NOL Hydroballistics Facility

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Introduction

DURING the past decade the service requirements of antisubmarine warfare (ASW) weapons have become more stringent because of the increased speed and depth of modern nuclear submarines. The kill effectiveness is related directly to the weapon transit time from the attacker to the attacked. Many of the modern weapons rely on high-speed flight through the atmosphere with re-entry into the sea on a trajectory leading to or near the enemy submarine. The water-entry phase of such missiles causes several design difficulties.

The missile, coming in obliquely to the water surface, experiences a side thrust, which causes broaching. This side thrust can be of such a magnitude that not only will the missile broach but it may also be destroyed because of excessive bending moments. Thus it is necessary to design the nose of the body properly in order to insure that the missile will enter the water and fly in a stable trajectory. One method of insuring stable water entry and a stable underwater trajectory is to design the nose so that all of the forces are axial. This can be accomplished by providing a flat on the nose of sufficient size that a cavity is created large enough to engulf the missile. By this means stable water entry and a stable trajectory can be achieved, but the axial forces on the missile become very large, particularly at high speeds.

This type of problem arose in connection with the development of submarine launched rocket (SUBROC) at the U. S. Naval Ordnance Laboratory (NOL). It soon became evident that data on high-speed water entry were unavailable and, furthermore, that facilities capable of testing under such conditions were limited. These facts necessitated extensive and costly full-scale tests on SUBROC.

Recognition of the possible future need of the Navy for high-speed water-entry missiles led the Bureau of Naval Weapons to recommend the construction of a facility capable of performing studies in this field. In 1963, Congress approved construction of such a facility at the Naval Ordnance Laboratory. It is scheduled for completion in January of 1966.

Testing Tank and Building

The requirements on the tank were the following: 1) capability for firing 3-in.-diam models at velocities up to 3000 fps, 2) controlled atmospheric pressure, 3) high water clarity, and 4) capability for studies involving underwater launching with or without exit to the atmosphere and study of underwater trajectories. Figure 1 shows a cutaway drawing of the Naval Ordnance Laboratory facility that is being constructed presently. The tank itself is 100 ft long, 35 ft wide, and 75 ft deep. The reinforced concrete building surrounding the tank provides support to withstand the high pressures generated at water entry and also the forces on the tank walls. The walls, top, and bottom of the tank will contain almost 200 observation ports, 16 in. in diameter and covered with $1\frac{1}{4}$-in. tempered glass. The tank will be concrete with a $\frac{1}{8}$-in. liner of 304 stainless steel, which will be anchored into the concrete. All of the tank walls will be provided with bosses on 6-ft centers for the support of equipment within the tank. Fifteen gun ports, 3 ft in diameter, will permit launching at almost any angle from above or below the water surface. Provision is made for later installation of rails on the floor of the tank for a mobile launcher.

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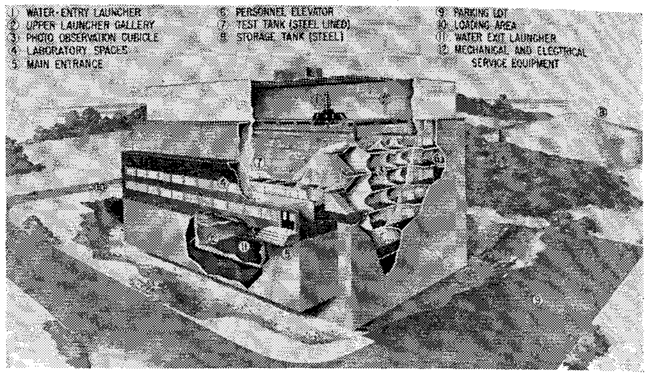

Fig. 1. Hydroballistic facility.

The diatomaceous earth filters used for water clarification will have a maximum capacity of 600 gal/min. Since the tank will contain 1.7 million gal of water, it will take at least 47 hr to pass all of the water through the filter. It is probable that the usual filtering rate will be only 400 gal/min, so that 3 days will be required for this operation. This rate would be inadequate if the water were withdrawn from the tank, filtered, and immediately returned to the tank. To improve the filtering effectiveness, a storage tank will be provided capable of holding all of the tank water. It will be possible to filter all of the water twice within a week by filtering all of it into the storage tank and then back into the main tank.

A single complete filtering can be carried out in 2 or 3 days. This is done by first "dumping" the water into the storage tank through a 3-ft-diam pipe in less than 15 min and then returning it to the main tank through the filter. This "dumping" potential is provided primarily to protect persons and equipment in case of window breakage. The storage tank will make it possible to change the water level in the main tank when required, or to drain the tank for maintenance, without loss of the filtered water.

Instrumentation

The tank will be used in the investigation of a wide range of test and research programs. Specifically, it is planned to conduct research in the following areas: 1) water entry, 2) fully wetted flight, 3) underwater launching, and 4) water exit (cavitating and noncavitating). In each of these areas, it is planned to measure axial and transverse forces, pressure distribution in the tank, cavity pressures, trajectories, stability, and damping, etc. NOL is presently developing and investigating instrumentation, which can be used to obtain these data under high-velocity conditions.

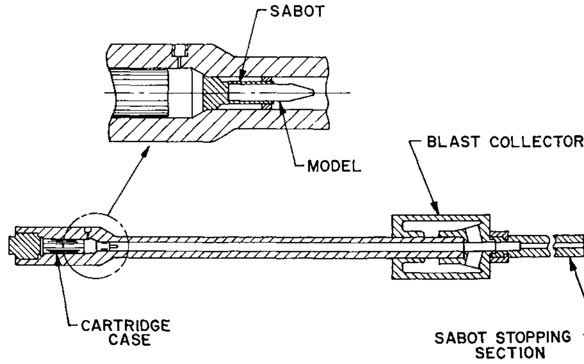

Fig. 2. Model launcher.

For the above-water launching of models, a 4-in.-i.d. gun has been designed. A schematic of this launcher is shown in Fig. 2. This is a powder gun using a conventional brass cartridge case. The model, which can be up to 3 in. in diameter, is carried in a high-strength metal sabot. The model and sabot are accelerated in the 10-ft-long 4-in. barrel by the burning propellant. At the end of this distance, the sabot enters a 3-in. aluminum section. The interference offered by this section slows and stops the sabot while the model is freed from the sabot. With a system of this sort it is possible to eliminate completely gun blast and powder fouling in the tank.

A 1-in.-i.d. scale model of this launcher was built and tested and indicated the feasibility of this type of launcher. A 1-in. sabot was stopped in 6 in. at an initial velocity of 3000 fps. The full-scale launcher will have the capability of providing a velocity of 3000 fps with an in-gun weight (sabot plus model) of 12 lb. It should be possible to stop the sabot, which will weigh approximately 6 or 7 lb, in a distance of 3 to 4 ft.

Two guns of this type have been designed and ordered. One will be fired through the top of the tank through angles from vertical to 50° to the vertical. The other gun will be operated on the side of the tank and will provide angles from 50° to 85° from the vertical.

All of the operations required in conjunction with the launching of a model into the tank will be controlled automatically in sequence and time. When the gun is fired, the sequencer will compute the missile speed, calculate the times at which the missile will reach preset distances or speeds, and trigger such events as flashtubes when required. More than 30 triggering operations can be effected, all controlled by a standard master oscillator.

The need to obtain water-entry axial and transverse forces, cavity pressures, trajectories, etc. has led to considerable instrumentation development. Some of the instrumentation concepts that have been considered and are under development or study are the following: 1) telemetry—to transmit pressures, accelerations, etc., 2) Doppler radar—to measure the velocity time of the missile at impact, 3) optical whip recorder—to measure the angular change of the missile at entry, 4) hydroballistics range—to set up a range system similar to existing aeroballistic ranges to determine forces and moments, and 5) photography—to study trajectories. Several other systems such as sonar, internal recording, lasers, etc. are in the conceptual phase but have not been investigated actively as yet.

The telemetry unit is being developed for NOL by the Harry Diamond Laboratory. It is a frequency-modulated system with a carrier frequency of 65 Mc and a maximum bandwidth of 300 kc. It is being designed to withstand accelerations greater than 100,000 g's. If successful, the telemetry unit will permit recording axial and transverse forces, as well as cavity and body pressures.

An experimental Doppler radar system is being tested to establish the feasibility of obtaining velocity time of the missile from water impact to cavity closure. This system is utilizing a K-band transmitter, and satisfactory Doppler shift has been obtained. One of the problems that has arisen is the background noise of the water surface and splash. This has introduced a beat frequency on the Doppler frequency. Effort is being devoted to eliminate this beat frequency by firing through a hole in a radar absorbing material placed about 1 ft above the water surface. An optical whip recorder has been constructed and is presently undergoing test and evaluation. Preliminary results have been encouraging, and it is believed that accurate angle-time data can be obtained at high velocities.

A feasibility study is being conducted on the use of a hydroballistics range similar in operation to existing aeroballistic ranges. The extreme damping caused by the high-density water makes the use of such a facility somewhat questionable since aeroballisticians normally require several model oscillations to determine the force and moment coefficients. The purpose of the study being made is to determine the feasibility and limitations of an accurately surveyed range, particularly in the early cavity phase of water entry. Although most of the instrumentation that I have described is being designed to provide data at water entry, we are also considering for future use instrumentation that can be utilized to give data for underwater launch conditions at velocities up to about 1000 fps.

Conclusion

In conclusion, the NOL facility has been designed to provide high-velocity water-entry data with a $\frac{1}{6}$ scale model of an 18-in.-diam, 9-ft-long missile. Velocities up to 3000 fps are possible with such a model, and launch angles can be varied from vertical to horizontal. In addition, the capability exists for launching vertically through the bottom of the tank or for mounting a launcher within the tank for studying underwater launch problems at velocities up to at least 1000 fps. Control of the atmospheric pressure provides control over cavitation scaling.

The size of the facility is such that scaled model tests of powered and maneuverable submarines or torpedoes are possible. At the present time, tests are being made in a small pilot hydroballistic tank to develop instrumentation for the new facility.