when the compressor is driven by the turbine, power is in fact far more sensitive to rpm than in the case of the piston engine. (The static thrust of our first flight engine — the W1 — was 860 lbs at 16,000 rpm, 1,000 lbs at 17,000 rpm and 1,240 lbs at the full design speed of 17,750 rpm.)

Item (3) was (and is) quite sound and becomes even more true when compressor and turbine losses are taken into account. Item (4) also proved to be sound in the event, but I cannot remember what I had in mind when I included (5). I am also puzzled by the fact that I did not include the advantages of low weight, absence of vibration, insensitivity to fuel type etc. However, a year or so later I was in the habit of including these.

The formula given for the maximum work per lb of air per second for a constant pressure cycle (the last formula in the article) looked very unfamiliar and I thought that there must be quite a serious misprint but on checking I found that, except that the coefficient 336 (the specific heat of air at constant pressure in ft lbs per lb) appeared as 356 it was correct for the ideal cycle. In later years I would have preferred it in the form

$$w_{max} = K_p T_o \left[\sqrt{\frac{T_m}{T_o}} - 1 \right]^2$$ where w is the work/lb of air/sec, K_p is the specific heat at constant pressure, T_m is highest cycle temperature and T_o is lowest cycle temperature (ie atmospheric static temperature in an open cycle engine).

A particularly interesting thing about this formula is that it indicated the beginning of a very useful line of reasoning. As time passed I acquired the habit of dealing with thermal cycles almost entirely in terms of absolute temperatures, temperature ratios and pressure ratios. Included in this system was the practice of thinking of velocities in terms of temperature equivalents and vice versa. (The conversion is given by $V^2 = 2 g K_p \triangle T$ where $\triangle T$ is the temperature change corresponding to velocity V. It happens that $\sqrt{2 g K_p}$ has the same digits as the factor for conversion of mph into fps — 1·47 — hence the useful rule that kinetic temperature rise in °C is equivalent to the square of the speed in hundreds of miles per hour, eg, if air travelling at 500 mph is brought to rest the temperature rise is 25°C ; for 1,000 mph it is 100°C and so on—hence the problems of kinetic heating which arise at very high Mach numbers).

In detail design one has to allow for a number of minor factors such as increase of specific heat with temperature, the fact that the mass flow in expansion is greater than the mass flow in compression due to the added fuel mass etc., but these secondary ' adjustments ' can be ignored for the purpose of preliminary design and especially for comparative purposes when seeking the optimum cycle for any particular application. With this system it is possible to ' work round ' a jet engine cycle in a matter of three or four minutes after a little practice.

When compressor and turbine losses are taken into account the above formula for w_{max} becomes modified to

$$w_{max} = K_p T_o \frac{T_o}{\eta_c} \left[\sqrt{\eta_c \eta_t \frac{T_m}{T_o}} - 1 \right]^2$$ where η_c is compression efficiency and η_t is expansion efficiency. This condition occurs at a temperature ratio $r = \sqrt{\eta_c \eta_t \frac{T_m}{T_o}}$

eg, for standard sea level conditions ($T_o = 288$°K) with $T_m = 1100$°K, $\eta_c = 0{\cdot}86$, $\eta_t = 0{\cdot}90$ the value of r for w_{max} is 1·72 which gives $w_{max} = 58{,}200$ ft lbs/lb or 106 hp/lb/sec. Thus the mass flow of air for 10,000 hp would have to be 94·3 lbs/sec.

Unfortunately, the temperature ratio for highest overall efficiency is substantially higher (about 2·1) so that peak efficiency can only be obtained at the sacrifice of output per unit flow, and vice versa.

In practice η_c decreases as temperature ratio (and therefore pressure ratio) is increased but η_t increases. Both effects are due to the conversion of losses into heat during the compression and expansion processes.

Well ! there is my apologia. If I did drop a few bricks, I can claim that I picked them up again a short time later and learned quite a lot in doing so.

When I look back over the years I am struck by my own relative pessimism at a time when others thought me a wild optimist. The power, size, reliability and performance of jet aircraft have gone far beyond anything I ever predicted. I was, however, usually over optimistic about time and cost, though, in my opinion, my estimates of time **could** have been achieved. For example, there was no serious obstacle to the introduction of the large by-pass ratio turbofan about, say, 1946 or the successful achievement of supersonic flight at about the same time. Unhappily, the contracts for our large by-pass ratio engine (the LR1) and for the Miles M52 experimental supersonic aircraft were cancelled.

1980 - Another College Journal Article

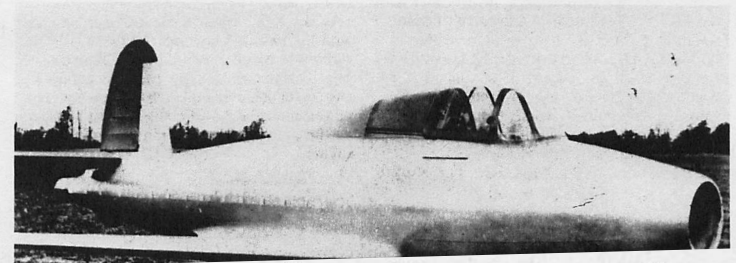
Forty years ago on 15 May 1941 the first British jet aeroplane, the Gloster Whittle E28/39, successfully completed its historic initial flight at RAF Cranwell. The development of this revolutionary design, which proved the principle of jet propulsion for aircraft and led directly to the first generation of jet fighters, the Meteor and Vampire, was due entirely to the brilliance and dedication of a famous Old Cranwellian, Sir Frank Whittle.

It was at Cranwell as a Flight Cadet (1926-28) that Whittle wrote the thesis that stimulated the train of thought which led ultimately to the jet engine. The thesis, which won him the Abdy Gerrard Fellowes Memorial Prize for Aeronautical Sciences, planted the seed in the mind of this brilliant aviator and scientist. As the seed germinated he began to work on his ideas for the development of a turbo-jet engine. Whilst at Cambridge University from 1933-36, where he graduated with a first class honours degree in Mechanical Sciences, he worked on the preliminary design of an experimental engine and sought to interest the Air Ministry and industry with his ideas.

Eventually, in 1936 a company called Power Jets, to which Whittle was loaned by the Air Ministry, was set up. His first engine ran successfully in 1937, and 2 years later in September 1939 the Gloster Aircraft company was granted an Air Ministry contract to design an aeroplane capable of jet propelled flight. The flying test-bed became known as the Gloster Whittle E28/39 ('E' for experimental and 28/39 from the number of the Air Ministry specification).

In less than 2 years the E28/39 was undergoing secret taxiing trials at Brockworth and on 11/12 May 1941 was taken by road to Cranwell for the flight test. Cranwell was chosen as the location because of its long runway, clear approaches and a certain remoteness which aided wartime security. After a few further taxiing trials the E28/39 was declared ready to fly.

BRITAIN'S FIRST JET FLIGHT



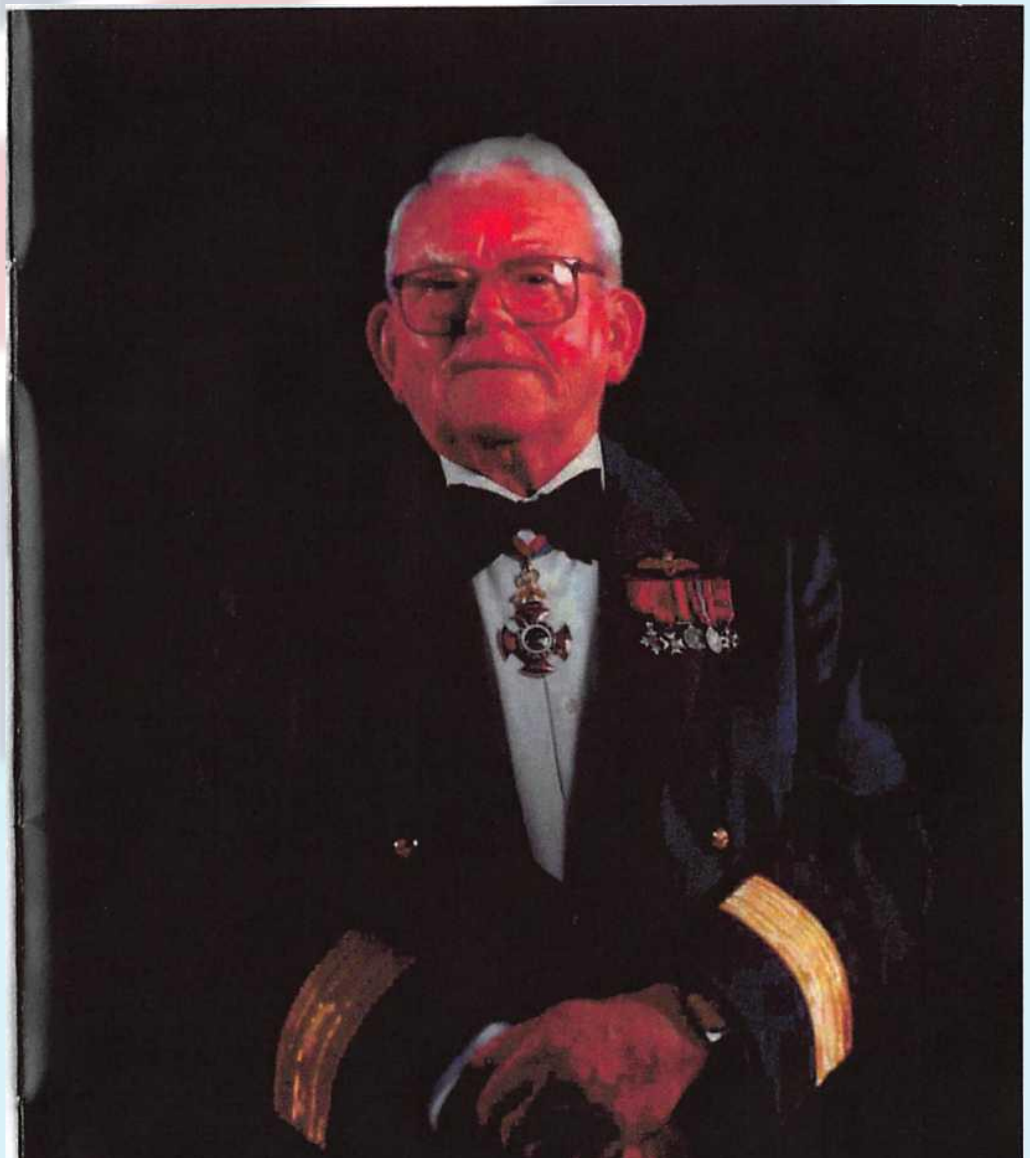
On 15 May, after waiting all day for the weather to clear, P E G Sayer, Gloster's chief test pilot, took the E28/39 down the runway. Everything went according to plan. The machine took off at 1940 hours, recorded a 17 minute flight and landed without a hitch. Frank Whittle, George Carter, the chief designer of Gloster's, and a handful of technicians were the only spectators. During the next 12 days the aeroplane completed some 15 flights and the 10 hours flying for which the engine had been cleared. From the birth of an idea in the mind of a young unknown RAF Flight Cadet, a unique event had taken place. History had been made.

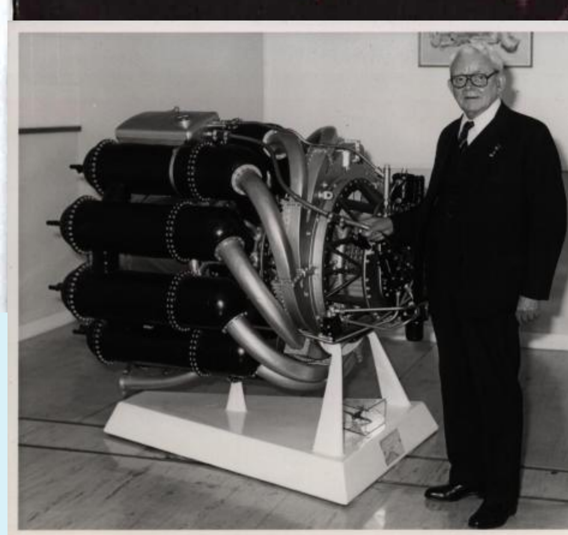
Whittle remained on the Special Duty List attached to Power Jets until 1946 when he became the Technical Adviser on Engine Design and Production to the Controller of Supplies (Air), Ministry of Supply. He retired from the RAF in August 1948 as an Air Commodore. Just before his retirement he received a Knighthood, having previously been granted a reward for his invention from the Royal Commission.

In the epilogue of his book 'Jet – The Story of a Pioneer' he recalls with pride and a touch of sadness:

"As the King touched me on each shoulder with his sword, I became the first Old Cranwellian to receive the honour of Knighthood. The satisfaction this gave me overshadowed any regret at leaving the Service in which I had served since the age of 16 and which had given me the training which had made possible the jet engine".

F Whittle - Honoured





Sir Frank maintained his determination to give the RAF a jet fighter and continued to show his characteristic singleness of purpose. When Rolls Royce took over work on the W2B engine in 1943, his goal was now in sight; but in order to achieve it the Company was nationalised and he had to sacrifice control of it, surrendering all his shares and rights.

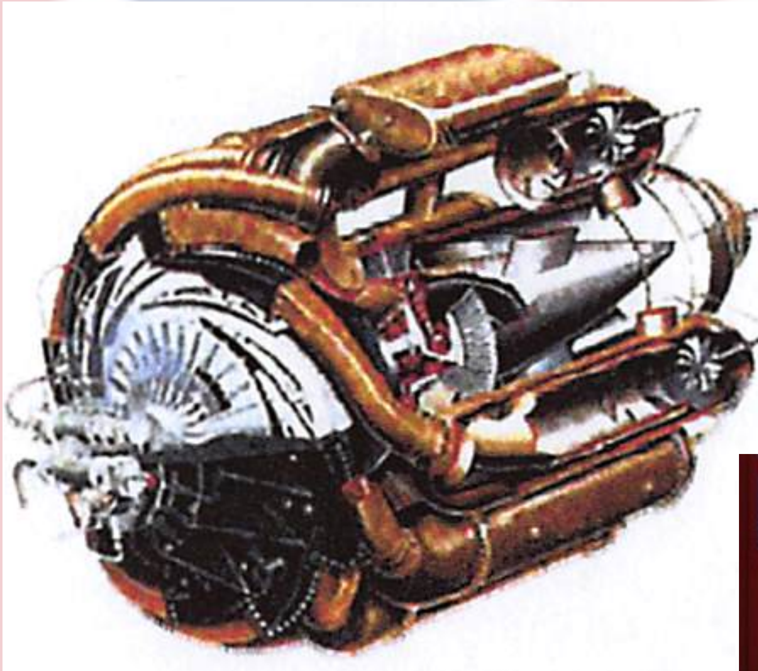
In 1946, Sir Frank accepted the post of Technical Advisor on Engine Production and Design (Air) to the Controller (Air) at the Ministry of Supply. However, he was taken ill on a lecture tour and had to retire from the RAF six months later on medical grounds, having attained the rank of Air Commodore. He was invested with his knighthood by King George VI in July 1948, the first Cranwellian to be knighted. For the rest of his life he worked with commercial airlines, developing supersonic aviation and advising leading engineering companies all over the world. He emigrated to America in 1976, becoming a Research Professor at the US Naval Academy in Annapolis.

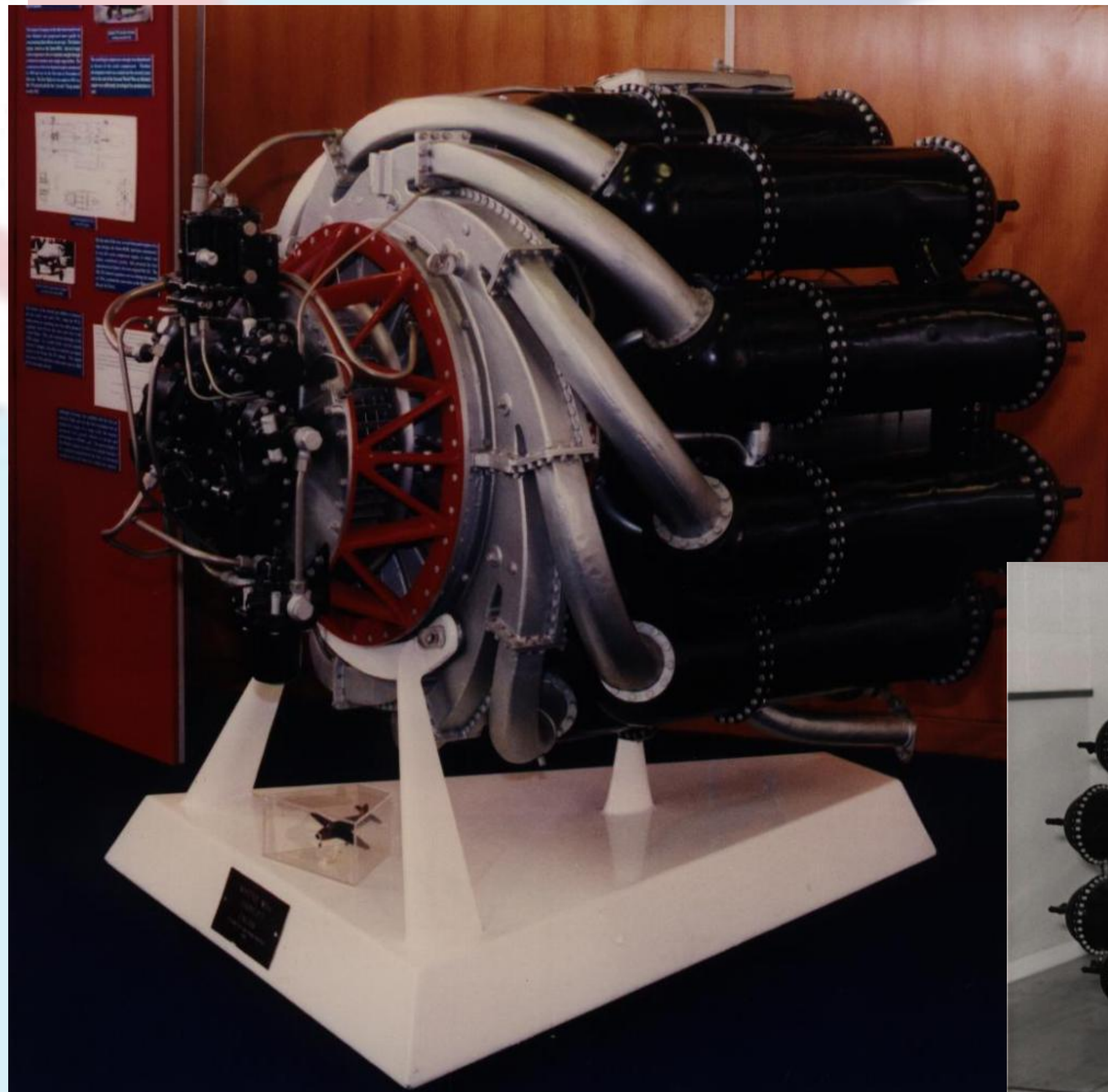
Sir Frank returned to RAF Cranwell on many occasions, and had a great affection for the College and the Station. The Royal Air Force had taken a shy and studious boy and turned him into an RAF officer and engineer. He was later to say that it was his Royal Air Force training that "made possible the jet engine".

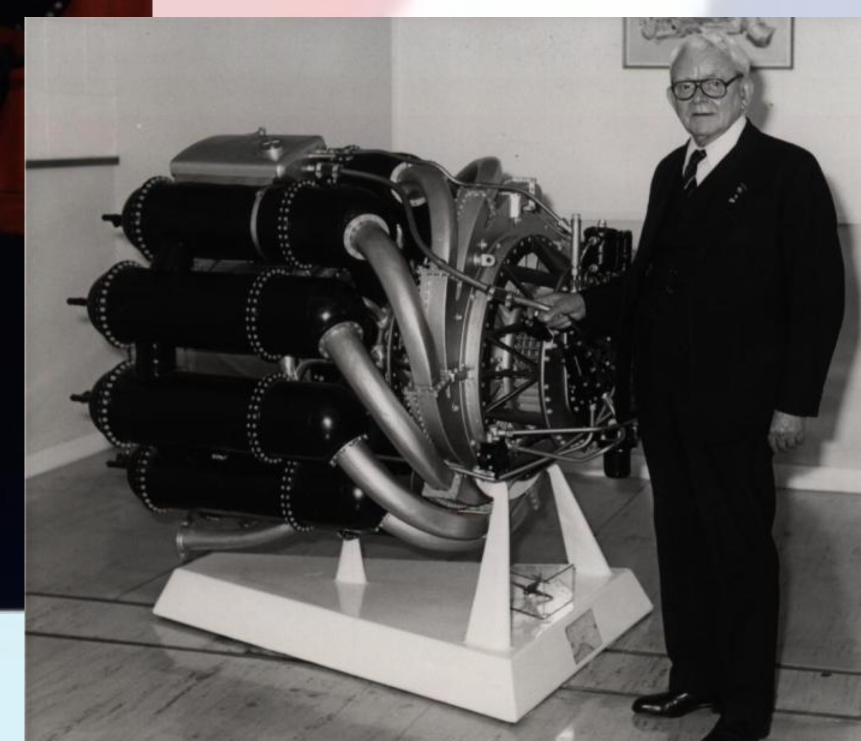
Sir Frank died on 9 August 1996 in Maryland at the age of 89. His ashes were placed in a memorial in the Station Church of St Michaels and All Saints at RAF Cranwell.

The Engine

The Powerhouse







January 1970 - College Journal Article (1a)

AIR COMMODORE SIR FRANK WHITTLE

SPECULATION *

By Flight Cadet F. Whittle.

I was once asked by an optimistic sub-editor of this magazine for an account of how I intended to reach the moon. I was naturally a little shaken at first, as I have never contemplated leaving this homely planet, but, thinking that I might write a little light fiction, I promised ; only to find that I cannot rise to the level of Verne or Wells. It, however, caused my thoughts to soar above the tropopauze (for the benefit of those who have never been initiated to the mysteries of meteorology, the tropopauze is that altitude above which the temperature of the atmosphere remains constant), and the following speculation is the result.

The trans-Pacific flight marks the greatest step in aviation to date, yet it is little more than a score of years since the crossing of the Channel by air was acclaimed as a marvellous feat. There is no reason to suppose that this progress is going to cease, and it is my intention to discuss possible lines of future development. We are not yet satisfied. We want greater range, greater speed, better freight-carrying ability, and more economical air travel.

The formula connecting distance which may be flown with the characteristics of an aeroplane using petrol is

$$R = 2800\ \phi\ \psi\ \eta\ \mathrm{Log.}\left[1 + \frac{\omega}{W}\right]$$

where R is the distance in miles which may be travelled in still air, by an aeroplane of weight W lbs. (without fuel) carrying ω lbs of petrol ;
ϕ is the thermal efficiency of the engine ;
ψ is the airscrew efficiency ;
η is the lift drag ratio of the whole aircraft.

It may be seen that R will be decreased by increasing the speed of a given aeroplane beyond that for its incidence of maximum Lift / Drag ratio, as the rapid increase of passive drag would cause a decrease of η.

It may also be seen that as R is in air miles, the actual range depends upon the winds encountered. Now above the tropopauze (about 35,000 feet) such things as depressions do not exist, because this region is isothermal, consequently there are no convection currents. Therefore winds, if any, will be of constant value.

There is another case for high altitude flight. The density of the atmosphere falls off very rapidly with altitude, and for an aeroplane flying at a given incidence (its best) at any altitude, its speed in level flight must be $\sqrt{\frac{\rho_O}{\rho_H}}\ V_O$, where V_O is its speed at ground level for level flight, ρ_O is the ground level density of air, and ρ_H is the density of air at the altitude of flight. As the lift and incidence are the same as for ground level, so also will be the drag. Therefore $HP_H = \sqrt{\frac{\rho_O}{\rho_H}}\ HP_O$, where HP_O and HP_H are the horse power for level flight at ground level, and the power for level flight at that altitude respectively. Similarly, as the air forces on the airscrew will be the same, $N_H = \sqrt{\frac{\rho_O}{\rho_H}}\ N_O$ where N_O and N_H are the rate of rotation

* This article first appeared in the ' RAF Cadet College Magazine,' Autumn 1928.

January 1970 - College Journal Article (1b)

of the airscrew at ground level and at that altitude respectively.

The value of $\sqrt{\frac{\rho_o}{\rho_H}}$ is given by the curve (Fig. 1).

This curve clearly shows that the most efficient method of obtaining great speeds is to attain great altitudes, as an increase of speed obtained through altitude does not mean an increase of landing speed.

For example, an aeroplane at 80,000 feet must go five times as fast as at ground level. The HP necessary for level flight must also be five times as great, so also must the airscrew revolutions.

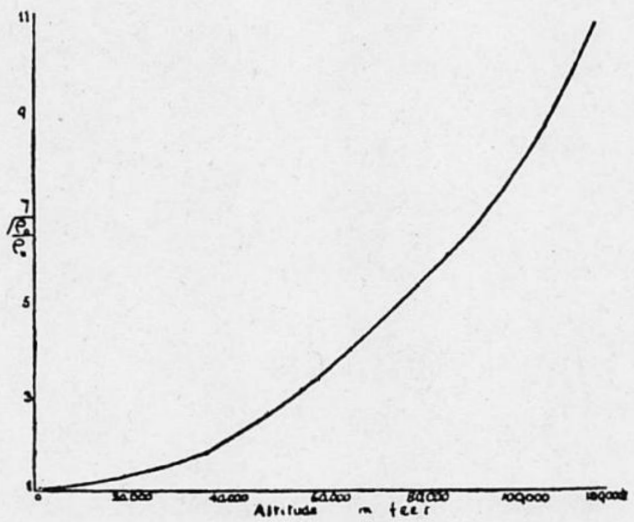


Figure 1

Example :—

Aircraft weight 2,000 lbs fully loaded.
Overall L/D of 10.
Air speed 60 mph at ground level.

Drag will be $\frac{2,000}{10} = 200$ lbs.

Speed is 60 mph = 88 fs.

$\therefore$ HP for level flight $= \frac{88 \times 200}{550} = 32.$

At 80,000 feet this machine would fly at 300 mph for the same incidence and would require 160 HP for level flight.

The reasons why we cannot yet reach these altitudes are :—

(1) The engine speed is limited, and thus the only method of obtaining the extra airscrew speed would be by gears.

(2) The tip speed of an airscrew is given by $\frac{V}{P} \times \pi D$, where V = velocity of aeroplane in ft / sec, P is practical pitch of air-screw in feet, D is airscrew diameter in feet. It has been found by wind channel research that the efficiency of an airscrew falls off as the tip speed approaches 1,100 fs, therefore for great speeds $\frac{P}{D}$ must be greater than one, and efficiency falls off for increasing values of $\frac{P}{D}$.

(3) The present type of aero engine depends for its power on the weight of mixture it takes into its cylinders per unit time, and as practical limitations prevent the increasing of revolutions as the density of the atmosphere decreases, a supercharger must be used which will supercharge the air to ground level density to maintain full power. A supercharger which will cope with the rarified atmosphere of great altitudes without absorbing much power has not yet been devised.

Even if winds do exist at these altitudes, their effect on aircraft would be very much less than at ground level. For instance, a 100 mph wind against a machine travelling at 300 mph at 80,000 feet would have the same effect as a 20 mph wind against the same machine doing 60 mph at ground level.

If such advantages are to be attained by high altitude flight, how are we going to overcome the difficulties which prevent it ? The solution seems to me to be the development of a more suitable power unit.

We have heard much recently about the rocket-driven car, and of proposals for an aeroplane to be driven on the rocket principle. The principle is this :—If gases be ejected from rest, under pressure in a chamber, through a nozzle, there is a reaction equal and opposite to the force giving the gas its kinetic energy in the nozzle. Now suppose W lbs of gas per second pass through nozzle with a final velocity V fs. Then the force exerted on the gas, and therefore the reaction $= \frac{W}{g} V$ lbs. The kinetic energy per second given to gas by heating agent $= \frac{W}{2g} V^2$ ft lbs — ie, power given to gas $= \frac{W}{2g} V^2$ ft lbs / sec. Now if the vehicle being driven in this manner has a velocity v.f.s. in the direction of the reaction, then the power for driving

$= \text{Reaction} \times v$ ft. lbs / sec $= \frac{W}{g} Vv$ ft lbs per sec.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{W}{g} Vv \div \frac{W}{2g} V^2 = \frac{2v}{V}$$

Now suppose we want a thrust of 200 lbs and we can at most pass 1 lb of gas per second through the nozzle.

$$\text{Then } 200 = \frac{W}{g} V = \frac{1}{32} V$$

$\therefore$ Velocity of gas = 6,400 fs

and the efficiency of the " engine "

$$= \frac{2v}{6,400} = \frac{v}{3,200}$$

where vfs is the velocity of the object being propelled. Thus in this particular case, we should require 1 lb of rocket mixture for every second of flight, and even if the velocity were as great as 300 mph — ie, 440 fs — efficiency would only be $\frac{440}{3,200} = 13.7\%$.

The rocket principle is obviously impracticable unless one applies it to a rotating nozzle where high linear speeds are possible ; then one is, of course, approaching the principle of the turbine, which I now propose to discuss.

January 1970 - College Journal Article (1c)

The steam turbine is the most efficient prime mover in common use. It has a high thermal efficiency compared with the aero engine and is a smoother running machine. Of course, a steam turbine is out of the question for aircraft owing to the enormous weight, but there seems no reason why an air turbine should not be developed, with petrol or crude oil as the heating agent. In the case of an air turbine the heating agent may mix directly with the working agent and thus exhaust via the nozzles. There being no heat wasted in flue gases, an air turbine should have a greater thermal efficiency than a steam turbine.

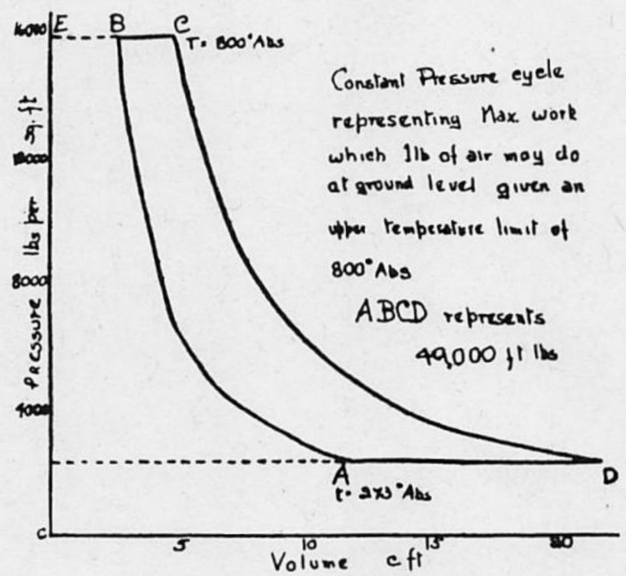


Figure 2

The cycle is shown in the two examples, Figs 2 and 3, which are actual constant pressure cycles for 1 lb of air at ground level (Fig 2) and at 115,000 feet (Fig 3).

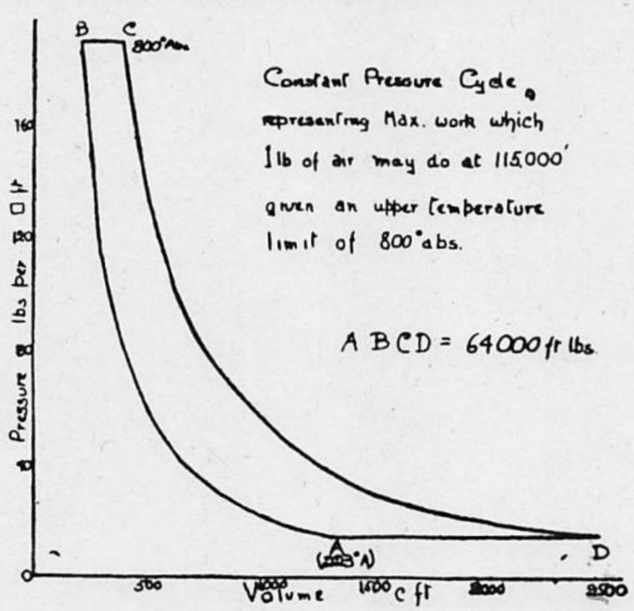


Figure 3

Air is compressed adiabatically AB. It then passes into a heating chamber and is heated at constant pressure BC. It then passes through the nozzles, expanding adiabatically CD, and finally cools at atmospheric pressure outside the engine DA.

The efficiency is given by $\eta = 1 - \frac{1}{R^{\gamma - 1}}$, where R is the compression ratio.

The velocity of the gas at the nozzles, on which depends the most efficient velocity of the turbine rotor [the most efficient velocity of the turbine blades $= \frac{1}{2} V \cos \alpha$, where V is velocity of gas at nozzle, and α is the angle that the axis of the nozzle makes with the rotor] is such that the kinetic energy of the gas equals the area ECDF (Fig. 2) ; thus the power of the turbine is not dependent on the rpm.

The power is given in the particular cases shown by

$$IHP = W \times \text{area } ABCD \div 550,$$

where W is the weight of air undergoing the cycle per second.

The maximum work which 1 lb of air may be made to do is only limited by the maximum temperature which the materials of the heating chamber will stand and the temperature of the atmosphere.

Maximum work $= 336 (\sqrt{T} - \sqrt{t})^2$, where T is the maximum temperature (absolute) and t is the atmospheric temperature (absolute).

The idea as a whole is very similar to the steam turbine, the differences being that air is pumped adiabatically into a heating chamber, where it mingles with a burnt petrol-air mixture instead of water being boiled. As far as the nozzles and rotor are concerned, such an engine would be similar to the steam turbine.

The advantages of such a power unit may be stated as follows :—

(1) The only limit to the compression ratio is the maximum temperature which the heating chamber may stand.

(2) Power is not dependent on r.p.m., as in the case of the petrol engine.

(3) The work which may be done by 1 lb of air increases with altitude, and partly compensates for the smaller quantity of air available.

(4) Supercharging does not appear to be necessary.

(5) Rotors of different diameters may be used to act as gearing.

The main disadvantage as far as air work is concerned is the gyroscopic effect of the rotors, but on reviewing the points for and against it seems as though the air turbine is the aero engine of the future.

January 1970 - College Journal Article (2a)

COMMENT ON SPECULATIONS OF 1928

by AIR COMMODORE SIR FRANK WHITTLE, KBE, CB, MA, ScD, FRS, C.Eng, RAF (Ret'd)

The Editor has asked me to agree to the re-publication of ' Speculation ' which appeared in the College Magazine for the autumn of 1928 shortly after I had graduated from the College. He also asked me to write a similar article giving my present views about the future. However, I felt obliged to excuse myself from the latter on the ground that, though I have kept in general touch with aeronautical engineering over the past few years, I have been mainly concerned with oil well engineering, and I would need to do a lot of brushing up to attempt such a task. Moreover, the thought was in my mind that one can stick one's neck out a long way as a Flight Cadet aged 21 and get away with it, but I cannot do that today with impunity. Inter alia, there is too big a risk of inadvertently forecasting things which may already be on the drawing board and under security wraps. That could lead to awkward questions as many would assume that I am ' in the know ' when, in fact, I am not. I have run into this difficulty in the past. For example, in 1943 I wrote a paper on probable developments in submarine design which was submitted to the Admiralty. A few years later (long after the war) I requested permission to publish. This permission was granted but only subject to important deletions, because I was rather too close to secret work then in progress. However, I agreed to the re-publication of ' Speculation ' and to write this commentary on it.

I fear it was a very amateur effort, but I suppose it has some historical value because — so far as I recall — it was the first article on a technical subject by me to be published. It was a condensation of part of my fourth term thesis " Future Developments in Aircraft Design."

Unfortunately, it was marred by printing errors to such a degree that it was probably only comprehensible to anyone so familiar with aerodynamic and thermodynamic theory that the mis-prints would have been obvious. The proofs were never submitted to me for correction, so I cannot wholly be blamed for the apparent errors though, undoubtedly, my handwriting was largely at fault. Generally speaking, the errors took the form of the Greek letter ' rho ' appearing as ' P ' ; the Greek letter ' gamma ' appearing as ' Y ' ; indices appearing as coefficients ; + signs instead of the word ' and ' ; 9 for the symbol ' g ' etc. eg

$$\sqrt{\frac{\rho_o}{\rho_H}} \quad \text{appeared as} \quad \frac{\sqrt{Po}}{PH}$$

As may be seen, I looked into the possibilities of rocket propulsion and into propellers powered by internal combustion turbines — it had not then occurred to me that the gas turbine was the best way of producing a propelling jet (for aircraft propulsion at least). The penny dropped just over a year later, by which time I had raised my sights to speeds of the order of 500 mph.

Though I did not know it at the time, the first formula in the article (for range) was a form of the Breguet Equation (the figure 2,800 was the calorific value of petrol in foot pounds per pound divided by 5,280 — to convert feet into miles). It can be applied to jet aircraft by the substitution of the appropriate efficiencies.[1] The formula tends to ignore climb and descent — I probably assumed that the extra fuel required for climb was compensated for by fuel saved on descent. It also requires that the flight condition is at constant lift / drag ratio ie, at constant incidence, which implies a gradual climb as the weight is reduced by fuel consumption. I did not then foresee that traffic control requirements would usually prevent adherence to this optimum flight plan. (With jet aircraft one must fly at a speed somewhat higher than that for maximum L / D because as the thrust of a jet engine varies only slightly with speed at cruising speeds any attempt to fly at maximum L / D — ie, minimum drag — would mean that the slightest deceleration would result in the drag becoming greater than thrust, thus causing further deceleration)[2]

My views about conditions in the stratosphere were distinctly optimistic but I could not know this as no-one had ever been there nor, so far as I knew, had anyone devised any means for regular exploration of the stratosphere. Such things as jet streams had yet to be discovered as also the fact that the tropopause is very much higher in the lower latitudes (I have seen cumulonimbus towering many thousands of feet above when flying across the Caribbean at 35,000 feet).

The discussion of propulsion by rocket leaves a great deal to be desired, but I was, of course, thinking only in terms of aircraft propulsion. (I think I would have been as disbelieving as anyone if someone had suggested that man would set foot on the moon within 31 years). I remember being very uneasy at the expression I derived for the efficiency of rocket propulsion because of the implication that if the flight speed became more than half the jet velocity, the efficiency would exceed 100% which is improbable to say the least of it. However, this condition would have meant flight speeds more than seven times greater than the 300 mph I was considering. I must have decided not to worry about such a seemingly remote possibility. One of the things I did not take into account was the work done in imparting kinetic energy to the vehicle in addition to overcoming drag. A satisfactory definition of the efficiency of rocket propulsion still seems to me to be a somewhat elusive thing.

The discussion of the gas turbine in the latter part of the paper is, I fear, very amateurish. It is evident that I was thinking only in terms of what was then known as the simple impulse turbine of the de Laval type and that I was still far from being familiar with turbine theory. The most serious defect of this section, is that I evidently assumed that the losses in the processes of compression and expansion would be negligible whereas, as I came to realise shortly after, compressor and turbine efficiencies were all important. The low values then usual for rotary machinery of this type was, coupled with the lack of materials capable of withstanding high stresses at high temperatures, the main stumbling block in the several unsuccessful attempts to develop the gas turbine in the early years of the century.

On reflecting on this serious defect in my argument, my embarrassment is somewhat mitigated by the knowledge that I wrote a paper entitled " The Case for the Gas Turbine " while I was a floatplane and catapult experimental test pilot at the Marine Aircraft Experimental Establishment, Felixstowe between January 1931 and July 1932. This paper was never published but, though I had still to receive my engineering training at Henlow and Cambridge, it shows that I

[1] It is now often written in the form

$R = \frac{V}{f} \frac{L}{D} \mathrm{Log}_e \frac{W_1}{W_2}$ where V is flight speed (mph if R is in miles or knots if R is nautical miles) ; f is specific fuel consumption in lbs / hr / lb of thrust ; W_1 is all up weight at beginning of cruise and W_2 is all up weight at end of cruise.

[2] When I embarked on the task of finding a range formula I fully expected to find that great increases of range could be obtained by flight at great altitudes and my disappointment was great when I was forced to accept that maximum still air range was independent of height.

January 1970 - College Journal Article (2b)

had greatly advanced in my knowledge of gas turbine theory and had acquired a much more realistic approach and become well aware of the importance of component efficiencies and the need for suitable turbine blade materials. By that time I was, of course, concentrating on the jet engine application of the gas turbine.

The advantages as listed at the end of ' Speculation ' also show that my ideas were still somewhat nebulous. The first would have been better stated as " The limiting pressure ratio is governed by the component efficiencies and the maximum cycle temperature which available materials will permit." Item (2) is wrong. I was evidently thinking of steam turbine characteristics. Even so it should have read " Power is not as dependent on rpm . . . . . ". However, as everyone now knows, when the compressor is driven by the turbine, power is in fact far more sensitive to rpm than in the case of the piston engine. (The static thrust of our first flight engine — the W1 — was 860 lbs at 16,000 rpm, 1,000 lbs at 17,000 rpm and 1,240 lbs at the full design speed of 17,750 rpm.)

Item (3) was (and is) quite sound and becomes even more true when compressor and turbine losses are taken into account. Item (4) also proved to be sound in the event, but I cannot remember what I had in mind when I included (5). I am also puzzled by the fact that I did not include the advantages of low weight, absence of vibration, insensitivity to fuel type etc. However, a year or so later I was in the habit of including these.

The formula given for the maximum work per lb of air per second for a constant pressure cycle (the last formula in the article) looked very unfamiliar and I thought that there must be quite a serious misprint but on checking I found that, except that the coefficient 336 (the specific heat of air at constant pressure in ft lbs per lb) appeared as 356 it was correct for the ideal cycle. In later years I would have preferred it in the form

$$w_{max} = K_p T_o \left[\sqrt{\frac{T_m}{T_o}} - 1 \right]^2$$

where w is the work/lb of air/sec, K_p is the specific heat at constant pressure, T_m is highest cycle temperature and T_o is lowest cycle temperature (ie atmospheric static temperature in an open cycle engine).

A particularly interesting thing about this formula is that it indicated the beginning of a very useful line of reasoning. As time passed I acquired the habit of dealing with thermal cycles almost entirely in terms of absolute temperatures, temperature ratios and pressure ratios. Included in this system was the practice of thinking of velocities in terms of temperature equivalents and vice versa. (The conversion is given by $V^2 = 2 g K_p \triangle T$ where $\triangle T$ is the temperature change corresponding to velocity V. It happens that $\sqrt{2 g K_p}$ has the same digits as the factor for conversion of mph into fps — 1·47 — hence the useful rule that kinetic temperature rise in °C is equivalent to the square of the speed in hundreds of miles per hour, eg, if air travelling at 500 mph is brought to rest the temperature rise is 25°C ; for 1,000 mph it is 100°C and so on—hence the problems of kinetic heating which arise at very high Mach numbers).

In detail design one has to allow for a number of minor factors such as increase of specific heat with temperature, the fact that the mass flow in expansion is greater than the mass flow in compression due to the added fuel mass etc., but these secondary ' adjustments ' can be ignored for the purpose of preliminary design and especially for comparative purposes when seeking the optimum cycle for any particular application. With this system it is possible to ' work round ' a jet engine cycle in a matter of three or four minutes after a little practice.

When compressor and turbine losses are taken into account the above formula for w_{max} becomes modified to

$$w_{max} = K_p T_o \frac{T_o}{\eta_c} \left[\sqrt{\eta_c \eta_t \frac{T_m}{T_o}} - 1 \right]^2$$

where η_c is compression efficiency and η_t is expansion efficiency. This condition occurs at a temperature ratio $r = \sqrt{\eta_c \eta_t \frac{T_m}{T_o}}$

eg, for standard sea level conditions ($T_o = 288°K$) with $T_m = 1100°K$, $\eta_c = 0{\cdot}86$, $\eta_t = 0{\cdot}90$ the value of r for w_{max} is 1·72 which gives w_{max} = 58,200 ft lbs/lb or 106 hp/lb/sec. Thus the mass flow of air for 10,000 hp would have to be 94·3 lbs/sec.

Unfortunately, the temperature ratio for highest overall efficiency is substantially higher (about 2·1) so that peak efficiency can only be obtained at the sacrifice of output per unit flow, and vice versa.

In practice η_c decreases as temperature ratio (and therefore pressure ratio) is increased but η_t increases. Both effects are due to the conversion of losses into heat during the compression and expansion processes.

Well ! there is my apologia. If I did drop a few bricks, I can claim that I picked them up again a short time later and learned quite a lot in doing so.

When I look back over the years I am struck by my own relative pessimism at a time when others thought me a wild optimist. The power, size, reliability and performance of jet aircraft have gone far beyond anything I ever predicted. I was, however, usually over optimistic about time and cost, though, in my opinion, my estimates of time **could** have been achieved. For example, there was no serious obstacle to the introduction of the large by-pass ratio turbofan about, say, 1946 or the successful achievement of supersonic flight at about the same time. Unhappily, the contracts for our large by-pass ratio engine (the LR1) and for the Miles M52 experimental supersonic aircraft were cancelled.

The Aircraft

Hosting the Engine for its Test Flight

The Whittle W.IX engine was installed in WAOA1, which undertook taxi trials at Brockworth airfield, near Gloucester.

The Whittle IV.I engine was then installed and the aircraft was transported by road to RAF Cranwell for its first official flight.

By July 1936, initial stages of the Whittle engine manufacture had begun and the first runs took place on 12th April 1937. During the early stages, the engine speed increased so rapidly that the staff had to sprint for cover. This became such an issue that the project had to be relocated to a disused factory at Lutterworth, where the local police suspected the engineers of being IRA terrorists making a bomb! Progress was hampered throughout 1937 and 1938 through lack of funding, which meant that they often had to use old components rather than manufacturing new. As the results of the test improved, so did the Air Ministry's confidence in the project and this brought further Air Ministry funding.

Power Jets' first contract for a flight engine with BHT to power it came in July 1939, with Glosters providing the experimental aircraft; the E28/39. In 1940, the Air Ministry decided that Power Jets would become a research organisation only, with BTH and Rover sharing the engine production costs. The situation worsened for Sir Frank when both companies, eager to obtain an operational jet fighter, ignored him and authorised Glosters to produce the F9/40 which became the Gloster Meteor. They also approved alterations behind his back.

The E28/39 made its maiden flight at Cranwell on 15 May 1941. Fg Off Gerry Sayer flew it to a top speed of 370mph at 25,000ft over the next few days. After this, there was much interest from all of the major aircraft companies, including some in the USA. So much so that six months later they had more jet aircraft than Britain! This American interest led to Sir Frank being sent over there to assist with the development of his engine. The visit was beneficial to both Sir Frank and the UK; as the knowledge that Britain had technology of major significance improved relations between the two countries.

Gloster (W4041/G) - Science Museum

Fg Off Gerry Sayer - Test Pilot

Phillip Edward Gerald Sayer OBE	
Born	5 February 1905 Colchester, Essex, England
Disappeared	21 October 1942 (aged 37) North Sea
Nationality	British
Occupation	Test pilot
Employer	Gloster Aircraft Company
Known for	Piloting the first flight of the first British jet aircraft
Spouse(s)	May Violet Ellen Wallace-Smyth (m. 1929–1942)
Parent(s)	Wing Commander E. J. Sayer MC (father)
Military career	
Allegiance	United Kingdom
Service/ branch	Royal Air Force
Years of service	1924–1929
Rank	Flying Officer

Sayer was transferred to the Reserve of Air Force Officers (Class A) on 2 March 1929, to become second test pilot with Hawker Aircraft, assistant to Group Captain P. W. S. (George) Bulman (who first flew the Hurricane on 6 November 1935).

In 1934, Hawker took over the Gloster Aircraft Company and Sayer was appointed chief test pilot in November 1934. On 2 March 1937, Sayer relinquished his reserve commission on completion of service, and was permitted to retain his rank.

On 15 May 1941 at 7.45pm, he took off from RAF Cranwell, near Sleaford in Lincolnshire in the Gloster E.28/39 (W4041/G) powered by the W.1 engine and flew for 17 minutes, flying at over 500 miles per hour (800 km/h), impossible for other aircraft at the time in level flight. That Gloster aircraft has been in the Science Museum since 1946. A second aircraft of the same type (W4046/G) would be demonstrated to Winston Churchill on 17 April 1943, having first flown on 1 March 1943; it crashed in June 1943.

On 21 October 1942, Sayer departed from RAF Acklington in a Hawker Typhoon to carry out tests of a gunsight involving gun firing into Druridge Bay Ranges, accompanied by another Typhoon. Neither aircraft returned, and it was assumed that they collided over the bay. He was replaced as Gloster's test pilot by Michael Daunt, who would be the first to fly the Gloster Meteor (powered by two de Havilland Goblin engines designed by Frank Halford) on 5 March 1943 at RAF Cranwell.

A Villager's Personal Memory - Mrs 'Bill' Bangay

From Alice Grant's Book of 1992, this extract was provided by Mrs Ada Gaskill in 2019

'Mrs' Bangay was the leading light of the village
(Bill* and her husband* was a bandmaster at the College

*I was working in the garden, when I heard this
funny whistling noise, she saw this strange
aircraft, so she ran into the house to tell her
husband & friend, that she had seen this unusual
aircraft with an umbrella - but they just laughed
at me.
What Mrs Bangay had seen was the flight of the
first jet engine (Her husband had been sworn
to secrecy) The aircraft was a Gloucester
meteor, designed by Frank Whittle at Cranwell

Reunited