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ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT

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**SOME NOTES ON UNITED KINGDOM  
EXPERIENCE IN THE TESTING  
OF VTOL AIRCRAFT**

by

R. T. SHIELDS

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NORTH ATLANTIC TREATY ORGANISATION

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SOME NOTES ON UNITED KINGDOM EXPERIENCE IN THE  
TESTING OF VTOL AIRCRAFT

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R.T. Shields

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## SUMMARY

Experience to date in the flight testing of VTOL aircraft in the United Kingdom is reviewed. Methods employed in the testing of three aircraft, the Rolls-Royce 'Flying Bedstead', Short SC.1., and Hawker P 1127 are considered. Special ground facilities, in particular gantries and perforated platforms, evolved for the testing of these aircraft are briefly described and experience with them is discussed. Instrumentation methods which have been employed are briefly discussed and some special aspects of the flight programmes adopted are noted. It is generally concluded on the basis of this experience that, for the testing of a future similar type of aircraft, a perforated platform with ground tethering would be the primary additional facility needed and that data recording requirements are mainly similar to those for conventional aircraft.

## SOMMAIRE

Dans ce rapport on fait le point de l'expérience obtenue jusqu'ici au Royaume-Uni sur l'essai en vol des avions VTOL, et examine les méthodes employées pour les essais en vol des trois avions suivants: le 'Flying Bedstead' de Rolls Royce, le SC.1 de Short et le P.1127 de Hawker. Les installations au sol, en particulier les portiques et les plate-formes à perforations spécialement étudiées pour les essais à effectuer sur ces avions sont brièvement décrites, avec indication des résultats obtenus. L'auteur donne une description sommaire des méthodes d'instrumentation employées et traite de quelques aspects particuliers des programmes d'essais en vol adoptés. D'après les enseignements tirés de cette expérience, il arrive à la conclusion générale que les essais à réaliser sur tout avion futur de même type nécessiteraient, comme principale installation supplémentaire, une plate-forme à perforations attachée au sol, et que les conditions requises pour l'enregistrement de données sont essentiellement analogues à celles applicables aux avions classiques.

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## SOME NOTES ON UNITED KINGDOM EXPERIENCE IN THE TESTING OF VTOL AIRCRAFT

R.T. Shields\*

### 1. INTRODUCTION

Experience in the United Kingdom in the flight testing of vertical take-off machines (other than helicopters) extends back now over a number of years to the first operation of the Rolls-Royce 'Flying Bedstead'. The first true VTO aeroplane, the Short SC.1, first flew (conventionally in 1957) and commenced hovering trials in 1958. Last year the Hawker P 1127, the prototype of an operational V/STOL strike aircraft, commenced its flight trials. Much experience has thus been accumulated, particularly in the firms concerned, in the testing of jet-lift vertical take-off aircraft.

Some account is given here of the methods used in carrying out these trials to date, in particular noting any special equipments and techniques which have been employed.

A brief description of each aircraft and the scope of the test programme conducted to date is first given.

### 2. AIRCRAFT AND TEST PROGRAMMES

#### 2.1 Rolls-Royce 'Flying Bedstead'

This machine was evolved, following on earlier proposals of Dr. A.A. Griffith for a jet-lift VTO airliner, in order to demonstrate the principle of jet lift and investigate suitable control and stabilisation systems.

It was basically two Nene jet engines, mounted back to back in a framework, with the jets deflected through a right angle to exhaust downwards. Control and stabilisation about all three axes was provided by downward air jets on outriggers fed by engine bleed air.

The initial hovering trials of the machine were made in a gantry (see Section 3). After a satisfactory control system had been evolved and proved safely in the gantry, free flying was then demonstrated satisfactorily. Further development trials were carried on at the Royal Aircraft Establishment, first at Farnborough and later at Bedford.

The R.A.E. programme was mainly concerned with the development of the autostabilisation system which was applied to the control jets to give stability in pitch and roll. Part of this programme was to establish an appropriate autostabiliser 'equation'; a simulator programme would obviously have helped here, but no suitable machine was available at the time. The autostabiliser basically had two separate lines, to which a further reference line was later added. A fault-detection system was evolved to cut out auto-

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\*United Kingdom

matically a faulty line; this was done by a comparison of demand and output signals. The tolerance used in such a comparator system is important, since a normal system may exhibit temporary large errors in some transient motions and, particularly if automatic cut-off is used, the fault detection must be highly reliable. Part of the flight programme was devoted to the development of a satisfactory fault-detection system.

On this machine, as on the others considered here, control of vertical motion is directly by the engine throttle with no automatic assistance. Engine response on these large single-spool engines was low (time constant about one second) and height control, while learnable by most pilots, was a fairly exacting task. It was considered essential for any new pilot to be cleared on the machine in its gantry for the ability to control height satisfactorily before being allowed to fly free.

In order to obtain a quantitative assessment of the relative merits of the various control and autostabiliser conditions tested, a standard manoeuvre was adopted, the time to perform which, together with the variability of this time, was used as the criterion of controllability. This manoeuvre commenced with the machine hovering at 50 ft over a given spot on a given heading; it then had to turn through 90°, move forward 80 yd and descend to 3 ft to hover over another given spot. This technique was considered very useful in supplementing pilot opinion with a quantitative test.

## 2.2 Short SC.1

This followed as the next logical step to the Bedstead, a research aeroplane embodying the same jet-lift principle. It is a small (approximately 7,500 lb) single-seat delta-winged aircraft with 5 Rolls-Royce RB 108 jet engines, four mounted vertically (with some fore-and-aft tilt for acceleration/deceleration control) and one used for propulsion.

This aircraft first flew conventionally, without the lifting engines, in April 1957 and hovering in its gantry was commenced in May 1958. The first full transition was made in April 1960. It has normal ailerons, elevator, and rudder and is controlled, in hovering flight, by air jets directed downwards at the nose, tail and wing tips. These jets are supplied by air bled from the lifting engine compressors and are operated differentially through the autostabiliser.

Much of the early programme was naturally concerned with testing the aircraft in conventional wing-borne flight, covering control, stability and performance work. Satisfactory conventional take-off and landing characteristics are, of course, essential for a research aircraft of this kind, both in order to perform some of the earlier phases of the test programme and for the emergency case.

Gantry flying with the lifting engines installed was commenced with initially very restrictive additional tethering (allowing only 3 inches lift-off) to allow the pilot to check operation of all the controls and also undercarriage behaviour. Normal gantry flying was then proceeded to, in which techniques of take-off and the suitability of autostabiliser characteristics were established. Finally, free hovering was performed from the low platform (see Section 3.2.1). Concurrently, in another aircraft, testing was proceeding to develop satisfactory start and run-up characteristics of the lifting engines in wing-borne low speed flight (130-160 knots indicated airspeed); intake and exit configuration modifications resulted. The effects of lift-engine operation on longitudinal trim were also found to be greater than anticipated, although in line with more representative tunnel tests made at the same time.

The whole of the autostabiliser and hydraulic actuators are triplicated, each of the three lines being powerful enough to control the aircraft on its own. In this system a pilot warning is given if one line differs by more than a specified amount from the others; the aircraft must then be landed immediately as a further fault cannot be tolerated. The tolerance to be used on this fault-detection system had to be established by trials after satisfactory autostabiliser performance had been obtained in flight test.

A full transition was proceeded to after tests to extend the lifting-engine air speed operation range from each end. Thus speed was gradually increased from a vertical take-off up to over 80 knots, stability and control being checked at each stage; similarly from normal wing-borne flight, at some 5,000 ft altitude to provide a safety factor, speed was gradually reduced, using the lifting engines, to below 80 knots, again checking handling at each step. Following these trials, full transition was demonstrated straightforwardly.

### 2.3 Hawker P 1127

This aircraft was designed for an operational role as a V/STOL strike aircraft. It is a single-seat swept-wing machine powered by a single Bristol BE 53 lift/thrust engine providing a jet direction rotatable from forward of vertical to full astern. Conventional flying controls are provided and control in low speed flight is given by air jets at the nose, tail, and wing tips; a single-line autostabiliser with limited authority is provided in pitch and roll. A central wheel undercarriage with wind outriggers is used.

The first tethered hovering was done in October 1960, initially one foot of freedom being allowed, later increased to 4 feet, after which free hovering was satisfactorily demonstrated. Again in the initial tethered trials all controls of the machine had to be assessed, modifications made where necessary, mastered by the pilot, and a satisfactory take-off technique evolved before untethered hovering could be attempted.

Conventional flying will be next tested and the transition explored in a similar manner to the SC.1 programme - gradually increasing speed from the low speed end and gradually reducing speed from the high speed end at altitude until the full speed range has been explored. Satisfactory handling at all directions of the thrust vector has to be demonstrated, after which the actual transition should again be straightforward.

## 3. SPECIAL GROUND FACILITIES

### 3.1 Gantry

This device was first used for the initial operations of the Flying Bedstead and, following on this experience, one similar in construction and operation was built by Messrs Shorts for the SC.1.

The SC.1 gantry is basically a structure built on an operating platform 6 ft high, consisting of upright pillars, one each side, 70 ft apart, carrying a cross-girder 45 ft above the platform. A system of weights, pulleys, and cables is incorporated to limit the aircraft's freedom of motion. A drag cable is taken outwards from each

undercarriage leg to a pulley at each pillar base and a lifting cable passes round a pulley on the aircraft sling up to pulleys on the middle of the cross-girder. Each of the cables goes to a winch drum, on the ground at each side, whose speed is limited by a motor and ratchet system to allow a maximum rate of descent of 10 ft/sec. Tension weights are used to keep the cables taut.

The limits of permitted movement are determined by stops on the cables, to allow maximum freedom while preventing the aircraft striking the structure or falling off the platform. Permitted displacements are some 17-23 ft fore-and-aft, up to 17 ft laterally (both figures depending on aircraft height and reducing with it) and about 30 ft vertically.

The platform is some 50 ft square and is perforated to reduce ground and recirculation effects (see Section 3.2.1).

In operation therefore the gantry can allow the aircraft to move freely in a cube of some 30 ft in each dimension, the only restriction within this volume being in the limitation of vertical descent to a maximum of 10 ft/sec. Thus if, anywhere within this volume, the engine throttles are closed the aircraft will be returned at a safe speed and attitude to the platform. The aim is thus to allow as much freedom as possible for hovering trials while providing an emergency recovery in case control should be lost, from mechanical failure or any other reason.

A serious incident in fact occurred with the Flying Bedstead in its gantry when control was lost and it came sharply up against a cable stop with power still on and crashed. In such a case, if the thrust is not cut well before a tether limit is reached the tethering arrangement itself may increase the hazard. To minimise the chances of such an incident the aircraft should not be flown too near to the limits of its tether and the SC.1 in its gantry was not deliberately flown to more than about half the possible displacement, i.e. it was kept within a 15 ft cube. This still, of course, gives considerable freedom for testing control in hovering and, in particular, to safely master vertical control via the engine throttles.

There does not seem to be a corresponding incident that could be quoted where it was firmly established that the gantry had in fact saved the aircraft from an otherwise dangerous situation. Nevertheless, in the initial stages of the trials of the Flying Bedstead and the SC.1 there is no doubt that the gantry proved a valuable aid. When the control systems themselves and the piloting techniques required were both somewhat unknown, it provided a valuable safeguard whilst undoubtedly giving pilots confidence in performing potentially hazardous tests, particularly in the initial testing stages.

After the aircraft has been successfully flown free, the gantry has still served a useful role in new pilot-familiarisation flying. The important new control parameter the pilot must master with current jet VTO aircraft is height control via the engine throttles; this must be learned with the aircraft restrained in a safe way while allowing enough freedom in height to give a realistic response. It would be expected that height control via the lift engine throttles, being effectively an acceleration control, with some lag additionally, would prove a very difficult piloting task, particularly to hold constant height. This has been found to be so initially but it has also proved surprisingly learnable. This learning phase can be safely accomplished in the gantry.

While providing a necessary function for initial hovering trials, there are obviously limitations to how much can be achieved in the gantry. The vertical freedom is quite adequate for the hovering programme and much greater than can be achieved by other simpler methods of tethering. The lateral freedom, while still much greater than can be obtained with ground tethering, is still restrictive. The pilot must maintain a more accurate ground position than may otherwise be necessary to keep well within tether limitations. This can detract from the testing task by reducing the attention available to the prime test purpose, resulting in a piloting technique that is not fully representative. Another factor commented on in the SC.1 gantry is the pilot's inability to see the platform (which is 6 ft above the ground) from some hovering positions and so to judge properly his height and plan position above it.

### 3.2 Perforated Platform

Some sort of ventilated surface is required for at least the early trials on a new jet lift type, for pilot familiarisation, and for any protracted flying requiring very low hovering or slow lift off.

This is to suppress adverse effects arising from lifting jets near the ground which may otherwise result in:-

- (a) Overheating of the underside of the aircraft and undercarriage.
- (b) Ingestion of hot air (causing loss of thrust), and possibly debris, by the engine intakes.
- (c) Loss of lift and aerodynamic trim effects arising from flow induced on the underside of the aircraft; if these effects are significant near the ground, they could, apart from the necessity for greater thrust, adversely affect control during take-off and hovering since they will diminish rapidly with increase of height.

#### 3.2.1 SC.1 Platform

For the SC.1 gantry this function is performed by the gantry platform which is some 50 ft square and 6 ft high. It is supported on Bailey Bridge type girders, the surface being of panels of open steel flooring, as used on ships walkways and large machinery installations. Apart from its supporting girder structure and that of the gantry, the space under the platform is open at all sides, permitting ready dispersion of exhaust gases. This platform design has proved effective in suppressing ground effects.

For untethered operations of the SC.1 a low level platform is used. This has the same type of reticulated surface as the gantry platform but is only some 20 inches high and 35 ft by 42 ft; it can be broken into sections for transporting. The height of this platform is not sufficient to suppress the recirculation effects with the flooring completely open and it has been found necessary to cover up all but a central hole with steel sheeting. This configuration works quite efficiently in reducing ground and re-circulation effects with the aircraft over the central hole, and, for an operational type of take-off where the aircraft is lifted immediately at unstick to at least some 10 ft, this presents no real restriction. For very low hovering and slow lift-offs such as may be incurred for development or training purposes, insufficient latitude is allowed for possible lateral drift; such flying from the platform has therefore been kept to a minimum.

Although used for pilot familiarisation after gantry clearance, and for normal operation, it is considered small for these purposes and there is a proposal to increase the size to 54 x 55 ft. Some increase in the central hole size is a possibility, but further development work would be necessary to prove it; a bigger margin would, however, be provided for lateral drift when landing after a high hover.

### 3.2.2 P. 1127 Platform

For the initial operation of the P 1127 Hawkers have built a platform flush with the ground over a pit 5 ft deep. This is used for both tethered and free flight and thus takes the places of both the gantry and the low level platform for the SC.1. The total platform and pit area is 40 ft wide and 88 ft long; the first 48 ft of the length is used as the operating area and is covered with grille floor panels under which a series of cascade deflectors, running across the platform and one foot in depth, guide the exhaust gases to the other end of the pit where the last 20 ft of length is a ramp to guide the gases up through a similar grille flooring; the intermediate 20 ft of the platform length is covered with steel sheeting. To assist further in guiding the exhaust gases to the exit end of the pit, vertical steel sheets run the full length of the pit at 4 ft spacing. The platform is sited with its exit end at the downwind direction of the prevailing wind, though in operation its performance does not appear to be sensitive to wind direction.

For the initial trials the aircraft was tethered in the middle of the platform operating area, cables from the nose and wing tips being taken down through bronze fairleads in the platform to be attached to stanchions at the floor of the pit. Some 20 cast iron disc weights totalling 560 lb are threaded at the end of each cable and, with the cable slack, lie on the floor of the pit. As the aircraft rises and the cable slack is taken up these weights are successively picked up so gradually increasing the tension as the tether limit is approached and reducing shock loads. This device appears very effective and the pilot is not usually aware when cable slack has been taken up and has to be kept informed by a ground observer.

This type of tethering, to be an effective safeguard, can allow only very limited aircraft motion and maximum heights of about 4 ft are intended; the first hovering flights were made with only one foot tether allowance.

Fairlead positions are arranged in the platform to enable the aircraft to be positioned, according to the wind, up to 135° either side of the design direction, in 45° steps. The platform has still been found effective in ducting the exhaust gases away from the aircraft up to the maximum directional change provided. The only 45° point not provided for is thus with the aircraft positioned opposite to the design prevailing wind direction; thus little practical limitation appears to be involved in the uni-directional layout of the platform.

This type of tethering is clearly much more restrictive than a gantry and realistic free hovering could not be very adequately assessed with it. The pilot's task to keep within the tether limits is more difficult than hovering free; it must however be ensured that the aircraft is not on the tether limits, which the pilot is not readily able to judge. The state of the tether cables should be recorded in the aircraft to assist proper assessment of the aircraft records and this is proposed to be done by simple event markers operated when the cable slack is taken up.

The philosophy of the use of such a tether system is primarily that it enables the height control to be assessed and mastered while safely restrained. This is an essential before any free hovering is attempted and is the first element in both aircraft initial flying and new pilot familiarisation. It does also permit of sufficient assessment of the attitude controls and autostabilisation to check that they can be used safely. The aim therefore with a new aircraft would be, once the height control is sufficiently proved and mastered by the pilot, to ensure that low hovering can safely be controlled, that untethered flying be proceeded to as soon as possible for further and more comprehensive testing of the attitude controls and auto-stabilisation. Untethered, the aircraft can now be allowed freedom to drift anywhere on the platform prepared area; since it is flush with the ground the edge can be approached without fear of ill-effects from landing on or beyond it. If the aircraft does drift off the prepared area while very low, however, adverse ground effects would be established and it should be landed immediately. However since the pilot's ability to control the machine in a safe and acceptable landing is established further test work can proceed at heights beyond the ground effect with no restriction in positioning.

### 3.2.3 R.A.E. Bedford Platform

A similar flush platform is planned by R.A.E. for the operation of research VTO aircraft. This platform will be larger than the Hawker one - 100 ft long x 50 ft wide over an 8 ft deep pit, with a ramp at each end of the pit; this should ensure complete independence from wind effects. With this bi-directional design no deflectors will be used below the floor grille but the pit depth of 8 ft is considered sufficient to ensure the dispersion of exhaust gases, particularly in the light of experience with the gantry platform; longitudinal walls 2 ft high along the pit floor will limit sideways spread of the exhaust gases and guide them to the ends.

### 3.2.4 Engine Running Base

Some form of engine running facility will be a normal requirement for engine servicing whenever vertical lifting engines are used, whether in test aircraft or operationally. It is not therefore properly associated with the aircraft testing phase but will be needed then.

The take-off platform could be used for some engine checking but it is not really suitable for the protracted running which engine testing might entail; in any case a separate facility is desirable.

Typical of the sort of facility required is the pit at R.A.E. Bedford. This is basically a trench 10 ft deep, 5 ft wide and 30 ft long; all but a 4 ft length at each end is covered with concrete slabs. The aircraft is tethered with its lift engines over one of these holes. This pit was originally of concrete with steel re-inforcing at the corners, but before use it was lined with steel as a precaution against concrete erosion. Probably a better construction would be a complete welded steel liner.

On the SC.1 gantry an octagonal manhole in the middle of the platform may be opened for engine running. Shorts have also evolved, for use with the SC.1, a portable ducting assembly which can be positioned under the lifting engines to collect the exhaust gases and divert them outwards to each side. There is little working experience as yet with this.

For an aircraft with deflectable jets such a facility would not normally be needed, since most normal engine running could be done with the jets horizontal. In the test stages at least, however, some running will be necessary with the nozzles vertical, in particular in the proving of the nozzle deflection mechanism. Such running could probably be satisfactorily done on the take-off platform without the need for a special facility.

#### 4. TEST INSTRUMENTATION

The special problems associated with flight test instrumentation for V/STOL aircraft have been considered in the paper by Dr. Brüning ('Flight Test Instrumentation for V/STOL Aircraft', AGARD Report 317). Here it is simply proposed to give a brief account of practice so far in the United Kingdom.

Test data acquisition may be considered in the three categories of (i) internal recording, (ii) telemetry, (iii) external flight path recording.

##### 4.1 Internal Recording

This has in each case been conventional paper trace recorders of the SFIM type, supplemented by other methods in particular circumstances. There is some feeling, as for conventional aircraft, that, particularly to meet the data-handling requirements raised by the recording of a large number of parameters, magnetic tape would provide a more suitable medium and R.A.E. will probably use this in future SC.1 tests. Engine parameters have been recorded again following conventional practice, by a camera observer using dial instruments.

Aircraft data recorded have covered aircraft motion (angular rates, attitudes, accelerations, incidence, sideslip, speed and height) and control movements (including auto-stabiliser operation). For the most part the existing techniques, as already developed for conventional aircraft, have been used and found satisfactory.

One aspect on which some development has been carried out for the SC.1 has been pressure sources; at low speed, standard instrumentation may give serious errors in speed, height and rate of climb indication from pressure information. The need here is in the first place an operational one, since the pilot requires these quantities to be adequately displayed to him. For static pressures a spherical source, uniformly perforated, on the nose boom has been shown to be fairly insensitive to flow direction and feeds a vertical speed indicator. In order to register low air-speeds both forward and reverse, two venturi-pitots facing fore and aft are used to provide the differential pressure for the gauge.

##### 4.2 Telemetry

This has not so far been used in a VTO aircraft in any of the testing to date but there are plans to use it in future, for the SC.1 trials to be made by R.A.E. Bedford and P 1127 development flying.

In each case the telemetry system used will be the R.A.E. Radio Department AM/FM narrow band VHF system, as currently used in U.K. for the safety monitoring of spinning and other potentially hazardous trials.

In neither case is the system to be used for primary data acquisition or in any way to replace internal recording. The main function is seen as an accident recorder.

The Hawker system will use the standard 8-channel (frequency multiplexed) version and will cover such basic parameters as speed, height and control positions. The presentation at the receiver, sited at the edge of the airfield, will be dials and pen traces, with a magnetic tape record. The possibility of using the system as a test aid where appropriate is also in mind, for example in flight resonance testing.

The R.A.E. proposals are somewhat more ambitious and it is hoped to obtain an assessment of the general potentialities of telemetry in this sort of programme, as a safety monitor and as a test aid. Time multiplexing also is used in this system to provide about 30 parameters, 6 continuous and the remainder sampled. The data are recorded on 'quick-look' pens and magnetic tape at the receiver and in addition a portable panel carrying six dial indicators can be used near the VTO base and plugged to any of the parameters desired. An observer will then be able to watch both these instruments and the aircraft at close quarters and act as a safety monitor to warn the pilot of possible critical conditions - it is envisaged that information on such items as hydraulic and electric supplies, auto-stabiliser operation and engine temperatures would be the most useful to watch and various combinations of parameters will be tried.

#### 4.3 Flight Path Recording

No systematic attempts have yet been made at flight path recording but no special equipment requirements are seen to arise in the VTOL field.

The application of flight path recording in future work would seem to be from the following aspects:

- (a) Demonstration of overall performance in take-off and landing, against a given requirement.
- (b) Assessment of automatic landing systems (accurate flight path data required to obtain deviations in position and velocity).
- (c) Measurement of accurate speed (especially vertical) and height in the low air-speed region where pressure errors of the aircraft source may be undesirably high; it may be possible to calibrate aircraft pressure sources by this means and thereafter use internal recording.

The R.A.E. plan is to use kinetheodolites for this work, the main requirement being under (b), with high accuracy needed.

Hawkers will use a conventional take-off camera technique, probably the F 47 camera, mainly for (a).

## 5. GENERAL CONCLUSIONS

### 5.1 Hovering and Take-off Base

The gantry has served a very important role as a safety device in the early stages of jet lift trials when little was known of the standard of control required for hovering, and of the piloting difficulties which might arise.

In the light of this experience it seems to be now generally agreed that a gantry would not be necessary for the testing of a future VTO aircraft, particularly one following present lines of development; for larger aircraft than so far tested a gantry along similar lines in any case becomes increasingly impracticable.

A perforated platform is undoubtedly a necessity, at least for long term operation, and a flush platform over a pit, along the lines of the Hawker and R.A.E. designs, appears to provide the most versatile facility.

Since any tethering, even in a gantry, must restrict piloting freedom, the general aim should be to keep it simple and dispense with it as soon as possible.

Height control and undercarriage behaviour, which on jet lift aircraft are likely to present new problems, must be initially assessed and mastered by the pilot with the aircraft safely restrained. This can be achieved with simple ground tethering giving very little free movement, as the Hawker experience has shown. At the same time the attitude control and stability can be roughly assessed for safety with gradually increasing freedom. A realistic assessment can only be obtained, however, with the aircraft unrestrained, and untethered hovering on the platform should be proceeded to when the pilot has established confidence in his ability to control the machine safely.

### 5.2 Test Instrumentation

On the whole conventional instrumentation techniques have been applied satisfactorily and in particular current paper trace recorders and associated transducers have been used satisfactorily. Problems arising from difficulties of obtaining suitable static sources in very low speed conditions may have to be met by measuring speed and height by external means (probably photographic) when these are required accurately.

Most of the arguments for the application of telemetry in the testing of VTO aircraft would also be applicable to any high performance aircraft. Since, during much of the testing of VTOL aircraft, the aircraft itself can be clearly seen by a ground observer monitoring the telemetered information, the safety value of telemetry may well be enhanced. A case might also arise if a large enough number of parameters were required to be recorded, when this might be done with less internal weight and space by telemetry than with internal recorders (the VTO aircraft is likely to be more sensitive to weight variation). This has not been a significant argument to date and, in fact, where telemetry is proposed it is in addition to internal recording, to serve as accident recorder, safety monitor, and test aid. The R.A.E. programme with the SC.1 may bring out other useful aspects of its use.

### 5.3 Test Programme

A test programme for initial proving trials obviously depends on many factors, apart from various design aspects. Some common features which would appear to arise from the experience discussed here may be noted.

Initial hovering work, from a suitable platform, as already discussed requires first the assessment, while tethered, of the vertical control, then of the attitude controls and stability.

Hovering trials may be extensive to achieve a satisfactory standard of control and stability. If the auto-stabiliser is multiplexed, with each line having high authority, the fault-detection system is important. Since, if a fault is indicated (particularly with a triplex system) the aircraft must be landed immediately, the error criterion used is important and may require some flight work to establish; reliable fault indication is necessary for efficient as well as safe testing. If a limited authority single-line auto-stabiliser is used it will be essential to demonstrate at an early stage that control can be satisfactorily maintained for an emergency landing with one auto-stabiliser channel (i.e. pitch or roll) failed.

The use of a standard manoeuvre, such as has been described for the Flying Bedstead trials, is a useful means of obtaining quantitative comparisons of the controllability provided with a range of control and auto-stabiliser settings. Such a method is very desirable, rather than relying solely on pilot qualitative assessment.

Satisfactory hovering characteristics having been established, handling is now investigated with forward speed increased in stages at low altitude.

For an aircraft able to take off conventionally, as the types discussed here, the upper end of the transition speed range is also explored, at a safe altitude, by reducing speed in stages until these speed ranges overlap. This flying, of course, is preceded by proving of the conventional flight characteristics and, for an aircraft with separate lifting engines, by engine starting tests in low speed wing-borne flight.

After these tests a complete transition can then be demonstrated and representative VTOL flying then proceeded to.

If the lift engines used are of a new type, engine development is likely to be an important factor in programme timing since the exacting engine conditions for hovering - high thrust and compressor bleed - will be associated initially with a short engine life compared with corresponding propulsive engine applications.

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| <p>AGARD Report 318<br/>North Atlantic Treaty Organization, Advisory Group<br/>for Aeronautical Research and Development<br/>SOME NOTES ON UNITED KINGDOM EXPERIENCE IN THE<br/>TESTING OF VTOL AIRCRAFT<br/>R.T. Shields<br/>1961<br/>11 pages</p> <p>Experience to date in the flight testing of VTOL aircraft in the United Kingdom is reviewed. Methods employed in the testing of three aircraft, the Rolls-Royce 'Flying Bedstead', Short SC.1., and Hawker P.1127 are considered. Special ground facilities, in particular gantries and perforated platforms evolved for the testing of these aircraft</p> <p>P.T.O.</p> | <p>533.652.6:533.6.05</p> <p>3c6d</p> | <p>AGARD Report 318<br/>North Atlantic Treaty Organization, Advisory Group<br/>for Aeronautical Research and Development<br/>SOME NOTES ON UNITED KINGDOM EXPERIENCE IN THE<br/>TESTING OF VTOL AIRCRAFT<br/>R.T. Shields<br/>1961<br/>11 pages</p> <p>Experience to date in the flight testing of VTOL aircraft in the United Kingdom is reviewed. Methods employed in the testing of three aircraft, the Rolls-Royce 'Flying Bedstead', Short SC.1., and Hawker P.1127 are considered. Special ground facilities, in particular gantries and perforated platforms evolved for the testing of these aircraft</p> <p>P.T.O.</p> | <p>533.652.6:533.6.05</p> <p>3c6d</p> |
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