The Unsteady Flow Cavitation Tunnel at the California Institute of Technology

B. J. S. Barnard
A. T. Ellis
M. E. Slater
Hydrodynamics Laboratory
California Institute of Technology
Pasadena, California

Abstract

In the Blow-down Water Tunnel at the California Institute of Technology, velocities of the order of 100 ft/sec are readily obtainable in a 2-3/4-in. square working section. The apparatus is described and several of its features which make it particularly suitable for cavitation studies are emphasized. Operation is automatic and a device is described whereby the controls may be preset to yield a desired combination of tunnel static pressure and velocity.

General Description

In essence the tunnel consists of two 200 gallon water tanks joined by an 8-in. diameter pipe which contracts locally to a 2-3/4-in. square working section. Fig. 1 is a schematic diagram of the tunnel, and Fig. 2 is a photograph of the entire installation. The working section is of lucite and the tanks and those pipes which are in contact with the water are glass lined. Joints are made with teflon gaskets and thus contamination of the water by corrosion is minimized. The tunnel is usually operated with about 200 gallons of water; this amount allows maximum running times to be achieved. The water is forced from the upper tank through the working section into the lower tank by compressed air. A spherical compressed air reservoir of about 3-ft diameter is used for storage purposes and is connected to the top of the upper tank

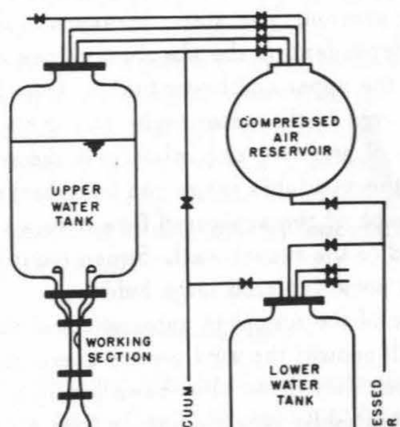

FIG. 1 SCHEMATIC DIAGRAM OF TUNNEL.

by four 1-1/4-in. diameter pipes each having a solenoid operated valve with a hand valve in series with it for flow control. To accomodate the accumulation of water in the lower tank and the decrease in air volume above it, air is allowed to escape from the top of the tank through two 1-1/4-in. solenoid operated valves. These valves also have hand valves in series with them.

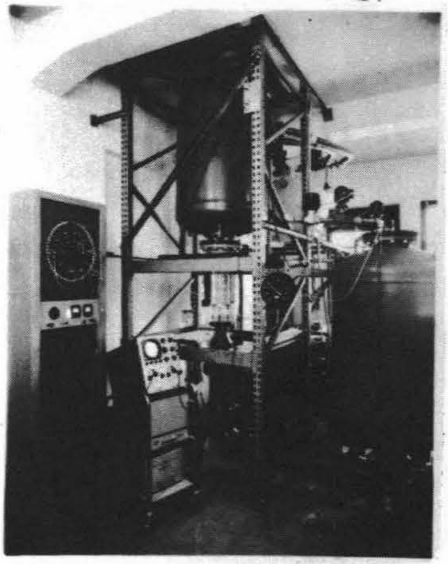

FIG. 2 PHOTOGRAPH OF TUNNEL.

The solenoid valves may be opened and closed in any prearranged sequence while the tunnel is operating and the air pressure in the upper and lower tanks thus controlled. It is the difference in pressure between the air in the upper and lower tanks that controls the velocity in the working section. The static pressure in the working section is dependent on the absolute values of the air pressure in the upper and lower tanks. Thus by regulation of the pressures in the water tanks during operation any combination of pressure and velocity in the working section within the available range can be achieved. Fig. 3 is a photograph of the separated flow over a circular arc foil attached to the tunnel wall. Strong cavitation is visible with some isolated large bubbles.

Operation of the tunnel is automatic and the solenoid valves which control the air flow are energized at predetermined times during the blow-down process. The valves are relay operated by electric pulses from a controller. The controller consists of a 60 contact rotary switch which performs one revolution during the blow-down operation. The switch is driven by a synchronous motor through gears which are interchangeable for adjustment of the switching rate. The motor is so connected that it stops automatically after one revolution of the switch. For moderate tunnel speeds, i.e., in the range 30 – 50 ft/sec, the gears are set so that one revolution of the switch takes place in 15 sec. Thus the valves may be operated at 0.25-sec intervals.

For cavitation studies distilled water is used. The removal of dissolved gases is achieved by evacuating the air above the water to nearly vapor pressure. Provision has been made for passing the water slowly through a vessel where it is subjected to an ultrasonic field to

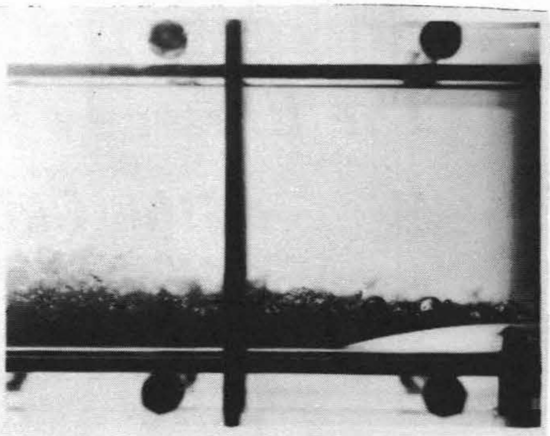

FIG. 3 CAVITATION OCCURRING OVER A CIRCULAR ARC FOIL.

promote release of the gases. A filter capable of removing 0.5 micron particles is also incorporated to ensure that the water is relatively free from cavitation nuclei.

Detailed Description

The nozzle is square in cross section, and upstream and downstream of the contraction the sides are parallel. The contraction profile was based on Tsien's analytical method[1] for an axi-symmetric contraction cone which converts a uniform velocity profile upstream from the contraction to a uniform flow downstream. The area ratio is 6.5. The nozzle was cast inside a concentric 10-in. to 4-in. iron reducer from an epoxy resin, and projects into the upper tank when bolted in place. To approximate a uniform flow upstream from the contraction a square bellmouth entrance, half-round in section, is attached to the upstream end of the nozzle.

The working section is 2-3/4-in. square by 14 in. long and is fabricated from 1-in. thick lucite. It is easily removed from the tunnel and disassembled for access to the model. In Fig. 4 it is shown with a circular arc model in place. At a cross section 2 in. from the upstream end of the working section a pair of platinum electrodes are mounted in the middle of opposite faces, flush with the inside wall surface. These electrodes are for the electrolytic seeding of a cavity in contact with a wall. The electrodes may also be useful for incorporation in an electro-magnetic flow-meter to obtain a continuous record of mean velocity in the working section.

Downstream from the working section a lucite transition piece 6 in. long converts the pipe from a 2-3/4-in. square to a 4-in. round cross section. The second part of the diffuser is a standard 4 in. to 8 in. concentric iron

[1]H. S. Tsien. "On the Design of the Contraction Cone for a Wind Tunnel," *J. Aeronaut. Sci.*, Vol. 10, 1943, p68.

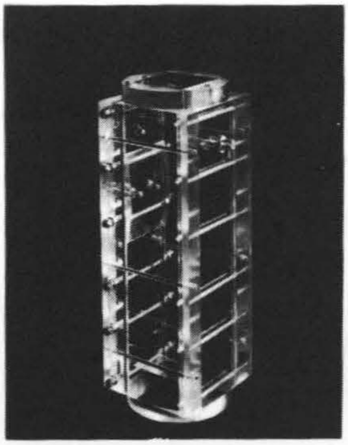

FIG. 4 THE WORKING SECTION.

diffuser. It is followed by a flexible coupling to relieve the lucite working section of stresses arising from slight movements of one of the tanks, or from initial lack of fit between them. The bellows of the flexible joint are of teflon.

Pressure taps exist in the compressed air reservoir and in both tanks for connection to transducers. A flush diaphragm pressure transducer is mounted in the wall of the working section to record the tunnel static pressure there during cavitation experiments.

Operation

The water is first transferred to the upper tank by evacuating it or pressurizing the lower one. Thus the initial air pressure in the upper tank may be set at any desired value. The pressure in the lower tank is then about 5 psi greater due to the hydrostatic head. The valves venting the lower tank to atmosphere or vacuum may be set to control the outflow of air during the blowdown operation such that the pressure above the water, and hence the static pressure in the working section is regulated. Tank pressures above atmospheric are obtained by throttling the escape of air to atmosphere; lower pressures are maintained by throttling the flow to a vacuum receiver. The valves admitting the compressed air to the upper tank are operated in the following way. Initially, sufficient valves are opened for a short interval to charge the upper tank to a higher pressure. Subsequently, this pressure is regulated so that, in conjunction with the pressure in the lower tank, the required values of tunnel velocity and pressure are maintained by incremental operation of the valves. When the water level in the lower tank is nearing the top, the flow is brought to rest by opening the upper tank to atmosphere and closing the valves venting the lower tank. The compression of air then arrests the flow without shock.

Measurements of the rise time of the water surface in the lower tank have shown that the pressure drop between the upper tank and the working section gives a reliable estimate of velocity.

Conclusion

Provided the water is allowed to remain a sufficient time in the upper tank before blowdown, very low turbulence levels are to be expected. At large tunnel velocities only short flow durations are obtained with the limited capacity. However, the primary object in view is to study the collapse of cavities in the flow, and hence observation times of a few milliseconds are sufficient.

Investigations in which the flow separates from or adheres to the model are possible by choice of the model shape and adjustment of the velocity and static pressure in the working section.

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