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DESIGN AND TESTING OF A LARGE SCALE HELICOPTER FUSELAGE MODEL IN THE R.A.E. 5 METRE PRESSURISED WIND TUNNEL

BY

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ABSTRACT

1. Background

With the advent of higher helicopter forward speeds and the ever mounting consumer demands for high performance, the parasitic drag and other aerodynamic characteristics of the airframe are assuming substantially increased importance.

The use of small models in atmospheric wind tunnels with consequent low Reynolds numbers is still the main tool for the achievement of aerodynamic targets although scale effect is still not generally well understood in bluff body aerodynamics. A need, therefore, is identified for high Reynolds number data for fuselage/rotor head combinations. The paper describes the work proceeding at Westland Helicopters Limited designed to meet this requirement.

2. Summary of Logic

The nature of the airflow over any body is dependent on the non dimensional parameter, Reynolds number, which governs the boundary layer growth rate and it's ultimate separation from the body surface.

The need for high Reynolds number testing is already well established in fixed wing aircraft design and the RAE 5 metre tunnel has already been used extensively for Hawk and Airbus.

The aim of this project is to study the influence of Reynolds number (and to a lesser extent, Mach number), on a number of important parameters associated particularly with helicopter airframe aerodynamics and to simultaneously improve the data resolution by an order of magnitude.

3. Scope

The paper describes the philosophy involved in planning for design, manufacture and initial testing of the first helicopter airframe model in the RAE pressurised high Reynolds number wind tunnel.

Extensive model testing at low Reynolds number in conventional wind tunnels and theoretical calculations have been necessary to provide the information required to design the large model and this work is detailed in the paper.

To avoid costly repetition of basic test equipment a common-to-all-models, all purpose, box rig containing the requisite structural integrity to carry the fuselage on a variety of model struts is described. Equipment is included to rotate the head and to simultaneously measure the forces and moments whilst provision also exists for the mounting of a number of scanivalves for surface and off body pressure measurements and for the simulation of engine intake/exhaust flows.

Preliminary data from the first model test is included in the paper and the observed effects of Reynolds number discussed.

1. INTRODUCTION

Aerodynamic development of the helicopter is at a relatively early stage compared with its fixed wing counterpart and, until recently, the bulk of research and development has been concentrated on structural, dynamic and mechanical problems.

The aerodynamic design of rotors, however, has been receiving attention in recent years in the development of new blade sections and specially shaped tips to improve performances, but this has not been matched by similar efforts on airframe aerodynamic design.

As helicopter speeds increase airframe parasitic drag becomes the dominant factor in aircraft power required and ultimately as fuel costs escalate, drag will undoubtedly become a very important factor in direct operating costs. Furthermore, helicopter airframe drag is several times higher than the equivalent weight, fixed wing design, so there is considerable scope for improvement.

The rotor head, which usually has a high frontal area and a non aerodynamic profile is normally the major drag producing component.

Apart from the basic head drag, there are two other influencing factors, (discussed in detail in Ref. 1) these are:

(a) The head is situated in a high supervelocity area necessitated by the requirement for the engine gearbox and payload to be mounted as closely as possible below the rotor centre for stability reasons.

(b) There is an interference effect due to the head causing an increase in the fuselage drag. This effect may or may not be exacerbated by rotation of the head depending on the design.

The fuselage and engine/gearbox cowls can also produce significant parasite drag levels if little thought is given to aerodynamics.

Hence, at Westland Helicopters, an intensive effort is underway to study and optimise fuselage, cowl and rotor head drag.

2. PHILOSOPHY OF RESEARCH PROGRAMME

Initially the research activity was confined to testing in a small atmospheric wind tunnel with Reynolds numbers an order lower than full scale.

The aerodynamic effect of fuselage fineness ratio, afterbody and forebody shapes was first examined, followed by a study of several practicable engine/gearbox cowling shapes of both two and three engine configurations.

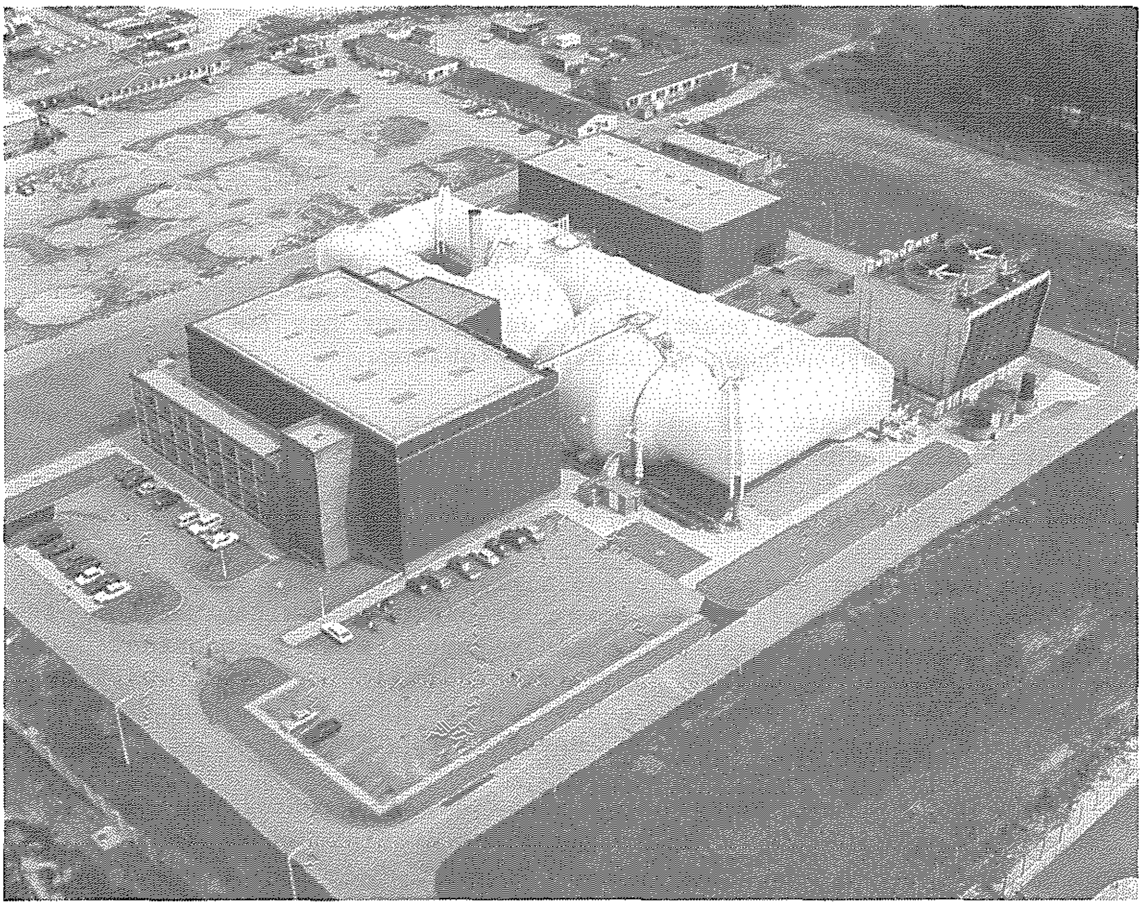

FIG. 1 THE RAE 5 METRE WIND TUNNEL

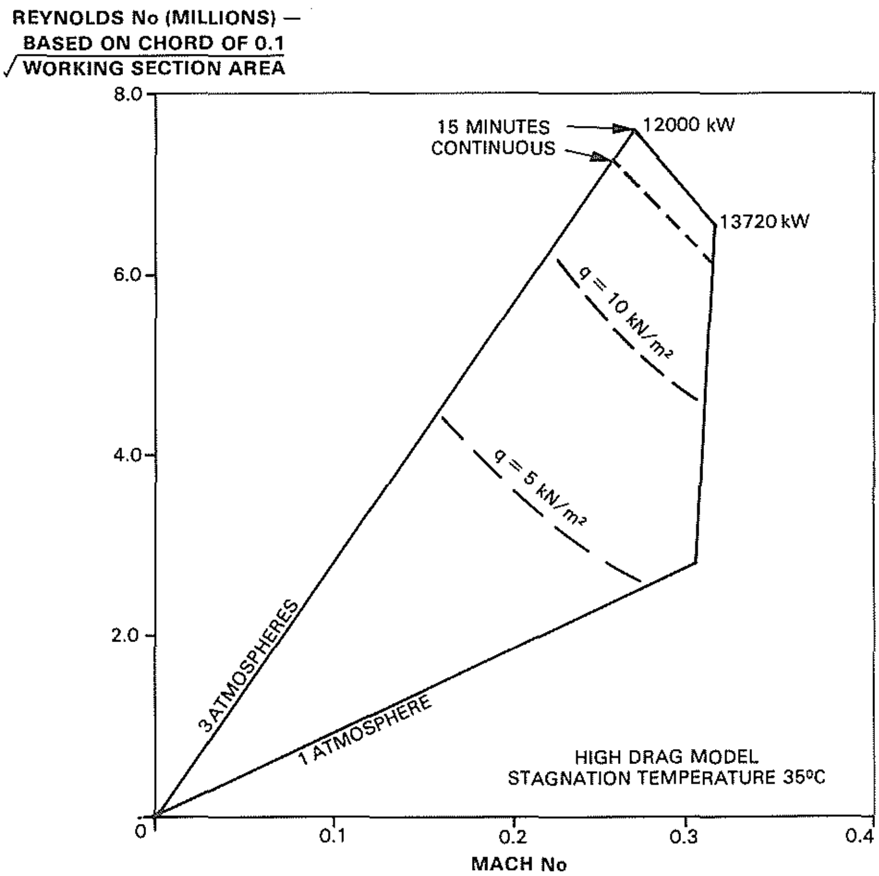

FIG. 2 REYNOLDS NUMBER VS VELOCITY (TUNNEL OPERATING ENVELOPE)

Also, tests with and without an advanced design of rotor head were made to assess the performance of each cowl design in the presence of a rotor head.

From these studies, the optimum fuselage/cowl/rotor head configuration was chosen for tests in the RAE 5 metre wind tunnel (Ref. 2 & Fig. 1) to further develop optimum body aerodynamics at Reynolds numbers near full scale. (Fig. 2).

However, it was realised at this stage, that the difficulty and expense of model modifications or the building of new models, (which would undoubtedly be required in the future), would be prohibitive. Therefore a decision was taken to build, as a basis for the first and all future models, a helicopter test rig incorporating all conceivable test equipment combined with the facility for mounting the model components and wind tunnel support struts.

3. HELICOPTER TEST RIG

The requirements for the rig were defined as follows:

(a) To provide mounting points for a number of support struts and a sting.

(b) To allow various fuselage and cowl shapes to be attached.

(c) To provide a power source for rotor head rotation.

(d) To provide a means to measure rotor head forces and moments with particular emphasis on drag and torque.

(e) To allow the passage of an air supply enabling representation of engine exhaust flow to be made.

Initially the feasibility was examined of producing such a rig to match the appropriately scaled requirements of a variety of helicopter designs.

Two typical aircraft were considered, these being sufficiently representative of Westland fuselage designs to ensure that the majority of future fuselage shapes could be accommodated around the one test rig. (See Fig. 3).

The major limitation was that the maximum length of any model should not exceed 5 metres, meaning that fuselage widths and heights would be dictated by the appropriate scale.

Provision was also made for the measurement of about 300 surface pressure measurements, meaning that 6 scanivalve and associated control equipment would need to be accommodated.

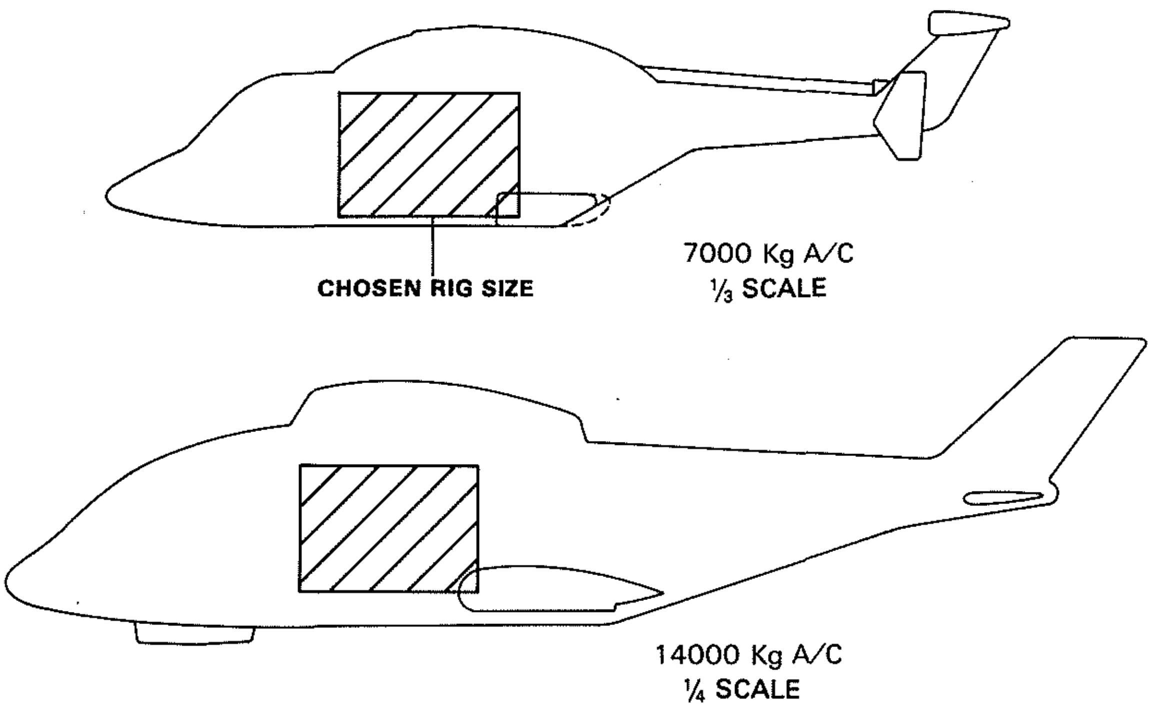

FIG. 3 TEST RIG SIZING

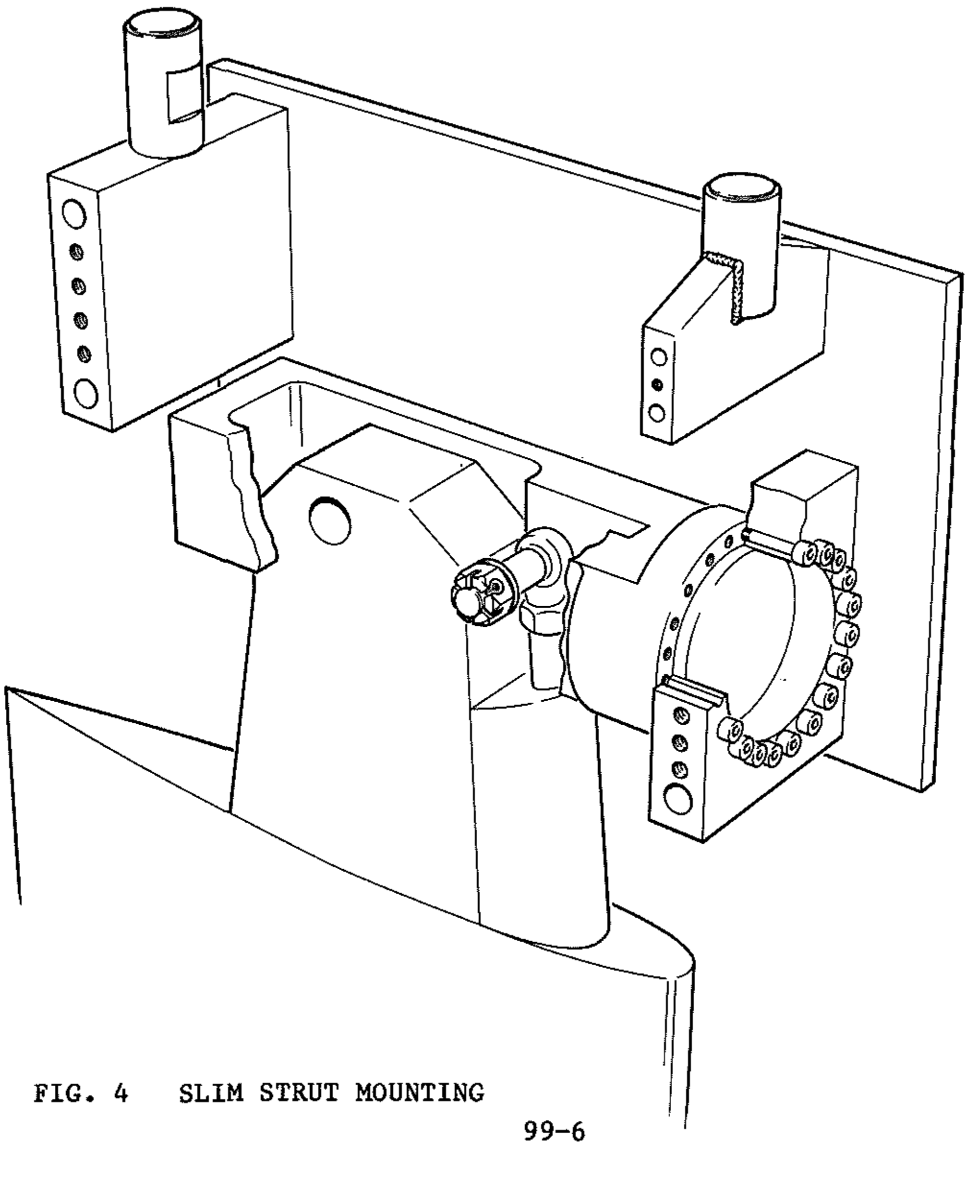

FIG. 4 SLIM STRUT MOUNTING

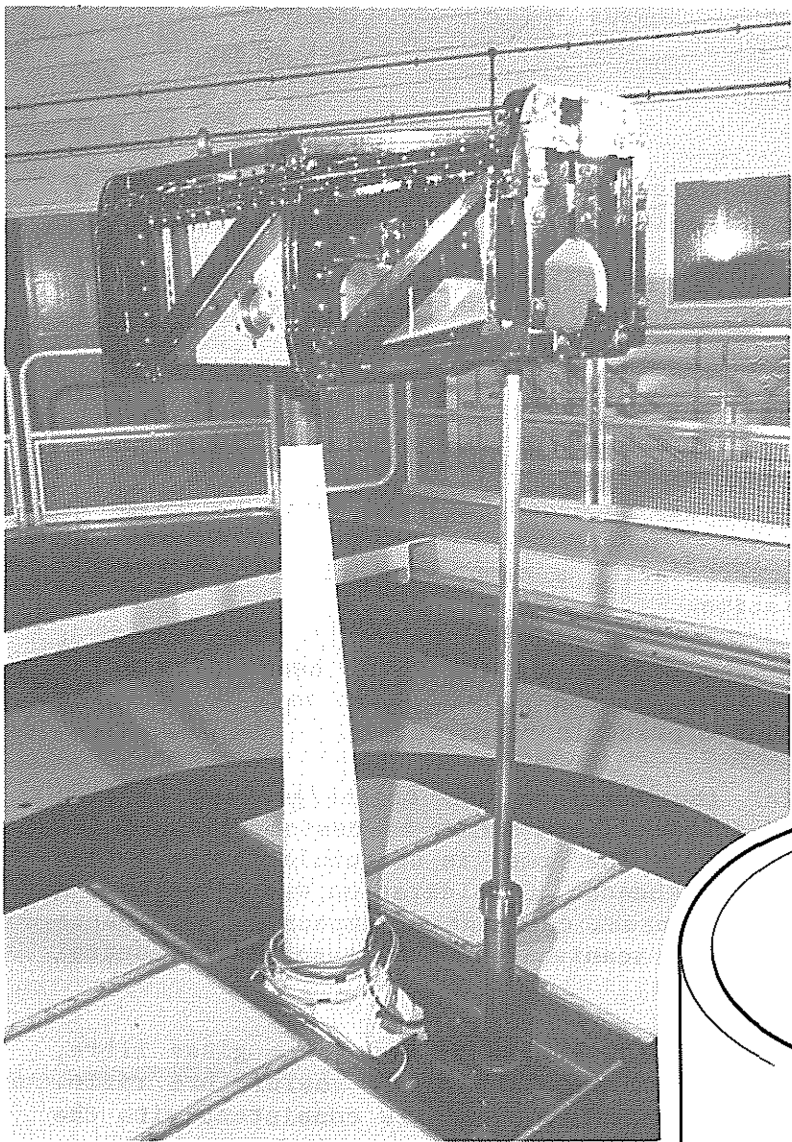

FIG. 6 RIG WITH SPACE FRAME
(ON ROUND STRUT)

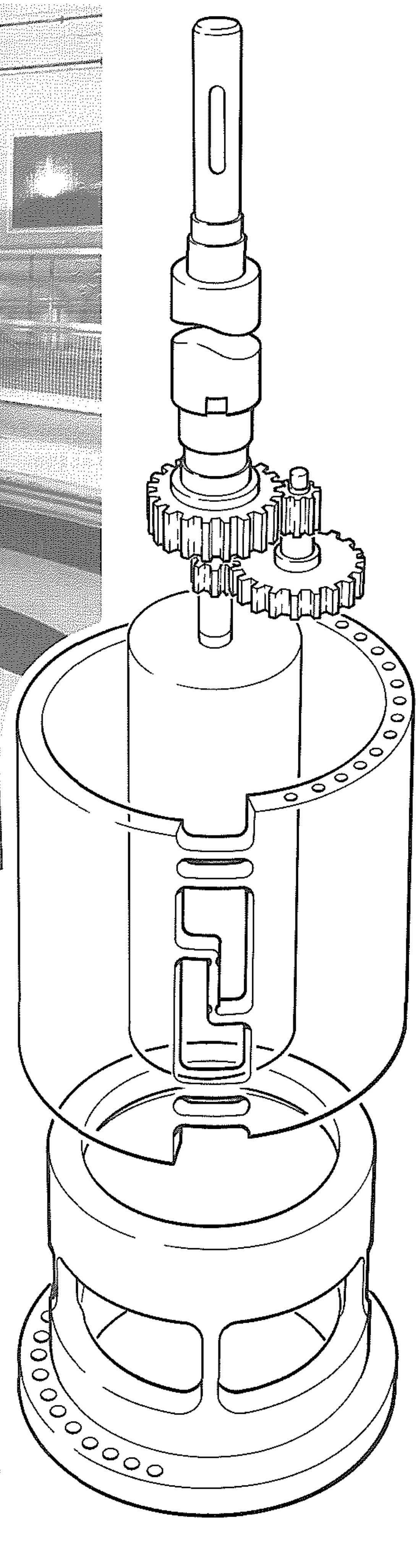

FIG. 5 DRIVE MOTOR, GEARBOX AND BALANCE

From the preceeding specifications, the rig took the form of two vertical plates, allowing the fixing of four model supports viz:

(a) A slim 'aerodynamic' strut (incorporating an incidence control mechanism) for longitudinal measurements (See Fig. 4).

(b) A round strut for directional measurements and also for surface pressure work.

(c) A strain gauged sting mainly intended for tare measurements.

(d) A 'blowing' strut incorporating a compressed air supply for engine exhaust simulation.

Also mounted between the plates are the rotor head drive motor and strain gauged balance (Fig. 5) and provision is made for ducting to be installed when exhaust blowing is required.

The main support for the fuselage and engine/gearbox cowling components is supplied by a space frame which is custom designed for each helicopter model. (Fig. 6). The frame is of tubular steel welded construction with aluminium bulkheads. Consideration was given in the frame design process to the eventual carriage of empennage components and also to the storage of scanivalves and associated control equipment.

The body components are hollow shells of 6mm thick glass fibre, having a 45° warp and weft weave and with a low resin/fibre ratio. The result produces an ultimate strength which is consistent with the aluminium bulkheads to which the components are attached.

The shells are produced from female moulds which, in turn, are formed around male plugs of the required shapes.

This method has several advantages:

(a) A smooth accurate surface finish is obtained.

(b) A rapid and easy installation can be achieved and

(c) the simple introduction of surface pressure tappings from the inside surface is possible.

4. LOW REYNOLDS NUMBER TESTING

A considerable amount of testing has now been completed on small scale models (approximately one-sixth scale full size) at low speeds (about 30 metres/sec) in atmospheric wind tunnels.

The preliminary tests were designed to investigate the effect of body fineness ratio, various practicable nose shapes and the influence of rear body taper rate and upsweep.

The second phase of testing was then concerned with the optimisation of engine gearbox cowl shape and its level of compatibility with the rotor head. Several practicable possibilities have been examined at low Reynolds number.

From the test data, the optimum configuration was chosen for testing in the 5 metre wind tunnel over a range of Reynolds numbers. Surface pressure measurements were made on the small model to provide the essential incremental loading information and overall model forces and moments data was used to verify the integrity of the complete model on the various strut mountings. With tunnel speeds of up to about 100 metres/sec and static pressures up to 3 times atmospheric, the model loads become far more important than for normal low speed atmospheric testing and the structural integrity of both model and mounting must be proven by a recognised authority.

5. THE MODEL

As described in Section 3 the model is constructed from fibre glass shells mounted on a load carrying space frame. With regard to the external body shape, this was dictated by a requirement to *optimise (particuarly for drag) the airframe/rotor head configuration* of a twin engined helicopter of approximately 8000 kg. The small scale model test data, of course, was used to make the appropriate choices.

For sizing purposes, it was assumed that the RTM 322 engine (of similar size to the T700) would power such an aircraft and that the main gearbox size would be no greater than that of the W30 (the latter to be achieved using advanced design features currently under development). A side intake design was assumed as a basic requirement.

An advanced technology flexing semi-rigid, 5 bladed rotor head was decided for the first test. In this initial work the head was fixed, but for future tests, the head will rotate giving a better representation of the flow over the cowl and also providing the opportunity to measure the rotor head force and moment data over the complete Reynolds number range. (See Fig. 7).

6. TEST DATA

For the aircraft under consideration the model scale was defined as 5/16. Therefore at a maximum tunnel speed of 300 ft/sec and at 3 atmospheres pressure, full scale Reynolds number was achieved up to an equivalent full scale speed of 166 kts.

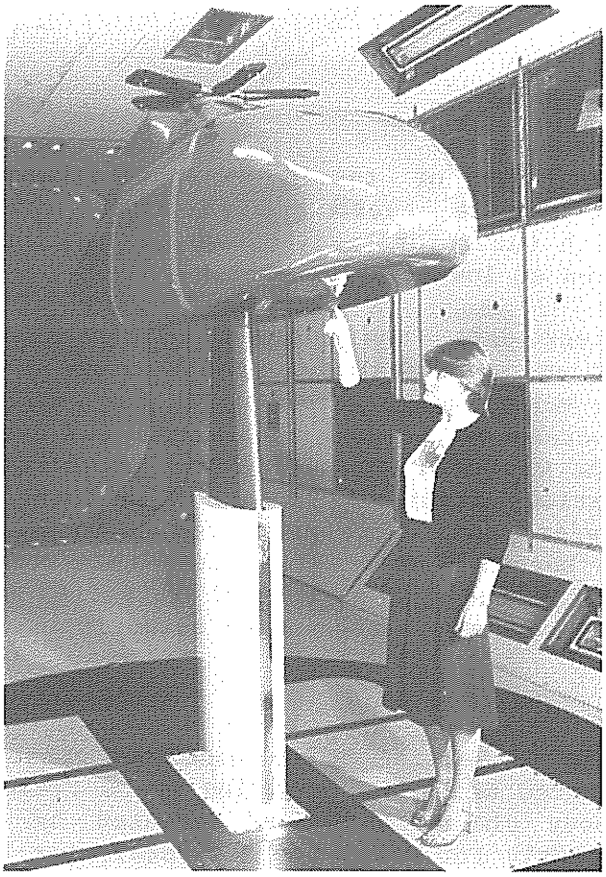

FIG. 7 Model on Slim Strut

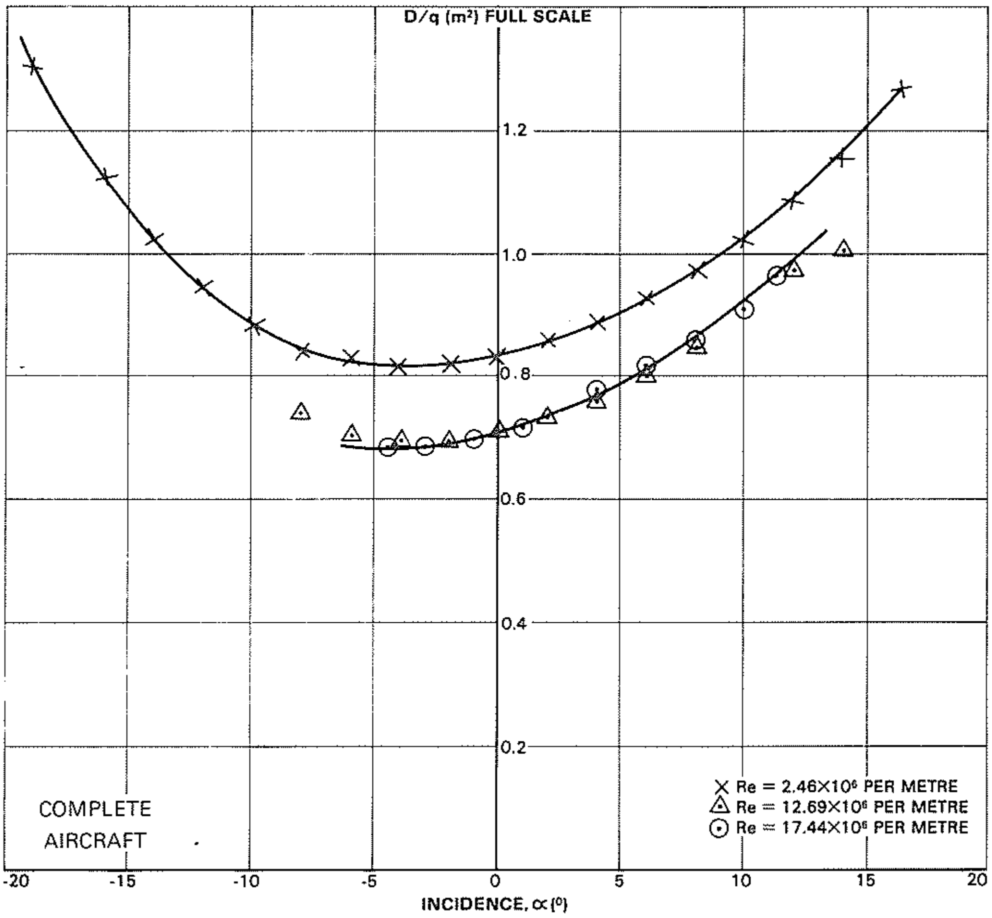

FIG. 8 DRAG VS FUSELAGE INCIDENCE
(BLADE INCIDENCE = 15°)

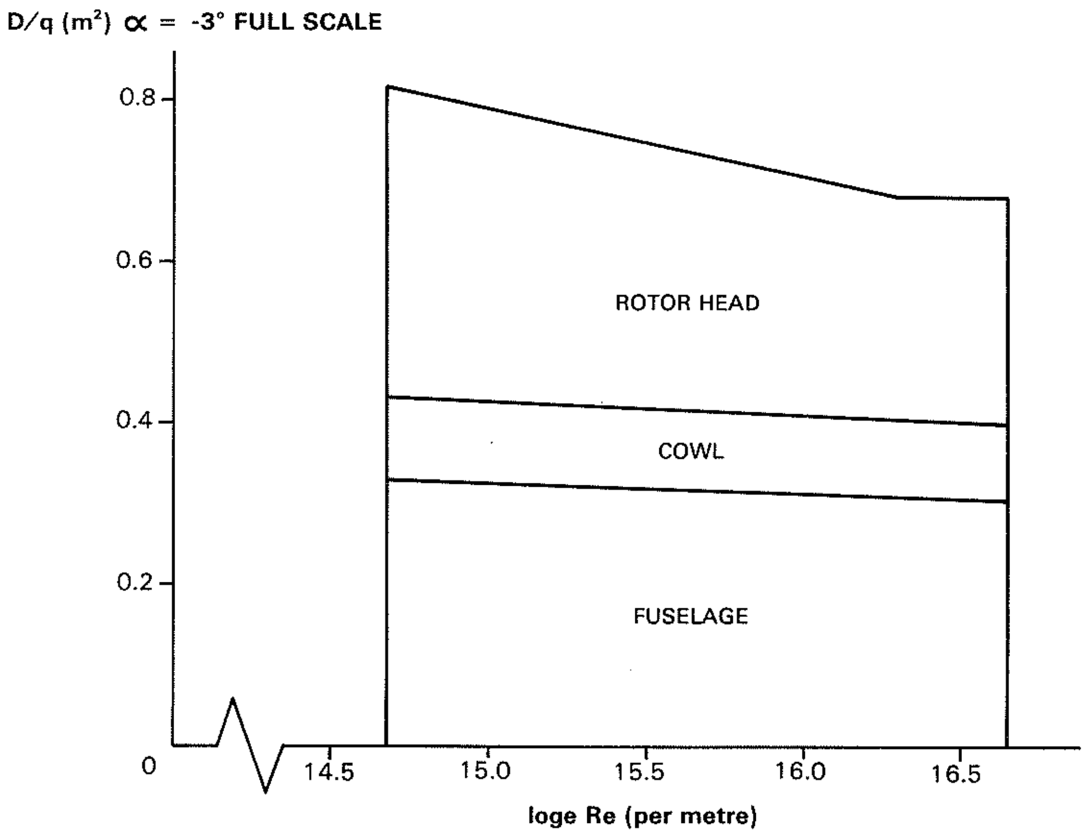

FIG. 9 DRAG VS. log Re (FUSELAGE INCIDENCE -3°)

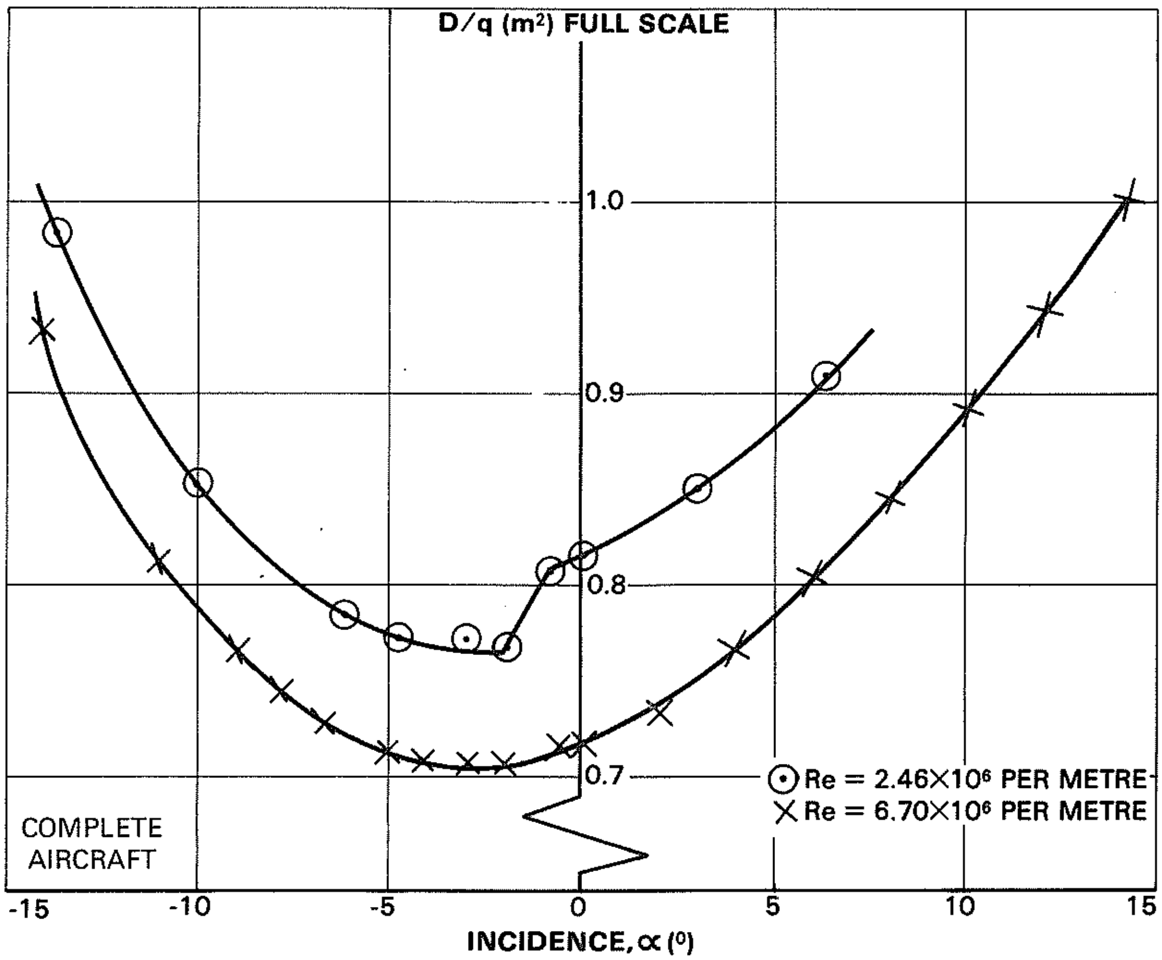

FIG. 10 CRITICAL DRAG EFFECT

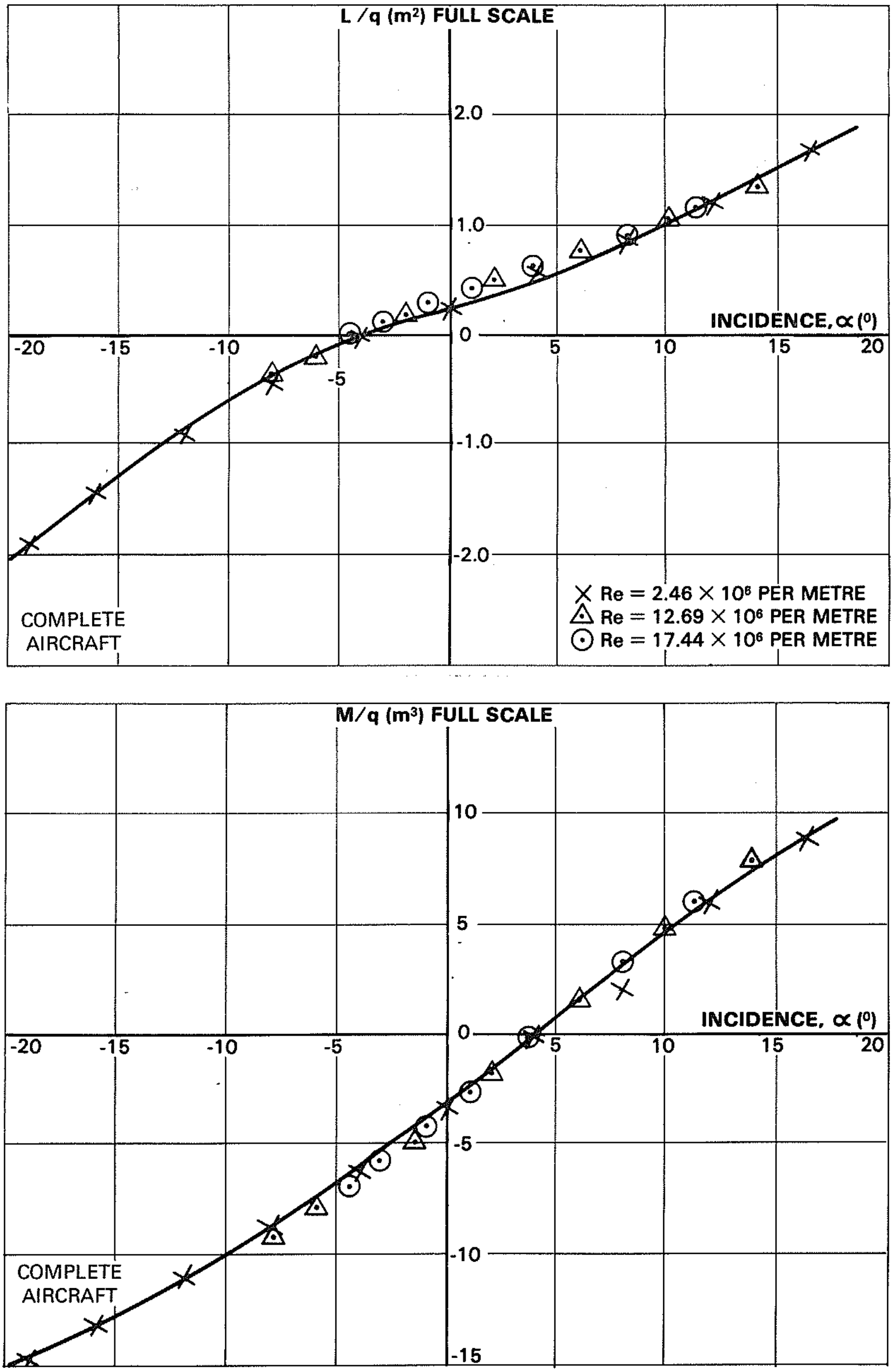

FIG. 11 FUSELAGE LIFT AND PITCHING MOMENT VS FUSELAGE INCIDENCE

6.1 Drag - Figs. 8 and 9

For the fuselage only, the reduction in drag from the minimum test Reynolds number up to full scale is roughly consistent with standard skin friction theory. The same appears to be true when cowl drag is added. However the rotor head drag shows a large reduction in drag due to Reynolds number, far greater than that due to skin friction. This may be due to a change in interference drag and will be investigated fully in the second test series (scheduled for early 1985) when the head will also be rotating.

Another interesting phenomen found in these original tests was the presence of critical flow conditions at the lowest possible test Reynolds number (2.5×10^6 per metre) leading to large sudden increases in drag (particularly with a head blade angle of 10°) at certain fuselage attitude settings. These critical conditions were confirmed by check testing but were not present when the Reynolds number was increased to 6.4×10^6 or greater (Fig. 10).

Most current helicopter model testing is carried out at Reynolds numbers less than the minimum quoted above, so this phenomenon could be present in many cases. Again there could be changes in the above observation when the head is rotating so this effect also will be investigated in the next test series.

6.2 Lift and Pitching Moment

As may have been expected these characteristics were not greatly influenced by Reynolds number variation. (See Fig. 11). However when a tailplane is added in future testing, there should be some effect.

6.3 Future work

As mentioned previously, the next phase (January 1985) will feature rotor head rotational effects and there will be a preliminary investigation into the effect of sponsons and empennage characteristics.

7. FLOW VISUALISATION

Some limited flow visualisation work was carried out using wool tufts. The static rotor head was in position for all the tests.

Very little flow disturbance was observed over a large incidence range even on the cowl to the rear of the rotor head. See Fig. 12. This situation may, of course, change when the head is rotating.

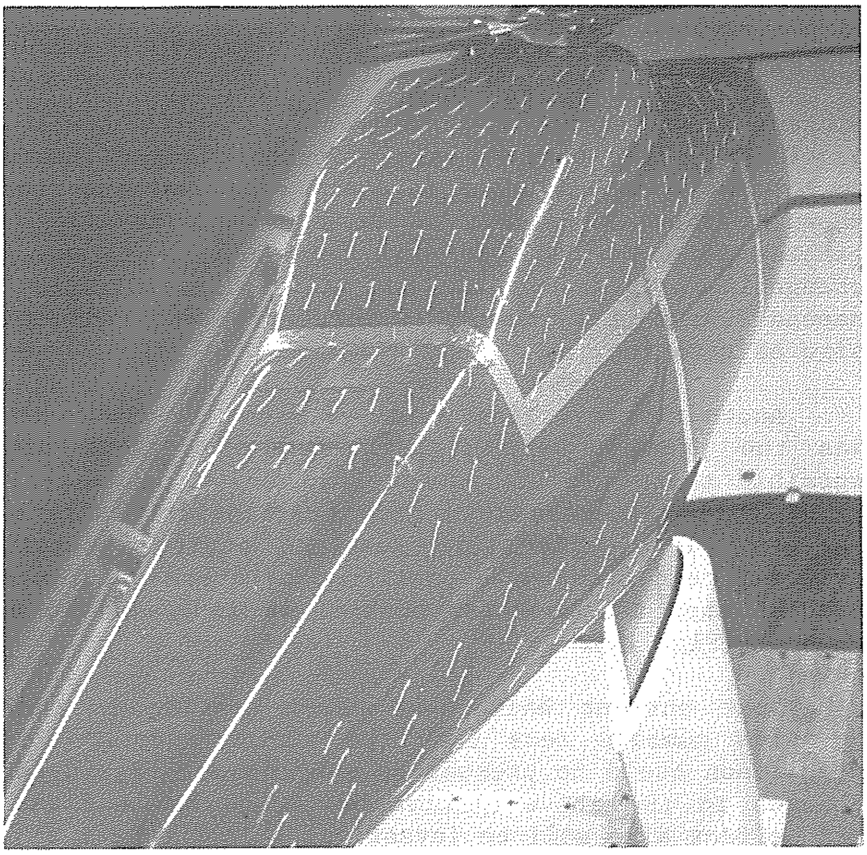

FIG. 12 COWL FLOW VISUALISATION

8. CONCLUSIONS

8.1 A requirement for high Reynolds number testing on helicopter fuselages and rotor heads has been identified to optimise aerodynamic design and minimise drag for future helicopter designs.

8.2 A versatile, helicopter-airframe-test rig, suitable for a variety of fuselage designs, has been designed and constructed.

8.3 The first airframe shape has been fitted to the rig and successfully tested in the RAE 5 metre wind tunnel.

8.4 No unexpected Reynolds number effects on fuselage/cowl longitudinal characteristics were noted, but large changes in rotor head drag, with Reynolds number and some 'critical' drag changes were observed.

9. REFERENCES

1. J Seddon, An Analysis of Helicopter Rotorhead Drag based on New Experiment. Paper presented at the Fifth Rotorcraft Forum 1979.

2. The RAE 5 Metre Pressured Low Speed Wind Tunnel, HMSO, July 1976.

10. ACKNOWLEDGEMENTS

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