# Computer Controlled Traversing Rig for Pedestrian Level Wind Measurements

by

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## Introduction

There are two main methods for measuring pedestrian level winds in wind tunnel simulations: erosion techniques and point methods. Erosion methods are commonly used at the University of Auckland using bran as the erosion material (see Ref 1), but a current research project is also looking at automating the point method using a vertically orientated hot-wire as the sensing element. This has the advantage of being able to accurately measure the wind-speed statistics at a certain point, as it is capable of measuring gusts due to its high frequency response. The two main disadvantages of using hot-wires are that they are very fragile, and can easily be broken due to contact with a dust particle etc, and it can be very time consuming to manually position a single hot-wire at many different measurement points for a typical commercial wind environment assessment.

This paper describes research being undertaken to develop an automated process for carrying out the "point measurement technique" using a hot-wire mounted on a computer controlled traversing rig in order to speed up the testing. The initial idea for this automated approach to measuring pedestrian level winds came from BMT Fluid Mechanics in the UK, where the second author spent a Sabbatical Leave in 1999. BMT were developing methods to "teach" a computer controlled traversing rig system where to make measurements by a person in the wind tunnel using a hand-held controller which moved the traversing rig.

## Basic Concepts of the Automated Measurement System

The present automated system for measuring pedestrian level winds using a hot-wire probe in the de Bray wind tunnel required the use of the original 2-d traversing rig (*y*-motion across wind tunnel and *z*-motion vertically) developed by Andrews (Ref. 2) but it needed the addition the third axis, *x*, along the wind tunnel. This was done by positioning a stepper motor on the wind tunnel roof, and pulling the original 2-d traversing rig along rails on the inside of the wind tunnel walls using cables. The design of this third axis was done by Barthel (Ref. 3) who also carried out most of the original software design of the system.

The original 2-d traversing rig and the turntable was driven by stepper motors and had been designed to be controlled by a PC from the parallel printer port. This had been done for many years using software written in Turbo Pascal running under DOS, which wrote directly to the printer port, and instructed the required channel to step in the required direction on a step-by-step basis. However, with the arrival of the various Windows operating systems, it became more and more difficult to communicate directly with the printer port. In addition, it was difficult for current students to use software running under DOS. Hence with the requirement for the extra x-motion channel for automating pedestrian level wind measurements, the decision was made to change the system dramatically.

The new system is shown in Fig. 1 and has the following features:

- An extra stepper motor for the x-direction has been added.
- A micro controller is positioned between the computer and the stepper motor control box
- A remote controller was built which communicates directly with the Micro controller
- The software required to run the system was written in Labview

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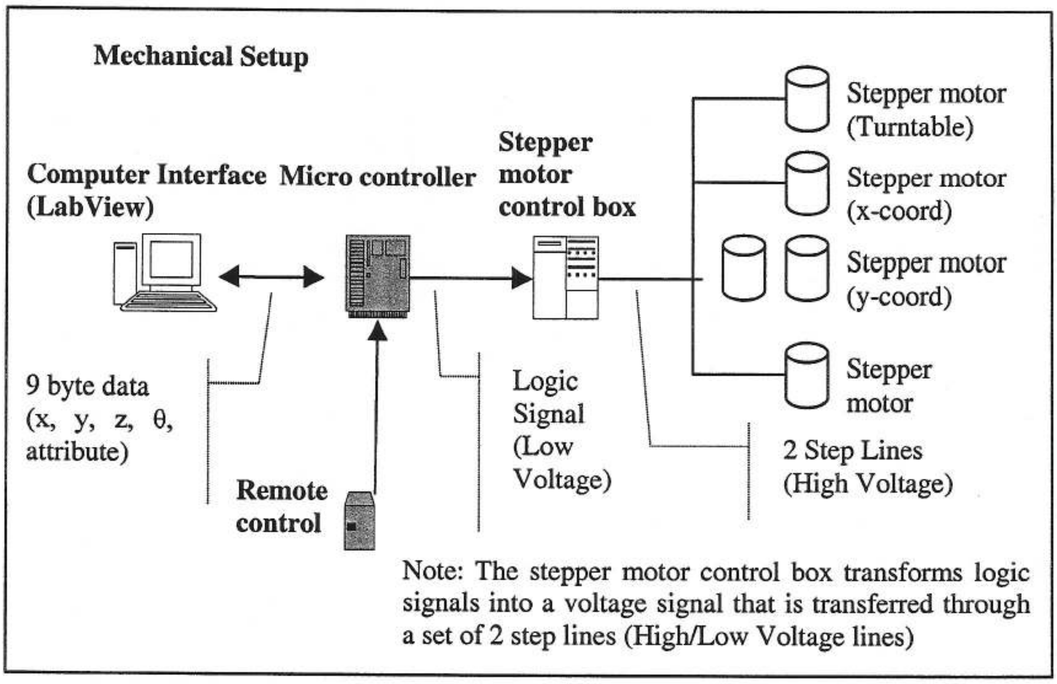

Note: The stepper motor control box transforms logic signals into a voltage signal that is transferred through a set of 2 step lines (High/Low Voltage lines)

**Figure 1 Schematic diagram of the mechanical set-up of the measurement system**

The basic concepts behind automating the testing are now described. The probe attached to the traversing rig can be driven to all the desired test points by an operator in the wind tunnel using the remote control unit, and the coordinates of the measurement points recorded by the controlling computer program. Waypoints can also be introduced by the operator to enable the probe to travel in straight-line motion between measurement and waypoints without colliding with a building model. In this manner, the controlling computer program learns where it has to position the probe subsequently.

After being taught, the hotwire probe is calibrated, and then testing takes place. The turntable is orientated to the first direction, usually 0 degrees true, and the statistics of the wind characteristics at the various measurement points recorded. The probe is then traversed vertically out of the way and the turntable rotated to the next direction, say 30 degrees true, and the probe moved to the same measurement points as before, and the process repeated until all the wind data are recorded. Finally, the wind data for each direction at each point are combined with reference climate data, and the wind comfort categories for each measurement point determined.

## Description of Hardware

The handheld controller is directly connected to the micro-controller via a RS232 interface (serial port) and allows the mechanical movements of the traversing rig to be directly controlled by an operator. It is built around a joystick, in which horizontal planar movement of the joystick results in similar movement of the traversing rig. Twisting the joystick in a clockwise or anti-clockwise manner results in vertical traverse rig movement in the same sense as a right-handed corkscrew. When the probe has been driven to a desired point, 1 of 3 buttons can be pressed to denote a particular attribute: a measurement point, a way point, or delete last point. A fourth button is used to lock/unlock the remote control.

The Micro-controller communicates with the stepper motors through the control box. The control box converts the logic signals from the computer into higher voltages which power the stepper motors in a standard manner. Essentially, it sends the required number of pulses with a direction signal in a sequential fashion in order to make the stepper motors turn as required. The micro-controller therefore frees up the computer, and so communication between the computer program and the micro-controller are simply traverse rig co-ordinates and turntable angles in terms of stepper motor counts, and the attribute associated with each point. This is necessary, because whereas the previous Turbo Pascal programs running under DOS on 486 computers could send pulses to the printer port at a higher rate than the stepper motors could react, it has been found that modern computers using Labview running under Windows are unable to send pulses quickly enough to the printer port of the computer in order for timely operation of the measurement system.

## Programming

The software used to carry out the automated measurements is a commercial package called LabView©. It is a widely used language to pre-program a large variety of mechanisms. It was initially chosen, as it is flexible, being able to control a large variety of components, while more importantly capable of receiving analogue signals from an input source. LabView© is a high-end graphical language which allows the user to set up an entire program through a visual interface. This enables the language to be efficiently learnt and easily manipulated by a new and inexperienced user (e.g. a student). In essence LabView© is a program which enables data to be sent to or received from a set of mechanical and/or electrical hardware.

The Labview© program developed during this work has an initial "Setup" sub-program phase where the user enters the wind directions to be tested, and can change various default values such as the conversion factors between steps and motion, the sampling frequency, the sample duration, and must also supply various directories to store the results. The next sub-program records the measurement and way points as the system is "taught" where to go while the operator moves the probe to the required locations using the remote control. Communication between the computer program and the micro-controller is in a 9-byte ASCII code configuration. These 9 bytes contain the $x$, $y$, $z$, and $\theta$ coordinates of each point in terms of steps, as well as its "attribute", as described earlier.

The calibration sub-program is run next and enables the user to calibrate the hot-wire by locating it near to a reference pitot-static probe, and recording the hot-wire voltage simultaneously with the dynamic pressure. The barometric pressure and air temperature must also be inputted to the system. The calibration used is a second order polynomial for velocity in terms of hot-wire voltage. The input for this part of the process is through an A/D converter, with the hot-wire connected to one input, and the pitot-static probe connected to another input.

The measuring sub-program also receives input from the A/D converter. With the model at a certain orientation, and the probe at one of the measurement points, time histories of the hot-wire voltages are recorded. The calibration is applied, and then the mean, standard deviation, maximum and minimum values are recorded for further processing. This process is repeated for all test locations and required turntable orientations.

## Validation

The automated systems described in the foregoing is still under development, and was only made operational at the end of 2002. One validation test has been carried out, and further details are available in Ref. 4. This validation test verified that the complete system operates as desired, but the results themselves are subject to error for two reasons. The measurements were obtained at 45-degree intervals, whereas the normal angle interval for such tests is 30 degrees, and the hot-wire was positioned in a horizontal orientation, whereas it should have been vertical to more correctly simulate a person standing in the street.

Wind tunnel tests were carried out using a 1:400 scale model of the vicinity of Queen Elizabeth II Square, a notoriously windy area of Auckland City. A set of results was available from a wind tunnel test using an erosion method developed at the University of Auckland (Ref. 1). A set of results were also obtained using the automated hot-wire system described in this paper. The results are shown below, and it can be seen that the two different methods give very similar wind comfort categories.

**Figure 2 Comparison of results for Queen Elizabeth II Square – erosion method (left), automated hot-wire (right); Green – Category B, Red – Category C, Blue – Category D.**

## Conclusions

The automated point measurement technique for pedestrian level wind measurement using a hot-wire as the wind speed sensor has been fully implemented in the de Bray wind tunnel.

The program designed for the automated point measurement technique allows the user to designate the measurement points where the wind speed measurements will be automatically taken at each desired wind direction.

The automated point measurement process has been partially validated by comparing results in Queen Elizabeth II Square obtained using the automated hot-wire method with previous results obtained using the erosion method.

## References

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