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Grabe, W. H. K.

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PREPARED BY W.H.K.G.

CHECKED BY E.P.C.

NATIONAL RESEARCH COUNCIL

DIVISION OF MECHANICAL ENGINEERING

OTTAWA, CANADA

LABORATORY MEMORANDUM

SECTION Engine Laboratory

NO. NRC-ENG-31

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DATE March 1962

SECURITY CLASSIFICATION Open

SUBJECT VTOL Downwash Flow Study Simulating Cells No. 4 and No. 5 of the Engine Laboratory

PREPARED BY W.H.K. Grabe

ISSUED TO

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SUMMARY

A flow study was undertaken as to whether Cells No. 4 or No. 5 of the Engine Laboratory would be suitable for ground effect work. The use of a 3 ft. fan buried in an appropriate airfoil was anticipated. The existing ground effect rig was employed for this investigation, and two enclosures simulating Cells No. 4 and No. 5 were erected on the movable ground plate. The motion pictures which were taken of the tuft screen revealed that ground effect work in both cells would severely suffer from re-circulation due to the relative nearness of the walls. Re-circulation would be greater, though, in Cell No. 5, the smaller of the two.

1.0 OBJECTIVE

To investigate the feasibility of ground effect work in Cells No. 4 or No. 5 using a 3 ft. fan surrounded by an appropriate airfoil. Special attention was to be paid to wall effects and re-circulation of the downwash.

2.0 APPARATUS AND METHODS

The ground effect test rig in Cell No. 1 intake of the Engine Laboratory was employed for this flow study. The effective part of the rig consisted of a 1 ft. diameter fan of 29 blades which was buried in a 20% thickness wing section of 3 ft. chord and 5 ft. span. Both ends were unobstructed except for the suspension structure.

Cell No. 4 has a 25 ft. by 25 ft. cross section, corresponding to 8 1/3 by 8 1/3 fan diameters (for a 3 ft. fan). The possible maximum fan exit distance from the floor is 18 ft. or 6 fan diameters. By working in fan diameters or downwash diameters at the exit, a scaled down enclosure was erected on the movable ground board of the test rig. Since we investigated one plane only, namely the one at half span at right angles to the wing, two walls 8 ft. apart were placed spanwise equidistant from the centre of the fan. A partial ceiling of 4 ft. by 5 ft. was installed 18 in. above the bellmouth. The remainder of the ceiling area and the ends of the rectangular enclosure were left open. To simulate Cell No. 5, the walls were drawn together to 5 ft. distance and the floor level was raised to a position 3 ft. away from the fan exit. Thus the existing relative space conditions in Cells No. 4 and No. 5 were fairly well simulated.

Tufts consisting of hard cotton were tied on wires strung vertically between ceiling and floor or airfoil and floor so that a pattern of tufts in 6 in. squares resulted. Lighter tufts were rejected because of the extreme wear on them especially in the downwash region.

As a means of recording the flow field, Mr. J. deBlois of the Photographic Section installed and operated an Arriflex camera, a reflex type motion picture camera which had a wide-angle lens attached to it. Photolamps provided the necessary illumination.

In order to cover a wide range of possible downwash velocities, it was decided to run the fan at 4000, 6000, 8000, 10,000, and 12,000 RPM for 1 minute at each velocity. At 12,000 RPM the fan exit velocity was approximately 425 fps. During the whole running time, the motion picture camera was in operation. The local static pressures on the upper and lower side of the airfoil were recorded so that, if necessary, a comparison with our unobstructed ground effect tests (no artificial side walls) could later be undertaken.

3.0 RESULTS AND DISCUSSION

The films have been developed and are kept at the N.R.C. Photographic Section for reference. An attempt has been made to represent the flow fields at 12,000 RPM by means of symbols. Figure 1 shows the case where the flow in Cell No. 4 is simulated; Figure 2 represents Cell No. 5. As can be seen, a strong unspoiled downwash impinges upon the floor and spreads in a fairly low surface flow radially outwards. Where it hits the obstructing walls, the flow is diverted upwards and follows the walls until it is again deflected by the ceiling. The flow on the leading edge side shows no significant difference from that on the trailing edge one. The greater restriction in the case of Cell No. 5 is indicated in the strong upward flow (Figure 2) as compared with the more turbulent and weaker flow in the case of Cell No. 4 (Figure 1). As can be expected, the re-circulation is much greater in case 2. Of all possible vertical planes leading through the centre of the fan the one chosen, the traverse section, is the smallest one. Therefore, the conditions found in respect to re-circulation should be the worst possible.

The two figures, and even better the films, reveal a strong re-circulation of the downwash due to the narrow spacing of the opposing walls. No re-circulation was observed in our ground effect studies where the walls of the cell were 21 ft. apart (21 fan diameters). The strength of the re-circulation depends on the downwash velocity and was at its maximum at the top RPM.

4.0 CONCLUSION

Neither Cell No. 4 nor No. 5 of the Engine Laboratory is recommendable for ground effect tests using a 3 ft. fan buried in an appropriate wing section. Possibly, Cell No. 4 could be used for this purpose if proper deflectors were designed and installed in order to prevent the downwash from re-circulating. One must bear in mind, however, that the choice of employing larger airfoils might be restricted. Cell No. 5 would prove to be too small even with deflectors being installed.

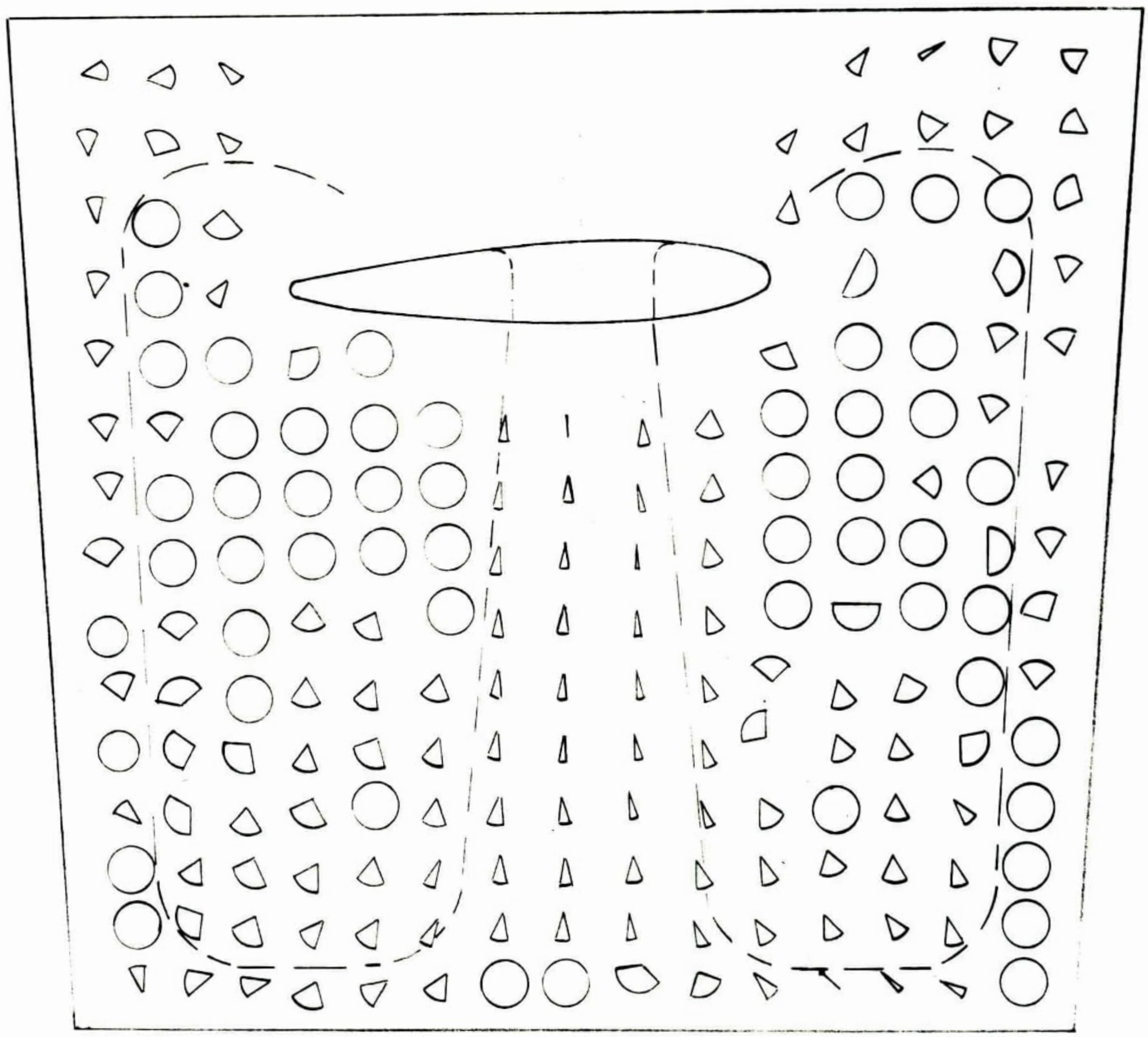

FIG. 1

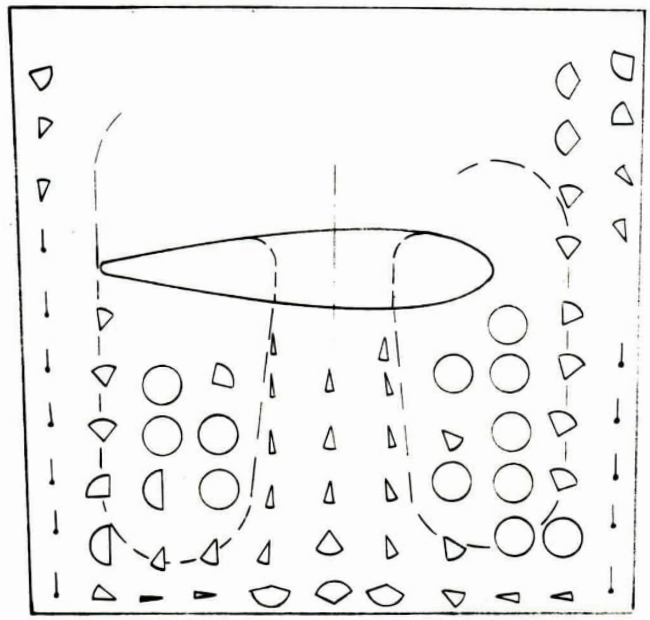

FIG. 2

: Strong flow in direction away from point.

: Erratic flow mainly within sector from A to B.

: Turbulent flow without any predominant direction.