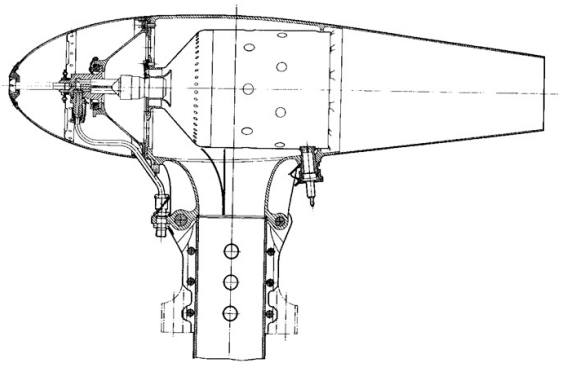
ROYAL AERONAUTICAL SOCIETY
LOUGHBOROUGH BRANCH

A joint lecture with IMechE Young Members
19 November 2019
The Fairey Rotodyne
David Gibbings, MBE, CEng, FRAeS
Ex Westland Chief Flight-Test Engineer

It is rare to say that this was a lecture like no other – we had, perhaps, our oldest ever speaker and whose positive character was clear immediately when he had no qualms to acknowledge that he suffers Parkinson disease. It had reduced the strength of his diction, and he had to make his presentation while seated, yet there was no evidence that his memory, and his ability to speak with confidence of the technical aspects of one of Britain's most unique, pioneering, and fascinating aircraft of the post-WW2 period has been diluted.

The Fairey company is hardly heard of nowadays, but in the past it was a firm that seemed never able to walk away from any challenges, and its history (it stretches back to 1915) has been somewhat fragmented because its endeavours were spread across a wide spectrum. We were not presented with a deep history, the speaker kept to his own experiences as former Chief Flight Test Engineer on the unique Fairey Rotodyne.

The presentation looked back to the immediate post-WW2 period, when many leading German engineers joined the British aviation industry. He attributed development that led to the Rotodyne to one man in particular, August Stepan. He was an Austrian engineer who had worked with fellow countryman Friedrich von Doblhoff, the instigator of a helicopter concept which used rotor blades with tip jets. The concept of using tip-mounted 'hot' jets using a fuel/air mixture fed through the rotary blades from an engine-driven compressor was considered by Germany in the latter stages of WW2 for small ship-borne rotorcraft. The configuration avoided using gearing to drive the rotor, and as there would be no torque reaction, it also avoided the need to counteract rotor torque. This alleviated the need for a tail rotor, or the use of contra-rotating blades. It was mechanically ingenious and also operationally simple.



A rotor blade tip-jet

The Fairey Gyrodyne 1954

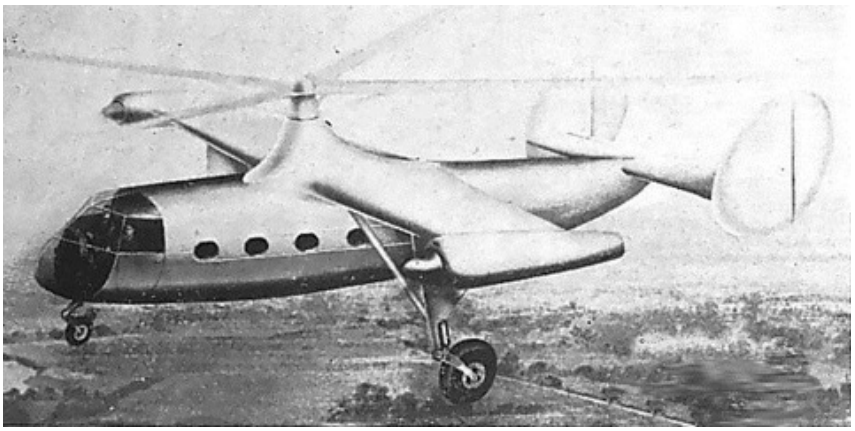
Dip.Eng Stepan was one of several engineers that came into Britain from Europe after WW2 as there was interest and support for many of their forward-looking ideas in aircraft companies and research organisations. After joining Fairey, Stepan instigated the Gyrodyne and Ultralight projects, two small but significant projects that did not reach production, but

flew and showed the capabilities of this unique technology.

The speaker was involved in these programmes. As development took place the company evolved a rotorcraft division, and supported a test facility for research and development at White Waltham. The Gyrodyne conducted its first free flight on the aerodrome in January 1954, and a full transition from helicopter to autogyro flight was achieved in March 1955.

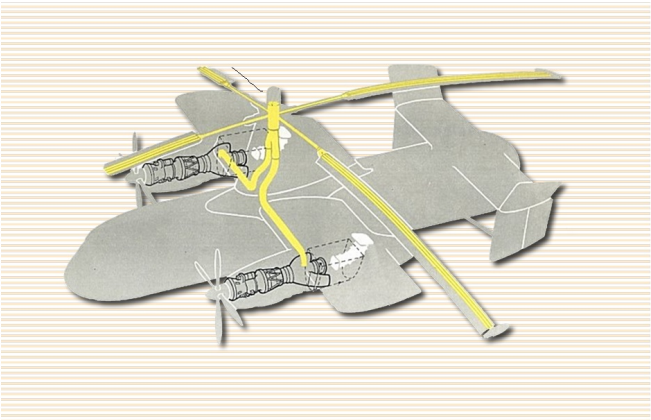
The Fairey Ultralight 1955

The Ultralight was a small rotorcraft intended to be used for military reconnaissance and casualty evacuation. Designed by Fairey it first flew in 1955 and demonstrated at airshows operating from a military flat-bed lorry. It had been conceived as a straightforward, low cost and easily transportable rotorcraft. It won acclaim for its simplicity and the versatility it offered for front-line support in reconnaissance and medivac roles. However, production funding from the UK military was not forthcoming, and more conventional and larger (still small – e.g.: Saunders Roe Skeeter) helicopters were preferred for service duties. Fairey continued to promote the concept and kept the type in development, but had to abandon the project in 1959.



An early (1950) Rotodyne concept: 20 seats; RR Dart powered

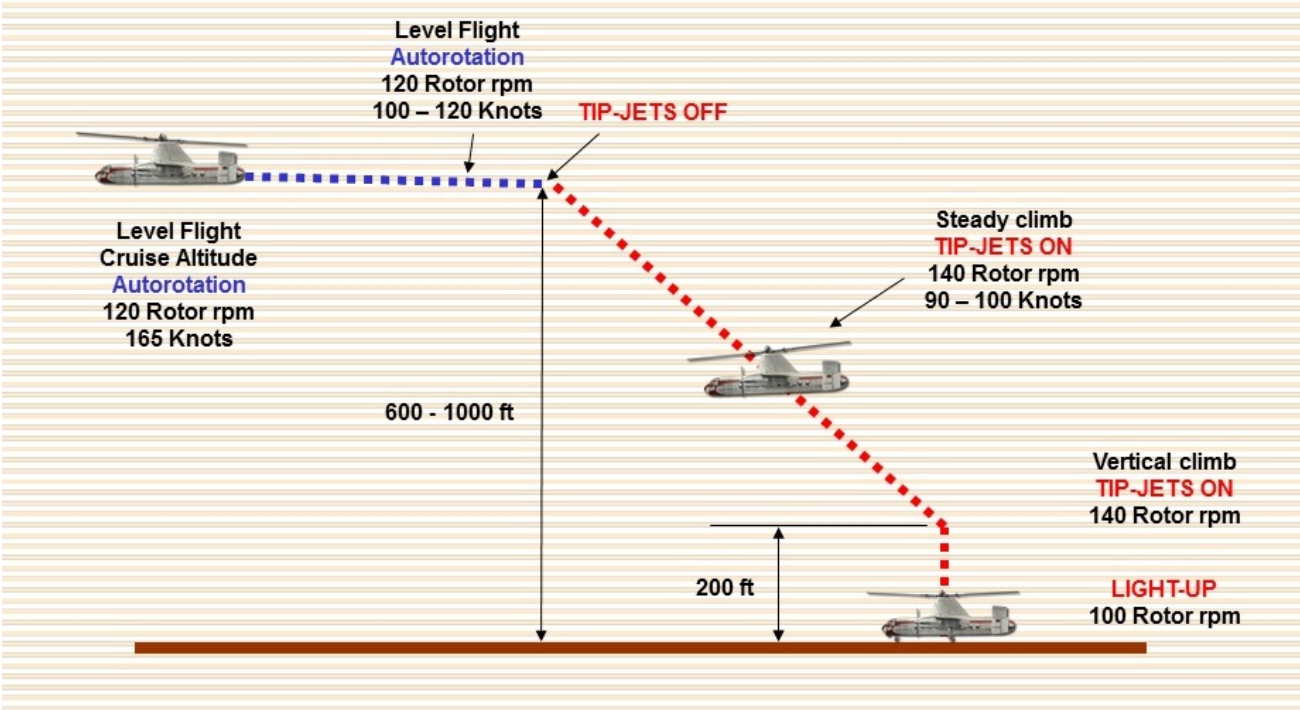
These were the precursors to the Rotodyne, which would be the largest aircraft to use a powered rotor, a term used to describe a system that would convey air to the rotor tip and creating a high pressure jet of air at the tip of each blade there. There was no longer the gyroscopic effect, that causes a conventional helicopter to want to spin with the rotor, and so it dispensed with the need for a tail rotor. The drawback is that it need a high mass flow of air/fuel mix to the rotor tip. On such a large aircraft as the Rotodyne a considerable mass flow was necessary, and the emergence of gas-turbine aero-engines were able to meet such a requirement. The design therefore had two turboprop engines, one underslung on a stub wing on either side of the aircraft. The wing was smaller than on a conventionally-powered aircraft and would provide lift force when the aircraft was cruising, and in cruise the rotor, although now unpowered, turned naturally and augmented wing lift.



Rotodyne power system

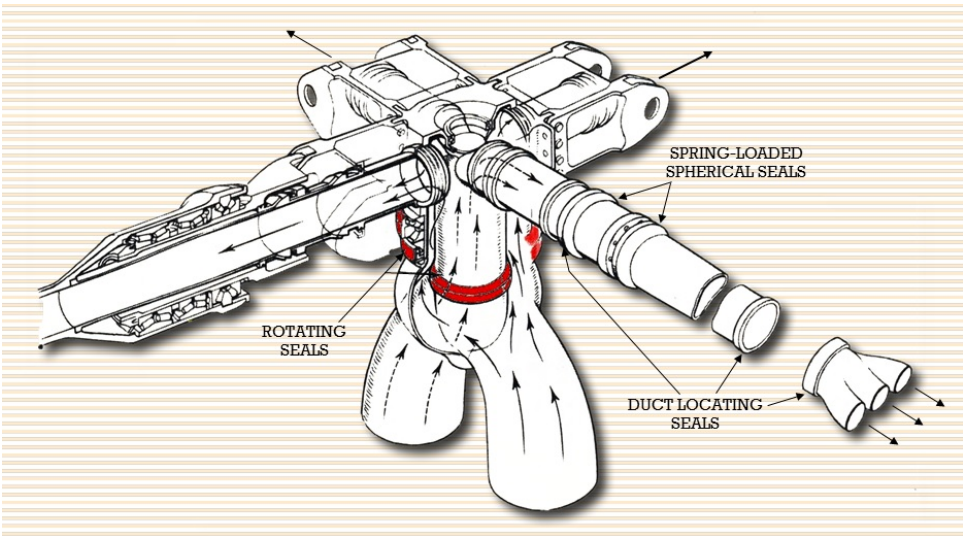
After a lengthy search for a suitable engine,

the Rotodyne was developed around two 2,800 shp Napier Eland N.El.7 turboprops. This engine could support a substantial air bleed from the compressor. The bleed flow from both engines was combined and an air-fuel mixture appropriate to the tip-jet needs was delivered to the rotor head through flight phases other than cruise. When cruising the aircraft was an autogyro and needed no air supply from the engines, it was only in low-speed flight regimes that it was a powered-rotor helicopter. The design of the systems involved was based on experience from trials with the Gyrodyne and Ultralight and full-scale rotor trials on specially created rigs. The rotor head did not



Rotodyne transition from hover and climb (helicopter mode) to cruise (autogyro mode)

have as much mechanical complexity of a conventional helicopter, but instead had to accommodate the sizeable piping that would deliver fuel and air through the hub, and along each rotor blade length to the 'tip-jet' at its extremity.



Rotodyne rotor head

This unique aircraft drew interest from several potential operators. In the USA a number of helicopter services were already underway, using helicopters to fly between city centres and airports, as this saved time and offer door-to-door services. In the UK, during 1951-52 British European Airways (BEA), no doubt aware of these developments, presented a requirement for a passenger-carrying rotorcraft to meet a

similar need. The Ministry of Supply proceeded to sponsor a series of design studies, and this was the chance that Stepan and his team at Fairey had wanted. They chose to submit the Rotodyne as a contender design, and set to be considered alongside conventional and dual-rotor helicopters.

Initially the project was based on a 30-seat aircraft using turboprop engines, and proposed using three Armstrong Siddeley Mamba engines. This changed to be a 40-seat design using Bristol engines, and subsequently the definitive design had two Napier Eland engines.

In April 1953, the Ministry of Supply contracted for the building of a single prototype of the Eland-powered variant for research purposes. It was to be the largest (40 to 50 passenger), fastest (150 mph cruise speed) rotorcraft – and it had the exceptional range of 250 n.m.

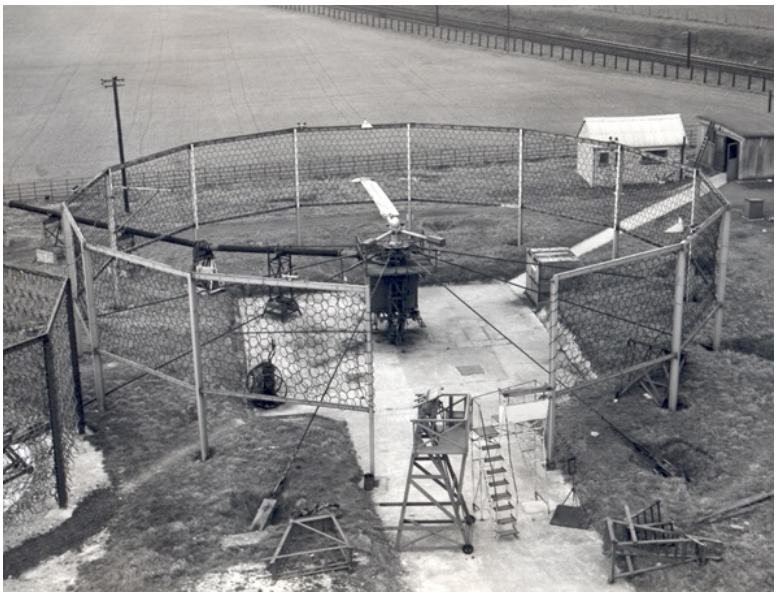
The major airframe components: fuselage, wings, and rotor assembly were manufactured in the Fairey factory at Hayes. These and tail components brought down from the company's Stockport factory, were assembled at White Waltham. Meanwhile, research facilities were built at White Waltham and a full-scale static test rig was assembled at RAF Boscombe Down, to test a fully operational rotor and powerplant arrangement. The most significant trial on the latter rig was the attainment of a 25-hour approval test before first flight.

Static test rig at Boscombe Down

The company's research investment set up a dynamics department associated to the test rigs to study rotor blade natural frequencies and mode shapes in conditions of flap, lag and torsion. There was also analysis of response to non-simultaneous light-up of tip-jets, and airframe response to rotor vibration. The investment in an Elliot 803 mainframe computer was mentioned, and highlights the considerable amount of modelling and trials analysis that was necessary.

The project was now proceeding towards its ultimate goal of presenting a fully flyable airframe, but in 1956 UK military interest was withdrawn. This left the project reliant on government support from civil budgets, achieved by reclassifying it as a research and civil prototype aircraft. Funding was resumed in December 1956, with support for both the Rotodyne and Eland engine until the end of September 1957. A requirement for any continuation beyond this period was subject to technical attainment, and a firm order from BEA. Meanwhile, Fairey and Napier (parent company was English Electric) were also required to take on portions of the costs of the all-civilian development programme.

By April 1957 the Boscombe Down rig was fully representative of the aircraft power system and controls, and was being used to test flight-acceptable components. In addition the airframe was instrumented with strain gauges, and engine/tip-jet system capabilities were being assessed. The rig was used too for pilot familiarization, assessment of rotor and power system endurance and maturity, the gathering of rotor blade stress data, and assessments of potential noise-reduction (silencer) system possibilities.



Single blade test rig at White Waltham

Research conducted at White Waltham on the single blade research facility assessed the large diameter rotor dynamic properties as it rotated at up to 140 rpm. Vibration in high speed cruise and in transition and hover modes were assessed, and high stress modes during high speed manoeuvres and in the rotor rundown phases. Rig data was used to devise vibration damping solutions in a flexible pylon (the structure atop the fuselage and below the rotor), and the use of blade lag dampers. Information from these trials also led to the rear fuselage being stiffened.

As all military interest had evaporated, a large proportion of the civil market was being eroded too. Commercial plans were being re-orientated towards larger and still mainly propeller aircraft designs. These remained runway-based and could offer more competitive operating costs that earlier aircraft types, and challenged the Rotodyne.

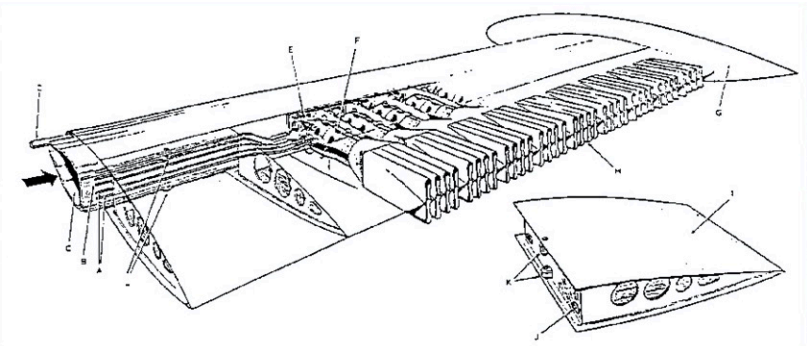
The presentation referred also to the announcement of a predicted cost for a continuing programme being double the original estimate, and cited technical uncertainty regarding resolution of noise and operating costs goals, suggesting that the project was facing more uncertainty. There was also little sign of interest amongst potential customers to invest in the development necessary to evolve essential operational infra-structure.

The late 50s were a time when UK defence strategies, and the programmes that the government would support changed drastically, not least with the example of Sir Duncan Sandys declaring (erroneously) that future military aircraft would be replaced with missiles. The Rotodyne was not involved, but affected. It was around this time that government informed aviation companies that they would be required to merge into new businesses. The Fairey helicopter division was given no option other than to merge with the helicopter divisions of Westland, Bristol and Saunders-Roe. They were to become the single production source of all rotorcraft, civil and military, and coalesced under the name Westland. The eventual merge of the companies did not take place until May 1960, and thereafter the aircraft flew at the Westland Rotodyne. It was a project that the speaker regarded as treated with respect, and the account we received was positive towards the cordial relationship that was built in the new team.

On 6 November 1957 the only Rotodyne ever completed conducted its first flight at White Waltham, piloted by W.R. Gellatly and J.G.P. Morton. It had a temporary fixed undercarriage that was strain gauged to measure if vibration and load levels were as expected, and soon after appropriate dampers were integrated in the definitive retractable landing gear. Initially only helicopter mode flights were conducted, but eventually the aircraft was able to do transitions and to fly in autogyro mode with the undercarriage units retracted. The first transition took place on 10 April 1958, and was performed at 4,000ft. Further trials were to continue until September 1961 when the single example completed its 434th flight.

Trials had included taking the aircraft to the Battersea Heiiport in London, where the flight trials team had monitored the aircraft's noise. The data they acquired on monitoring the noise was presented, and comparative noise measurements were included to emphasise that the noise levels – invariable quoted in many sources as unacceptable – were less than many other noises regularly experiences in city environments. In many respects this was heartening, but whether the technology would have evolved to reduce noise levels is something on which we can only posture, but there was evidence of considerable work on this, with a slide showing a 10-element tip-jet with attenuated exhausts. It was stated that rig trials suggested it could provide a 16dB noise reduction. It is notable that the noise values he quoted for transport, whether motor traffic or underground trains, have been attenuated considerably in the 50 or so years that have elapsed, but one has to admit that the team was addressing problems in a comparative and rational manner.

Fairey Rotodyne first flight: 6 November 1957



Design for10-element 'quiet' rotor-blade tip-jet

All potential commercial orders had now disappeared, and without government support the programme had to be declared finished. Our speaker was not to condemn this choice, unfortunate as it was, but the subsequent destruction of the prototype and the failure to preserve the essential data they had accumulated was classified as "UNFORGIVABLE!"

He conveyed a sense of lost opportunities as he presented a brief review of many related projects that have been developed – the compound wing and transition-capable aircraft that have integrated helicopter VTOL

Late flight of Rotodyne in Westland Aircraft markings

capability with a number of innovative autogyro and/or wing components to support aircraft in flight. The modern types achieve higher speeds and have the benefits of numerous new technologies. However, such things come at a price and development is still almost wholly within the military sector.

By 1963 August Stepan, the man who had been the driving force that led to the Rotodyne's predecessors and the grand programme itself, choose to return to Germany. This was an action presumably resulting from the cancellation of the Rotodyne project and the withdrawal of Fairey from the helicopter business. His work and the spirit he planted at White Waltham led to our speaker personally acknowledging his knowledge, strength and personality.

Most people present were undoubtedly amazed at the tenacity, humour and confidence that showed throughout the presentation by a man so challenged by personal circumstances that are unenviable. The session attracted some 150 attendees, and there was an understanding and heartfelt reflection on what had been a genuine and well-paced walk through reflection of a not-to-be-forgotten unique aircraft. Realistic in its balance of joy at attainment, and sorrow at the ease with which much learned is so often consigned to be left behind, spoke well of a feeling shared by almost all attendees.

Lecture notes by Mike Hirst