Model fitting results for: D:CALSG.APN

Independant variable	coefficient	std. error	t-value	sig.level
D:CALSG.BETA_1	0.000074	0.000016	4.5679	0.0000
D:CALSG.BETA_2	-0.006578	0.000129	-50.9194	0.0000
D:CALSG.BETA_3	0.000473	0.000125	3.7957	0.0002
D:CALSG.BETA_4	-0.000545	0.000084	-6.4526	0.0000
D:CALSG.BETA_5	-0.000233	0.000071	-3.2609	0.0012
D:CALSG.BETA_6	0.003718	0.000065	57.2276	0.0000

R-SQ. (ADJ.) = 0.9122 SE = 0.037481 MAE = 0.025672 DurbWat = 0.133

450 observations fitted for 0 missing val. of dep. var.

Output for regression of the N moment versus β

APPENDIX C

INSTRUCTION MANUAL FOR OPERATING THE 1.5m SQUARE WIND TUNNEL USING THE 12mm STING BALANCE AND THE UPM 60 DATA ACQUISITION SYSTEM FROM A PERSONAL COMPUTER.

Table of Contents

List of Figures

1 INTRODUCTION

The purpose of this manual is not to replace the existing manuals from the respective components to the big wind tunnel system but to make the operation of this wind tunnel easier for those people not concerned with the finer details of each component.

It is also intended to reduce the wasted time spent figuring out how to use a particular piece of equipment. This is necessary since the system comprises different pieces of equipment with their own inherent logic. The coupling of these systems also follows the logic of the person responsible for the linking and setup. This implies that a person has to master many forms of logic which are not consistent.

It has been attempted to make this manual as easy to use as possible without limiting the capabilities of the equipment by leaving out vital information.

Please feel free to consult the manuals supplied with the individual instrumentation. This will only be necessary for those people intending to modify the system in any way.

2 LIST OF PARTS FOR CALIBRATION

1 CALIBRATION STAND

2 CALIBRATION BODY

3 LOADING JIG

4 KNIFE EDGED LOOP

5 HANGER (MADE OF 3MM BRASS WIRE)

6 HANGER (MADE OF 2MM BRASS WIRE)

7 SMALL ALLEN KEY TO FIT CALIBRATION BODY

8 TWO SHORT PIECES OF 19MM ALUMINIUM TUBING

9 CALIBRATED MASS PIECES (NOT YET WITH TUNNEL)

3 COMPONENTS USED IN CALIBRATION

CALIBRATION STAND

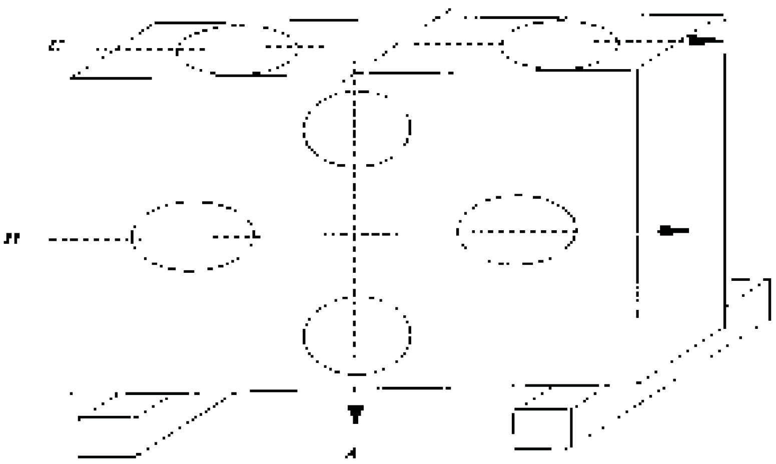


Fig. 3.1 Schematic of the calibration stand.

A) Centre line along which the sting must be placed for calibration of the X component. The direction of the arrow indicates the direction of the sting from the support to the loading point (head of arrow).

B) Centre line along which the sting must be placed for calibration of the Y and N component. The arrow direction follows the same convention as before.

C) Centre line along which the sting must be placed for calibration of the Z, M and L component. The arrow direction follows the same convention as before.

CALIBRATION BODY

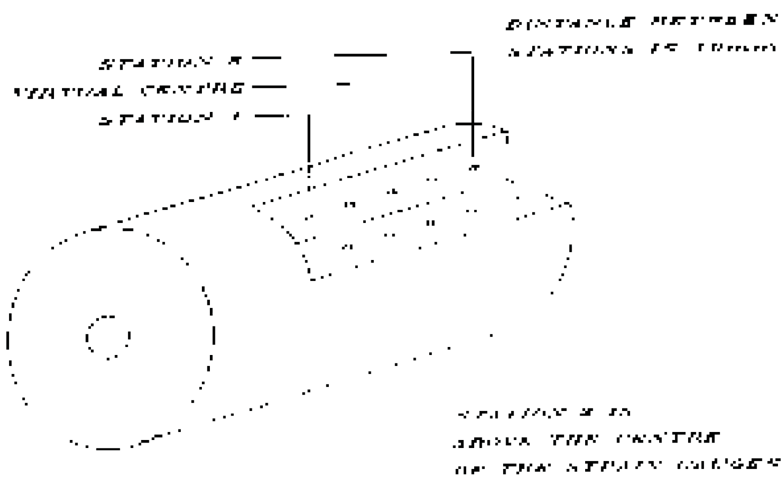


Fig. 3.2 Schematic of the Calibration Body.

LOADING JIG

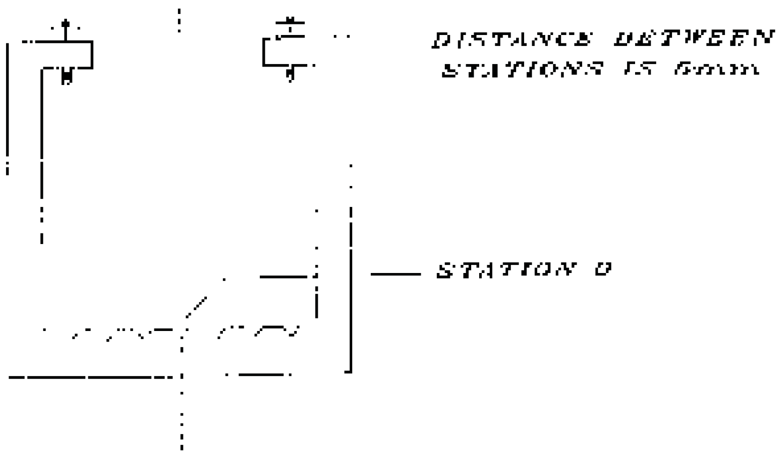


Fig. 3.3 Schematic of the Loading Jig.

HANGER

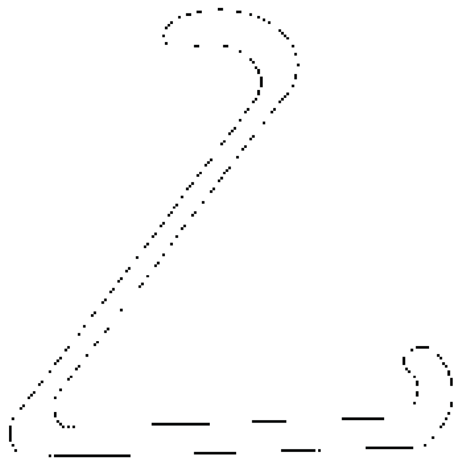


Fig. 3.4 Schematic of the Hanger.

KNIFE EDGED LOOP

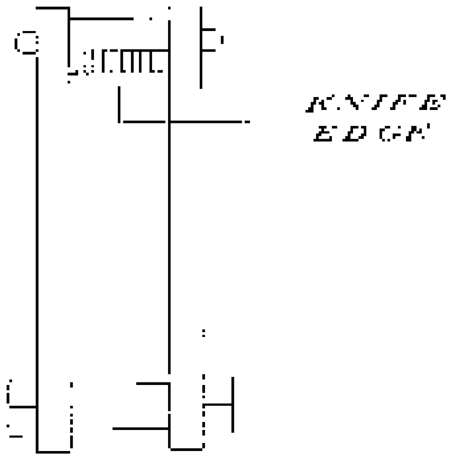


Fig. 3.5 Schematic of the Knife Edged Loop

4 DESCRIPTION

The data acquisition system is comprised of several individual sections. The measurements taken for any test were the two angles giving the position of the model, the three forces and three moments on the model, the wind velocity, the rotational velocity of the sphere and the temperature in the test section. The rotational velocity was only relevant to the tests which were carried out on the spinning sphere. All the others will be needed for any tests carried out in a wind tunnel.

The temperature was measured manually and inserted into the results via the computer keyboard. This was required to find the density on the particular day. The density is used to calculate most of the non-dimensional derivatives like C_D, C_L and Re.

Before any loads were applied a zero reading was taken. The value of the zero reading was subtracted from all readings because only differential voltages were used to calculate the required measurement.

4.1 FREE STREAM VELOCITY

The velocity is measured by means of a micromanometer and a Pitot tube. This device gives a voltage output that is proportional to the differential pressure picked up by the Pitot tube. The Pitot tube measures the difference between stagnation pressure and static pressure which is commonly known as the dynamic pressure. Ensure that the manometer used is the Furness model FCO 11. This manometer was bought for this tunnel and the program will only read correctly if it is used, as other manometers have different relationships between the voltage out and the differential pressure. The relationship between the voltage output and the differential pressure is, one millivolt per Pascal. This voltage is read into the UPM 60 unit.

4.2 UPM 60

The UPM 60 is a multi-point measuring device that can measure up to 60 channels. This device can measure Wheatstone bridges, voltages, currents and resistances. All the transducers are connected to this unit. The unit has the capability at present to use 40 channels. The channels being used are:

10) Angle of attack
11) Angle of yaw
12) X force
13) Y force
14) Z force
15) L moment
16) M moment
17) N moment
20) Velocity

The reason for the jump from channel 17 to 20 is that the angles and forces are measured by means of Wheatstone bridges and therefore use the module designed for this purpose. This module is designed to take ten channels. The velocity however is measured using a voltage input. The module for this purpose uses channels 20 to 30. The the UPM 60 has a skip function which is used on channels 18 and 19.

4.3 ANGULAR MEASUREMENT

The angles of attack and yaw are also measured by means of a Wheatstone bridge. The rotation of the relevant shaft turns a potentiometer more commonly called a variable resistor. This change in resistance is measured and the angle can therefore be determined. The output from the bridges measuring attack and yaw were also sent to the UPM 60. These components did not have a calswing connected to their circuit since the readings were not felt to require calswing accuracy.

4.4 12 mm STING BALANCE

The three forces and three moments were measured by the six component sting balance. This device is a rod shaped sting, with flexures cut into it to attach strain gauges. There are two main sections in which measurements are taken. The first is closest to the model attachment point. This section has a transverse beam mounted so that any axial force results in bending of this beam. The beam had four strain gauges mounted on it in the configuration that is sensitive to the measurement of moments and insensitive to forces. These gauges were connected in a Wheatstone bridge to give the required sensitivity to loading. The second section had four beams running longitudinally. These were also gauged so that the remaining forces and moments could be measured. Theoretically these loads were insensitive to the axial force because of its line of action, and to the other loads respectively because they were either orthogonal or in the case of moments, the line of action was through the centre of the gauging. Since in practice the orthogonality and positioning can only be achieved within tolerances a certain amount of cross linking occurs. To eliminate these effects a 6 X 6 calibration matrix is used.

Incorporated into the sting circuit was a calswing load. This is an electrical load applied to each bridge circuit without any other load. This should give the same result every time the bridge is measured. However, since the voltage measuring device may be temperature dependant and there may be the need to use separate instrumentation to calibrate and test with, the calibration is still valid as long as the same resistors are used in their respective circuits. The calswing is operated by means of relays. When the relays are energized the resistor is connected into the circuit and as soon as it is switched off the resistor is removed from the circuit. The relays are housed in a control box ensuring that the same resistors are used for the same components in each test.

The differential voltages for a given loading were then divided by the calswing to give a beta factor. This factor is dimensionless and therefore should be the same on any measuring device. However the UPM 60 does not behave in this manner since the device processes the reading using a gauge factor of two on the raw readings. This means that the calibration matrix on this device will not be the same as that for a voltmeter.

4.5 INTERFACE

The UPM 60 has the capability of being linked to many output devices ranging from a thermal printer to a computer of either the pc variety or the HP type. In this particular case the output device is a pc. The data is transferred to the pc via a RS 232-C link. This is a very slow process but it is the cheapest and easiest method of capturing the output.

5 GETTING THE UPM 60 TO TALK

First switch off the power to both the computer and UPM 60. Then check that the serial cable is plugged into both the computer and the UPM 60. Next check that the 72 pin plug is in the back of the UPM 60 firmly. This plug must be in the second slot from the left when looking at the back panel. The two wires from the micromanometer must be plugged into the third panel at the sockets marked 17a and 17b. The other end of this wire must be plugged into the micromanometer.

Now that the wiring is correct check that the computer, control box and UPM 60 are plugged in. Now switch on all three devices.

First setup the front panel as in the following section and then run the program to collect data.

5.1 SETTING UP THE FRONT PANEL

There are a few keys that it is essential the user familiarizes himself with before going any further.

On the right hand side of the front panel there is a box containing push buttons. These are the setup keys. In the top section of the box there are the four arrow keys and the two memory or 'store' keys. The upper key is for storage of a single entry and is designated by a single dot. The lower key is for group storage and is designated by two dots chained together.

The arrow keys are used for changing values so that the input can be set at desired values rather than the start-up values. The vertical arrows change the flashing value by one level. That is if the channel number is being set and the unit is flashing, then the up arrow will increase the channel number by one. The horizontal arrow keys move the cursor left or right. In simple terms it makes the option to the left or right start flashing.

In the lower section of the box are various conditions that can be set. To show which option is being changed a yellow LED lights up when the option is selected.

When the power is switched on all the lights on the front panel light up. After a short while they go off and only the light above the 'first channel' lights up. This is the prompt to start the setup routine.

Whenever a setup command has been accepted by the UPM 60 it will display the letters 'Idle'. This means that the unit is ready for the next instruction. After changing a setting and pressing one of the store keys wait until the 'Idle' display is seen before starting to input the next command.

1) If the LED above the **'first channel'** button is not on press the button. Using the arrow keys select **10** and press single storage.

2) Select **'final channel'** and set it to **20**, then press single storage.

3) The next variable to be set is the **'unit'**. Since the units for all the channels are the same except for channel 20 the group storage will be used initially and then channel 20 will be corrected.

   Press the **'unit'** button and check that its LED is lit up. Now using the vertical arrows change the lit LED to the one next to **µm/m** and press the group storage twice. This has set the units for all channels from 10 to 20 to **µm/m**.

   Channel 20 should be displayed at this point but if for any reason it is not then change the displayed channel so that channel 20 is displayed by using the vertical arrows. Now press the **'unit'** button and set the units for channel 20 to **V(mV)** using the vertical arrows. Press the single storage button twice. This has set the units for channel 20 to Volts.

4) The next variable to be set is the channel program. Again the common setting will be used with group storage and then the exceptions will be set. **NOTE** If a channel is set to be skipped it can not be reversed without switching off the UPM 60 to reset it to default settings.

   The channel program command sets three variables. They are the excitation option, the device type and whether the channel must be skipped, monitored or just measured. The monitor variable is displayed between measurements with its last reading showing.

Press the **'channel program'** key. Using the vertical arrows set the excitation option to **5V DC**. Then use the horizontal arrows to set the type of device LED flashing. Using the vertical arrows illuminate the full bridge light and press group storage twice.

Using the vertical arrows display channel **10**. Then press the channel program and set the excitation to **5kHz** and press single storage twice.

Repeat this procedure for channel **11**.

Using the vertical arrows display channel **18**. Using the horizontal arrows get the lower LED in the right hand column to flash. Then using the vertical arrows set it to **'skip'**. This is the centre setting in its range. Press single storage twice.

Repeat this procedure for channel **19**.

5) Now change the display from channel 10 to channel 20 in increments of 1 and check that the settings correspond to the following list.

CHANNEL	EXCITATION	UNITS	DEVICE TYPE
10	**5 kHz**	**μm/m**	**FULL BRIDGE**
11	**5 kHz**	**μm/m**	**FULL BRIDGE**
12	**5 V DC**	**μm/m**	**FULL BRIDGE**
13	**5 V DC**	**μm/m**	**FULL BRIDGE**
14	**5 V DC**	**μm/m**	**FULL BRIDGE**
15	**5 V DC**	**μm/m**	**FULL BRIDGE**
16	**5 V DC**	**μm/m**	**FULL BRIDGE**
17	**5 V DC**	**μm/m**	**FULL BRIDGE**
18			
19			
20		**V(mV)**	**FULL BRIDGE**

6) **Press the 'additional function'** key and then the down arrow until U30 **d20** is displayed. Press the right arrow once for the zero in U30 to flash. Now press the **up** arrow until **U31 RS 232** is displayed or **U33** for both the RS 232 and the thermal printer to operate. Press single storage.

   Press **'additional function' and** get the display to show **U40 300**. Change this to **U46 19200** and press single storage.

7) Press single cycle and see that the channel cycles from **10 to 20**.

8) Press the **'recording'** button into the on position and press **'repeat cycle'**.

The system is now set to measure data and send it to the computer.

<u>NOTE</u> Once the computer starts reading from the UPM 60, it locks the front panel control and will only release it in the middle of a cycle or if it is switched off.

6 INTERFACE PROCEDURE

6.1 WIRING TO THE STING

The wires from the sting are connected to the 25 pin connector which allows for the insertion of extension cords. The end of the cords are passed through the control box which contains the calswing circuit, to the UPM 60. The Control box is connected to the UPM 60 via a 72 pin plug

The wiring information below is for use only when making extension cords re-connecting the sting to the 25 pin D plug.

PIN NO	COMPONENT	CONNECTION
1	X	SUPPLY
2	X	SUPPLY
3	X	OUTPUT
4	X	OUTPUT
5	Y	SUPPLY
6	Y	SUPPLY
7	Y	OUTPUT
8	Y	OUTPUT
9	Z	SUPPLY
10	Z	SUPPLY
11	Z	OUTPUT
12	Z	OUTPUT
13	L	SUPPLY
14	L	SUPPLY
15	L	OUTPUT
16	L	OUTPUT
17	M	SUPPLY
18	M	SUPPLY
19	M	OUTPUT
20	M	OUTPUT
21	N	SUPPLY
22	N	SUPPLY
23	N	OUTPUT
24	N	OUTPUT

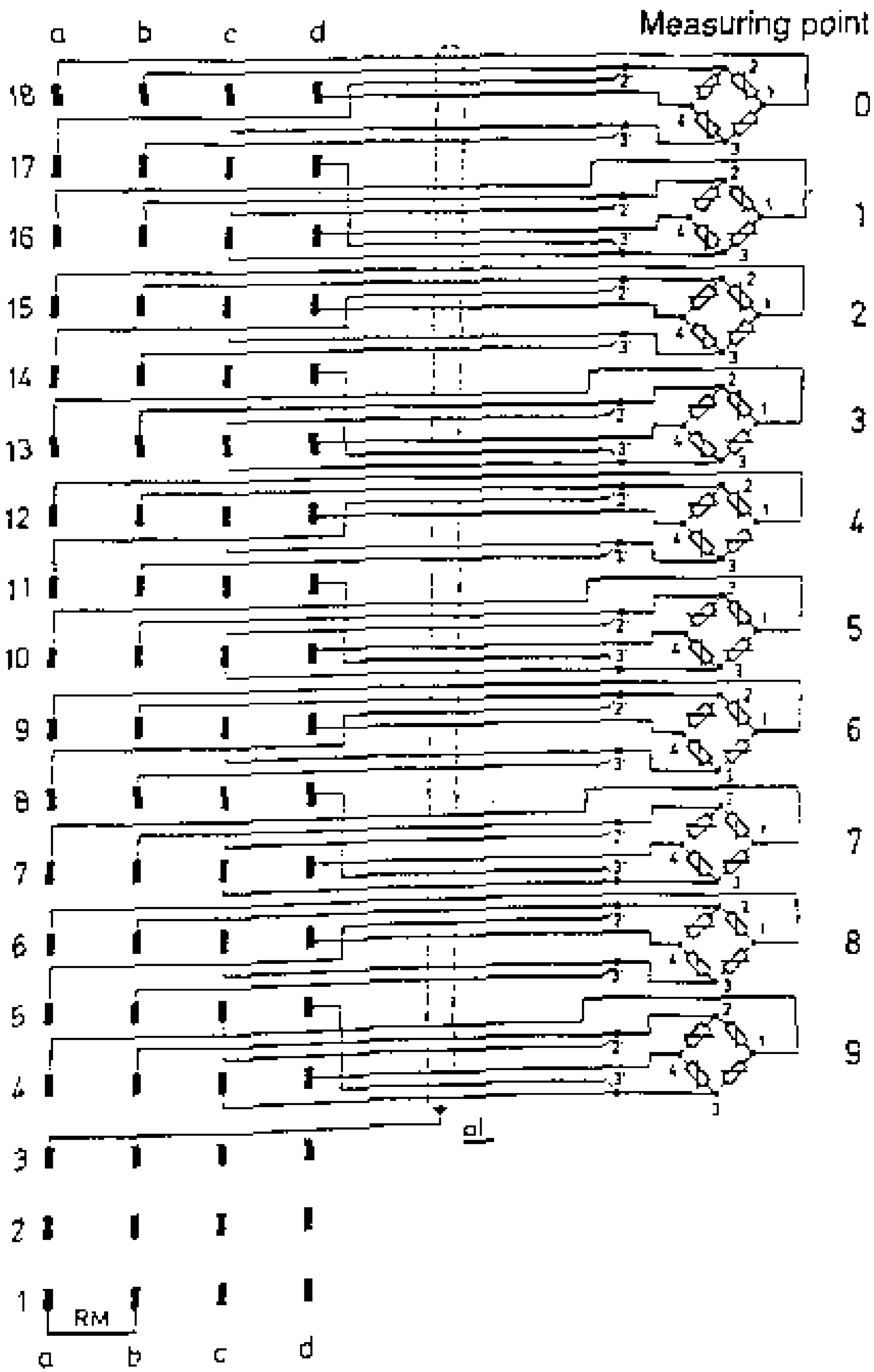
6.2 WIRING TO THE ANGULAR DISPLACE-MENT TRANSDUCERS

The wiring to the angular displacement transducers was also connected through the control box. To facilitate the removal of the system without cutting the wires a 9 pin D connector was used. The wiring table is given below.

Once again the connecter was used only between the transducers and the control box.

PIN NO	COMPONENT	CONNECTION
1	ATTACK	SUPPLY
2	ATTACK	SUPPLY
3	ATTACK	OUTPUT
4	ATTACK	OUTPUT IN CONTROL BOX
5	YAW	SUPPLY
6	YAW	SUPPLY
7	YAW	OUTPUT
8	YAW	OUTPUT IN CONTROL BOX

6.3 WIRING TO THE 72 PIN PLUG OF THE UPM 60



7 CALIBRATION OF STING

The calibration of the sting is critical as the accuracy of the results are dependant on the accuracy of the calibration. The calibration process is divided into four parts.

1: LOADING THE STING

2: MULTIPLE LINEAR REGRESSION

3: BACK SUBSTITUTION

4: COMPARISON

Instructions for each section can be found under separate headings.

When loading the sting the applied moments can be increased by either increasing the moment arm or increasing the force. It is suggested that both of these methods are used to give an accurate calibration.

On inspection of each pair of flats on the calibration body one will find five pairs of locating dimples. Numbering them from the end of the sting from one to five the virtual centre is situated in line with the fourth pair. The virtual centre is situated along the central axis of the sting, so when loading using the loading jig the central notch is designated zero and the numbers increase in the positive Y direction.

7.1 LOADING THE STING

Place the calibration stand on a flat table and weigh down the legs. The stand appears to be a short piece of 200mm x 75mm tubing with feet and lots of holes. Remove the sting from the support system within the tunnel by removing the four M5 bolts in the uprights. Attach the sting to the two short pieces of 19mm aluminium tubing and place it in the calibration stand. Re-connect the sting to the UPM 60 and switch on the computer, UPM 60 and the control box. In the directory called **tunnel** there is a program called calibrat.exe. Run this programme. First run the test shown as option 1 to see that the UPM 60 is communicating correctly with the computer. If there is an error a message will be displayed on the computer screen. If the menu returns and asks for your choice of option then the communication link is operating correctly.

Once it has been ascertained that the setup is correct insert a floppy disk in the disk drive. Ensure that the disk is formatted and has at least one file on it or the program will terminate.

Bolt the sting in the stand so that the weights will load it in the Z direction. Place the calibration body on the end of the sting and line it up so that one pair of flats are horizontal, and the other pair can be seen if looking in the positive Y direction. Now tighten the grub screw finger tight. Place the knife edged loop onto the loading jig such that the knife edge fits into the notches in the loading jig. Hang the loading jig on the calibration body and place the hanger through the loop.

The sting can now be loaded in the Z direction with Z forces and L and M moments. Run the program for different loading condition of these components.

Now place the sting in the stand to calibrate the Y force and N moment as above.

The procedure must now be repeated for the X force by aligning the sting vertically downward. To do this the calibration body must be removed and the load applied using the thin hanger through the hole at the end of the sting.

Note that the multiple regression programme can only work with vectors of up to 560 points. This means that the number of readings multiplied by the number of tests must be less than 560.

7.2 MULTIPLE LINEAR REGRESSION

The output from the calibration program must now be processed. The calibrat.exe program will do this by making use of option 2. The output file is then imported into a spreadsheet program to create a file of applied load, beta factors and finally calculated loads will be added.

The applied load for each component must be given for each reading. This means that before linear regression can be performed the worksheet must have twelve columns, the six applied loads and the six β factors. The worksheet must then be imported into STATGRAPHICS or a similar program that can perform multiple linear regression. The following instructions are for the STATGRAPHICS package and would have to be modified if another package is used.

Perform the multiple linear regression using the six β factor vectors as the independent variables and the forces and moments as the dependant variable. The intercept must be suppressed and the accuracy must be set to 99.99. The programme solves for one dependant variable at a time so the procedure will have to be repeated six times.

The output from the regression is a column vector that must be sorted so that the coefficient of β_1 is at the top and β_6 is at the bottom. This vector is transposed and used as a row in the calibration matrix with the solution for X as the top row and N as the bottom row.

Create an ascii file called stingcal.dta with the 6X6 calibration matrix in it.

7.3 <u>RE-SUBSTITUTION</u>

Copy the file stingcal.dta to the C:\TUNNEL directory and use option 4 in the calibrat.exe program. This will multiply the calibration data by the newly created calibration matrix. The output file will have the same name as the input file but will have the extension PR2.

7.4 <u>COMPARISON</u>

The output file can then be imported into the worksheet made to perform the multiple linear regression and the calculated loads can be compared to the applied loads graphically to show where the errors are more pronounced.

It is suggested that the type of graph used for this is a line plot. This means that each successive test is placed one after the other and the tests need not be numbered before the graph is created.

8 CALIBRATION OF YAW AND ATTACK TRANSDUCERS

The calibration of the angular displacement transducers is more simple than that of the sting balance. Here a simple linear regression is used and can be carried out on most programmable calculators or in a simple spreadsheet. The UPM 60 is set up as before but the system is set so that "RECORDING" is off. The system is also set to manual measurement and the relevant channel is selected (ie. 10 for ATTACK & 11 for YAW).

The reading for the set angle is noted and a linear regression is performed to give the gradient of the slope.

To calibrate the angle of attack the angle can be measured with the aid of a clinometer. Care must be taken not to place excessive loads on the sting itself.

The yaw angle can be measured with the aid of a piece of fishing tackle placed across the tunnel through the centre of the turn-table perpendicular to the flow. A protractor can then be stuck to the turn-table such that its centre is aligned with the centre of the turn-table.

At the zero yaw position the locking bolt under the turn-table fits into a notch. This is useful for re-zeroing the table before tests. Once again only the slope of the fitted straight line is used and the intercept neglected as the zero reading is subtracted from all readings before manipulation.

9 USING BWTAVG.EXE TO RUN TESTS

This programme was written primarily to run wind tunnel tests on a spinning sphere. This necessitated the incorporation of a few extra variables that are not used in conventional wind tunnel testing. An example of this is rotational velocity. This particular variable is carried throughout the manipulation of data and does not affect the processed results in any way. It therefore can be left at zero for all tests where the model is not spinning. Other variables however may not be ignored since they do affect the outcome of the processed results. Two of these are the angles of attack and yaw. If a support system other than the parallelogram system with the angular transducers is used, it must be noted that the translation and rotation of the forces and moments will have to be done by hand. It must also be noted that if the distance from the strain gauges to the centre of gravity of the model is changed, then the translation and rotation of the forces and moments will have to be done by hand since the transformation matrix setup in the programme will be invalid for this case. It is for this reason that the format of the raw data and the processed data will be given here. The file created during the processing of data prints out the forces and moments at the strain gauges, the centre of gravity before rotation and at the centre of gravity after rotation.

The programme has four options and operates in much the same way that CALIBRAT.EXE does. The four options are:

1: TEST RIG

2: RUN TEST

3: PROCESS DATA

4: EXIT

9.1 TEST RIG

This section tests the handshaking between the UPM 60 and the serial port of the computer. It will detect a communication error and certain setup errors in the UPM 60 but will not determine if the transducers are working correctly or not.

9.2 RUN TEST

The tests run using this programme collect the raw data in the form of voltages and stores them in a file using the experimenters filename and the extension .RAW. This file contains the following data:

ATMOSPHERIC PRESSURE

NUMBER OF ACTIVE CHANNELS

NUMBER OF TESTS

NUMBER OF READINGS PER TEST

ZEROS FOR EACH CHANNEL

CALSWING FOR THE SIX COMPONENTS ON THE BALANCE

ROTATIONAL VELOCITY OF SPHERE

DENSITY

TIME OF TEST AS GIVEN BY THE UPM 60

OUTPUT OF EACH CHANNEL

The atmospheric pressure need only be read once in a while and therefore it is read into the programme only before each series of tests. The number of channels is defaulted to nine. The next input is the number of tests to be run. In the case of the tests on the sphere this implied the number of tests at a particular rotational velocity, location and free stream velocity. The number of readings per test is used to give the experimenter the option to process his data as he sees fit and to give a reasonable average. The zero readings stored are the averages of ten readings taken before the tests begin. These readings should be taken without any loading on the model. The calswing values are also an average of ten readings taken without experimental load. Before each test the rotational velocity is inserted into the computer via the keyboard. The tunnel temperature is also inserted at this point. This is used to determine the density of the air in the tunnel which is then stored. Each set of readings is stored with the time. If the time on the UPM 60 has not been set during setup this will just give an indication of the time between readings.

The layout of the Fn.RAW file is as follows where # denotes number.

1 Atmospheric pressure, # of channels, # of tests, # of readings per test

2 Zeros for each channel

3 Calswing from channel three to eight

4 Rotational velocity for test 1, Density for test 1

5 Time for reading 1

6 Output for reading 1

Lines 5 & 6 are repeated according to the number of readings per test specified by the experimenter. After this lines 4 to 6 are repeated according to the number of tests specified by the experimenter. This file is stored as an ascii file on floppy disk and can be accessed by use of any text editor.

9.3 PROCESS DATA

This section can be used if the test was run using BWTAVG.EXE option 2 as long as the distance from the strain gauges to the centre of gravity remains 0.201m. The translation and rotation may still have to be carried out by hand but the transformation matrix converting from raw data to forces and moments will still be valid.

The output is given in the form of the average force or moment or other variable for each test. The layout of the file called Fn.PRA is as follows:

# of tests, # of readings

Density, Velocity, Rotation, Attack, Yaw, X, Y, Z, L, M, N, X, Y, Z, L, M, N, X, Y, Z, L, M, N

10 PROCEDURE FOR WRITING PROGRAMMES TO RUN TESTS

The procedure suggested here is based on personal experience. You can use any language of your choice as long as it can control a serial communication port, but it is suggested that the language that is chosen can be compiled to give a faster rate of reading.

The first thing to remember is that all raw data should be saved in a file. This is in case there is an error in the manipulation of the data, it can be re-manipulated without the necessity to rerun the entire test or set of tests.

The conditions that do not change from reading to reading like atmospheric pressure, should still have the capability to be modified between tests in case there is a delay in testing and a storm is brewing. This can result in a significant change in atmospheric pressure.

Allow a variable to maintain its value until the operator intends changing it without having to type it in continuously as this is time consuming and tiresome. Also enter all those conditions that are not part of the actual testing like atmospheric pressure and temperature, before taking any readings so that once the test commences it can be completed as quickly as possible with as little running around as possible. It is suggested that the data is stored after each set of reading so that should the system hang up or a power failure occur the minimum amount of work is lost. For this reason it is also suggested that the data files remain closed as much as possible, since if the file is open at the time of a power failure it will be lost completely. The problem of power failures may appear to be an unnecessary precaution but it must be remembered that the equipment is in a laboratory with lots of other people using many different types of equipment and not always thinking of who might be affected if they trip a circuit or switch it off for modification.

If the system has been set up as instructed above then the routine to read in the data is given below.

```
22000 REM TAKING READINGS -----------------------------------------------------
22010 OPEN "COM1:19200,E,7,2" FOR INPUT AS #1 LEN = 8000
22020 FOR I = 0 TO NN
22030 FOR J = 1 TO NCHAN + 2
22040 AA$(I, J) = INPUT$(22, 1)
22050 NEXT J
22060 NEXT I
22070 CLOSE #1
```

The numerical values of the relevant readings may be obtained by using the following routine.

```
20860 FOR I = 1 TO NRED
20870 TTIMES$(I) = MID$(AA$(I, 1), 7, 8)
20880 FOR J = 1 TO NCHAN
20890 DAT(I, J) = VAL(MID$(AA$(I, J + 1), 7, 9))
20900 NEXT J,I
```

The data is now in DAT(I,J) and can be used as required. Where TTIMES is the time variable, NN = NTEST - 1 and Ntest is the number of tests, NRED is the number of readings and NCHAN is the number of channels.

11 RECIPE FOR USING THE SYSTEM

1) Switch on all the electrical equipment about one to two hours before the time intended for its use.

2) Set up the front panel as set out in section 3.1.

3) Leave the system to settle for between one and two hours.

4) You are now ready to run a test.

5) When the test is completed please switch off all equipment and park the computers hard drive.