TRAINING CENTER FOR EXPERIMENTAL AERODYNAMICS

THE LOW SPEED TUNNEL L-1

by

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INTRODUCTION

The low-speed wind tunnel L-1 is the largest testing facility at T.C.E.A. and, completed in 1950, it is the oldest still in existence at the Centre; the Eifel tunnel built in 1923 was dismantled in 1958.

L-1 is a low-speed tunnel of unusual design in that it can be operated in three different configurations:

1. as an open jet tunnel of 3 metre dia. (9.8 feet),
2. as a closed working section tunnel of 2 metre dia. (6.5 feet) and
3. as a vertical-jet (spin) tunnel of 3 metre dia.

Changes in configuration can be obtained easily by the movement by means of auxiliary electric motors of certain parts of the circuit.

All three configurations have a common length of return circuit which includes the two contrarotating fans driven by a D.C. motor whose continuous rating is 580 KW. The rotational speed of the fan is controlled by a Ward-Leonard system.

A six component mechanical balance of the suspended type can be used with either of the two horizontal working sections.
GENERAL LAYOUT

Fig. 1 shows a plan view of the tunnel with the closed working section in operation. When not in use this section with its diffuser (B) is stored alongside the return circuit as indicated by dotted lines. The position of the open jet section A when not in use is also shown. The displacement of both A and B sections is made electrically along rails fixed to the ground.

To obtain the third configuration, namely the vertical jet tunnel which operates with a mainly open return circuit, the fourth corner and contraction cone C are rotated through $90^\circ$ about the axis ss. Fig. 2 shows a view in elevation of the vertical-jet configuration. Above the working section, the air is deflected from the ceiling of the building by corner vanes and returns through the building to the intake I which is lowered in front of the entrance to the first corner, sections A and B being located in their stored position.

The driving system is shown on fig. 1 with the d.C. motor M, the two contra-rotating fans F with driving gears and bearings located inside a streamlined nacelle and the lubricating system L installed just outside the tunnel.

The part of the tunnel starting at the first corner and ending just after the third corner is made in reinforced concrete. The first three cascades of corner vanes are made in pre-stressed concrete. The contraction cone with the fourth corner is made of light alloy. Sections A and B for the open jet and closed working section configurations respectively are made of steel plates welded together. The diffusers in the circuit have total angles varying between $5^\circ$ and $6^\circ$.

A honeycomb is located just ahead of the contraction cone as shown in figs 1 and 2. There are no turbulence screens.
DRIVING SYSTEM

D.C. current is supplied to the driving motor by a motor-generator set. The power rating for continuous operation is 580 KW but the motor can be overloaded for a limited time of 15 minutes to 870 KW.

Speed control is achieved through the field current of the generator by acting on the excitation of the auxiliary field generator. Fig. 3 gives a schematic layout of the electrical circuits.

The drive shaft from the motor enters the tunnel at the second corner and is directly coupled to the first stage of the fan system consisting of ten magnesium alloy blades. The second stage of nine blades is driven at the same speed but in the opposite direction through an inverter gear system. Bearings and gears are housed in a streamlined nacelle. The angle of pitch of the blades can be adjusted at rest.

The lubricating system located outside the tunnel consists of an oil tank with heating elements for cold weather operation, an auxiliary oil pump which is overridden at a given fan speed by a main oil pump geared in the nacelle to the drive shaft, and an oil cooler (using water) for hot weather or high-power operation. Electrical thermometers are installed at all the bearings of the drive system so that temperatures can be checked during operation.

OPEN JET TUNNEL CHARACTERISTICS

The working section has a diameter of 3 m (9.8 feet) and is 4,60 m long (15 feet). In this configuration, the axis of section A (fig.1) is made to coincide with the axis of the tunnel; section A consisting of a collector A 1 and a cylindrical pipe A 2. The collector is of variable geometry being made of four equal longitudinal sections which are pivoted at the downstream end. The outward movement of these sections, which are geared together,
increases the flare diameter and the size of the four longitudinal slots separating the sections thus increasing the leakage in the collector. The opening of the flare is adjusted as to avoid pulsations of the air in the jet which can be extremely violent. The setting adopted was determined during the early calibration of the tunnel. A rather small flare opening has been chosen together with the additional leaks produced by 2 rows of 36 holes of 0.2 m diameter drilled around the circumference of the cylindrical pipe A 2 just downstream of the collector A 1. Under these conditions the tunnel is free of pulsations and there are no measurable static or dynamic pressure gradients along the working section from 1 meter (3 feet) to 4 meter (13 feet) downstream of the contraction cone.

The maximum continuous speed of the tunnel is 65 m/sec and the maximum variation of the dynamic pressure across the working section is ± 1% of the mean value.

The contraction ratio for this tunnel is 4.

A six component mechanical balance, which is described in some detail below, is supported on reinforced concrete beams above the working section. A three-point suspension is used for the models. The two forward points are located 2 m (6.5 feet) downstream of the contraction cone.

THE CLOSED WORKING SECTION CHARACTERISTICS.

For this configuration, the axis of section B is made to coincide with the axis of the tunnel as in fig. 1.

The diameter of the working section is 2 m (6.5 feet) and its length 2.5 m (8 feet). Access is obtained through two large door fitted with plexiglas windows. Section B begins with a small contraction to reduce to 2 m the exit diameter of the main contraction cone C.
The maximum velocity is 110 m/sec (360 ft/sec) and the maximum variation of dynamic pressure is ±1% across the working section.

The contraction ratio is 9.

The six component mechanical balance can also be used with this tunnel.

THE VERTICAL JET TUNNEL CHARACTERISTICS

The conversion to the vertical jet tunnel is achieved by displacing section A or B whichever is in operation, away from the center line of the tunnel to its stored position, rotating the contraction cone C to its vertical position and lowering the intake fairing I in front of the first corner section. These operations can be performed in fifteen minutes approximately or less if the fairing I is not used. Electric motors control the displacement of the moving parts. Rotation of the contraction cone C which is balanced is done through a 2 H.P. motor in approximately 30 sec.

A photographic view of the working section is given in fig.4. The jet diameter is 3 m (9.8 feet) and the maximum velocity 30 m/sec (100 ft/sec). The working section starts at the lower end of a slightly diffusing cylindrical section K of 2.1 m length which is lowered 1.1 m into the contraction cone C. Wire grids are attached to the lower end to produce a suitable stabilizing saucer shaped velocity gradient across the working section for tests on free spinning models. When in position, section K protrudes 0.7 m into the test room and is followed by the open jet part 1.75 m long of the working section. The air is then collected into the cylindrical duct L attached to the cascade of turning vanes located near the ceiling. There is a slight gradient in static pressure along the working section in order to stabilize the height of free-spinning models.

Equipment for this tunnel includes a vacuum chamber for checking the dynamic inertia of models, two 16 mm cameras, a time marker and a magnetic
triggering system for the control surfaces of models under test. This latter system uses d.c. current produced by a small auxiliary motor generator set available in the low-speed tunnel laboratory. The current when switched on energizes a 48 wire coil surrounding the working section, thus producing a magnetic field. This field acts on a small magnet located in the model being tested thus triggering the control surfaces which have been selected to operate. The electrical circuit is shown on fig. 5. To operate the system, the "contactor" 1 having been switched on, button 2 is pressed so energizing coil 3 and closing switch 4 in the d.c. line to the main coil around the working section. After 3 seconds the time delay switch 5 opens through the action of coil 6 of the delay switch. The system is thus ready again for operation.

THE SIX-COMPONENT MECHANICAL BALANCE

The balance is supported on two reinforced concrete beams above the center line of the tunnel. The general lay-out is shown in fig. 6. The model is supported in the inverted position at 3 points. The two forward points which fix the pitch axis are 0.8 m apart; the rear point can be adjusted by 2 cm steps from 0.38 m to 0.56 m aft of the pitch axis. Except for the part of lift taken by the wire attached to the rear suspension point the aerodynamic load on the model is transmitted through a strut or wire suspension system to two box structures with 3 arms each which are attached to the lower plate but can rotate about vertical axis passing through the front suspension points.

Linkages, which are shown in the photograph of fig. 7, connect the lower plate to the balance elements fixed to the upper plate, and are such as to separate the aerodynamic load on the model into the three components of force and the three components of moment. The ranges for the 6 components are given in the following table.
The angles of incidence and yaw of the model can be changed during tests. Their ranges are $\pm 30^\circ$ for incidence and for yaw. Pitching movement is obtained by raising or lowering the wire attached to the rear suspension point. Yaw control is achieved by rotating the whole balance through the desired angle; the 3 armed box structures rotating automatically through the same angle in the opposite direction to keep the struts or the profiled suspension wires aligned to the air flow. The six balance elements are all the same, their range being 70 kg. They are auto-balancing, the equilibrium sensing device being a hydraulic one. The displacement of the rider weight on the screw beam is controlled by an oil servo motor, the number of turns of the screw beam to restore equilibrium being proportional to the disturbing force applied to the balance element. All readings are transmitted by selsyn systems to counters installed in the control room near the tunnel. Forces are given directly in kg and moments in kgm. Changes of incidence and yaw are also operated from a desk in the control room.
HIGH-PRESSURE AIR SUPPLY

High-pressure air is available in the L-1 tunnel for tests requiring high energy air such as in boundary-layer control. The system (see fig. 8) includes a 10 m³ reservoir (350 Cu ft) in which air can be stored at 15 atmospheres absolute, a 10 H.P. two stage reciprocating compressor, a 4 ins. air duct, two pressure regulating valves set in parallel to keep downstream pressure constant at the desired value, and an orifice plate for mass flow measurement. The valves have been designed to regulate the downstream pressure in the pressure range between 1.05 and 5 kg/cm² for rates of flow varying between 0.016 to 2.750 kg/sec (MKS).

The time to pump up the reservoir from atmospheric pressure is 3 1/2 hours.

AIRCRAFT MODELS WITH POWERED PROPELLERS

Small motors which can be fitted in models to drive propellers are included in the tunnel equipment. Power supply to these motors is through a variable frequency set consisting of a d.c. generating set driving a d.c. motor coupled to a 220 V 12 KW 500 C/sec. Alternator motors available for propellers are of 3 types:

1) 220 V, 15,000 RPM, 2 H.P.
2) 220 V, 30,000 RPM, 1 H.P.
3) 24 V, 30,000 RPM, 3 H.P. with a 220/24 V transformer.

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SCHEMATIC LAYOUT OF ELECTRICAL CIRCUITS

FIG. 3
FIG 4. WORKING SECTION OF SPIN TUNNEL WITH MODEL IN FREE FLIGHT
Fig. 5. ELECTRO MAGNETIC TRIGGERING SYSTEM FOR CONTROL SURFACES. (SPIN TUNNEL)
Fig. 6. SIX COMPONENT MECHANICAL BALANCE LAYOUT
FIG. 7A. SIX COMPONENT BALANCE WITH MODEL SUSPENDED BELOW IN OPEN JET TEST SECTION
FIG. 7B. DETAILED VIEWS OF SIX COMPONENT BALANCE
Fig. 8. HIGH PRESSURE AIR SUPPLY.

ORIFICE PLATE FOR RATE OF FLOW MEASUREMENT.

TO MODEL

AUTOMATIC PRESSURE REGULATING VALVES.

AUXILIARY RESERVOIR FOR PNEUMATIC OPERATION OF REGULATING VALVES.
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