# OPERATIONS MANUAL

## EIDETICS INTERNATIONAL, INC.

## PREPRODUCTION

## FLOW VISUALIZATION WATER TUNNEL

PREPARED FOR

MCDONNELL DOUGLAS CORPORATION
ST. LOUIS, MISSOURI

**Sections from the manual, scanned Feb. 2004. Some of the controls and other features were changed somewhat when the tunnel was obtained surplus and installed at Purdue.**

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# 1.0 INTRODUCTION

The purpose of this manual is to introduce the user of the Model 1520 Water Tunnel to the various components of the facility, describe the operations procedures, and to suggest proper maintenance in order for the user to enjoy maximum utility and minimum problems. It is strongly recommended that the user read through this manual prior to initial operations.

## 2.0 FACILITY DESCRIPTION

The Visual Aerodynamics Flow Visualization Water Tunnel is a closed circuit facility suitable for studying a wide range of aerodynamic and fluid dynamic phenomena. Its key design features are high flow quality and horizontal orientation. The horizontal configuration facilitates model access, enables models to be readily changed without draining the water from the tunnel, and provides for visualization of the flow axially from a downstream transverse window. The facility is operated as a continuous flow channel, i.e., the water level in the test section is not required to be at the top of the test section walls. Typically, the water level is adjusted to be approximately 2" below the top of the walls, negating the need for a sealed cover and providing simple access to the model while the tunnel is running. The entire circuit is constructed of noncorrosive materials supported by a structural steel framework.

The test section is nominally 15" wide, 20" high and 64" long. It is constructed principally of glass to permit maximum viewing of the model. The test section and discharge plenum are configured to allow simultaneous viewing of a model from the top, bottom, both sides and from the rear. Viewing from the rear is especially advantageous when studying flow structures in the cross-flow plane. The centerline of the test section is 66" above the floor, resulting in 56" underneath the test section for convenient viewing and setup space for either direct or indirect (with a mirror) visual access for photography through the bottom of the test section. The tunnel centerline is near eye level for side and rear views. The test section flow velocity is variable from 0 up to 1.0 ft/sec. For most flow visualization testing using colored dye on the model surface, velocities in the range of 0.3 to 0.5 ft/sec are found to produce the best results. The model support, mounted from the top of the test section, is readily removable.

### Circuit Component Descriptions

The following subsections describe the components of the basic tunnel circuit. Sketches of the facility are shown in Figs. 1 and 2. Photos of the tunnel and model support are shown in Fig. 3. The tunnel, with proper work area occupies a space approximately 30 ft. x 15 ft. The maximum height of the tunnel is approximately 6-1/2 ft. Ceiling height in the tunnel room should be 9 ft. minimum to permit installation/removal of the screens, models, etc. The facility will require a tap water supply and conventional drain system. The tunnel, when filled, contains approximately 1,000 gallons of water weighing approximately 7,500 lbs. The structure weight is about 1,000 lbs. The pump/motor is a 15 Hp, 900 gpm centrifugal flow unit requiring a 208V-230V, 3-phase, 60 Hz, 20 amp circuit. Floor structure should accommodate a distributed load of 100 psf. All components prior to final assembly will pass through a 7 ft. x 6 ft. doorway.

### 2.1 Delivery Plenum/Flow Conditioners

Water is circulated at a flow rate up to 900 gallons/minute to provide up to 1.0 ft/sec flow rate in the test section. It enters the delivery plenum through a perforated cylinder arrangement located at the upstream end of the plenum. The perforated assembly absorbs sufficient energy to assure uniform delivery of water across the length of the cylinder. At the downstream end of the delivery plenum, there is a section with flow conditioning elements. The first is a perforated stainless steel plate which reduces the turbulence to a small scale. A honeycomb flow straightener constructed of plastic tubes and two fiberglass screen sections are placed downstream of the perforated plate. These flow conditioning elements can be easily rearranged or replaced to alter test conditions at the user's discretion.

## 2.2 Contraction Section

The contraction section has an area ratio of 6:1. The geometry has been selected to provide the minimum contraction length consistent with good velocity distribution, turbulence reduction, and avoidance of local separation and vorticity development.

## 2.3 Test Section

The test section internal dimensions are: 15" wide, 20" high, and 60" long. The sidewalls diverge slightly to compensate for boundary layer growth and to maintain uniform flow velocity throughout. It is constructed of a steel frame with tempered glass on three sides. The glass provides thermal stability and scratch resistance, and ensures permanent optical qualities. The model support system attaches to the top of the test section and the model is tested in an inverted position. The model support has a removable panel to provide easy access to the model while the tunnel is running and to vary the background for photography.

The level of flow quality (measured outside the wall boundary layer and below the surface flow) up to 1 ft/sec flow velocity in the test section is:

Turbulence Intensity Level: <1.0% RMS

Velocity Uniformity: $< \pm 2\%$

Mean Flow Angularity: $\leq \pm 1.0°$ in both pitch and yaw angle

## 2.4 Discharge Plenum

The configuration of the discharge plenum downstream of the test section is a unique feature of this water tunnel. The plenum incorporates a downstream viewing window to allow direct viewing of the model from the rear, eliminating the need for mirrors. The discharge plenum configuration has been designed to insure that no flow angularity or turbulence is developed which could propagate upstream into the test section.

## 2.5 Return and Supply Piping

From the discharge plenum, the water flows downward through two vertical pipes into a collecting header. From the header, the water flows forward along the side of the tunnel (to keep the area under the test section free of obstacles for optimum viewing ) through a supply pipe to the pump lying directly beneath the contraction plenum. Vibration isolation joints are provided between the pump and supply/return piping. A fitting and valve is provided at the low point of the piping to permit draining the facility.

## 2.6 Pump/Motor

The water is circulated with a 900 gpm capacity centrifugal flow pump driven by a variable-speed 15 Hp electric motor. The test section flow velocity can be varied between 0 and 1.0 fps, irrespective of the changing head losses in the test section due to model size and attitude. Pump controls are mounted on a panel located near the test section area. Instrumentation to measure and read out the test section velocity is provided.

## 2.7 Dye Supply System

A pressurized, six-color dye system using water-soluble food coloring is provided with individually routed lines from the dye cannisters to the model support system. The system allows precise control of the rate of dye emission and provides a means of blowing air out of the dye lines going to the model. The dye cannisters are pressurized with air using a small compressor and the pressure level is controlled by a pressure regulator. The quantity of dye is regulated for each cannister by individual valves located on a panel near the test section.

## 2.8 Inlet Suction System

It is important to simulate the mass flow through the engine inlets for real aircraft models. A suction system consisting of a small pump and appropriate valves, and a flow meter is provided to vary the flow through engine inlets as desired to simulate zero to maximum thrust for a wide class of airplanes.

## 2.9 Filtration System

Gradual discoloration of the water results from continued use of dye. The coloration can be removed periodically by adding a small amount of chlorine to the water. A filtration system is also provided for filtering and cleaning the water. This system utilizes a 3/4 Hp pump/motor with a strainer and a filter unit. The filtration system is normally operated when the tunnel is not in use, typically overnight. After extended operation, the water must be replaced. Tunnel drain and fill connections are provided for this purpose.

## 2.10 Model Support System

The model support system utilizes a C-strut to vary the pitch angle and a turntable to vary the yaw angle. The C-strut and the turntable are driven by remotely-controlled electric DC motors and the pitch and yaw angles are displayed in digital form. The C-strut arrangement permits continuous pitch motions up to 50° between the limits of -10° and 110°. This is accomplished by a unique sliding C-strut/sting assembly that allows the initial pitch angle to be set at -10° and in 15° increments from 0° to 60°. From any initial pitch angle, motor-driven anglular motions of up to 50° is allowed. Angles of attack from +10° to -110° can be achieved by simply rolling the model 180° around the sting. The turntable normally provides ±20° in yaw. Yaw angles to ±30° can be accomplished with a 10° adapter.

The model attitude is controlled with a two-axis spring-loaded gimbal (joy stick) mounted in a hand-held remote "mouse" control box. The box is tethered to the main control to allow the controls to be remotely operated from different positions around the water tunnel. Thus the model attitude can be controlled by an operator situated at the top of the test section, at the end view window, or on either side of the test section.

The entire model support can be lifted off the top of the test section if needed. Typically, the model is accessed by rotating the model support platform on hinges attached to a permanent base plate about a horizontal axis perpendicular to the test section centerline. The model then rests out of the water on the platform above the test section. Dye tubes are carried from the outside of the tunnel to the model base through the interior of the C-strut.

## 3.0 COMPONENT DESCRIPTIONS/OPERATIONS

### 3.1 Control Panel

The main control panel, shown in Figs. 4 & 5, has the following items on the panel face:

Model support main power switch
Floodlight power switch
Inlet suction pump (mass flow) switch
Dye system compressor switch
Filter power switch
Flow velocity display meter
Pitch angle display meter
Yaw angle display meter
Pitch angle offset meter
Yaw angle offset meter
Pitch offset adjustment dial
Yaw offset adjustment dial
Pitch angle meter null adjustment
Yaw angle meter null adjustment
Run indicator light
Flow velocity speed control dial
Pump motor stop button
Pump motor start button
Selector switch for control source ( e.g., tunnel/mouse or auxiliary)
Model support enable button
Model support stop button

**the automated model support system was not obtained with the tunnel and is not available.**

The "mouse" control box shown in Fig. 6 has a 2-axis gimbal joy stick for control of the model support system. One axis is for pitch control and one is for yaw control.

#### 3.1.1 Power Switches

The model support power switch enables the model support motors and potentiometers, the flow meter, and all displays. The floodlight power switch enables the test section floodlight. The filter power switch enables the diatomaceous earth filter system which filters out any particulates which are suspended in the water. The dye system switch enables the dye system compressor. The suction system (mass flow) switch enables the suction system pump.

#### 3.1.2 Display Meters

The flow velocity meter shows the test section velocity in ft/sec. The pitch angle and yaw angle meters show pitch and yaw angles in degrees. The run indicator light shows that the pump/motor is enabled. Beneath the pitch and yaw meters there are adjustment potentiometers to allow the user to null out the meter readings to adjust for model misalignment in the test section. Beneath the main pitch and yaw meters and the null adjustment pots are additional meters and potentiometers to set specific offset angles to account for either bent stings or movable sting brackets to increase the angle range. For example, if the yaw angle is offset with the bent sting of +10°, the yaw offset pot would be adjusted until the yaw offset meter reads +10°. This value is automatically added to the yaw angle readout on the main meter (see Section 3.1.3).

### 3.1.3 Pitch/Yaw Offset Angle of Adjustment **does not exist**

The pitch offset dial allows the user to bias the pitch angle readout by an amount equal to the various pitch offset angles that can be set in the pitch axis support system. For example, if the model is supported on the C-strut with a user-selected sting position of +15° rather than 0°, then the selector switch will be set at +15° and the reading will automatically add the 15° to the actual angle of pitch readout. The selector switch can be set at any angle between -10° and 60°. This means, for example, that if the model is pitched upward by +50° from the initial position and the sting has a +45° offset, the actual pitch angle is 95° and will be displayed as such.

### 3.1.4 Pitch/Yaw Null Adjustments **does not exist**

For most model installations, it will be rare when the model is mounted on the sting so that the model is perfectly aligned with the tunnel free-stream when the model support position readouts read zero. For convenience, the simplest way to align the model with the free-stream is simply to rotate the model support in each axis until the model is aligned with the flow. This will result in a non-zero angle reading on the pitch and yaw angle readouts. This misalignment error can be nulled out with the null adjustments located under the pitch and yaw offset meters.

### 3.1.5 Speed Control Dial

The flow velocity speed selector dial is a ten (10) turn potentiometer which allows the operator to select a test section velocity. Turning the dial clockwise will increase the speed of the tunnel. The speed control drive will "change gears" as the tunnel increases in speed. This is normal and is the result of output drive frequency changes from the drive unit to the pump motor.

### 3.1.6 Pump Motor Stop/Start **Wait until motor is completely stopped before restarting! Risk of damage!**

The pump/motor stop/start buttons are located on the left side of the panel. The start button enables the pump motor. The Run indicator light will come on when the pump motor is activated. The procedure for operating the tunnel is outlined in Section 4.0. The Stop button cuts electrical power to the pump motor.

### 3.1.7 Selector Switch, Aux/Tunnel **does not exist**

This selector allows the user to choose the location for control input. The main control box has all of the tunnel control functions. The mouse provides control for driving the pitch or yaw axes of the model support only. The mouse control box on a 20-foot long cable allows the user to control the model support from other locations around the tunnel such as from the end window and from the top of the test section. The Aux input mode allows an external signal to be input to the model support system from another signal source through an RS232C interface. An example would be an input command originated from a desk top computer to produce an oscillatory pitch motion.

3.1.8 Model Support Enable/Stop Buttons does not exist

In order to initiate control to the model support system after the control panel is powered up or after the control mode selection switch is moved from Tunnel to Aux, or vice-versa, the enable button must be pressed. This is primarily a safety feature to prevent the model support from moving without an intentional command whether by a manual pot position on the mouse control or by an input command from the computer in the aux mode. Switching from one mode to the other will also require a deliberate action by the user to enable the model support to respond. Once the enable button is pushed, the model support will respond to the command that is present. Pushing the stop button at any time will kill the power to the pitch and yaw drive motors and the model support will not respond until the enable button is pushed.

3.1.9 Model Attitude Controls model support was not obtained with tunnel

The model attitude is controlled by a 2-axis gimbal located on the "mouse" control. Deflecting the gimbal control stick back towards the bottom of the mouse will increase the angle of attack of the model. Deflecting the stick forward will decrease the model angle of attack. Stick deflection to the right will move the model in the positive yaw direction; stick deflection to the left will move the model in the negative yaw direction. The amount of stick deflection determines the rate at which the model moves. As a safety measure each axis has limit switches to prevent the operator from exceeding the angular limitations of the model support in any direction.

3.2 Pump/Motor Assembly

The pump motor assembly consists of a Berkeley Model B6ZPL centrifugal flow pump and a Baldor 15 Hp electric motor. The motor has continuously variable speed up to 1760 rpm. The pump is constructed with a cast iron housing and impeller.

3.3 Model Support automated support does not exist

The model support system was described briefly in Section 2.10. Figure 3 shows various components of the system. Pitch angles are varied by driving the sting mechanism on a C-strut and the yaw angle is varied by rotating a turntable. With a straight sting attached to the C-strut, the pitch angle can be varied from 0° to 50°. Sting-mounting brackets can be mounted on the C-strut at angle positions of -10° and from 0° to 60° in 15° increments, allowing the pitch angle to be continuously variable over the 50° travel range on the C-strut from a minimum angle of 0° to a maximum angle of 110°. Pitch angles between +10° and -110° could be achieved by rolling the model 180° on the sting, if desired.

The yaw angle is continuously variable between -20° and +20°. Yaw angles to 30° can be achieved by inserting the 10° bent sting rather than the standard straight sting, with some caution to avoid placing the model too far off the centerline of the tunnel resulting in the model hitting the sidewall.

Operation of the controls for the model support was described in Section 3.1.9. The basic operation is to drive the model to the desired position in either axis with the mouse control pots.

## 3.4 Dye System

The dye system consists of six pressurized one-quart cannisters for different colors, a compact compressor, pressure regulator, and required valves to meter the dye output from each cannister. The compact compressor pressurizes a small reservoir to approximately 50 psi which acts as a pressurized air reservoir for the entire dye system. A pressure regulator is mounted between the reservoir and the dye cannisters to control the pressure in the cannisters. Each one-quart size cannister has a shut-off valve between the pressure regulator and the cannister. On the outlet side of each cannister is a precision throttle valve that allows the amount of dye to the model to be closely controlled. Typical pressure level for the air reservoir is less than 10 psi. It can be increased as necessary to blow out air bubbles that may be trapped in the dye lines to the model or inside dye reservoirs inside the model. The dye solutions are typically one-part concentrated liquid food coloring to four-parts water. Standard colors can be mixed to achieve virtually any colors desired.

A description of the cannisters can be found in the Appendix in the Brochure on Micro-Fog Lubricators by Norgren. The pressure regulator (Norgren) and compressor (Thomas) are also detailed in the brochures in the Appendix.

## 3.5 Inlet Suction System

The inlet suction system consists of a small pump that sucks water, via a plastic tube, through the model inlet openings and discharges the water into the discharge section of the water tunnel. The suction system has a valve to control the flow volume through the inlet and a flow meter to measure the flow rate. The inlet flow is determined by calculating the desired flow volume rate compared to the free-stream velocity to properly simulate the capture area of a full-scale aircraft at various power settings from idle power to full maximum thrust settings. With no flow through the inlet, the flow around the model will behave as with a blocked inlet, rather than a flow-through inlet. This is because the inner wall of the inlet opening is sealed to the internal tube leading to the pump and the flow cannot pass through the inlet unless it is pumped through. The inlet suction pump must be primed before use. Once the prime is lost due to an air pocket in the suction tube, the pump will no longer pump water until it is reprimed. The pump is primed by squeezing the hand pump barrel several times to drive the air pocket out of the suction tube. The suction pump should be on and the control valve fully open during the priming process.

## 3.6 Filter System

**This system replaced 2003, new unit is similar. This is usually not used, to increase particle count for LDV.**

The filtration system can be used when accuracy in the test section velocity is not required since the extra flow due to the filter system is not sensed by the in-pipe flow sensor. The filter system is a high-performance swimming pool filter unit (Sta-Rite Posi-Flow Model 35TXR) with the capability of circulating 35 gpm. It is powered by a 1/2 Hp motor and can be run continuously. The filter is a cleanable cartridge. The filter should be used to clarify the water in conjunction with common household bleach to remove the discoloration of the dye. After several days of constant use without adequate filter circulation time, it may be necessary to drain and refill the tunnel with fresh water.

Details on how to clean the filter cartridge can be found in the Appendix in the filter manufacturer's "Owner's Manual."

### 3.7 Flow Meter

The tunnel velocity is measured in ft/sec by a Signet flow meter. The probe is a strut-mounted insertion-type flow metering system using a paddle wheel for fluid velocity measurement. The probe is mounted in the return plumbing circuit where it measures the flow velocity in the pipe. This velocity is then scaled proportionally and displayed as the test section velocity. This configuration allows for the test section velocity to be accurately displayed while a model is mounted in the test section. This configuration does require that the operator maintain the tunnel water level at two inches below the top of the fiberglass tanks in order to rely on the calibration of the meter.

## 4.0 TUNNEL OPERATION

### 4.1 Filling the Tunnel

The Model 1520 Water Tunnel has a capacity of approximately 1000 gallons. The tunnel can be filled by coupling the discharge valve with a 1-1/2" diameter water supply line, or with a regular garden hose simply mounted in the tank. After filling the tunnel, it is desirable to eliminate air bubbles in the honeycomb flow conditioner. The procedure for doing this is outlined in Section 8.1.

### 4.2 Start-up Procedure

After the tunnel has been filled to the normal operating level (approximately 2" below the top of the fiberglass tanks), turn the speed control dial to zero. Turn the lever on the gray power box for the speed control drive unit to the "on" position. Allow 2-3 seconds for the capacitors to charge up before selecting the start button. When the start button is activated, the green indicator light will come on and stay on as long as the pump motor is enabled to the speed control. It is normal to hear a "clunk" coming from the pump motor when the speed control drive enables/disables the pump motor. The speed control unit is controlled by a ten-turn potentiometer located on the lower left face of the control panel. Turning the dial clockwise will increase the speed of the tunnel. The speed control drive will "change gears" several times as the tunnel increases in speed. This is normal and is the result of output drive frequency changes from the drive unit to the pump motor.

> Special Note: If the tunnel is operated at speeds in excess of 1.0 ft/sec, the operator must make sure the pump is not cavitating. Excess vibration or a sound like marbles passing through the pump are two common indications. Running the pump in this condition for excessive time periods will damage the pump. Never run this pump without water in the tunnel. Catastrophic damage will result.

To stop the tunnel pump/motor, activate the Stop button. The pump will go through a pre-set deceleration phase which allows for smooth transition from a flow to no-flow condition. Only after the pump has stopped is it safe to switch off the speed control drive unit (gray box mounted on tunnel frame). Listen for a relay to close before turning off the main power box.

The motor controller was replaced in Jan. 2006, so these safety rules are no longer absolutely necessary, but they are still good general rules to follow.

## 4.3 Setting Tunnel Flow Velocity

After the tunnel is operational, it is recommended (but not necessary) to perform a tunnel speed performance measurement. This is to provide the user with a correlation of speed potentiometer dial setting and test section flow velocity. Starting with a dial setting of 1.0, record the flow velocity in the test section. Increase the setting by 0.5, allow 30 seconds for the flow velocity to stabilize, and record the test section velocity. Repeat this procedure until a dial setting of 10.0 is achieved. Plotting of this data will provide the user with a quick reference of speed potentiometer setting for any desired velocity of the tunnel. The flow meter readout will still be used as the final guide to precise setting of the speed.

## 8.0 MAINTENANCE/SERVICE

The overall maintenance of the water tunnel facility is minimal. The following recommendations are based on common sense practices and first-hand experiences with facilities in our own laboratory. If the tunnel is not being used regularly, it is suggested that the facility be run at 0.5 ft/sec for 30 minutes once every two weeks.

### 8.1 Tunnel Circuit

The tunnel circuit should be drained approximately every three to six months and the walls and floor of the fiberglass components and glass test section brushed with a medium stiff brush or sponge with detergent and water, and rinsed thoroughly. Flow conditioners should be cleaned by directing a fine spray from a hose nozzle through the flow conditioning section in both upstream and downstream directions. It is desirable to pull the flow conditioners out completely for a more thorough cleaning and inspection once a year. When the tunnel is refilled, extra effort should be made to clear the flow conditioners (especially the honeycomb section) of the air bubbles. This can best be done by directing the output of a hose nozzle underwater in the downstream direction against the perforated plate. Preferably, this should be done with the tunnel running at about 0.5 ft/sec. If the bubbles are not cleared, the flow quality will suffer since the water will not flow through all the honeycomb tubes uniformly. Another method that works reasonably well is to use a 4" wide paint brush on a long handle and "sweep" the water towards the perforated plate which will force the air bubbles towards the contraction section.

Periodically, a visual inspection of joints between the various tunnel components to detect leaks is also recommended. Leaks should be repaired as required before they become too large to repair without disassembly and re-assembly.

### 8.2 Dye System

Approximately every three months (more often if not used regularly) the dye cannisters should be drained and flushed out with water with a light scrubbing of the interior of the cannisters to prevent dye buildup on the walls. The dye plumbing should be flushed with water by forcing clear water through the whole system by pressurizing the cannisters and opening the throttle valves. The discharged water from the dye system can simply be run into the test section prior to draining and flushing the entire tunnel as recommended in Section 8.1.

The compressor tank should be drained of accumulated moisture once per week as instructed on the tank.

Dye tubes and manifolds should be inspected once a week to detect leaks.

8.3 Model Support

The only maintenance required for the model support is to check periodically for loose bolts, nuts and hardware pieces, and to keep the surfaces wiped clean of any mineral deposits, etc. Wires should be inspected for cracks or wear in the insulation. The drive motor belt tracks should be inspected occasionally for wear or to be sure that they remain securely fastened to the C-strut and turntable arcs.

8.4 Suction Pump

Check the suction pump and attached tubing to detect leaks or cracks in the tubing. Check to see that suction system is properly primed for operation.

8.5 Filter System

The filter element should be cleaned or replaced as recommended in the manufacturer's brochure. It is recommended that the filter maintenance be performed approximately every 300 hours of operation.

## 10.0 FIGURES

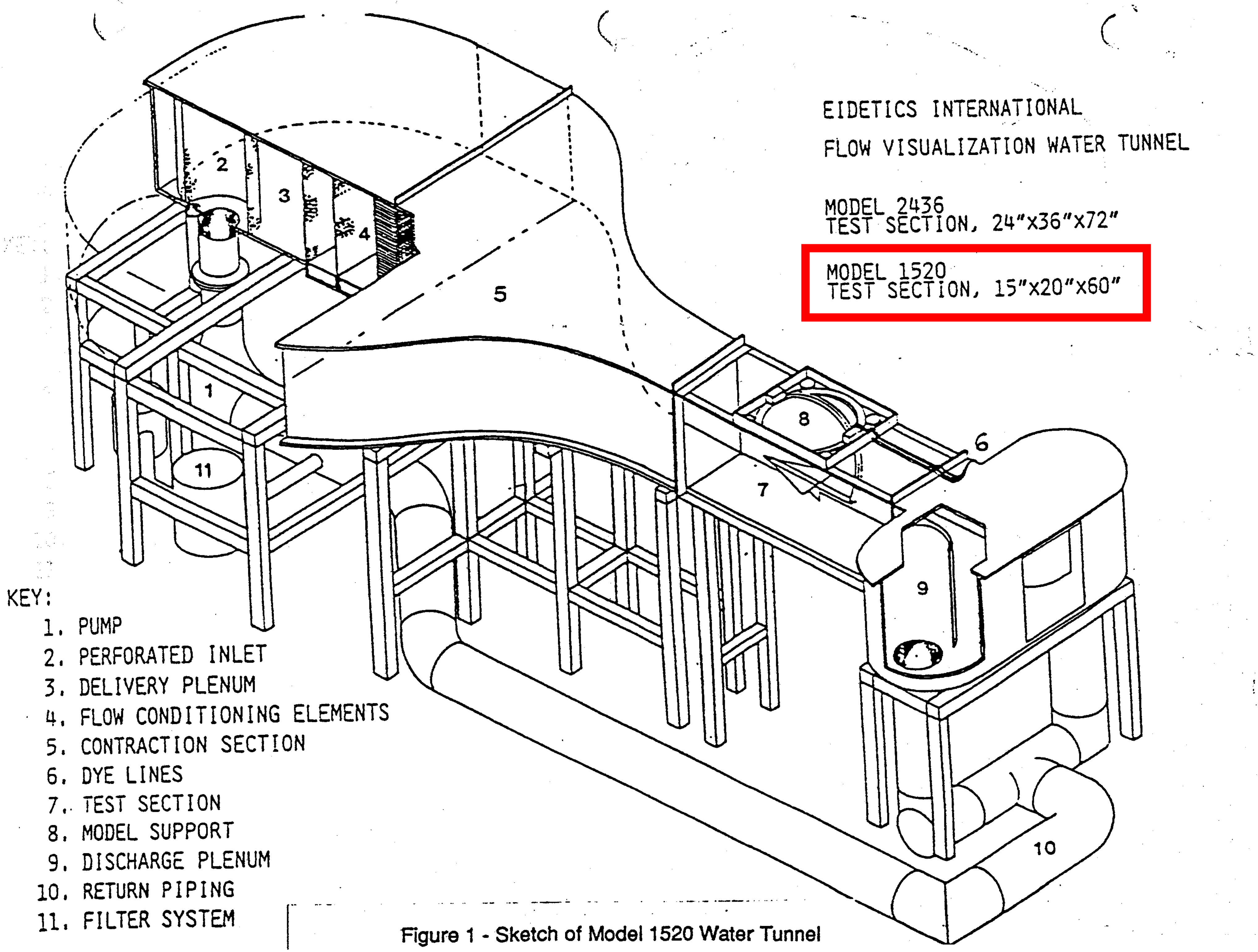


Figure 1 - Sketch of Model 1520 Water Tunnel

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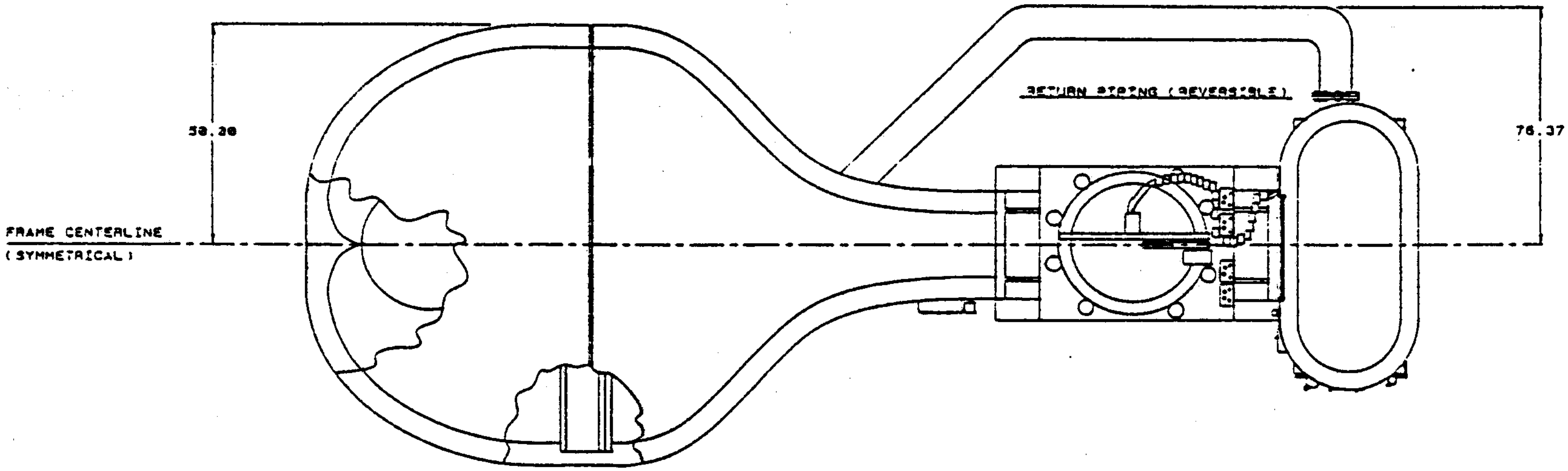


Figure 2b - Planform View of Model 1520 Water Tunnel

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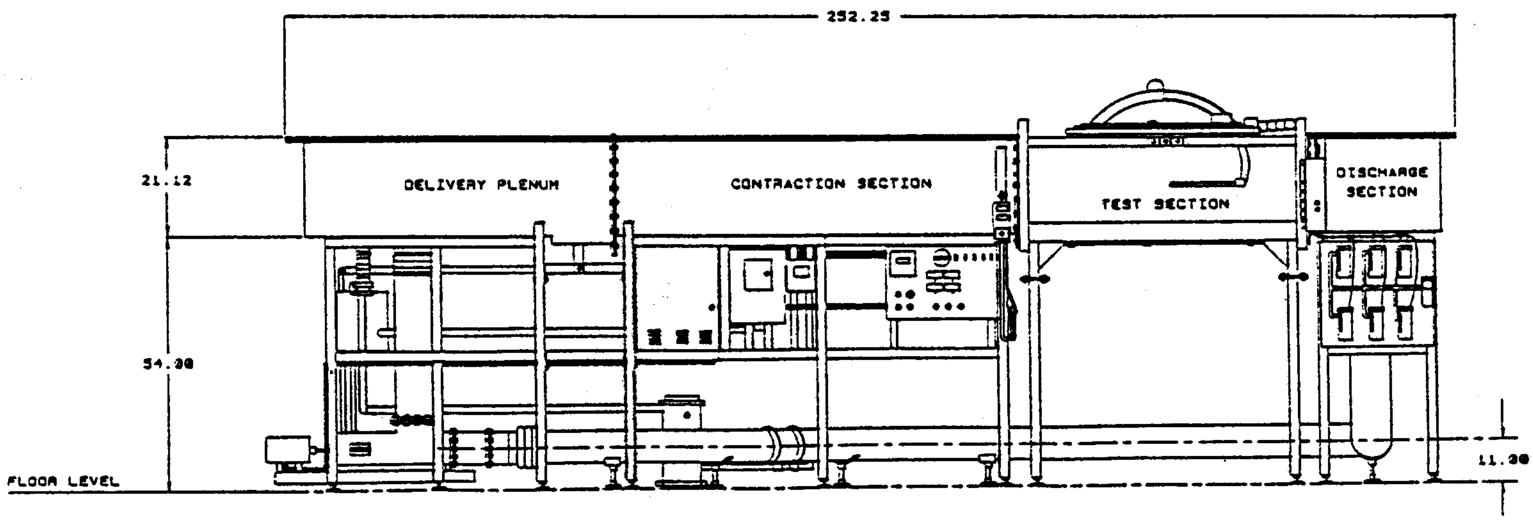


Figure 2a - Side View of Model 1520 Water Tunnel

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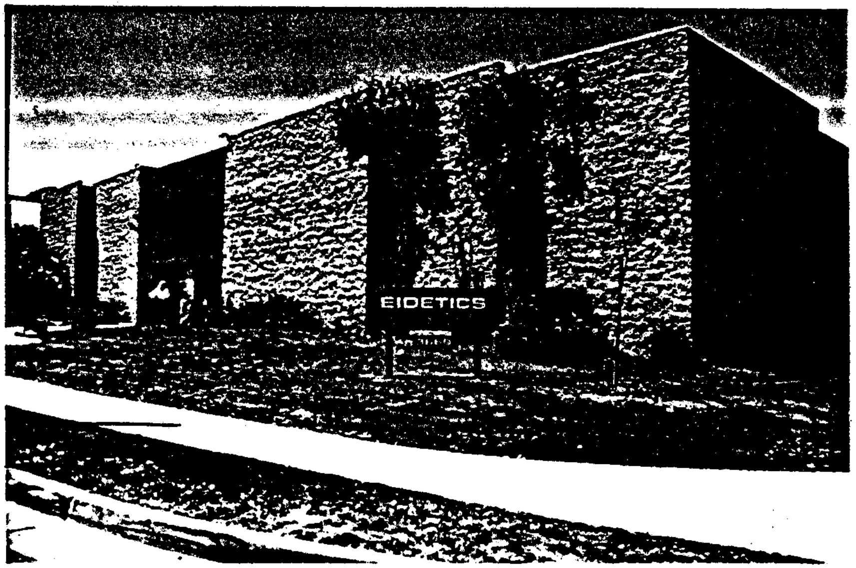
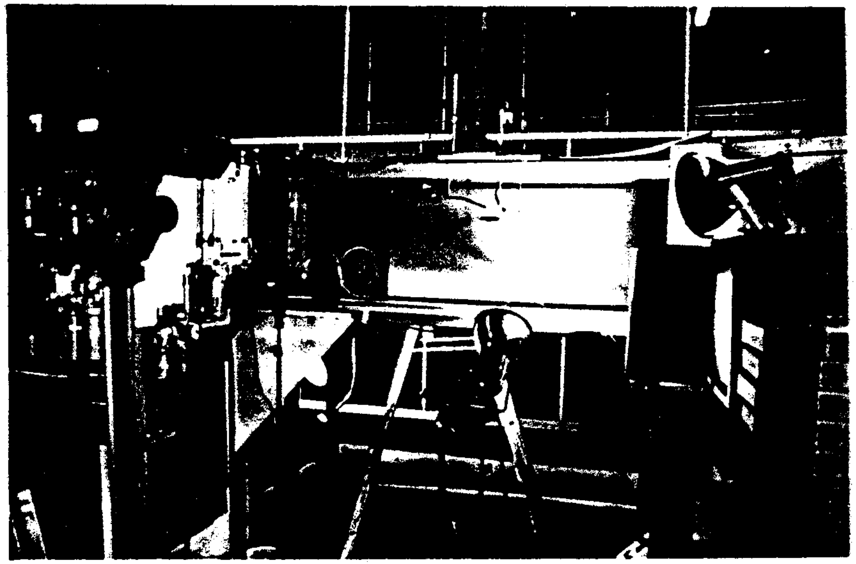
# FLOW VISUALIZATION WATER TUNNELS

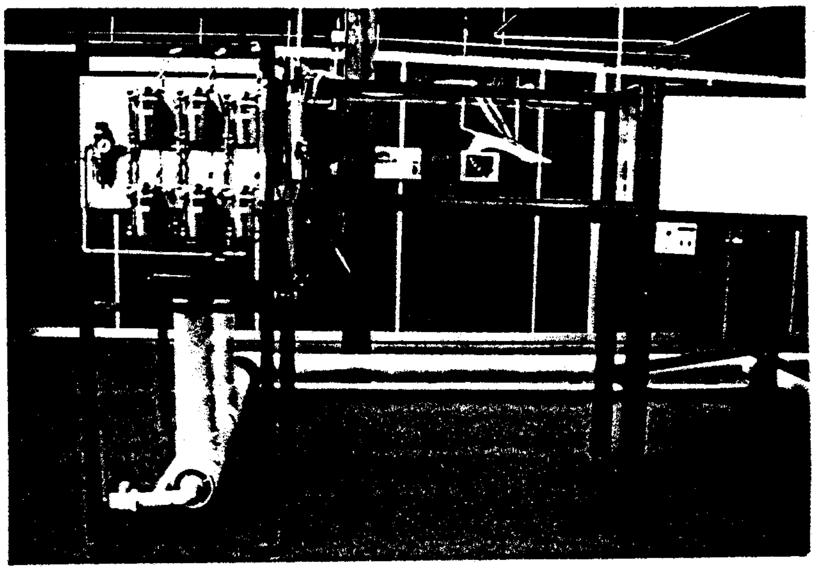



**EIDETICS FACILITY**



**MODEL 1520 TEST SECTION**

**DOWNSTREAM VIEWING WINDOW**



**TEST SECTION/DYE SYSTEM**

Figure 3A - Preproduction Model 1520 Water Tunnel

Caution! After filling the tunnel with water, vent the air from the top of the large stainless steel swimming-pool-type filter that contains diatomaceous earth. Otherwise the compressed gas could be vented explosively. Alternatively, and usually, valve the filter out of the system so there is no pressure to it.

THIS FILTER OPERATES UNDER HIGH PRESSURE. WHEN ANY PART OF THE CIRCULATING SYSTEM (e.g., CLAMP, PUMP, FILTER, VALVES, ETC.) IS SERVICED, AIR CAN ENTER THE SYSTEM AND BECOME PRESSURIZED. PRESSURIZED AIR CAN CAUSE THE LID TO BE BLOWN OFF WHICH CAN RESULT IN SEVERE INJURY, DEATH, OR PROPERTY DAMAGE. TO AVOID THIS POTENTIAL HAZARD, FOLLOW THESE INSTRUCTIONS.

1. **Open the High Flow Air Relief Valve until it snaps into the full open position (this only requires a quarter turn counter clockwise.** Opening this valve rapidly releases air trapped in the filter. (on top of filter tank)

2. Stand clear of the filter tank, then start the pump.

3. Close the High Flow Air Relief Valve after a steady stream of water appears.

4. The system is not working properly if:

   a. A solid stream of water does not appear within 30 seconds after the pump's inlet basket fills with water.

   b. The pressure gauge indicates pressure before water out-flow appears.

   If either condition exists, **shut off the pump immediately**, open valves in the water return line to relieve pressure, and clean the air relief valve, (see Section I). If the problem persists, call American Products Customer Service at 1-800-828-6123.