Ludwig Wittgenstein, destined to be one of the most influential philosophers of the western world, entered Manchester University in 1908 as an aeronautical engineering research student. At Manchester he devised and patented a novel aero-engine that employed propeller-blade tip-jets. As a first practical step to the realization of this device, Wittgenstein constructed a variable-volume combustion chamber, but on departing for Cambridge he abandoned all further work on the project. The plans of this chamber survived and are presented in this paper. This article includes a detailed description of the drawings and an analysis of the probable function of the system.

Keywords: Wittgenstein; aviation history; combustion chambers; jet engines

INTRODUCTION

In 1908 Ludwig Wittgenstein (1889–1951) came to England and enrolled in Manchester University as a research student in aeronautics, which at the time was an elementary academic discipline. There he stayed for approximately two years before moving to Cambridge. A previous paper sought to collate all that had been recorded about his Manchester work against a background of the contemporary state of English aeronautics. Wittgenstein, with a family background in the engineering industry, arrived in Manchester after a rigid German education in the physical sciences. His aeronautics activities culminated in a patent (1910) for a unique aero-engine employing an airscrew driven by propeller-blade tip-jets. The paper also enlarged on a completely independent reappearance of his ideas some 30 years later when various types of short-lived hybrid rotorcraft emerged with rotors driven by blade tip-jets. These included the Doblhoff WNF 342 V4 (1945) and later the Fairey Rotodyne (ca. 1957). Additionally, it was postulated that by his proposed use of centrifugal flow compression Wittgenstein anticipated, although in a different physical configuration, the gas-turbine aero-engine developed during the 1930s by Frank (later Sir Frank) Whittle (FRS 1947).

Wittgenstein began his own researches in the Engineering Department after an initial period at the university’s meteorological outstation (Glossop), where he had participated in practical work on the aerodynamic design of high-flying kites. In the department he designed...
and constructed a variable-volume combustion chamber from which the combustion gases exited through a nozzle, thus enabling him to optimize exhaust nozzle geometries appropriate for the blade-tip combustion chambers that he envisaged. Plans of the chamber have survived.

WITTGENSTEIN’S ENGINEERING RESEARCH ACTIVITIES

There are several important figures in the history of the plans. The root source of information on Wittgenstein’s engineering experiments at Manchester is his fellow student William Eccles. They developed a close friendship that endured well into the 1930s. Eccles is shown as a student in the upper left-hand corner of figure 1, which is a photograph of the Physics Department in 1910. It seems that when Wittgenstein left Manchester, Eccles became the recipient of some of his friend’s documents including the plans of the combustion chamber.
Professor Wolfe Mays (1912–2005), when he was a Cambridge student, attended Wittgenstein’s lectures and knew Wittgenstein personally. His academic career—he became an eminent philosopher in his own right—took him to Manchester University, where he taught from 1946 until his retirement in 1979. Prompted by an enquiry from Professor G. H. Von Wright, Mays dispatched a letter to the Manchester Guardian newspaper asking for anyone who had known Wittgenstein during his Manchester period to ‘get in touch with me.’\(^3\) Printed in the newspaper on 1 February 1954, it resulted in a telephone call from Eccles the following day. A meeting with Eccles ensued that resulted in Mays writing a number of articles on Wittgenstein’s Manchester period.\(^3\)–\(^5\) These confirm that Wittgenstein had constructed and experimented with a variable-volume combustion device and that three surviving plans of the system were in Eccles’s possession. Professor Brian McGuinness interviewed Eccles at the latter’s retirement home in Ireland for his biography of Wittgenstein and included full mention of the Manchester period.\(^6\)

The plans were eventually passed on to the Stonborough family, who in turn lodged them in the Austrian National Library, Vienna (Professor Elisabeth Leinfeller, personal communication). (Wittgenstein’s sister Margarethe had married Jerome Stonborough. Her great-nephew John Stonborough, currently living in London, has no additional information to offer.)

Professor Joseph Ernest Petavel (1873–1936) (FRS 1907), head of the Engineering Department, was an internationally acknowledged expert on the combustion of gases and is a peripheral figure in the literature with regard to Wittgenstein’s stay in Manchester. It is evident that he encouraged Wittgenstein by providing a compressor from the Physics Department and also recommended him for a research studentship.\(^7\) Wittgenstein is mentioned several times in the Archives of the University of Manchester (John Rylands Library). The following are typical statements: ‘Mr Wittgenstein came from Austria with a view to making an experimental study of aerodynamics and proposes to complete a year’s residence’;\(^8\) ‘Mr Wittgenstein has continued his investigation on the rate of combustion of gaseous mixtures under high pressure’.\(^9\) The second of these reports is dated well into Wittgenstein’s stay in Manchester and it is hard to believe that Petavel did not take an interest in the combustion chamber and provide advice at this advanced stage. The importance of Petavel’s work on the design of the device is emphasized in the analysis below.

**APPRAISAL OF THE SURVIVING DRAWINGS**

The plans are reproduced in figure 2. The drawings consist of three sheets, each measuring 25 inches by 38 inches. A blank rectangular portion 8 inches by 6 inches is missing from a corner of one. They are slightly discoloured with age but are otherwise in good condition. Figure 2a is a composite of two of the plans (Wittgenstein’s sheets were not large enough to encompass a drawing of the full assembly); they have been combined to give the reader an impression of the overall shape of the system. Figure 2b is an enlarged version of the upper section of figure 2a, labelled to clarify the appraisal. Figure 2c is the third of Wittgenstein’s drawings, showing additional valves and fittings. Taken together, figure 2a and figure 2c comprise the five drawings relating to the variable-volume combustion chamber.

The two drawings in figure 2a are a cross-section and an exterior view of the main assembly. The large cylindrical pressure vessel measures \(18\frac{1}{2}\) inches long and would have been machined from cast iron with an inner combustion chamber 3 inches in diameter surrounded by a ‘water jacket’. The water jacket is an annular volume filled with liquid water to absorb energy and reduce the inner wall temperature; it has an outside diameter of
Figure 2. The plans of Wittgenstein’s aero-engine. (a) Combustion chamber section and external view. The dashed horizontal line shows the matched boundaries of the original drawings. (b) Enlarged version of the upper section of (a). Labelled components: A, main combustion chamber; B, supersonic exhaust nozzle; C, ignition port; D, piston-head mixing chamber; E, gas inlet port; F, cooling water jacket. (c) Secondary parts and attachments. Labelled components: A, ignition device; B, valve with coolant flow; C, brass valve; D, lubricated hollow shaft. (Courtesy of the Austrian National Library (Vienna) and the Master and Fellows of Trinity College, Cambridge.)
$6\frac{1}{2}$ inches. The overall length of the device is approximately 38 inches, not including the piston shaft. This design has many features in common with a ‘small furnace’ described by R. S. Hutton and J. E. Petavel, including the basic dimensions, the water-jacket design and the location and dimensions of various apertures.\textsuperscript{10,11} The drawings also have a similarity to those outlined in Petavel’s published work on high-pressure machinery.\textsuperscript{12} The paper by Hutton and Petavel includes a photograph of a combustion unit that strongly resembles Wittgenstein’s complete system as shown in figure 2a. The dimensions marked on Wittgenstein’s drawings match those indicated in Hutton and Petavel’s paper so closely that it is reasonable to suppose that some exterior fittings may have been copied or adapted; at the very least it seems likely that instrumentation could have been common to both devices. Wittgenstein had his combustion chamber constructed in the works of ‘Messrs Cook’.\textsuperscript{3} Petavel notes that the ‘University Engineering Works’ at Manchester was responsible for the
general arrangement and assembly of his apparatus.\textsuperscript{12} When Petavel came to Manchester from the Royal Institution (RI), he persuaded the university to install Charles W. Cook, a mechanic working at the RI, in a small engineering works attached to the university.\textsuperscript{13} Cook eventually became the scientific apparatus maker to the university.\textsuperscript{14}

The main functional components of the design are labelled in an expanded view in figure 2\textit{b}. Inside the main chamber a sliding piston arrangement varies the volume of the combustion zone at the top of the cylinder; this is achieved by rotating the circular handle...
located at the far end of the device. A similar mechanism had been employed by Petavel to feed carbon rods into electric furnaces. The piston has a hollow shaft with a valve that allows fuel to be introduced into a space behind the piston through several small radial holes. The diameter of these holes has not been dimensioned on the drawing, and it may have been that the piston head was replaceable so that the diameter could be varied. The maximum capacity of the main chamber is approximately 85 cubic inches using this piston head. The annular volume within the piston head forms a pre-combustion mixing chamber with a volume of approximately 6 cubic inches. Two radial ports of different sizes are shown at the lower end of the main chamber beneath the water jacket, permitting two different gases to be supplied; one of the gases would have been compressed air. No equipment is shown on any of the drawings for pumping the fuel. The fuel-air mixture is then introduced into the main combustion chamber through an annular gap in the piston head. The mixture would probably be ignited in the chamber by using an electric arc at the side of the combustion chamber; details of the ignition device are shown on the supplementary drawings. Had Wittgenstein proceeded with his project, electric spark ignition would almost certainly have been used for an aero-engine configuration.

The most distinctive addition to the basic chamber design is a simple water-cooled supersonic exhaust nozzle of the de Laval type 2 inches in length situated at the top of the chamber. The emerging jet of hot combustion products could be used for thrust measurements and thus for the development of exit nozzle geometries required for small combustion chambers fixed to propeller-blade tips. A more straightforward adaptation would be to feed the hub of a hollow-bladed propeller directly to repulsion jets on the blade tips. The nozzle is simple to change because it is screwed into the chamber and restrained with a bolted flange. Cooling water circulates around the nozzle through the two radial hose fittings shown at the top of the drawing. An additional feature of Wittgenstein’s design is two radial bars that are sketched at each end of the main chamber in the exterior view. These would probably connect to a restraining structure within the laboratory. With the chamber mounted vertically, and the exhaust facing upwards as shown, the exchange of nozzles could take place without significant water leakage. In this configuration the resulting force on the apparatus and the supports would have been in the downward direction.

The drawings labelled in figure 2c represent some secondary components of the system. Further additional components would be required for operation of the complete unit, but these may already have existed and additional drawings may not have been required. The dimensions of the external thread of the part on the left-hand side of this drawing (1-inch Gas) are the correct size for it to be screwed into the radial port in the main combustion chamber above the piston. Its hollow cross-section forms a steel cylindrical side passage, probably designed to contain the ignition device, or ‘plug’, the latter fashioned from a cylinder of insulating material, such as ivory or ceramic, with a steel spindle core. The design allows the insulation for the ignition plug to be restrained in compression and seems to owe its form to earlier work by Petavel. Petavel explained that this configuration was needed to compensate for the brittleness of the insulating materials available at the time. The spindle’s end would form one of the electrical poles and ignition could be achieved by an arc created within the main chamber, or by fusion of a thin wire attached to the spindle. The inner section is removable by unscrewing the circular handle to allow replacement of the terminal piece without breaching the water jacket. A small threaded part, without dimensions, is sketched protruding through the handle; this could be the external terminal of the ignition plug. The terminal would connect to a power supply, and the electrical circuit would be completed by
attaching the other end to the casing of the chamber. Similar ignition plugs were used later by W. Bone et al.\textsuperscript{16} The overall length of this piece is approximately 12 inches.

The drawing in the centre of figure 2c illustrates a steel assembly bolted to a base plate. A valve regulates fluid flow through a hollow tube held in place by a three-way brass connector screwed to the base of the assembly. The connector allows a second fluid (probably a coolant) to circulate around the tube. Some dimensions are missing (for example those for the base plate) and it is difficult to relate the overall function of this component to the main assembly of figure 2a. The partial assembly measures approximately $10\frac{1}{2}$ inches long, not including the shaft.

At the right of figure 2c is a simple steel valve that would have been used to regulate gas flow into the chamber at the rear of the piston; the drawing lacks a seal. The steel component measures $5\frac{1}{4}$ inches in length. The drawing at the top right of this figure shows a brass part, 4 inches long, with ports for the lubrication of a sliding hollow shaft. The function of this part is unknown because the dimension of the main external thread (approximately $1\frac{1}{2}$ inches) does not match the internal thread on any of the remaining parts.

The complete device is suitable for combustion experiments with pressurized gas mixtures and would have been able to operate in this configuration. For a given fuel-air mixture, movement of the piston varies the main chamber volume and thus the pressure during combustion. The internal shape of the nozzle for optimal thrust is governed by the pressure difference between the combustion chamber and the outside atmosphere.

**ON THE VIABILITY OF WITTGENSTEIN’S PATENTED CONFIGURATION**

Comment has on the whole been unfavourable; for example, an engineering friend of Mays (with some hindsight) complains, ‘why … all this trouble—could he [Wittgenstein] not have made a gas jet to push an aeroplane through the air in the way modern jets do?’ The friend argues that it is inefficient to power a propeller in this manner; that is, by converting the momentum of a gas into the rotational energy of a propeller.\textsuperscript{3} However, one can apply what amounts to an engineering topological transformation to the engine, making the propeller synonymous with the compressor in a centrifugal-flow gas turbine.\textsuperscript{1} The transformation can be taken one step further: the exhaust gases from the turbine may be used to drive an additional turbine mounted on the main rotating shaft (a small residual thrust remaining). The shaft is connected to a propeller by means of reduction gearing. The resulting turbo-prop engine is well known to be very efficient when used in lower-speed, low-altitude aircraft, and is a proven example of ‘powering a propeller by the momentum of a gas’.

One article\textsuperscript{17} (translated here from the German) that discusses Wittgenstein’s patent in greater technological detail confirms and adds to points made previously.\textsuperscript{1} It notes that the patent does not specify Wittgenstein’s ideas, if any, for an ignition system. It regards as ‘unclear whether a real demonstration model was ever built’. It goes on to state:

> [The centrifugal forces have to be such that] the pressure of the compressed air as well as the pressure in the fuel line is greater than the combustion pressure [thus avoiding flashback].

To successfully [use centrifugal forces] as a feed pump the dense fuel can be accepted. However … the much lighter air [would only be sufficiently compressed] if the propeller rotated at speeds giving rise to blade tip velocities substantially above the sonic velocity.

Note that comparable tip-jet schemes in later aircraft pump the fuel to the blade-tip-mounted combustion chambers and use a compressor for the air.\textsuperscript{1} (A high centrifugal acceleration is required for the compression of air.) Other problems noted include
inadequate requisite performance of then available compressor(s)—pressure tight mountings into the propeller blades having to cope with hot gases emerging from a centrally mounted combustion chamber [as opposed to blade tip combustion], an unachievable requirement since the technology pertaining to the strength and heat resistance of materials was not available at the time and was not to be resolved for several decades.

Despite these insoluble problems, the scheme was considered by the article’s authors to be ‘fundamentally ingenious’, as indeed it was in about 1909.

CONCLUSIONS

In a letter addressed to Wittgenstein, one of his old Linz schoolmasters resuming contact in 1915 asked, ‘Was ist aus der Flugmaschine geworden?’ [‘What became of the flying machine?’] At school Wittgenstein had shown a particular interest in aeronautics. The enquirer may have been unaware of Wittgenstein’s change of vocation from aeronautical engineering to analytical philosophy. The answer is that Ludwig’s innovative design was never to be completed. His researches at Manchester never progressed beyond the construction of the ‘variable volume combustion chamber’ and using it to optimize exit-jet nozzle geometries.

The role of Professor Petavel as his supervisor has been emphasized here. Design features of combustion chambers incorporated in Petavel’s considerable researches in this area are reflected in the construction details of Wittgenstein’s chamber (although Ludwig gets no mention in an extremely comprehensive 8000-word obituary of Petavel as having been a research student in Petavel’s Engineering Department). Biographies, large or small, of Wittgenstein always include the Manchester period, and some philosophy academics have related Wittgenstein’s involvement with aeronautical engineering to their own interpretations of his philosophical works.

Wittgenstein’s combustion research was conducted a century ago when the technology was immature. He faced formidable problems, some of which would not be solved for many years. If he had persevered with what was a complex and difficult exercise and even achieved a measure of success as the necessary supporting technology caught up with his requirements, the emergence of more conventional aero-engines accelerated by the demands of World War I would have more than improved on anything he had to offer. Still, as described previously, the basic idea of tip-jet-driven propellers found an application in hybrid rotorcraft developed many years later and are even being revived today.

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NOTES


Wolfe Mays, ‘Recollections of Wittgenstein’, in Ludwig Wittgenstein: the man and his philosophy (ed. K. T. Fann), pp. 79–88 (Dell Publishing Co., New York, 1967). This was a reproduction of Mays’s feature article entitled ‘Wittgenstein’s Manchester period’ as printed in The Guardian on 24 March 1961. The version in The Guardian includes an illustration of one of the plans (see figure 2a, cross-section drawing only). One infers that Mays took copies of the plans [‘which he was proud to have located’] (Lemco, op. cit. (note 1), p. 43).


Extract from Department of Physics Report, included in the Report of Council to the Court (1907/1908). University of Manchester Archive.

Extract from Department of Engineering Report, included in the Report of Council to the Court. (1910/11). University of Manchester Archive.


R. S. Hutton, Recollections of a technologist (Pitman & Sons Ltd, London, 1964). Hutton makes no mention of Wittgenstein in this book. A lecturer in electro-metallurgy at the university, he acknowledges the help he received from Petavel. In 1932 he became the first Goldsmith’s Professor of Metallurgy at Cambridge. Incidentally, he married Professor Schuster’s daughter Sybil. See also note 14.

J. E. Petavel, ‘On the design of machinery for very high pressures’, Engineering (26 July), 97–98 (1907).


T. E. Broadbent, Electrical engineering at Manchester University (Manchester School of Engineering, University of Manchester, 1998).


