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Distinctive research and test facilities exist at the U.S. Navy's Arctic Submarine Laboratory, San Diego, CA. These facilities include the unique Arctic Experimental Pool, sea ice model basin, large entry cold chamber, dry cold laboratories, various pressure chambers, and seawater pond along with supporting facilities. The unique Arctic Experimental Pool holds approximately 950 m³ of seawater (pumped from the Pacific Ocean). The air temperature can be held as low as -60°C and sea ice up to a thickness of 5 feet can be grown while controlling the salinity and air content of the water. The sea ice model basin can be sustained at -20°C and filled with fresh water, seawater, or "doped" water. The sea ice model basin has a towing carriage above the surface and a towing sled on the bottom of the pool. The special features of the unique facilities are discussed as well as the complete details of all of the facilities. These facilities were built following the end of World War II to study the many problems associated with working or operating in sea ice and/or low-air temperatures. The first major results of tests in the facilities include development of the snorkel spray ring for the induction masts of submarines and initial ice-breaker model tests that contributed to the design of the U.S. Polar class. The facilities have been refurbished recently and are available for conducting research experiments and engineering testing.

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INTRODUCTION TO THE U.S. NAVY ARCTIC LABORATORY

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Abstract

Distinctive research and test facilities exist at the U.S. Navy's Arctic Submarine Laboratory, San Diego, CA. These facilities include the unique Arctic Experimental Pool, sea ice model basin, large entry cold chamber, dry cold laboratories, various pressure chambers, and seawater pond along with supporting facilities. The unique Arctic Experimental Pool holds approximately 950 m³ of seawater (pumped from the Pacific Ocean). The air temperature can be held as low as -60°C and sea ice up to a thickness of 5 feet can be grown while controlling the salinity and air content of the water. The sea ice model basin can be sustained at -20°C and filled with fresh water, seawater, or "doped" water. The sea ice model basin has a towing carriage above the surface and a towing sled on the bottom of the pool. The special features of the unique facilities are discussed as well as the complete details of all of the facilities. These facilities were built following the end of World War II to study the many problems associated with working or operating in sea ice and/or low-air temperatures. The first major results of tests in the facilities include development of the snorkel spray ring for the induction masts of submarines and initial ice-breaker model tests that contributed to the design of the U.S. POLAR Class. The facilities have been refurbished recently and are available for conducting research experiments and engineering testing.

History

The Arctic Experimental Pool was originally conceived to solve the problem "How to neutralize/defend against the attacking submarine in the ice in the Gulf of St. Lawrence." The German single U-boats that devastated shipping in the North Atlantic in the winter (1943 to 44) would hide under the ice. In 1952, the Arctic Experimental Pool was designed and constructed in an old mortar battery on Point Loma which was part of the Navy laboratory there (which has had numerous names over the years starting with the Navy Radio and Sound Laboratory in World War II and is the Naval Ocean Systems Center today (with another pending name change in 1992)).

In 1969 to 1970, the Arctic Experimental Pool operated as a model basin for the Coast Guard and a north slope oil project. Both ice breakers and the design of the ice-strengthened tanker MANHATTAN (ice-breaking-bow modification) were tested.

In 1970, the design of the sea ice model basin was started and construction was completed by 1974.

Since 1984, the Arctic Experimental Pool has been modified to allow variation in the air content of the ice and to prevent adhesion of the growing ice sheet to the sides of the pool.

Facilities

The complex facilities that comprise the Arctic Submarine Laboratory share two common refrigeration plants. Ammonia is used as the refrigeration fluid in a normal Carnot cycle. The ammonia chills a large volume of methylene chloride which is then pumped to the necessary heat exchangers to cool water (initial cooling of the water in the pools or cooling the water in the large pressure chamber), chill the air over the water/ice, or to cool the air in the cold rooms.

Main Pool

The Arctic Experimental Pool is one of a kind in the Western Hemisphere (and maybe throughout the world) that can grow true sea ice in the same manner as nature grows sea ice in the Arctic but with predictable and controlled conditions. The water is filtered and pumped in from the Pacific Ocean. Then the water is chilled to near freezing by circulating it through a heat exchanger. When the water nears its freezing temperature the remainder of the freezing and ice growth process is done entirely by extracting the energy through the water/air and then the water-ice-air interface using a heat exchanger in the air 2 m above the water surface. The salinity and air content of the water before freezing starts can be controlled to desired parameters. As the freezing process goes on, the salinity and air content of the water is varied or maintained as needed for the particular experiment. Seasonal variations in salinity can be simulated and a summer melt season may be simulated to provide "multiyear" ice. The overhead coil system gives a continuous complete "cold sky" that can be driven to about -60°C. This unique feature simulates arctic winter radiation exchange where the air-temperature gradient is highly variable depending on the ice thickness and a stirring of air volume. (See Table 1.)

Once the temperature in the pool (approximately 975 m³) is lowered to near freezing the rate of ice growth is a function of the air temperature. Figure 1 shows the thickness of ice and growth time for three different air temperatures

Table 1 Pools

	Arctic Experimental Pool	Sea Ice Model Basin
Length	23.7 m	30.5 m
Width	8.53 m	9.1 m
Depth	4.87 m	1.27 m
Water/ice types	seawater	seawater, fresh, doped
Min. air temperature	60°C	20°C
Max. ice thickness	1.5 m	12.7 cm

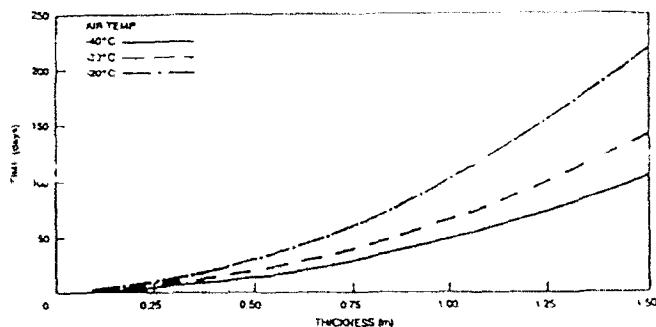


Figure 1. Growth rate of ice sheets.

A controlled buoyancy impact vehicle (Figure 2) can be released at different speeds (and thus, different momentums on impact) to permit studying the forces involved in impacting sea ice from underneath. An observation room on the bottom of the pool, a periscope, and various underwater cameras permit observing and recording experiments from beneath the ice sheet.

An ice jack is installed in one end of the pool to permit rafting of part of the ice sheet.

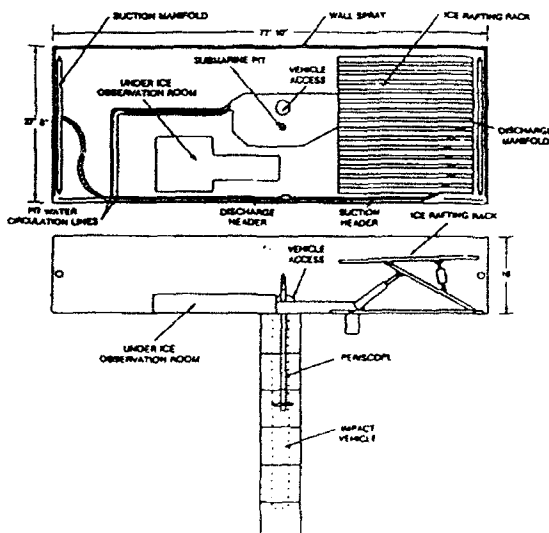


Figure 2. Arctic Experimental Pool.

Sea Ice Model Basin

The sea ice model basin (Figure 3) is similar to many towing basins except that the surface may be an ice sheet. The cooling and freezing process is similar to the main pool although "seeded/doped" ice (fine grained, urea, etc.) may also be grown. Additionally, the sea ice model basin has a towing carriage (typical model-towing carriage) above the surface and a sled on the bottom to facilitate towing a submerged body without the towing mechanism breaking the ice sheet. This sled can test a body impacting the ice with lateral as well as a small vertical motion relative to the ice.

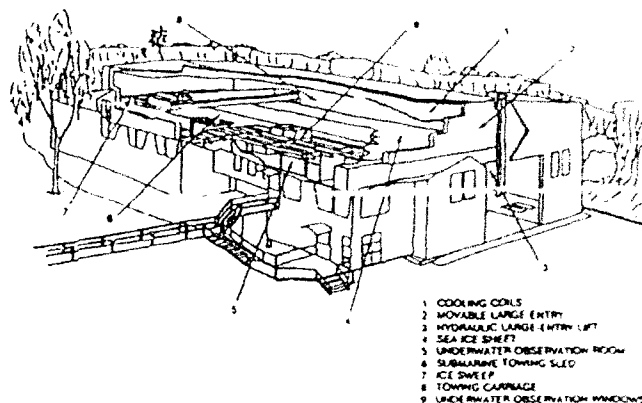


Figure 3. Sea ice model basin.

Large Entry Cold Chamber

The large entry cold chamber (Figure 4) was built to provide the ability to chill large objects (vehicles, small submersibles, ROVs, UUVs, etc.) which may be subjected to low-air temperatures (during transport or storage). The maximum floor loading is 2440 kg/m³. The chamber can be used as a dry chamber or to test low-air-temperature icing of systems under salt or fresh water spray conditions.

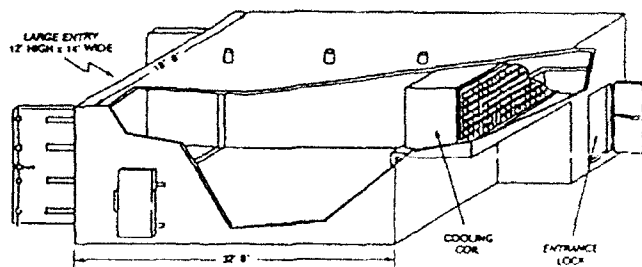


Figure 4. Large entry cold chamber.

Cold Rooms

Two dry cold laboratories are available (Figure 5). The air temperature in each room may be individually monitored and controlled. While not normally used for "wet" work, a small tank (< 567 liters) may be installed with a circulating pump to grow sea ice while under continuous observation (such as by laser). (See Table 2.)

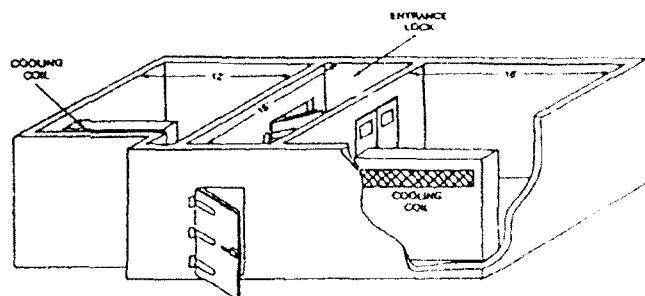


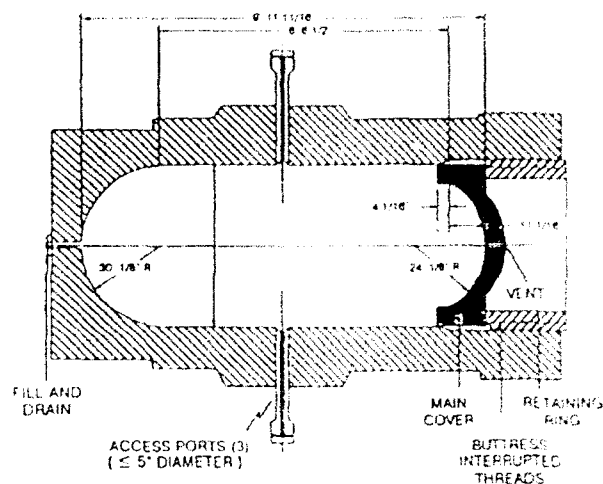
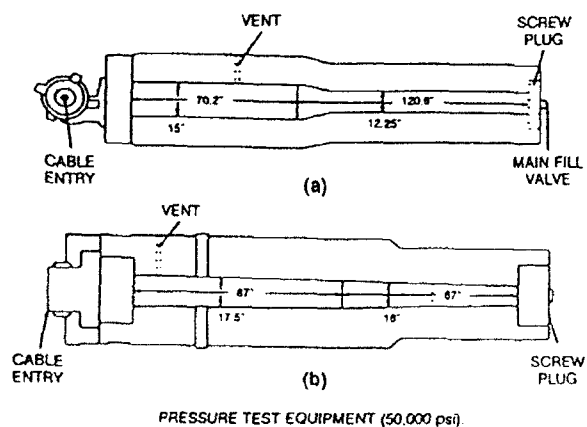
Figure 5. Dry cold laboratories.

Table 2. Cold rooms and chambers

	Large Entry	North Lab	South Lab
Length	9.1 m	4.57 m	4.57 m
Width	4.87 m	3.65 m	4.57 m
Height	3.35 m	2.12 m	2.13 m
Min. air temp	-45°C	-45°C	-45°C
Dry/Spray	Both	Dry	Dry
Entry Size	3.35 m X 4.24 m	1.98 m high X 1.01 m wide	

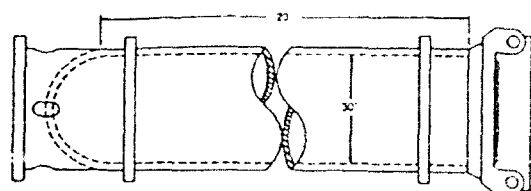
Pressure Facilities

A variety of pressure test chambers are also located at the Arctic Submarine Laboratory (Figure 6a through e). The chambers' general capabilities are given in Table 3. The large pressure tank (Figure 6-c) may also be operated over a temperature range of 0° to +90°C.



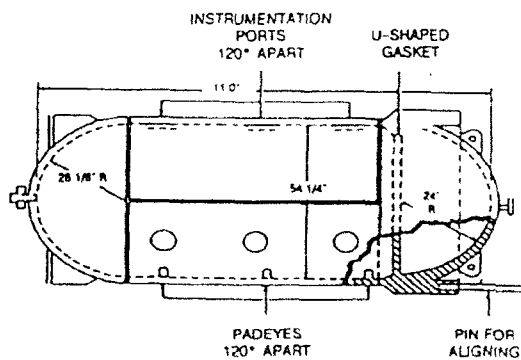
PRESSURE TEST EQUIPMENT (10,000 psi)

(c)



PRESSURE TEST EQUIPMENT (1,500 psi)

(d)



PRESSURE TEST EQUIPMENT (1,000 psi)

(e)

Figure 6. Pressure test facilities

Table 3. Pressure tanks

Tank	Length	Diameter	Pressure MPa	Shape
12 in. gun	4.82 m	31 cm	345	A
16 in. gun	3.91 m	40.6 cm	345	A
Chicago tank	3.04 m	40.6 cm	70	B
Note 1				
Mare Island tank	3.35 m	1.37 m	7	B
Pasadena tank	7.01 m	76 cm	10	C

Note:

1. This tank may be operated at a controlled temperature in the range from 0° to 90°C

Shapes:

- (A) A gun barrel which has a larger diameter than that given at the breech and a slight taper in the length.
- (B) A cylindrical tank with hemispherical ends.
- (C) A cylinder with flat ends.

Conclusions

The U.S. Navy's Arctic Submarine Laboratory was designed and built specifically to do scientific and engineering tests of sea-ice sheets. The additional support facilities are

Physics Laboratory,
Chemistry Laboratory,
Optics Laboratory,
Electronics Laboratory,
Dark Room, and
Machine Shop.

A variety of typical tests are

Pre-field/proof of concept tests;
Ice penetration methods (from above and below);
Sonar performance tests;
Through-ice transmission measurements (laser/IR/
acoustic/IR);
Ice physics tests;
Ice fracture mechanics tests;
Ice thickness measurement systems;
Ice movement systems;
Seawater salinity variation tests;
Long-term cold soaking of equipment;
Component strength measurements versus ice;
Geophone performance;
Remotely Operated Vehicle (ROV) operation under ice;
Hull coating (SHI, etc.) abrasion tests; and
Structure atmospheric icing effects.

These facilities are ideal to do the laboratory testing of sea ice to validate models and compare with field experiments. The facilities provide a capacity, which may well be unavailable anywhere else in the world. These facilities are available for any user on a cost reimbursable basis.