THE DEVELOPMENT OF A BOUNDARY LAYER IN A PORTABLE WIND TUNNEL

J H Tubb* & G H Moore*

1. INTRODUCTION

The Western Australian Department of Agriculture has a soil conservation research programme which is attempting to determine the economics of soil loss due to different farming practices.

The characteristics of a portable wind tunnel constructed for erosion studies is described in Section 2.

Proposed modifications to the portable wind tunnel have been carried out in a Plint TE44 wind tunnel and the results are described in Section 3.

1.1 Notation

d : surface roughness, cm

Z_o : height in cm where velocity is zero

U_∞ : bulk velocity, ms^{-1}

U_z : velocity ms^{-1} at height z

U_* : drag velocity, ms^{-1}

σ_u : root mean square velocity, ms^{-1}

2. PORTABLE WIND TUNNEL

2.1 Introduction

Five years ago Carter and Marsh (1980) decided to build an open circuit wind tunnel similar to the trailer mounted tunnel constructed by Armbrust and Box (1967) at the US Department of Agriculture Field Station at Big Spring, Texas. The design was modified to suit the Western Australian research programme and the general arrangement of the basic tunnel is shown in FIG. 1.

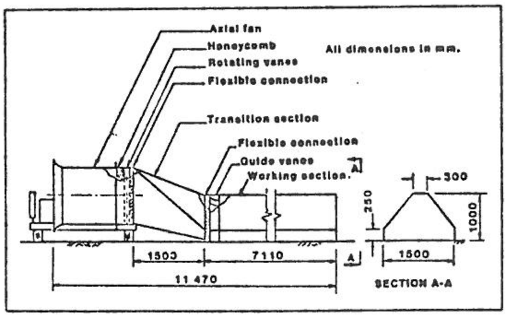

FIG. 1. Schematic Arrangement of the Portable Wind Tunnel

2.2 Wind Tunnel Components

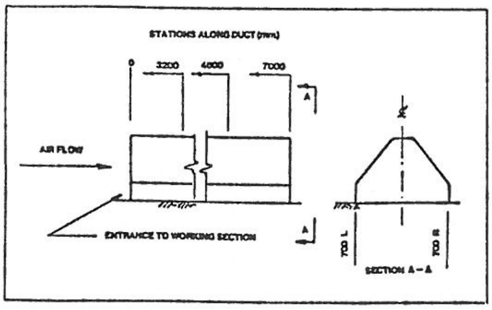

FIG. 2. Traverse Stations

A wind speed of 100 kmh^{-1} was required on the centre line of the duct. The tunnel has been described by Carter, Moore and Marsh (1985). A logarithmic-linear velocity relationship up to the centre line of the duct was required. The driving unit was a diesel engine coupled to a simple single-stage axial fan unit. The cross sectional area of the working section was approximately one square metre and the shape, shown in FIG. 2, was selected to increase ground coverage.

* Western Australian Institute of Technology

Turbulence (gust) generators in the form of seven rotating vanes were installed vertically across the outlet from the fan unit. These vanes may be fixed or rotating.

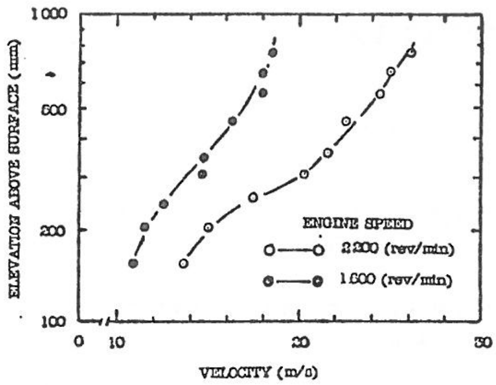

FIG. 4. Velocity Profiles just Upstream of Station, 0-0, on the Centre Line of the Duct. (Without Honeycomb Straightener)

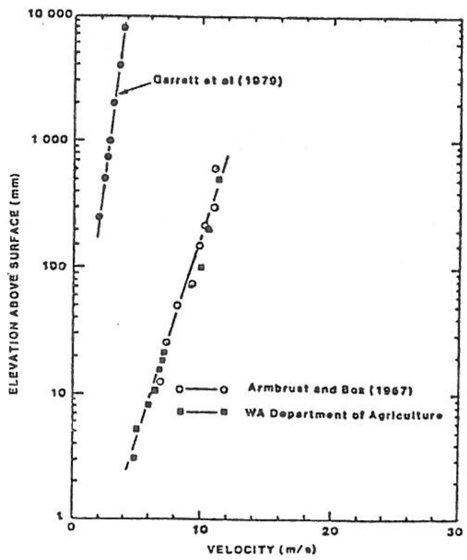

FIG. 3. Natural and Tunnel Wind Profiles

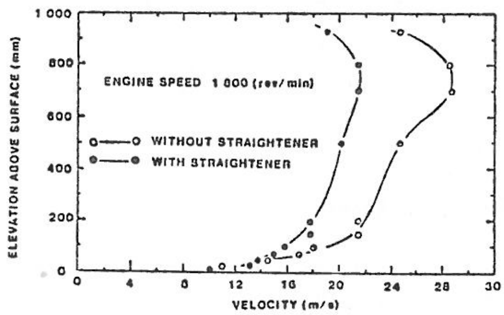

FIG. 5. Velocity Profiles at High Speed over a Cut Lawn Surface with and without Honeycomb Straightener at Station 7000.

2.3 Wind Tunnel Characteristics

The general variation of velocity with height in the tunnel was as shown in FIG. 3 together with a natural wind profile obtained by Garratt et al (1979).

Velocity profiles at the entrance to the working section are shown in FIG. 4.

The profile generated showed the influence of the "flow down" transition section on the inlet profile to the working section and indicated the need for further work in this area. The effect of the honeycomb straightener is shown in FIG. 5. The honeycomb removed an undesirable bulge in the upper part of the working section velocity profile.

Typical working section profiles over 10 mm roughness are shown in FIG. 6.

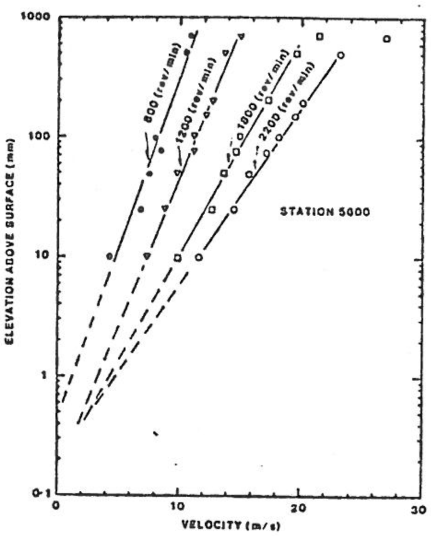

FIG. 6. Relationship between Drag Velocity and Engine Speed

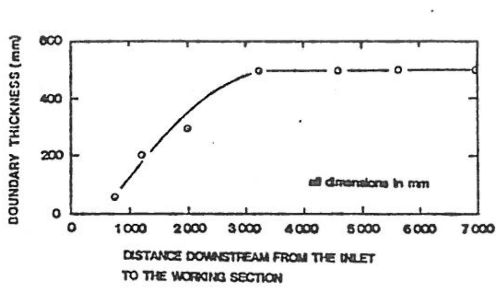

FIG. 7. Development of a Boundary Layer along the Working Section of the Tunnel

The development of a straight log-linear velocity profile with distance from the inlet to the end of the working section is shown in FIG. 7.

2.4 Initial Tunnel Performance

This wind tunnel designed for comparative field studies of ground covers and soil erodibility, has been successful in this type of research. Flow conditions similar to those obtained in the field have been achieved along approximately 60% of the working section. The tunnel does have an undesirable swirl component.

2.5 Current Work

Velocity traverses using a NPL Pitot-static tube with a precision manometer were performed in the tunnel. The tunnel was fitted with certain flow conditioning devices. These devices consisted of a trip and associated ramp situated at the beginning of the tunnel working section. The use of a 25 mm trip and associated ramp in fact did induce a more stable and developed boundary layer. This can be seen from FIGs. 8 and 9 where the straight line log-linear profile is evident FIG. 8, and the value of von Kármán constant is shown to be ≑ 0.4, which is the accepted value FIG. 9.

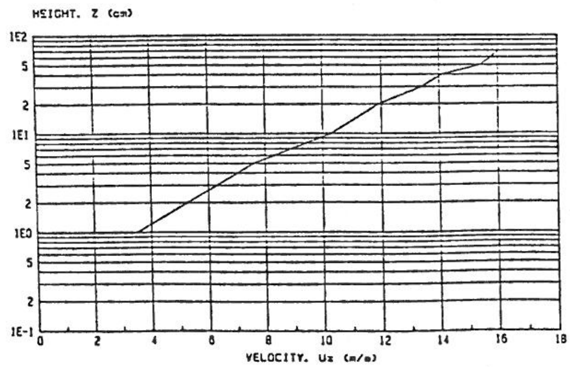

FIG. 8. Friction Velocity Graph 1400 rpm - with trip with ramp

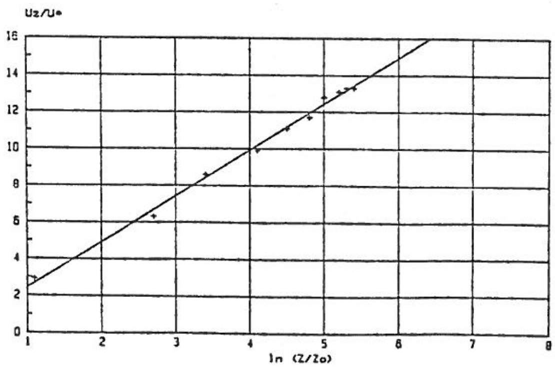

FIG. 9. Logarithmic Law Graph 1400 rpm - with trip with ramp

FIG. 10 shows the velocity matrix again at the end of the tunnel. This matrix was used to obtain lines of equal velocity. This shows the tunnel to be plagued with secondary flow effects which are to be expected in the corners of this tunnel.

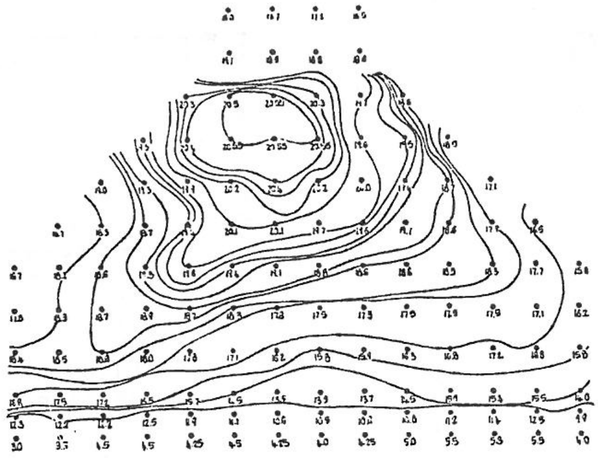

FIG. 10. Velocity Contours at exit from Tunnel.

3.0 PROPOSED MODIFICATIONS CARRIED OUT IN THE PLINT WIND TUNNEL

The Plint TE44 Wind Tunnel is an aerodynamic tunnel manufactured by Plint and Partners, England. Modifications to the tunnel included a trip with associated rough surface. A number of traverses were performed using a Disa hot-wire anemometer coupled to a HP86 microcomputer.

The boundary layer development for these flow conditioning devices are described using the straight line log-linear profile, a boundary layer profile and the value obtained for von Kármán constant. von Kármán's constant was $\doteq$ 0.4, and the value obtained for σ_u/U_* in the constant stress layer was 2.35.

Graphs relating to these may be seen in FIGs. 11, 12 and 13 respectively. These criteria provided typical values for constants and shapes for graphs showing the boundary layer to be fully developed and in equilibrium.

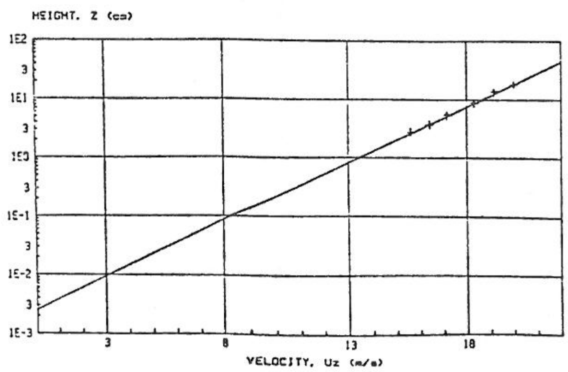

FIG. 11. Friction Velocity Graph
End of Rough Surface
20.02 m/s.

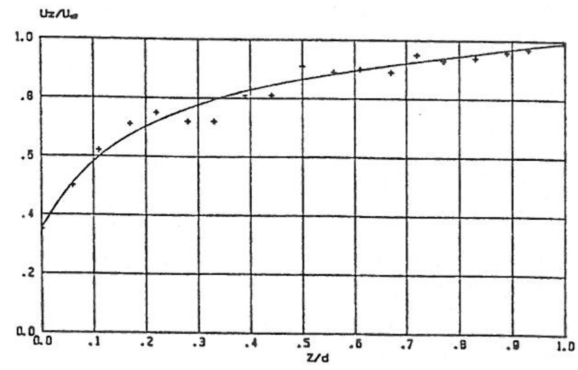

FIG. 12. Turbulent Boundary Layer Profile
End of Rough Surface
20.02 m/s.

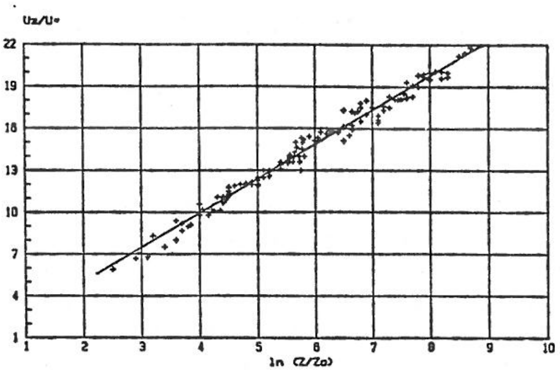

FIG. 13. Logarithmic Law Graph - all Surfaces and Velocities.

4. CURRENT RESEARCH WORK IN THE DEPARTMENT OF MECHANICAL ENGINEERING

The following projects are being carried out in the Department of Mechanical Engineering.

(a) Turbulence levels in the portable wind tunnel.

(b) Efficiency of saltation gauges.

(c) Improved methods of measuring drag velocity under soil blowing conditions.

(d) Alternative methods of collecting samples from saltation gauges.

(e) Flow patterns and efficiency for two air elutriators and saltation gauges.

Gusting produced by rotating vanes will always cast doubts on readings and results obtained under soil blowing conditions. Research is necessary to devise instrumentation to operate in this hostile environment.

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