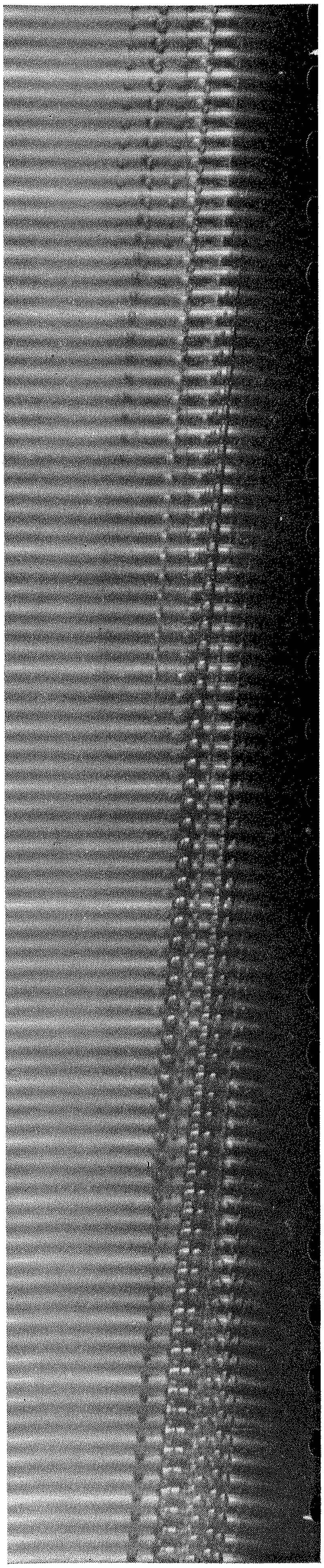


This section from the Hydrodynamics Laboratory's movie shows how pictures taken at 20,000 frames per second tell the life history of a cavitation bubble. Starting at sixth frame from top, right, a bubble is born, then grows, collapses and rebounds—all in less than 1/200 of a second. Through such minute observation of bubble formation engineers hope to find the fundamental cause of cavitation and so come up with a cure.

The high speed water tunnel and a movie are helping engineers design better hydrodynamic equipment

Life and death of a bubble

CAVITATION HAS BEEN A HEADACHE to engineers for years. Particularly has it been a headache to owners, operators and designers of hydraulic equipment. It attacks the propellers that push a ship, the pumps for a city's water supply, the turbines in a hydroelectric plant.

Now, researchers at Caltech have come up with some relief for this headache—in the form of a motion picture that magnifies time the way a powerful microscope magnifies tiny bacteria.

Cavitation is a kind of boiling. It is a special kind of disturbance that is likely to occur when an object moves through liquid at very high speed. Powerful forces resulting from cavitation chew up cast iron as if it were soap. Pump impellers become grooved until they are useless, pipes become peppered with holes, propeller blades chewed to pieces.

Needless to say, this is very costly chewing. The owners of the old **Mauretania** had to send her into drydock after four transatlantic trips to have her worn propeller blades repaired. The **Normandie** was a bit less fortunate in this respect; she could make but one round trip before a visit to drydock. Designers of hydraulic machinery have improved propellers since the **Normandie's** day, but fast liners must still have periodic propeller repairs—just as the turbines in hydroelectric plants have to be inspected regularly so that worn-out parts can be replaced, or new metal welded into the holes.

Through the years, engineers have found out many things about what cavitation causes, and they know in general what causes the cavitation. But they will have to find out **how** cavitation causes its damage before they can come up with a cure. This is what Caltech's researchers have set out to do. Already they have discovered some things that may ultimately affect the design of every machine that moves in a fluid.

All hydrodynamics researchers know that cavitation is like boiling. But researchers at the Institute have found that cavitation is made up of bubbles—bubbles that form and break, reform and break again. The mechanics of cavitation—the way in which the bubbles, or cavities, are formed, grow, collapse and rebound—are still almost completely unknown.

This is where the Institute's movie comes in. The movie is a unique tool for examining these bubbles, for looking at them when they are formed, for studying their life and the way in which they die. The special cameras developed for making the movie can take pictures at the rate of 20,000 frames per second. When you watch the movie for twenty minutes, you are watching what happens in one second. The movie makes one-tenth of a second seem bigger than a minute, and thus becomes a time microscope, an instrument for blowing up a second until it is 1,250 times its former size, so that researchers can examine it and watch all the things that happen during it.

The laboratory in which these researchers work is the only one of its kind in the country. Set up in 1941 at the request of the Office of Scientific Research and Development, it spent the war years working on problems of rockets, depth bombs and torpedoes, and later, on the launching of the aircraft torpedo. The present laboratory building was completed in 1944. Installation of equipment for investigation of hydrodynamics problems of interest to hydrodynamics enginees everywhere, was completed in the fall of 1947.

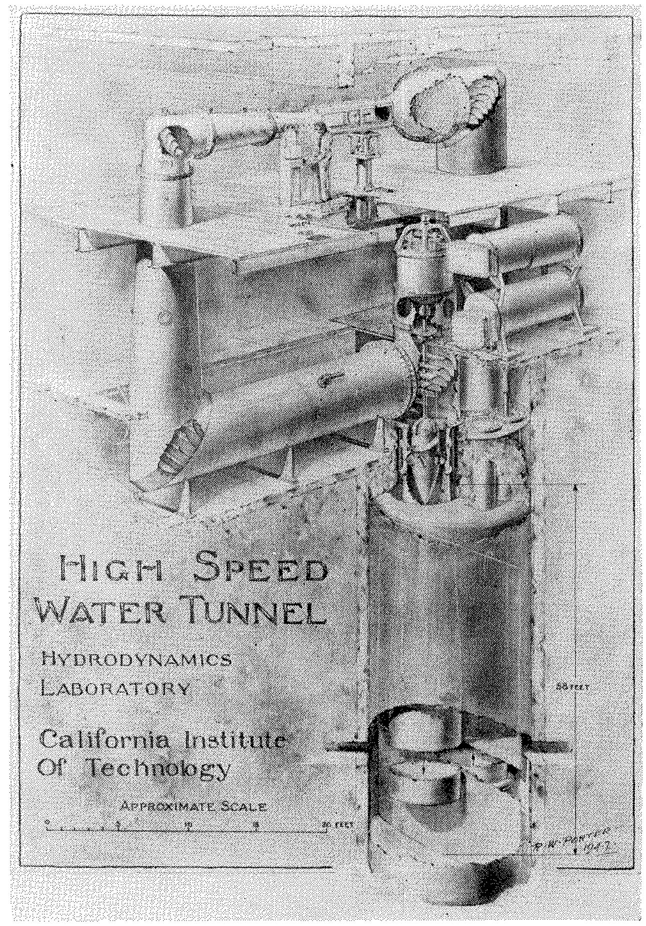
There are facilities in the laboratory for the study of a multitude of hydraulic problems; cavitation is but one of these. Most of these problems can be explored with the aid of the water tunnel, an instrument that is very similar to the wind tunnel, the chief tool of the aerodynamics engineers.

The Institute's Hydrodynamics Laboratory has two such tunnels. One is used for the study of surface phenomena. The water in it flows at any speed up to 20 m.p.h. The tunnel is so designed that the atmospheric pressure above the free surface of the water can be controlled carefully. The other tunnel is entirely filled with water, and can be operated at much higher speeds.

Additional facilities

Besides the two water tunnels, the laboratory operates a ripple tank for studying wave formation, as in a harbor, and a "polarized light flume" for making visible the flow patterns around a ship speeding through water—or around the spillway of a dam. There is also a tank designed for the study of launching problems. But it is the high speed water tunnel that is of greatest use in cavitation work, and no other tunnel in existence can approach it in performance.

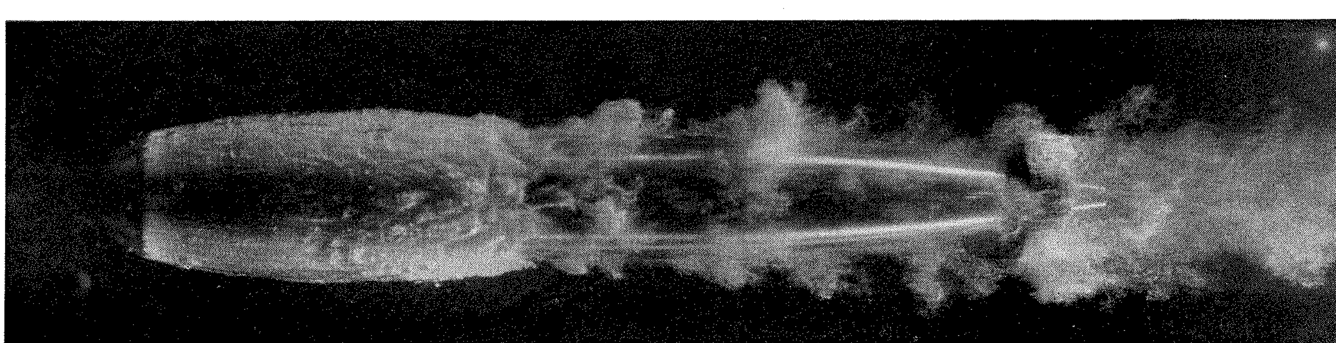
The tunnel is like a long pipe which has been joined at the ends. The water in it travels along a carefully designed 340-foot path. The working chamber, or part of the loop in which the model is mounted, is 14 inches in diameter and six feet long. Here the water pressure is lowest, and the speed highest. At its top speed, the water travels through the section at 100 feet per second. The chamber has windows at its top and sides so that researchers can watch and photograph the bubbles as they form and break around the model inside.



Drawing shows tunnel construction. Model two inches in diameter is mounted in working section at top of system.

The resorber system

Besides the circulating system and the instruments for controlling temperature, pressure and velocity of the water in the tunnel, there is another control system, a unique arrangement known as a "resorber." This is in fact a re-absorber; it puts back into solution any bubbles that have come out during cavitation



By studying pictures like this one of cavitation bubbles forming around a model in the tunnel, Institute engineers find out which shapes are best, which worst, for hydrodynamic efficiency in pumps, turbines and propellers.

so that the water will be smooth and even again when it completes its circuit and re-enters the working chamber. The resorber system is built into an 85-foot shaft, dug straight down into the ground under the Laboratory. Thus, behind the tiny model in its small working chamber are literally tons of equipment filling up a good part of the large building.

When the pumps are turned on, the water starts to circulate. When it gets to the working chamber it is made to rush past the model, and pressure changes occur. Cavitation bubbles are formed wherever the pressure is lowered to the water's boiling point, and each bubble or cavity formed is then pushed by the moving water along the model until it runs into an area of higher pressure. There the bubble collapses as water in areas of higher pressure pushes into the cavity from all sides. In addition to the cameras, there is a battery of recording instruments for keeping track of the forces that act on the model during this boiling process.

It is when the water smacks against itself, rushing into the cavities, that the forces are set free which are responsible for cavitation damage. But at the same time something else happens that is a mixed blessing for the hydrodynamics engineer. The water slapping against itself makes a great deal of noise—just as air does when it rushes in to fill the cavity caused by a lightning discharge. The smacking air is thunder, and the thunder of cavitation, while it warns engineers when something is beginning to cavitate, also makes pumps objectionably noisy, and causes vibration that annoys the passengers on an ocean liner. Worst of all, however, is the fact that cavitation slows down flow, or increases resistance to flow. And this, in turn, means that pumps and propellers cannot operate at maximum efficiency, and that objects running with heavy cavitation are difficult to control.

These are some of the problems hydraulics engineers face, and the problems the California Institute of Technology researchers have set out to solve. The tools of their investigation—the water tunnel, the special high-speed movies, the models—have been developed to the point where the engineers know how to control pressure and velocity in order to make any good shape cavitate or any bad shape stop cavitating. And recently, through studying their photographs, they have reached some tentative conclusions about different types of cavitations. Formerly engineers thought all cavitation bubbles acted the same way. Now Institute researchers have identified several kinds of bubbles which behave in several ways.

Engineering advances

The fruits of this research, made possible through the support of the Bureau of Ordnance, with the help of the Office of Naval Research, are being made available to industry and to other researchers. Already about a dozen firms and several universities have obtained copies of the Institute's moving picture. And the Institute research team has moved ahead into newer fields, toward more fundamental problems.

Located in a building next to the Guggenheim Aeronautical Laboratory of the California Institute of Technology, the Hydrodynamics Laboratory is an ideal spot to study the widest ramifications of its field. For the flow of water and the flow of air are related, and the research being done by these two laboratories gives promise of ever-widening discoveries and developments, which in turn give promise of more efficient pumps and turbines, better underwater shapes, even better fluid transmission for automobiles—and engineering advances that may affect every one of the millions of parts that operate in fluids in American industries.

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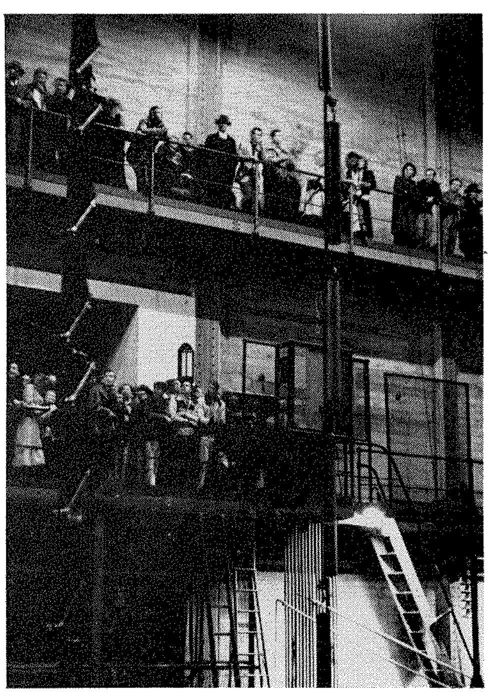
This review of cavitation studies in Caltech's Hydrodynamics Laboratory is the first of a series of reports on research in progress at the Institute.



Standing room only

Most popular of Caltech's Friday Evening Demonstration Lectures, held for the general public throughout the school year, is the one on high voltage, delivered by Prof. R. W. Sorensen. The demonstration in the High Voltage Laboratory which follows Prof. Sorensen's talk is still, after 25 years, one of the best shows on the campus. It proved to have its usual strong draw this year when, on a rainy Friday evening, almost 1,000 people stormed East Bridge. Prof. Sorensen obligingly gave his lecture twice, and the lab ran off three demonstrations, while a special police detail coped with the crush.

Specially designed for conducting researches requiring high-voltage electrical energy, the High Voltage Laboratory was built in 1924, with funds supplied by the Southern California Edison Co. The first laboratory in the country to have a reliable 1,000,000 volt power frequency, provided by a chain system of transformers designed by Prof. Sorensen, its facilities are available for research or for industrial tests. These facilities have been used to aid Southern California Edison in the development of high-voltage transmission lines, to furnish lightning protection of oil storage tanks for the oil industry, to test insulators for numerous utility companies.