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A NEW AIRFOIL RESEARCH CAPABILITY

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SUMMARY

The design and construction of a self streamlining wall test section for the Langley 0.3-meter transonic cryogenic tunnel has been included in the fiscal year 1978 construction of facilities budget for Langley Research Center. The design is based on the research being carried out by M. J. Goodyer at the University of Southampton, Southampton, England, and is supported by Langley Research Center. This paper presents a brief description of the project. Included are some of the design considerations, anticipated operational envelope, and sketches showing the detail design concepts. Some details of the proposed operational mode, safety aspects, and preliminary schedule are presented.

INTRODUCTION

In late 1974, a decision was made at Langley Research Center to support adaptive wall wind-tunnel research. This was accomplished by grants to the University of Southampton to support the work of M. J. Goodyer on the self streamlining wall concept (refs. 1 to 5), a grant to support the work of A. Ferri, and a request for funds for constructing a self streamlining test section for the Langley 0.3-meter transonic cryogenic tunnel to be based upon the design technology developed during the University of Southampton research program.

SYMBOLS

c model chord

h tunnel height

R_c Reynolds number based on model chord

x longitudinal distance

y vertical distance

424

DISCUSSION

The purpose of the new test section, in addition to providing airfoil test capability essentially free from floor and ceiling interference effects, is to increase the Reynolds number capability in the facility. This paper deals only with the design features and capabilities for the new test section and the reader is referred to references 1 to 5 for details of the concept. The proposed test section shown in figure 1 would have a 33-cm square test section and would be interchangeable with the two existing test sections for this facility. The new test section would make use of as much of the existing equipment as possible but would include a new minicomputer for the wall shape control.

Because the new test section must be compatible with the existing tunnel, its flow area must be about the same but the height and width could be different. As shown in figure 2, if the model chord is held equal to its span so that sidewall effects would be similar for all cases, an increase in chord Reynolds number can be achieved by reducing the tunnel height-width ratio. By making the tunnel height-width ratio equal to one as compared with the conventional two-dimensional tunnel ratio of four, an increase in Reynolds number by a factor of two can be achieved due to the increased chord allowed while maintaining the chord-span ratio. Although the blockage for this case is greater, the streamlined walls can still correct for it, as evidenced by the University of Southampton experience. The capability of the facility in terms of Mach number and Reynolds number is shown in figure 3 for the assumed chord-to-height ratio of 1.0.

The lower portion of this figure, which shows the existing Langley facilities and the current requirements of various types of aircraft, has been presented in reference 6. The currently envisioned region for advanced large cargo aircraft has been added. The point to be noted here is that the trend in requirements for transport aircraft is extended into the chord Reynolds number range of about 80×10^6 for advanced large cargo aircraft such as the spanloader concept. The envelope for the 33- by 33-cm test section of the Langley 0.3-meter transonic cryogenic tunnel is seen to adequately cover this requirement from the Mach number and Reynolds number viewpoints.

To illustrate the wall contouring capability, a typical streamlined wall shape is plotted in figure 4 for an NACA 0012-64 airfoil at a Mach number of 0.3 and angle of attack of 12°, or a lift coefficient of about 1.5. This is a potential flow solution and does not include any viscous effects. The case is for model chord c equal to tunnel height h and the two streamlines begin at $\pm y/h = 0.5$. The flexible walls are fixed at $x/h = 0$ and ends at $x/h = 4.5$. The quarter-chord of the model is located at the midpoint of the flex wall. Twenty-one jacks are mounted on each wall, with the downstream three being used for a fairing into the fixed diffuser. The close spacing of the jack in the region of the model is evident and is necessary to provide as close an approximation as possible to the streamline shape. For the case shown, the wall deflection from straight is about two-thirds the maximum design value. It should be pointed out that there will be limitations to this test section with respect to the maximum lift coefficient which can be tested as well as a Mach number limitation due to shock reflections and sonic velocities reaching the wall boundary. Sidewall boundary layer will be removed by the same mechanism as will be used for the existing 20- by 60-cm two-dimensional test section.

A generalized operational schematic is shown in figure 5. A typical section of the flex wall to which a position transducer, pressure tap, and jack are attached is shown on the lower portion of the figure along with the main computer on the upper portion. The main computer, through appropriate software programs, uses the measured pressures to compute the internal flow velocities, the position transducer to compute the external flow velocities, and sends drive pulses to the motor driven jacks to change wall shape if necessary. A scanivalve system will initially be used to scan the wall pressure although the system can be expanded to accommodate an individual transducer for each wall orifice. A microprocessor based safety system is used as a backup to the main computer to prevent the flexible walls from being overstressed, thus protecting them fro permanent damage.

Two view drawings of the proposed test section are presented in figures 6 and 7. From the end view (fig. 6) the tunnel flex walls and side walls are seen to be enclosed inside a plenum chamber which is the pressure vessel. The vertical sidewalls are solid and of one piece construction. The flexible top and bottom walls are attached through a thin, flexible membrane to two push rods which are connected to a crosshead. The crosshead is actuated by a motor-driven lead screw. The motors are staggered in vertical and lateral position in order to achieve the close spacing of the push rods which was desired. Both top and bottom wall actuating systems are the same. The angle of attack and traversing wake-survey-probe drive mechanisms are also located on the top of the test section. The model turntable is rotated by means of two push rods passing through the pressure vessel while the cantilevered survey probe is driven by a single push rod. All of the drive mechanisms and instrumentation are located outside of the tunnel pressure shell so as to be in an ambient temperature environment. The side view (fig. 7) shows the larger center door for model access as well as ports for instrumentation leads and boundary-layer removal flow ducts.

PROPOSED MILESTONE SCHEDULE

At present, the procurement package is being readied for advertisment. If acceptable bids are received, the contract could be awarded by late 1978 with about a 1-yr delivery time. The system is to be bench mounted for initial checkout of operation, which would extend to the end of 1979. The test section could then be mated with an existing low-speed compressor, bellmouth, and diffuser to provide some low-speed ambient temperature and pressure operational experience before committing it to installation in the Langley 0.3-meter transonic cryogenic tunnel circuit.

REFERENCES

1. Judd, M.; Wolf, S. W. D.; and Goodyer, M. J.: Analytical Work in Support of the Design and Operation of Two Dimensional Self Streamlining Test Sections. NASA CR-145019, 1976.

2. Goodyer, Michael J.: The Self Streamlining Wind Tunnel. NASA TM X-72699, 1975.

3. Goodyer, M. J.: A Low Speed Self Streamlining Wind Tunnel. Wind Tunnel Design and Testing Techniques, AGARD-CP-174, Mar. 1976, pp. 13-1 - 13-8.

4. Judd, M.; Goodyer, M. J.; and Wolf, S. W. D.: Application of the Computer for On-Site Definition and Control of Wind Tunnel Shape for Minimum Boundary Interference. Numerical Methods and Windtunnel Testing. AGARD-CP-210, Oct. 1976, pp. 6-1 - 6-14.

5. Wolf, S. W. D.; and Goodyer, M. J.: Self Streamlining Wind Tunnel-Low Speed Testing and Transonic Test Section Design. NASA CR-145257, 1977.

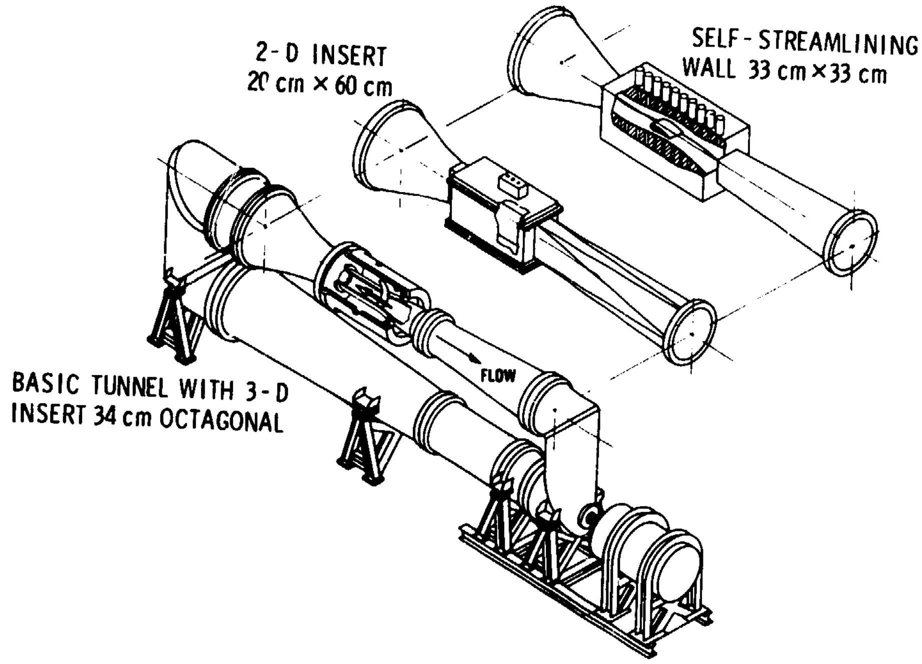

Figure 1.- Interchangeable test-section capability in the Langley 0.3-meter transonic cryogenic tunnel.

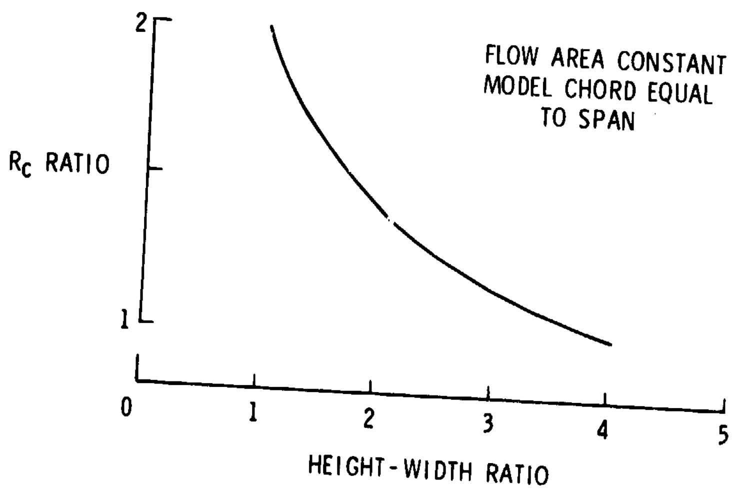

Figure 2.- Reynolds number variation with height-width ratio.

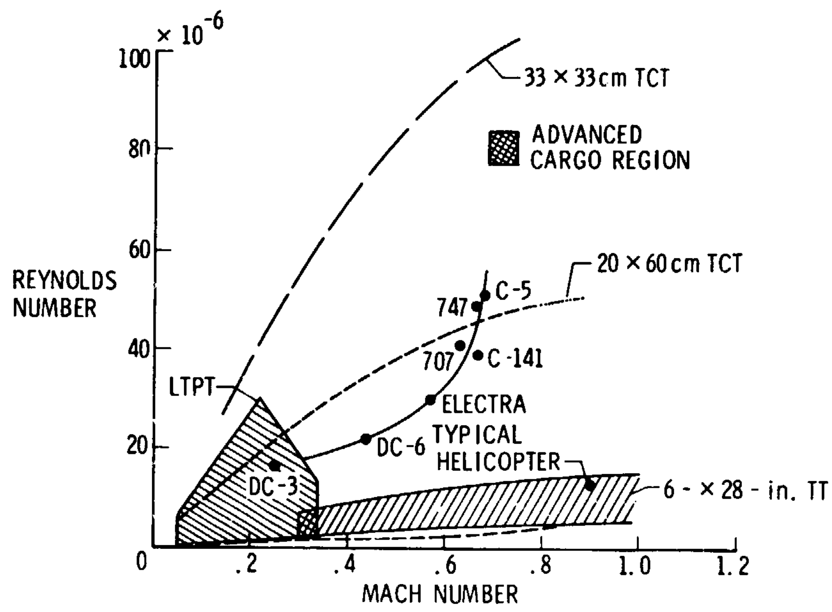

Figure 3.- Langley airfoil test capability.

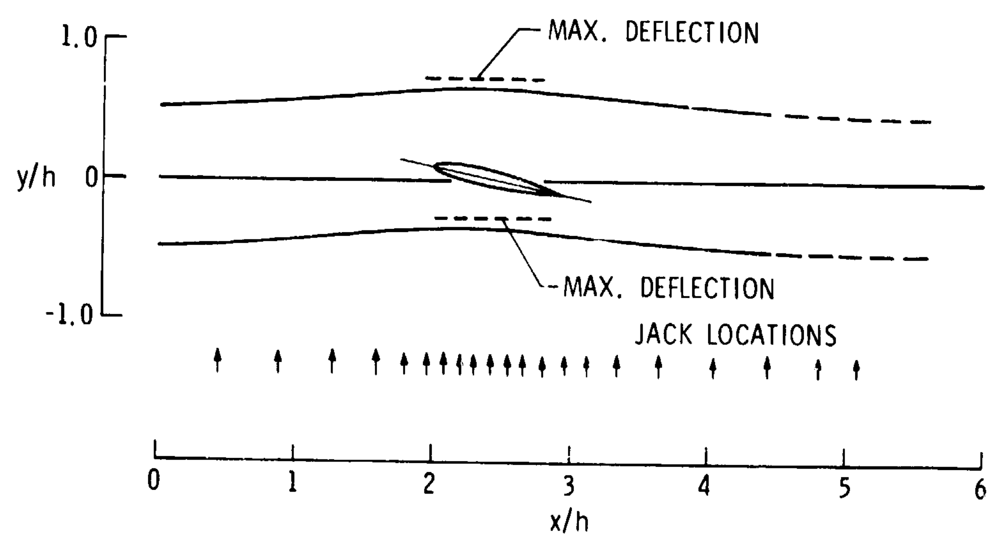

Figure 4.- Typical streamlined wall shape for an NACA 0012-64 airfoil at $M = 0.3$, $\alpha = 12°$, and $c = h$.

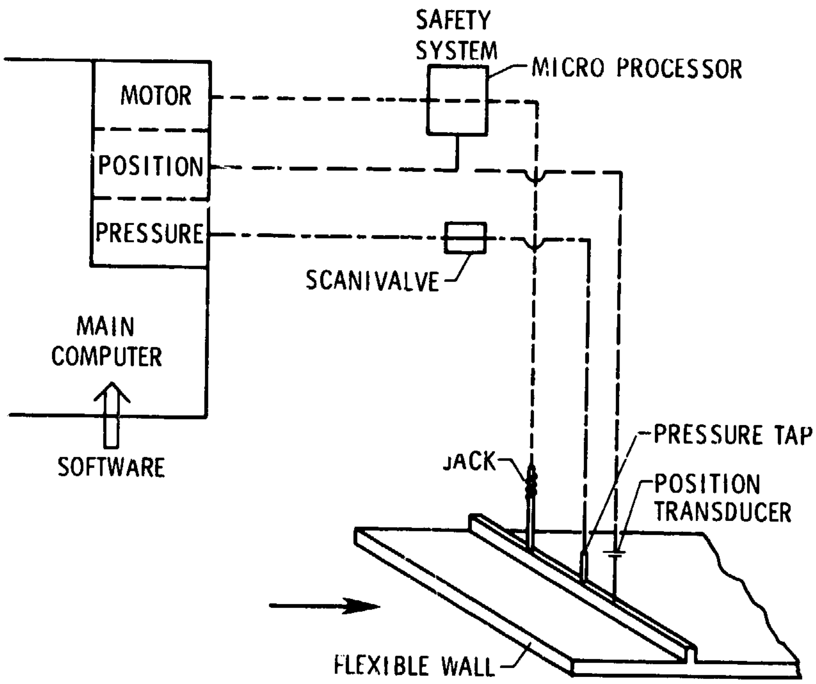

Figure 5.- Operation schematic.

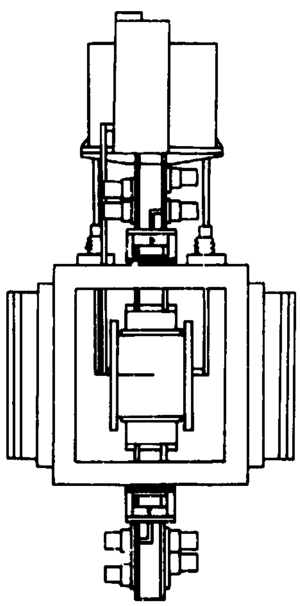

Figure 6.- End view of test section.

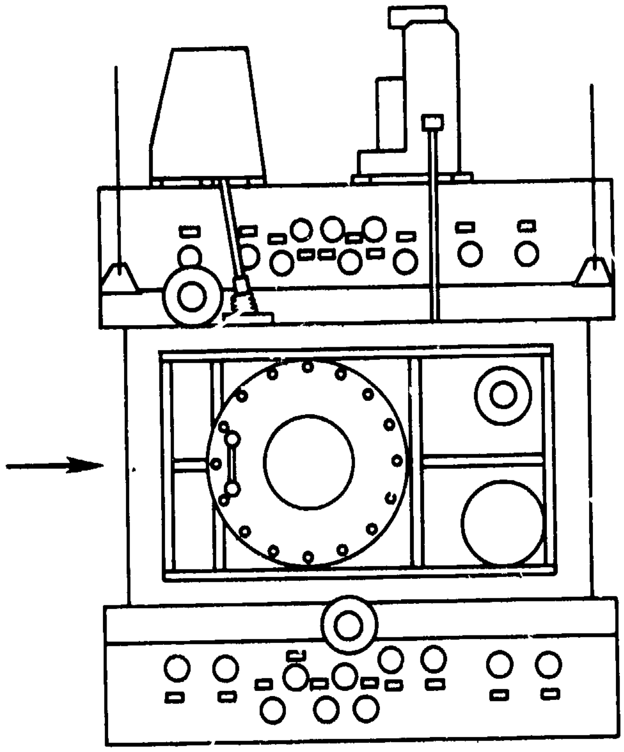

Figure 7.- Side view of test section.