WIND TUNNEL INSTRUMENTATION SYSTEM

INSTRUCTION MANUAL

CALIBRATION UNITS

X	MM	0.38
Y	MM	2.98
PRESS	MM of WATER	1.39
LIFT	Kg	7.96
DRAG.	Kg	1.02

INSTRUCTION MANUAL

WIND TUNNEL INSTRUMENTATION SYSTEM

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402B model
150 ft/sec
10 HP

CONTENTS

Description of the System

The **ELD** Wind Tunnel Instrumentation System is a complete basic instrument package which has been designed for use with subsonic wind tunnels in undergraduate student laboratories. Its functions include the measurements of lift and drag forces, static and dynamic pressures and the reporting of the axial and vertical position (X, Y coordinates) of a traversing probe. The system consists of 3 major components: the dynamometer assembly, the probe traversing assembly and the meter cabinet. (Figure 1).

Meter Cabinet The cabinet contains a printed circuit board, DC power supply, a DC voltage digital panel meter (the readout), 2 signal conditioner chips (lift and drag) and a pressure transducer. A mode selector switch, pressure selector valve, digital display and a power switch are presented on the front panel. Because of the visual interest to the student of the internal components, the back of the cabinet is fitted with a clear plexiglass panel. Calibration potentiometers and DIP switches for decimal point selection are arrayed on the back panel together with signal cable and pressure tube connectors.

The 5 operating modes are switch selectable and displayed on the digital panel meter in the selected engineering units. Analog output signals (simultaneous from all 5 modes) are available from a port at the back of the meter cabinet. (Figure 2).

Pressure Transducer A differential type consisting of a precision pressure capsule, a linear variable differential transformer (LVDT) and excitation, demodulation and amplification circuitry. Pressure is applied to the sealed cavity surrounding the pressure capsule. The reference pressure , either atmosphere or the test section static pressure, is applied to the interior of the capsule. The capsule deflects linearly in response to the differences in the applied pressures. The movable core of the LVDT is coupled to the pressure capsule and is translated within the LVDT armature as the capsule deflects. The resulting output voltage from the LVDT is proportional to the applied differential pressure. (Figure 3).

Pressure sensings are acquired from the test item via small bore tubing. The selector valve connects one of up to 9 sensings (including TOTAL pressure) to the transducer capsule. When the pressure mode is selected the measured differential pressure is displayed on the digital meter in the engineering units for which the system is calibrated, ie; inches of water, Bar, etc. The range of the transducer, which is normally supplied, is 0 to ±10"WG. Please consult the manufacturer's documentation accompanying the equipment for additional information and specifications.

Dynamometer Assembly The dynamometer is a two component device which is arranged for mounting on the external floor of the test section to measure lift and drag forces. The apparatus uses two pairs of restrained, cantilevered beams, separated by spacer blocks, for each axis. Forces generated by the model under test are conveyed to the dynamometer via a stiff strut and result in the deflection of the beam assemblies. These deflections are proportional (within range) to the magnitude of the applied forces. The deflection of each beam assembly is sensed by an LVDT (the armature moves with the deflecting beam and the core is fixed to the base block but adjustable for "zeroing"). Output voltage signals from the LVDT are demodulated and amplified by signal conditioning circuits. The resulting DC voltages represent the direction and magnitude of the applied forces and may be calibrated to readout in any desired engineering units, ie; pounds force, Newtons, etc. A shroud shields the major portion of the force strut from the air stream. (Figure 4).

Probe Traversing Assembly The two axis traversing mechanism is capable of positioning and reporting the location of a probe at any point in the upstream 75% of the test section vertical centerline plane. The device is driven manually via two handwheels and precision, high helix, aluminum lead screws running in polyurethane nuts (the longitudinal drive on the 24" test section uses a precision molded chain and sprocket arrangement). Minimal "backlash" is a characteristic of the drive system. Precision potentiometers are secured to the drive screws and report the location of the probe in each axis. The voltage signal from each potentiomenter is transmitted to the meter

The probe can be traversed from the floor to the ceiling and may be withdrawn through the neoprene seal in the cover slot. Longitudinal traverse begins near the upstream face of the test section. It's travel downstream is limited only by the horizontal dimension of the probe support assembly.

Two probes, a boundary layer total head tube and a pitot/static tube are furnished.

Standard Test Section Features The test section cover is removable and mounts the traversing assembly. Quick release fasteners align and secure the cover to the test section.

An access port is provided in the front sidewall (4" diameter on the 12" test section and 6" diameter on the 18" and 24" test sections). The port is closed during operation by a flanged plexiglass plug. Several of the models use dedicated plugs as mounting fixtures. A degree indexed scale surrounds the port. Stainless steel thumb screws secure the plug in the port. An aperture is provided in the test section floor for mounting the dynamometer. Metal inserts insure the longevity of the threaded mounting holes. A plexiglass plate with insert closes the opening when the dynamometer is removed. (Figure 1).

Installation and Operation of the Equipment

Meter Cabinet Position the cabinet on a bench or stand near the test section and at a convenient working height. A heavy wire bail is provided to permit the front panel to be inclined. Secure the two cable assemblies to their respective connectors at the rear of the cabinet. It is important to utilize the retaining screws. The cable assemblies are arranged by size and configuration so that they cannot be incorrectly installed.

The standard meter assembly requires 115 VAC/60 Hz/single phase electric service. Units prepared for export are arranged to operate on 220 VAC/50 Hz/single phase. A demountable service cord is furnished. A 1/2 amp fuse is installed in a fixture on the printed circuit board. The interior of the cabinet is accessed by removing the screws that retain the supporting pads on the bottom of the unit and lifting off the top.

The power switch, function controls and readout are located on the front panel of the instrument. Any one of the 5 operating modes may be selected for display by rotating the switch to the appropriately labeled index position. (Figure 5).

A rotary valve, located on the left side of the panel, selects the desired pressure sensing. See figure 6 for valve position vs. tube color identifier. A push-on-and-lock bulk head tube connector is mounted on the back panel. A 6'long, multicolored, tubing bundle is furnished with a mating connector to convey pressure sensings from the test item in the working section. 9 tubes are used. Separate tube connectors, located adjacent to the bulk head connector, are used for TOTAL pressure sensing and test section STATIC pressure measurement. Individual clear tubes are furnished for this service.

An analog output port is located at the lower left side of the back panel. A mating connector is furnished. Interface wiring is left to the user. A pin out identifier listing is found on figure 6.

Adjustment of the trimming potentiometers and the DIP switches is addressed in the calibration section

Dynamometer The dynamometer assembly is robustly built but should be treated with the same care as a quality SLR camera.

Installation of the dynamometer on the test section is a straight forward operation. Remove the plexiglass plate that closes the floor aperture. It is generally good practice to remove the test section cover as well. Orient the unit with the cable connector facing the port side of the test section and carefully insert the shroud through the floor aperture. Bring the base flush with the floor and aline the mounting holes. Using the appropriate tee handle allen wrench, install and tighten the furnished 10-24 x 1" long socket head screws. Insert the cable connector and secure the retaining screws. Install the appropriate strut (air foil or drag model) in the dynamometer base block and fasten with the 6-32 screws which are furnished. Select and install the desired model. Observe the lift and drag display and remove "tare" loads by adjusting the brass "zeroing" thumbwheels so that a 0000 display is presented while the tunnel is at rest.

Replace the test section cover and wall port plug if they have been removed. Start the wind tunnel fan, establish an appropriate air speed and observe and record the desired data.

To remove the dynamometer, first detach the test model and the signal cable and then carefully loosen the mounting screws while supporting the assembly with the hand. Withdraw the unit from the test section and store it in a safe place.

Probe Traversing Assembly The 12" wind tunnel cover, with the traversing device installed, can easily be handled by one individual. The 18" and 24" sizes generally require two persons to lift and position the assembly.

CAUTION: To avoid damage, insure that the probe is withdrawn through the cover seal before placing the cover on a flat surface such as a table or bench. The lead screws are made of aluminum and can be rendered unserviceable by mishandling. Avoid bumping the screws or dropping heavy objects on them.

Install the traversing assembly/cover on the test section. Use care in placing and aligning the quick release fasteners. Connect and secure the cable connector.

The numerical origin for the vertical, "Y", axis is the test section floor. Turning the "Y" handwheel clockwise moves the probe toward the floor and turning counter-clockwise moves it toward the ceiling. The datum for the longitudinal, "X", axis, is a line near the upstream end of the test section. Turning the "X" handwheel clockwise moves the assembly downstream, turning the handwheel counter-clockwise moves the assembly upstream. Select the switch positions "X" and "Y" ,on the meter, to display the distances from the datum point.

Two standard probes are furnished; a total pressure probe for boundary layer survey measurements and a miniature pitot/static tube for wake surveys and general investigations. Both use compression fittings with brass ferrules to seal to the stem tube and to permit convenient interchangeablity (a similar arrangement can be used to mount other probes such as a hot wire device). A small barbed fitting is provided at the top of the probe stem to connect the TOTAL pressure tube. A similar fitting is found on the bottom of the test section near the upstream end and is useful as a test section static pressure reference tap. Connect the STATIC tube to this fitting if desired.

Calibration Procedure

General The calibration technique used is to attenuate the amplified voltage signal from each transducer by adjusting the resistance of a precision potentiometer to yield a voltage in the range of ± 15 VDC representing the value of the desired engineering units.

Six potentiometers, fitted with turns counters and lever locks, are found on the back panel of the cabinet. Each is identified by name of function, ie; LIFT SPAN, etc. Five DIP switches, for decimal point location selection on the digital display, are accessible at the lower left side of the panel.

Dynamometer

Lift Component

1. Remove the dynamometer from the test section and and mount to the calibration fixture as shown in figure 4 or clamp the unit on a table or bench with the strut and shield extending beyond the edge.

2. Set the mode selector switch to LIFT and adjust the digital display to "zero" by turning the LIFT LVDT core thumbwheel.

3. Load the LIFT beams with known weights [hook type weights (either pounds or grams) are furnished with the calibration set] equal to the maximum range rating (see table, figure 7). Adjust the LIFT, SPAN potentiometer so that the digital display yields the desired units, ie; lbsf or Newtons. Using a pencil point or a small screw driver select the appropriate decimal point position on the LIFT DIP switch. The lever on the turns counter should be locked and the counter number recorded.

4. Demount the weight load. Verify the "zero". Adjust if necessary.

5. Reload the weights used in step 3. Adjust the display if necessary.

6. If desired, the linearity of the dynamometer can be verified by applying decreasing loads of known weights and recording and graphically plotting results of known weight vs: digital display. Lock the potentiometer setting and record the turns counter number if desired.

Drag Component

1. Remount the dynamometer on the test stand so that the drag beams may be gravity loaded.

2. Set the mode selector to DRAG and adjust the digital display to 0000 by turning the DRAG LVDT thumbwheel.

3. Load the dynamometer with known weights and adjust the DRAG, SPAN potentiometer and DIP switch following the procedure described above under "Lift", steps 3 through 6.

Pressure Transducer

1. Set the mode selector to PRESSURE.

2. Connect the clear tubing marked TOTAL to the valved tee fitting on one leg of the calibration air/water manometer (see the reference drawing, figure 3). Set the selector valve to the "0" position. Note that the other leg of the manometer and the tube marked STATIC are open to the atmosphere. Insure that the manometer columns are plumb using the adjusting screw and the spirit level mounted on the base.

3. Adjust the digital display to 0000 using the potentiometer identified PRESSURE, ZERO. (The transducer should be allowed a "warm up" period of approximately 10 minutes to stabilize the "zero" setting. Also, note that the "zero" will shift slightly when the cabinet leg is used. The instrument resolution is ±0.001" WG. A slight "zero" offset is significant only at very low pressure differences).

4. Open the valve at the tee and, using the rubber bulb, apply a pressure, equaling the maximum range of the transducer (standard, 10" WG), to the manometer and the transducer. Close the valve.

5. Adjust the PRESSURE, SPAN potentiometer so that the desired engineering units are displayed on the digital meter,ie; inches of water, TOR, kPa, etc.

6. Open the valve to vent the system. When the manometer fluid is at level rest, check and if necessary, adjust the "zero". Close the valve and reapply pressure as in step 4. Refine the digital display as in step 5, if necessary. Lock the potentiometer setting and, if desired, record the turns counter display for future reference.

7. Disconnect the manometer and reattach the TOTAL and STATIC tubing to the test section.

Traversing Probe Assembly

The test section cover should be mounted on the test section when the calibration is performed.

"X" Position

1. Set the mode selector to "X". Traverse the assembly to the upstream end of the test section (until it stops). The digital meter should display "zero". (If necessary the "zero" can be adjusted by loosening the set screw securing the potentiometer shaft and turning either the shaft or the lead screw. Retighten the set screw.)

2. Traverse the assembly downstream. Insert the precision scale (12" or 18") between the vertical plexiglas part at the upstream end of the cover and the face of the linear bearing on the traversing carriage. Adjust the "X", SPAN potentiometer to display the desired units, ie; inches, feet or SI units. Lock the potentiometer setting and, if desired, record the number.

"Y" Position

1. Set the mode selector to "Y". Remove the wall port plug. Position the probe end of the stem in the vicinity of the wall port. Install the desired probe. Traverse the probe toward the test section floor and then carefully bring it to contact with the surface of the floor. If necessary loosen the set screw securing the potentiometer shaft to the lead screw and adjust the display to "zero".

2. Hold the metal scale directly in front of and in

line with the probe tip. Traverse the stem upward to either the centerline or all the way to the ceiling of the test section. Accurately position the lower surface of the probe opposite the desired the major linear division. Turn the "Y" SPAN potentiometer so the desired units are displayed on the digital meter. Again, the turns counter number can be recorded if desired.

Model Set and Suggested Experiments

Airfoils Two airfoil sections are available with the standard set; NACA 0012 and NACA 4412 (other sections can be fabricated on a custom basis). These models are precision castings made using a filled epoxy resin. The material is quite strong but the models will not survive being dropped onto a concrete floor. 4" cord foils are furnished with the 12" test section set. 6" cord models are furnished with the 18" and 24" sizes. Two dimensional airfoils, one with pressure tap arrays and a second arranged for mounting to the dynamometer strut, are available. Refer to the reference figures for profiles (stations and ordinates) and pressure tap location data.

Suggested investigations include:

Measurement of static pressure distribution on upper and lower surfaces at various velocities and attack angles. Development and plots of pressure, lift and drag coefficients and comparisons with published data.

Direct measurement of lift and drag forces at various attack angles and velocities.

Wake surveys using the traversing probe.

Pressure Airfoil These airfoils are mounted to plexiglass wall plugs and are fitted with a small brass pin at the opposite end. The foil is inserted through the wall port and the pin is engaged in a hole in the far side wall of the test section. The airfoil's angle of attack is set by aligning the scribed index line on the edge of the plug with the degree scale surrounding the wall port. The individual numbered or color coded tubes are pushed onto the fittings on the plug leading from the pressure taps and the bulkhead connector is secured to it's mating connector at the back of the meter cabinet. Note that the NACA 0012 has only upper surface taps. Lower surface measurements can be made by setting the airfoil at a comparable negative attack angle.

Dynamometer Mounted Airfoil These airfoils are fitted with an aluminum insert block for fastening to the strut.

Mount the dynamometer as described earlier. Remove the test section cover. Fit the strut (it can be identified by it's oblique end) to the insert block on the airfoil. Thread a small socket head screw into the forward hole (the pivot) from the back side (opposite the port) of the insert and into the threaded hole in the strut. Snug the screw up finger tight. The aft screw on the insert secures the airfoil at specific attack angles. Fit the wall plug, scribed with the airfoil profile and cord line, into the wall port. Set the scribed index on the plug flange at the desired attack angle and tighten the thumbscrews. Adjust the angle of the airfoil so that the scribed profile is exactly superimposed over the airfoil. Tighten the aft screw using the supplied "L" shaped allen wrench. Set the mode selector switch to LIFT (and/or DRAG). Adjust the lift, and if necessary drag, "zeroing" thumbscrew to remove the "tare" weight of the model while the system is at rest.

Drag Model Set The standard set includes a smooth sphere, a roughened sphere, a chamfered disk, a cup and a hemisphere. The bodies for the 12" set are 2" diameter and the 18" and 24" sets are 3" diameter.

Remove the test section cover. Install the dynamometer with the drag model strut in place (identified by the threaded horizontal sleeve on the top). Screw the "sting" from the selected model into the threaded sleeve at the top of the strut. Set the mode selector switch at DRAG and adjust the drag "zeroing" thumbscrew to remove "tare" weight from the "at rest" digital display.

Start the wind tunnel fan and record the drag forces at various speeds for the assorted models. Calculate and plot drag coefficients.

The larger, 3" diameter, smooth sphere is suitable for use as a Turbulence Sphere. The method is to measure the drag at many tunnel speeds and then compute and plot the drag coefficient. The drag coefficient is then plotted against the calculated Reynolds number. The Reynolds number at which the drag coefficient equals 0.3 is termed the critical Reynolds Number (RN_C). Turbulence Factor = $385{,}000/RN_C$

Other bodies, with the same projected areas as the primary models, can be built by students and tested.

Boundary Layer Plate The plate is fabricated from precision ground, low carbon steel with a selenium oxide surface finish. The machined knife edge is a 15^{o} angle. Four struts are furnished which support the plate at the test section horizontal centerline. The struts have short studs at one end which screw into tapped holes in the lower surface of the of the plate. They are secured to the test section floor with 10-24 flat head machine screws. Note that 1/4-20 flat head screws close these mounting holes when the plate is not in use.

The plate is protected from corrosion with a light oil film and should be wiped with a clean cloth prior to use. It is good practice to reoil the plate and provide some protection for the leading edge during periods when it will not be in active use.

Remove the test section cover. Thread the struts into the bottom surface of the plate. Lower the plate into the test section and position the struts over the mounting holes. Thread the 10-24 screws from the bottom of the test section into the lower end of the struts and snug them tight with a screw driver. Fit the total pressure boundary probe into the traversing probe stem. Lift the test section cover, with the traversing probe, into position on the test section. Move the probe near the open wall port and inspect the orientation of the boundary probe to insure that it is parallel to the test section axis (the tube is quite stiff due to work hardening during the forming process, however, it can be adjusted by careful bending with the fingers). Minor variations in the plexiglass floor surface may bring the plate out of plane with respect to the axis of travel of the traversing assembly. It is possible to use the support struts as screw jacks and correct this discrepancy if it is observed. Connect the TOTAL tube to the fitting at the top of the traversing stem.

Set the pressure selector valve to the 0 position. The "X", "Y" and PRESSURE mode selections are used. Traverse the probe assembly so that the boundary probe is flush with the leading edge of the plate and just touching surface (but not deflecting the stainless steel probe tube). Record the X and Y positions of the leading edge of the plate for use as datums.

The boundary layer profile measurement procedure is straightforward. Establish a longitudinal and vertical measurement station table and traverse axially and vertically to each station, recording the total pressure at each point. Plot and compare the measured data to predicted values.

Cylinder The device is a smooth brass tube (3/4" diameter for the 12" set and 1 1/2" diameter for the 18" and 24" sizes) with one pressure tap at mid span. The tube is mounted to a plexiglass plug and has a small diameter pin at the opposite end.

Insert the cylinder into the test section through the wall port and engage the pin in the hole on the opposite side wall. The flange of the plug has a scribed index which relates the radial location of the pressure tap to the degree scale surrounding the wall port. Positioning the index at 0° orients the cylinder pressure tap at the stagnation point. Set the mode selector at

PRESSURE and connect one of the colored tubes (No. 1 ?) to the fitting on the cylinder plug. Turn the selector valve to the selected position.

Measurements of the pressure distribution about a cylinder can be obtained by successive observations as the wall plug mounted to the tube is rotated.

The traversing probe may be used in a wake survey mode downstream of the cylinder.

Storage/Maintenance

The instrumentation system components should be stored in a secure dry area when the equipment out of service. A good practice is to routinely cover the traversing assembly/test section and the meter cabinet with a simple cloth drape when it is no in use. The tools and spare parts and perhaps the smaller models could be kept in sturdy wood or plastic box or a small tool chest.

Mild cleaning solutions and soft cloths should be employed for cleansing the apparatus, models and the test section.

The airfoil models may warp if they are stored unsupported for extended periods. Insure that the free airfoil is laid flat on the upper surface and that the pressure foil is stored vertically or with the wing surface supported horizontally.

The boundary plate should be reoiled and the knife edge protected with a cardboard or wood guard prior to placement in storage.

Warranty/Service

ELD warrants its new products to be free of defects in workmanship and material for a period of one year from the date of delivery. Our warranty obligation with respect to components incorporated in our products , but not of our own manufacture, is limited to the warranty actually extended to us by our suppliers. (All components have a least a one year warranty but conditions are variable).

We will not be responsible for any damage or losses, direct or indirect, caused by or to the equipment by outside influences, including improper installation or modification, abrasion, corrosion, electrolysis, improper electrical supply, or careless handling, nor for transportation or other charges incurred in the replacement or replacement of defective equipment.

Any equipment that proves to be defective within the warranty period will, if returned to our plant, with transportation prepaid, be repaired or replaced free of charge, FOB: plant. Before returning materials, claimed to be defective, please contact us for return authorization and shipping instructions.

We reserve the right to substitute new or improved equipment as replacement components.

Maintenance and repair service for equipment whose warranty has expired can be arranged for by the company.

Bibliography

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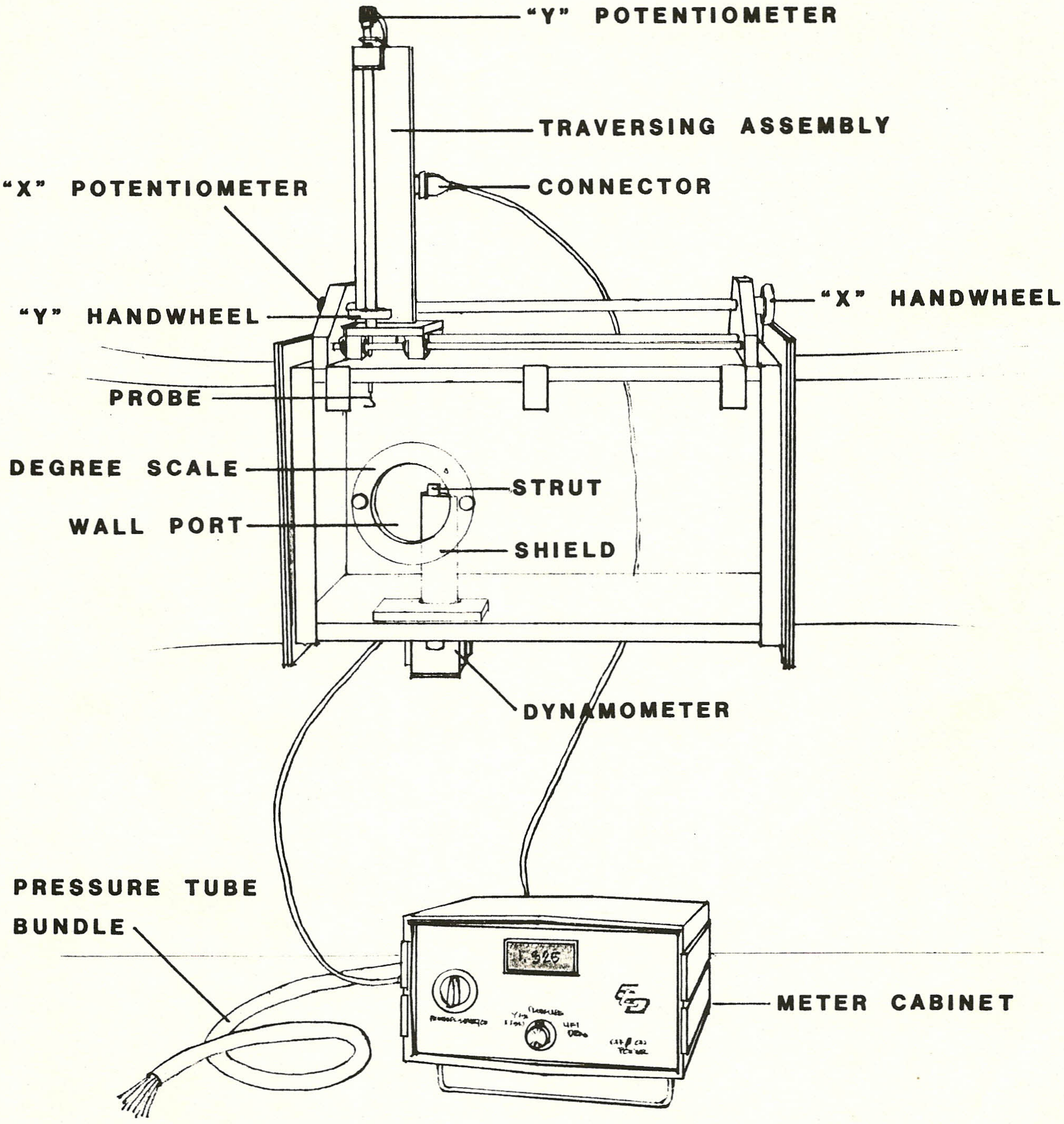
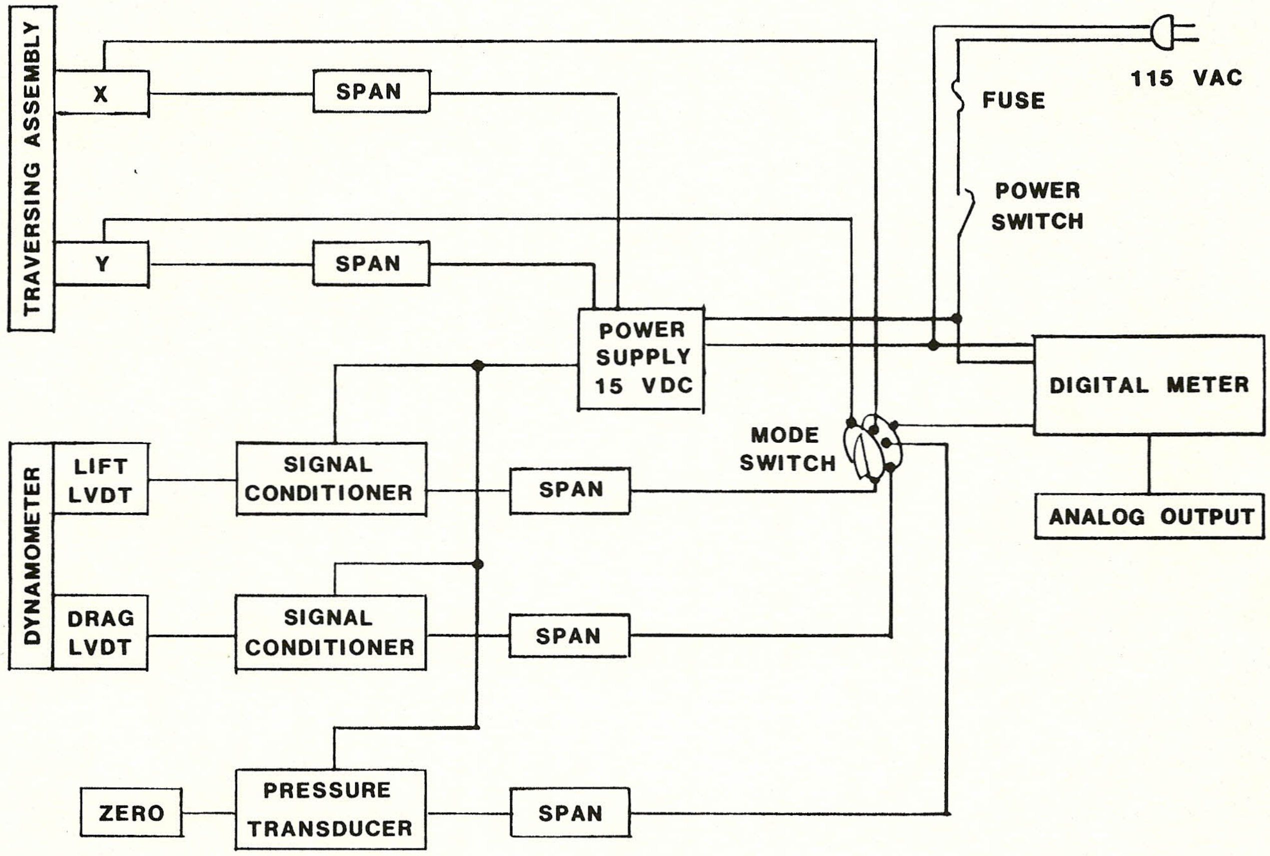
Theory of Wing Sections; Abbott; Dover Publications; ISBN 486 60586 8

Essentials of Engineering Fluid Mechanics; Olson; International Textbook Co.



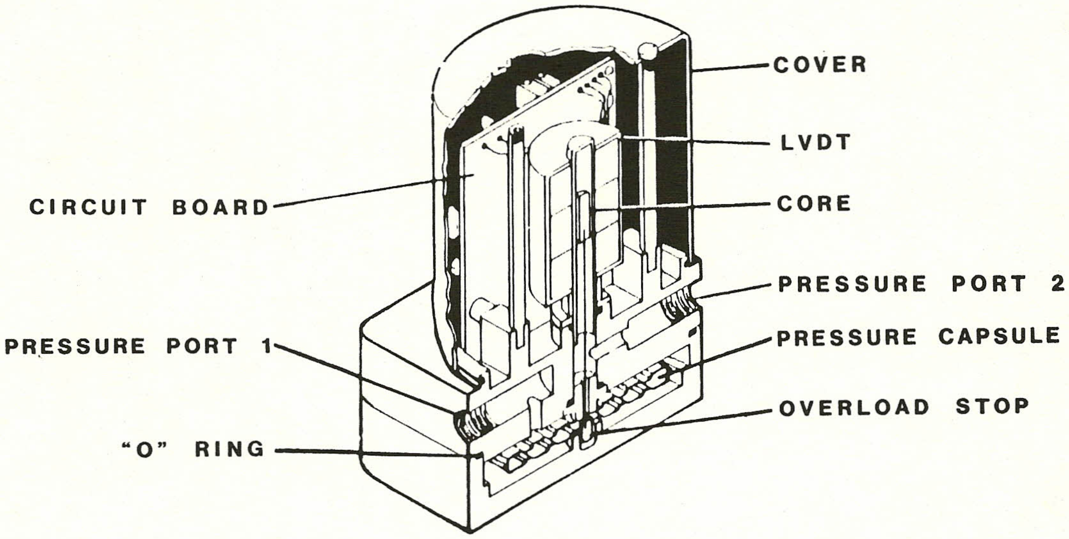
INSTRUMENTATION SYSTEM COMPONENTS

Figure 1

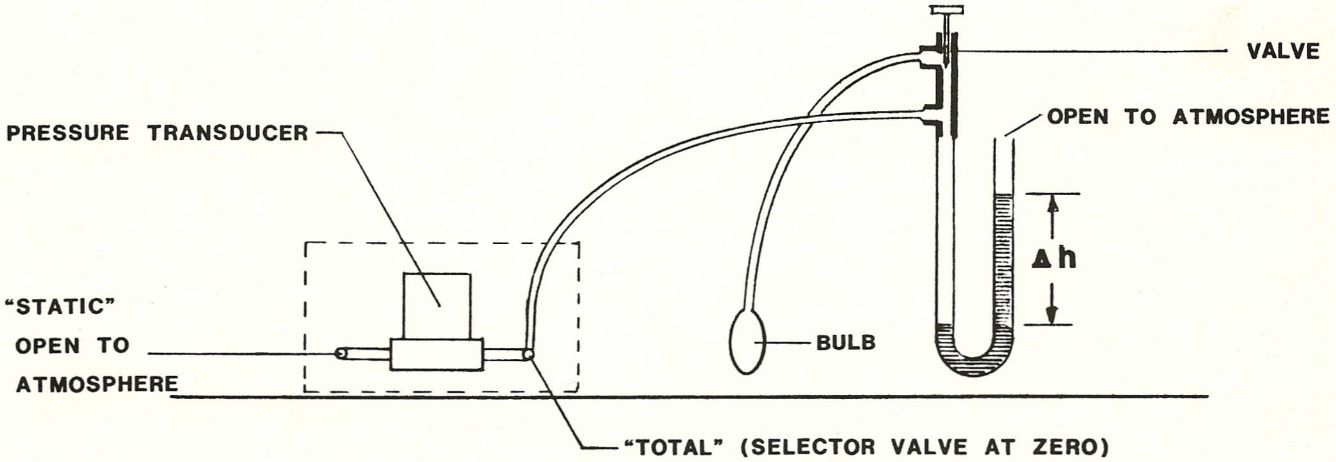


SCHEMATIC DIAGRAM

Figure 2

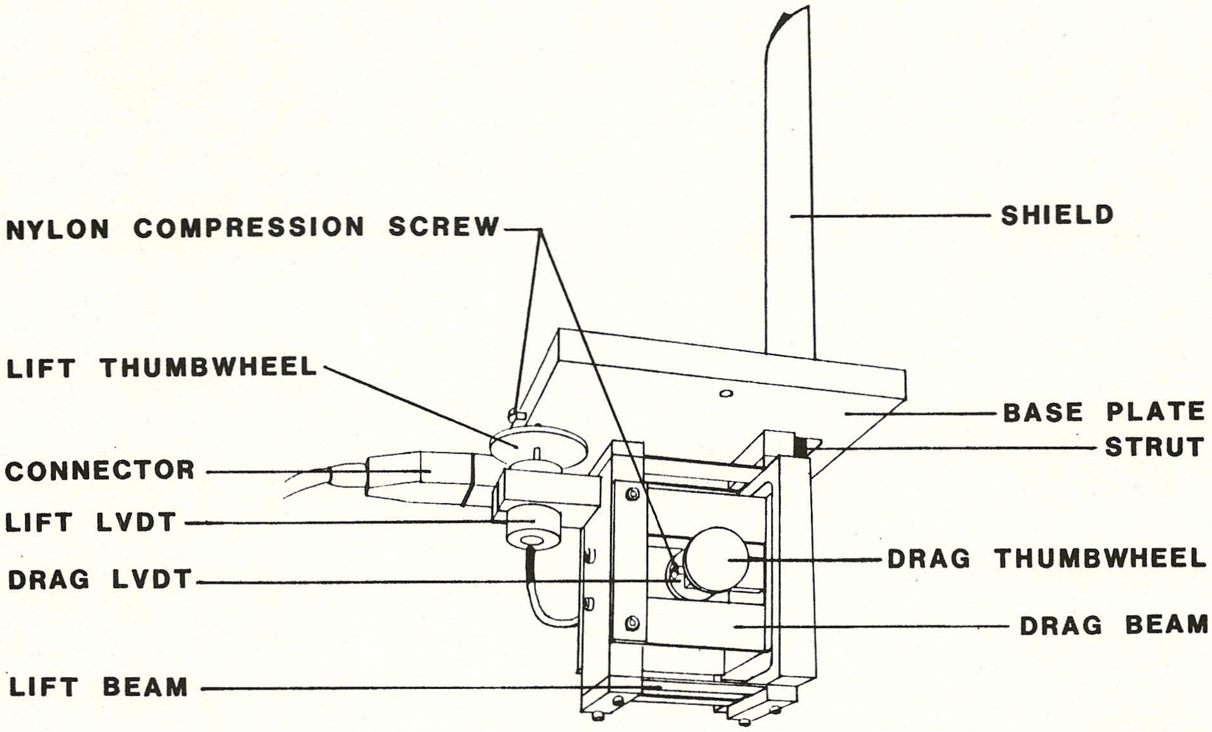


CUTAWAY VIEW OF PRESSURE TRANSDUCER

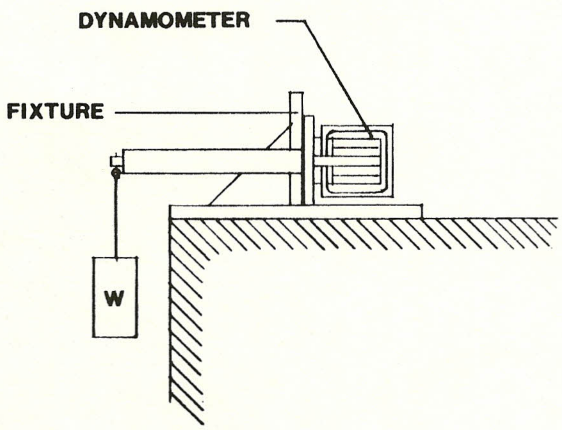


CALIBRATION ARRANGEMENT

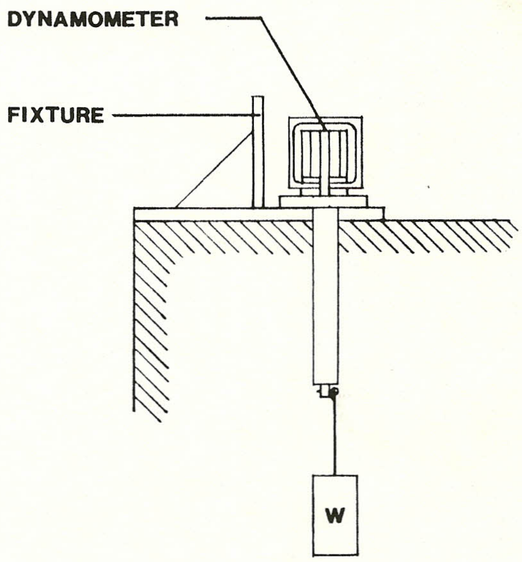
Figure 3



DYNAMOMETER ASSEMBLY



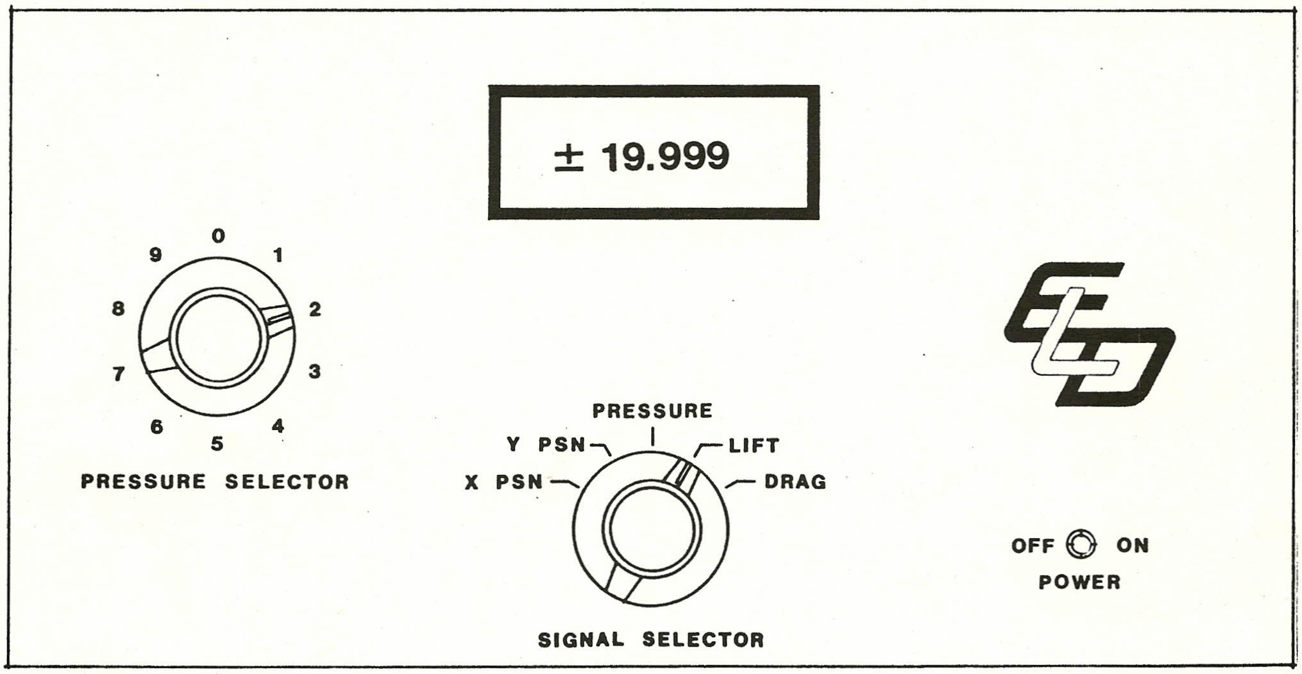
DRAG



LIFT

CALIBRATION ARRANGEMENT

Figure 4



METER FRONT PANEL

Figure 5

PRESSURE TUBE ASSEMBLY IDENTIFIER

Valve Position	Color
1	WHT
2	BRO
3	YEL
4	RED
5	VIO
6	GRN
7	BLU
8	ORG
9	GRA
10	NOT USED

NOTE: Valve position "0" selects the TOTAL pressure tap.

ANALOG OUTPUT PIN IDENTIFIER

Pin	Function	
✓ 1	Pressure	Brown
✓ 2	Lift	Blue
✓ 3	Drag	Green
4	"X" Position	
5	"Y" Position	
6	Spare	
✓ 7	Ground (Pressure)	Red
✓ 8	Ground (Lift)	Yellow
✓ 9	Ground (Drag)	Black
10	Ground (X)	
11	Ground (Y)	
12	Spare	

Figure 6

FULL SCALE RANGES FOR STANDARD VERSIONS

12" Test Section / 150 fps

Pressure transducer	0 to ± 10" WG differential
Lift	8 lbsf
Drag	5 lbsf

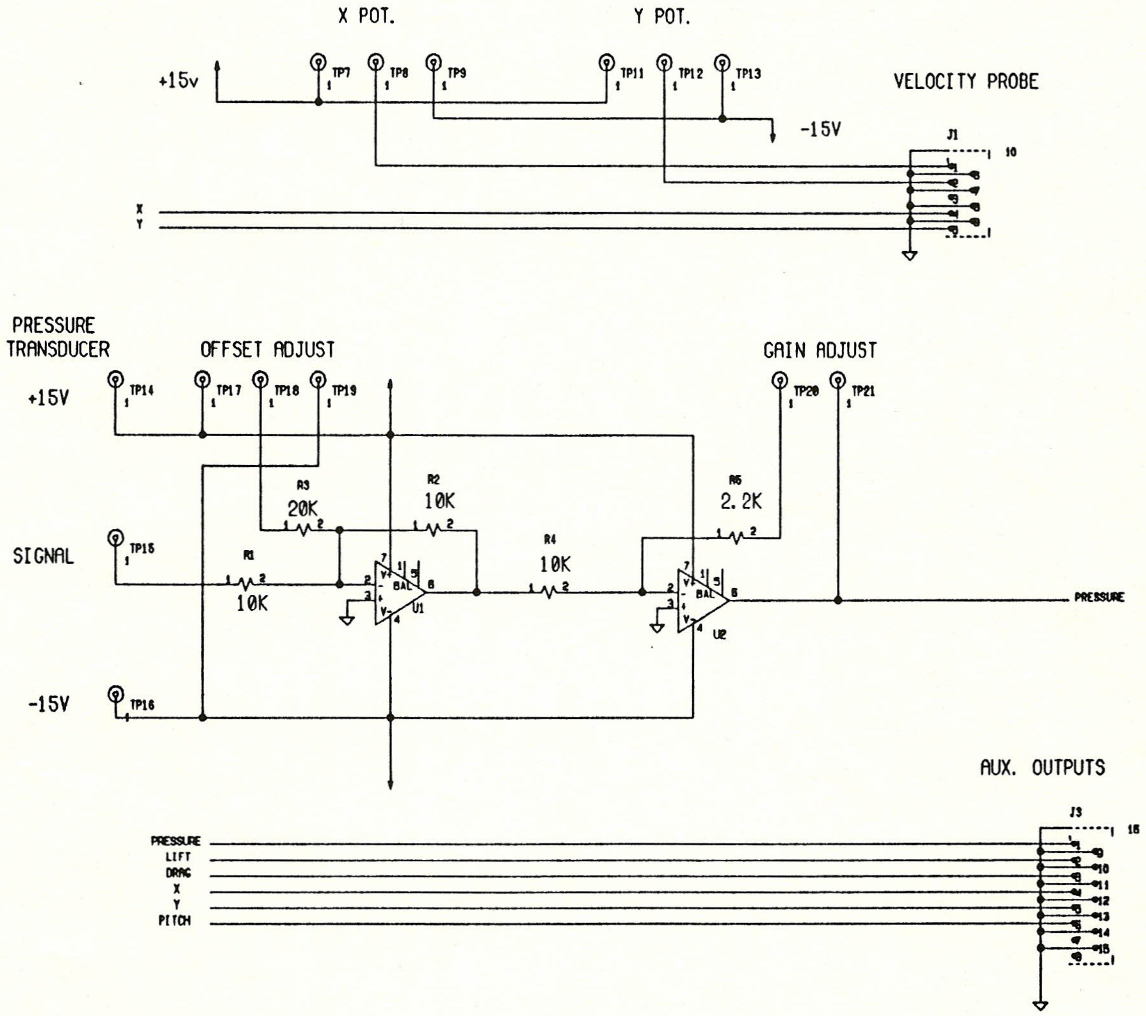
18" Test Section / 150 fps

Pressure transducer	0 to ± 10" WG differential
Lift	15 lbsf
Drag	8 lbsf

24" Test Section / 150 fps

Pressure transducer	0 to ± 10" WG differential
Lift	20 lbsf
Drag	8 lbsf

Figure 7



X, Y AND PRESSURE CIRCUITS	
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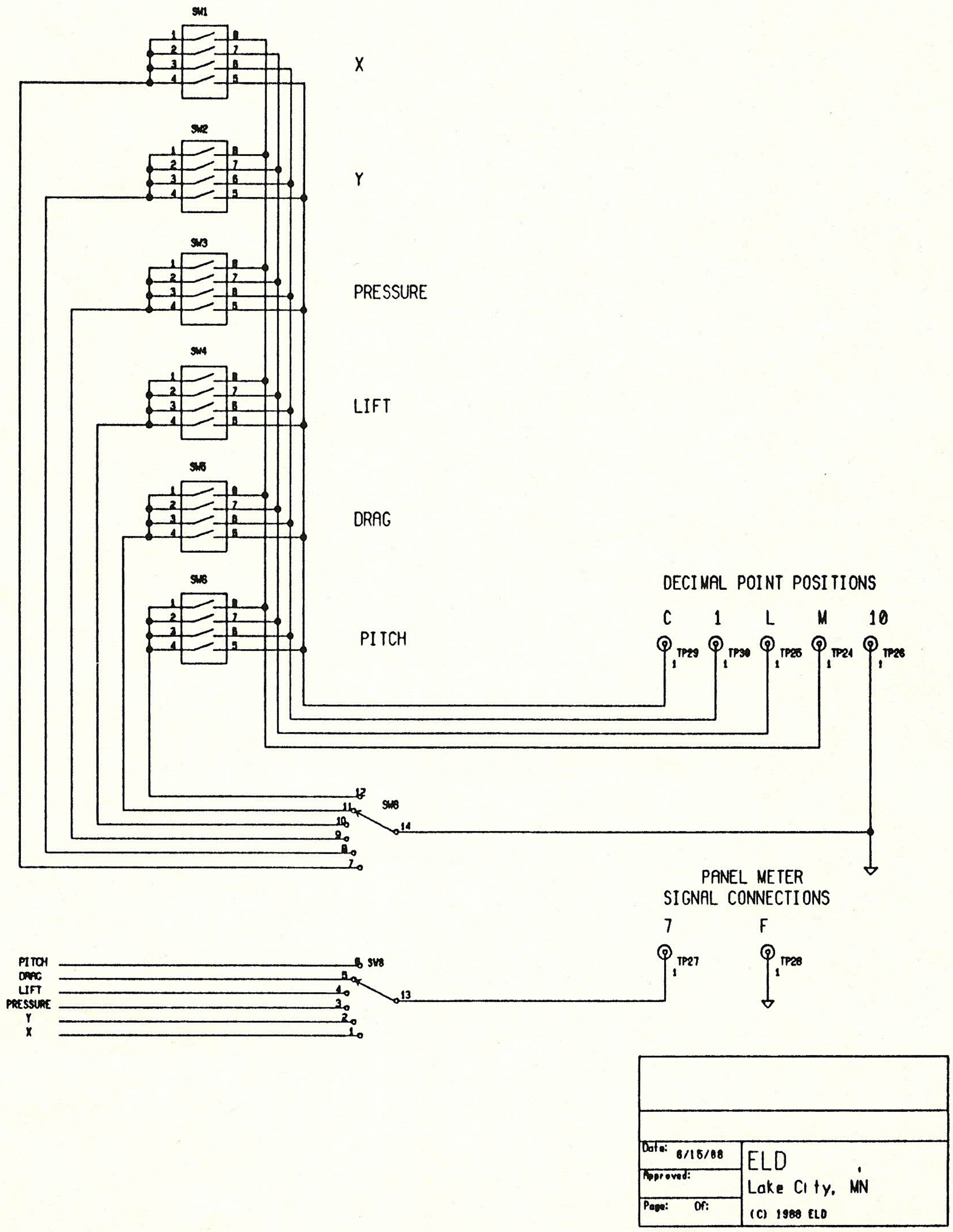
Figure 8


SW1
X
SW2
Y
SW3
PRESSURE
SW4
LIFT
SW5
DRAG
SW6
PITCH
DECIMAL POINT POSITIONS
C 1 L M 10
TP29 TP30 TP25 TP24 TP26
SW8
PANEL METER
SIGNAL CONNECTIONS
7 F
TP27 TP28
PITCH
DRAG
LIFT
PRESSURE
Y
X
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ELD
Lake City, MN
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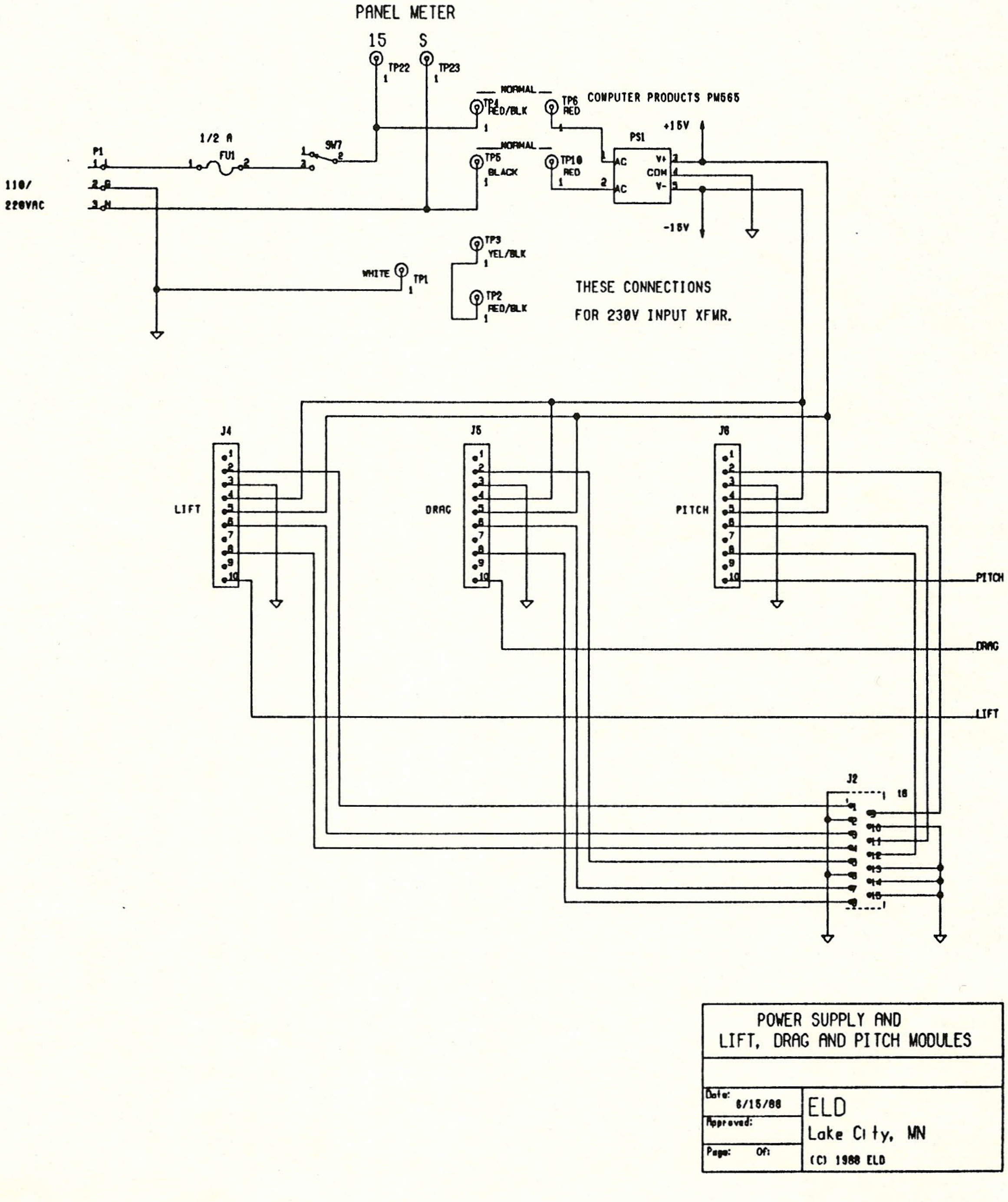
Figure 9



POWER SUPPLY AND LIFT, DRAG AND PITCH MODULES	
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Figure 10