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Technical Report

SUBMARINE HULKS AS PROTECTIVE SHELTERS

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SUBMARINE HULKS AS PROTECTIVE SHELTERS

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by

R. F. Swalley

OBJECT OF TASK

To determine the feasibility of using obsolete SS-212 (GATO) class submarine hulks as personnel shelters.

ABSTRACT

Various schemes are considered for emplacing a submarine hulk as an underground shelter. The most practical method is to dredge a slip into a beach area, float in the submarine, and cover it with sand.

Modifications to the submarine would be necessary before it could function as a shelter. It would be necessary to install a new electrical system, a new entrance, a modified ventilation system, and a renewed air-conditioning unit. The berthing facilities could be readily expanded to include 138 bunks. The overpressure capacity would be at least 267 pounds per square inch, with commensurate radiation protection provided by a cover of 8 feet of sand.

It is estimated that a submarine hulk could be adequately modified and emplaced for about $60,000. A breakdown of costs is given.

INTRODUCTION

The submarine pressure hull is a strong and durable structural unit. Also, the submarine is fitted to support life for a number of men under restricted conditions. With this potential it is reasonable to consider the submarine as a possible means for personnel protection during atomic, biological, or chemical attack. The Laboratory therefore was directed by the Bureau of Yards and Docks to make a feasibility study of the use of obsolete submarine hulks as protective shelters.

This study makes an assessment of the overall problems involved and the necessary alterations and additions to existing submarine equipment and facilities. In addition, a summation of all estimated costs, based on 1960 costs, is presented.

SUBMARINE TYPE

Currently, SS-212 (GATO) class submarines are being disposed of as scrap by the Navy. It is this class of submarine, the oldest still in service, that is considered in this report.

Much information was gained by an inspection of an SS-212 class submarine, the USS SUNFISH (formerly SS-281), at the Mare Island Naval Shipyard. This submarine had been decommissioned and used as a Naval Reserve Training Unit, and had been stripped of much equipment to provide space for classrooms. The condition of the SUNFISH represented the probable state of a submarine prior to its disposal.

Closely allied to the SS-212 class submarine is the SS-285 (BALAO) class. The SS-285 class, which constitutes the bulk of World War II "fleet" type submarines, differs from the SS-212 class only in the thickness of its pressure hull. Thus, except for overpressure resistance, this report could be considered to apply to the SS-285 class as well as the SS-212 class.

POSSIBLE SHELTER LOCATIONS

Movement Inland

Although it is conceivable to transport a submarine hulk weighing approximately 2,000 tons inland by land conveyance, the cost would be inordinate. It is immediately concluded that this economic factor precludes further consideration of submarine movement inland except by water. Thus, the use of submarines as shelters becomes essentially limited to coastal areas.

Movement Over the Beach

It would be possible to slide the submarine hulk over the beach to a nearby location where it could be buried. Sliding a submarine over the sand itself, however, would not be practicable, as the sand would tend to pile up in front of the craft. Some form of shipway would be required that would allow the hulk to slide without impediment. The cost of providing such a shipway and moving the submarine inland a moderate distance is estimated to be in excess of $50,000. This estimate makes this alternative impractical.

Beach-Slip Operation

A third alternative would be a beach-slip type of operation. By this method, a slip would be dredged in a relatively flat beach area and a submarine would be floated in and covered with sand. The area could be located along a principal river or inlet. The main costs for this method would accrue from the dredging operation. Differences in the type of beach, the location of the beach, and the condition of the sea would cause these costs to vary. For the purpose of this study these conditions will be considered to be nearly ideal.

The beach-slip method, the simplest and least expensive alternative, is the method selected for evaluation in this study. In the following analysis the design capacity of the submarine is taken to be 150 men, although berthing space for this number would not be provided.

MOVEMENT OF SUBMARINE (Beach-Slip Method)

The submarine would have to be towed to the beach-slip area from its berth. A representative distance for this movement is taken to be 100 miles. An estimate of towing costs based on commercial rates is $1,000; the estimate for moving the submarine into the slip is $1,500.

EMPLACEMENT OF SUBMARINE

Preparation of Site

An ideal beach site would be composed entirely of sand and have periods of low surf activity. Also the slope of the sea floor and beach would have to be small. For such a situation the average slope (to a point 400 feet inland) is taken to be 0.033, or a rise of 1 foot in 30 feet.

Normally, a fully equipped and loaded submarine of the SS-212 class has a draft of between 15 and 16 feet. As all of the supplies, some of the equipment and much of the superstructure would be removed, the draft will be taken to be 10 feet.

Figure 1 shows a cross section of the slip cut required at the mean high-tide location. A 50-foot margin between the stern of the submarine and the mean high-tide location would be allowed so that the berm would not be washed away by surf activity. As the submarine is 312 feet long, the cut would have to extend inland approximately 360 feet. The cross section of cut 360 feet inland from mean high-tide location is shown in Figure 2.

The dry excavation, which would extend down to sea level, would be 4,800 cubic yards. The cost for this excavation would be $450.

The continuous refilling with sand at a dredged slip due to lateral currents necessitates a high rate of excavation. To effect a sufficient rate it would be necessary to use a hydraulic dredge for the cut below waterline. A 12-inch dredge, which moves approximately 350 cubic yards per hour, is considered to be the smallest dredge that would accomplish the desired excavation with requisite speed. With 7,300 yards of wet cut to be made at 350 yards per hour, the operation would take 21 hours. It is assumed that the dredge would have to be transported a distance of 150 miles to reach the site of the beach-slip operation. The figures for the dredging operation, based on commercial estimates, are shown in Table I.

Table I. Dredging Costs

Mobilization and demobilization (150 miles movement)	$ 7,500
Dredging (21 hours at $150 per hour)	3,150
Contingencies (20 percent)	2,150
Total	$12,800

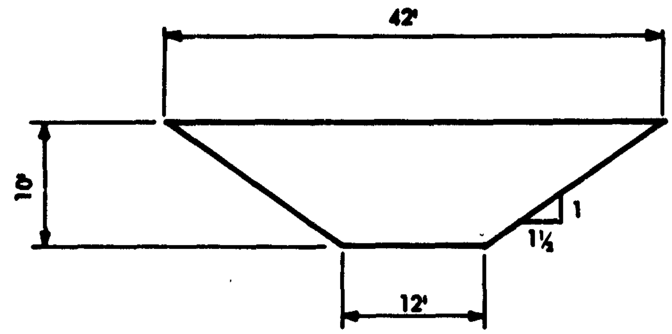

Figure 1. Cut at mean high-water mark.

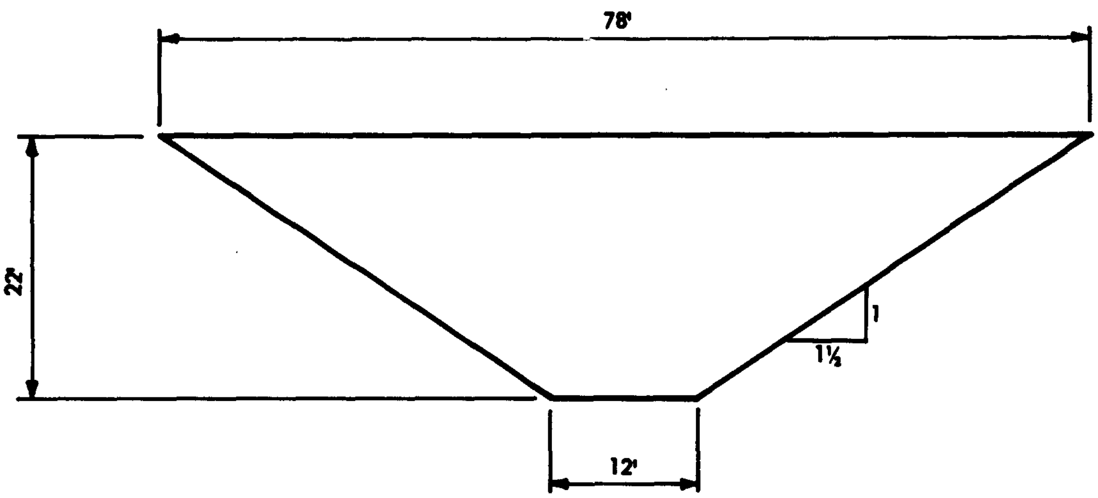

Figure 2. Cut at bow (inland) end of submarine.

Backfilling

After the submarine is floated into the slip and sunk onto its foundation of sand, it would be covered with sand for blast and radiation protection.

To minimize the height of berm, all or a portion of the superstructure must be removed. Two methods are considered: (1) the superstructure, including topside decking and the conning tower, would be completely removed to the top of the pressure hull; (2) the superstructure would be stripped to the top of the conning tower only.

Figures 3 and 4 indicate the manner of burial for Methods 1 and 2, respectively. Eight feet of sand cover is used above all portions of the submarine to provide adequate radiation protection. (Elevations indicated are elevations above sea level.)

For Method 1 the amount of backfill necessary would be 9,000 cubic yards. It is estimated that a D-8 tractor can backfill 150 cubic yards of sand per hour. At that rate, it would take 60 hours to complete the operation. At $16 per hour, the cost of backfilling would be $960.

For Method 2 the amount of backfill would be 14,000 cubic yards. The estimated time to move this amount of sand is 93 hours; the estimated cost is $1,500. Table II presents the anticipated cost of emplacement for both methods.

Table II. Cost of Emplacement

	Method 1	Method 2
Cost of tractor excavation	$ 450	$ 450
Cost of dredge excavation	12,800	12,800
Cost of backfilling	960	1,500
Total	$14,210	$14,750

SUBMARINE ANALYSIS AND REQUIRED MODIFICATIONS

Shock Resistance

The SS-212 class submarine is capable of withstanding hydrostatic pressure to a depth of 300 feet in sea water. This depth of water corresponds to a static pressure resistance of 133.5 pounds per square inch.

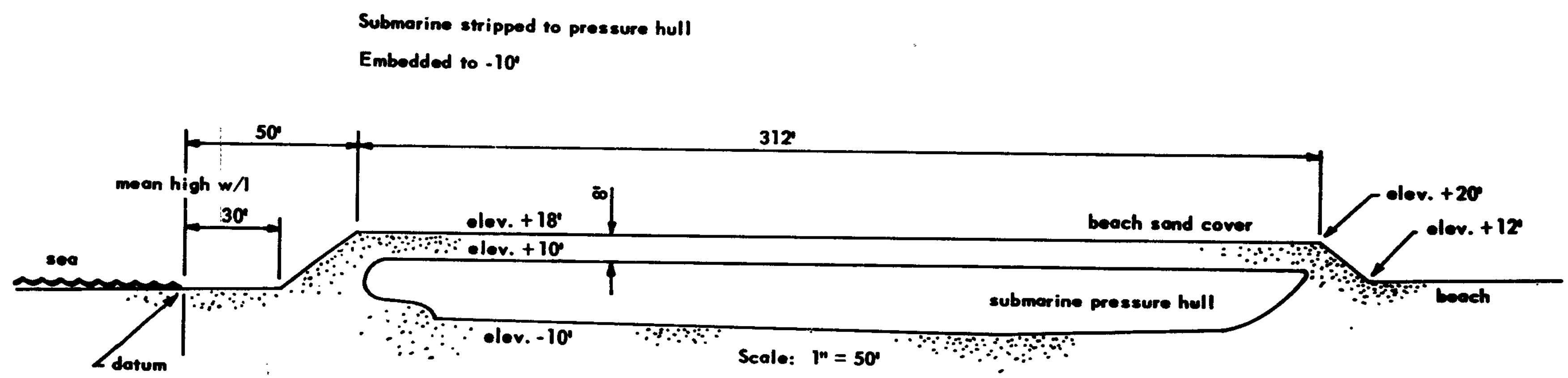

Figure 3. "Method 1" of embedment.

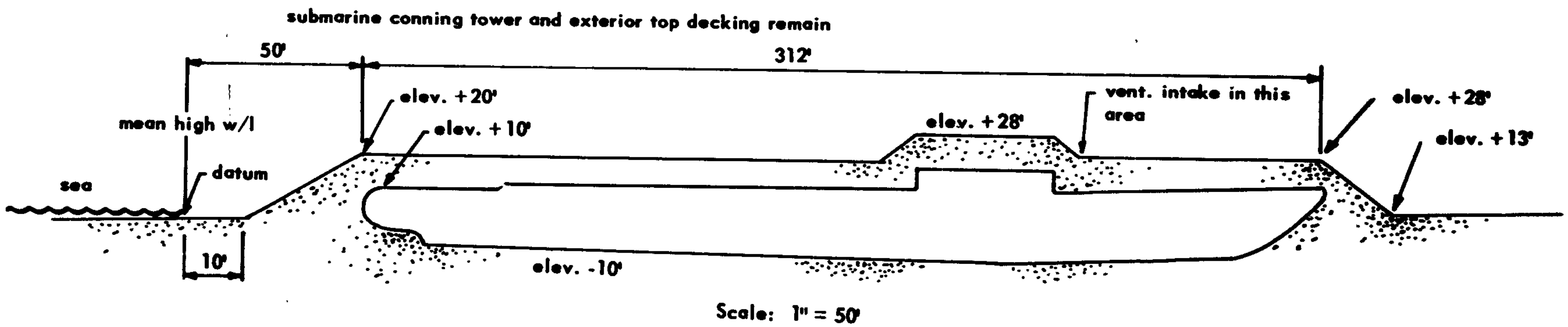

Figure 4. "Method 2" of embedment.

On the basis of laboratory tests it has been predicted that pressure hulls can withstand dynamic loadings of considerably greater magnitude that static loadings.[1] Actual nuclear tests that have been performed on submarines in shallow water indicate that the dynamic resistance of the submarine is greater than the rated static resistance.[2] However, for longer duration loads (from megathon-range detonations) it is expected that the dynamic resistance would more closely approach the rated static resistance.

Certain differences in the response of a submarine will occur when it is buried in saturated sand. The transmission of the shock wave will not vary greatly, as the attenuation factor, k, is 1.[3] The loads which are induced in a buried structure, however, are dependent upon the relative stiffness of the soil with respect to the structure and upon other parameters discussed in detail elsewhere.[4,5,6] It is expected that the loads induced through saturated sand would closely approach those imposed through water.[7] Some increase in the overpressure capacity of the submarine may be expected because of the beneficial effect of passive soil resistance, although weakening of the pressure hull due to corrosion after many years of service is also probable. It is anticipated that the deleterious effect of the latter condition would effectively cancel the beneficial result of the former.

Thus, an SS-212 class submarine, buried in saturated sand, could conservatively be counted on to withstand an overpressure from a long-duration shock wave of at least 130 pounds per square inch.

Structural Modifications

Superstructure Modifications. For Method 1 the superstructure, including the conning tower, would be stripped to the top of the pressure hull. The outside skin, however, which encloses the ballast tanks, fuel oil tanks and other tanks, would remain. The net cost of removing the entire superstructure would be $1,000; a portion of the gross cost would be offset by its salvage value.

For Method 2, in which the superstructure would be removed to the top of the conning tower, the cost would be $800. The height of berm for this method would be about 8 feet higher than for Method 1. (See Figures 3 and 4.)

Structural Modifications for Foundation. It is proposed that the submarine would rest directly on sand, without benefit of piling, and would be supported by its outer skin and associated intermediary plating. The total weight of the submarine would be approximately 2,000 tons, and, assuming an average diameter of 20 feet, would be covered by 2,510 tons of sand. This total weight of 4,510 tons acting over an area of 6,240 square feet would create a bearing pressure of 10 pounds per square inch, which is well within the bearing capacity of a saturated sandy soil.

As the intermediary plating weakens, differential settlement of the submarine would occur. To prevent this movement, it would be necessary to provide additional support between the outer skin and the pressure hull. This may be accomplished by partially filling some of the tanks with concrete. The depth of concrete necessary would be 4 feet; the width, 8 feet. The specific tanks to be filled are listed in Table III.

Table III. Tanks for Foundation Support

TANK		LENGTH (ft)
Normal fuel-oil tank		15
Fuel ballast tank, #3A-3B		12-1/2
Main ballast tank, #6A-6B		10
Main engine sumps, #3-#4		5
	Total	42-1/2

The total volume of concrete required would be 50 cubic yards. Assuming an in-place cost of $20 per cubic yard, the total cost of the concrete necessary for foundation support would be $1,000.

The weight of the concrete (100 tons) would cause the submarine to settle firmly on the sand underneath and would serve to help anchor the vessel from possible movement. The soil-bearing pressure is increased to only 10.3 pounds per square inch.

Entrance Design. The SS-212 class submarine has several overhead hatches with a diameter of 25 inches. These hatches, though suitable for emergency exits, would not serve as entranceways for two reasons. First, the rate of ingress would be insufficient to meet warning time limitations; second, the prevention of radiation streaming through the entrance structure would be difficult.

The best entrance would be a doorway cut in the side of the submarine near the bow (Frame 30), where the outer skin and the pressure hull are in close proximity. A generalized sketch of a possible entrance design is shown in Figure 5. The door would be a horizontal, sliding or rolling blast-resistant type.

It is estimated that the cost for the entrance structure and blast-resistant door would be $10,000.

<u>Emergency Exit</u>. Any of the present hatches would serve as emergency exits. The hatch most readily accessible for exit is located in the after torpedo room; it is also most distant from the proposed entrance.

Figure 6 presents a sketch of the proposed emergency exit. The trunk leading to the top of the berm would be filled with coarse gravel and sand to prevent radiation streaming. The only modifications necessary to the submarine would be the removal of the outer hatch and the reversal of the inner hatch so that it would open inward. When necessary to use the exit, the inner hatch would be opened and the sand and gravel would pour into the submarine, permitting escape.

The cost for the emergency exit is estimated to be $150.

Electrical Requirements

Power requirements for a submarine serving as a shelter are indicated in Table IV.

Table IV. Shelter Power Requirements

Air conditioning		10 kw
Ventilation		8
Pumps		5
Cooking		2
Lighting and communications		5
	Total	30 kw

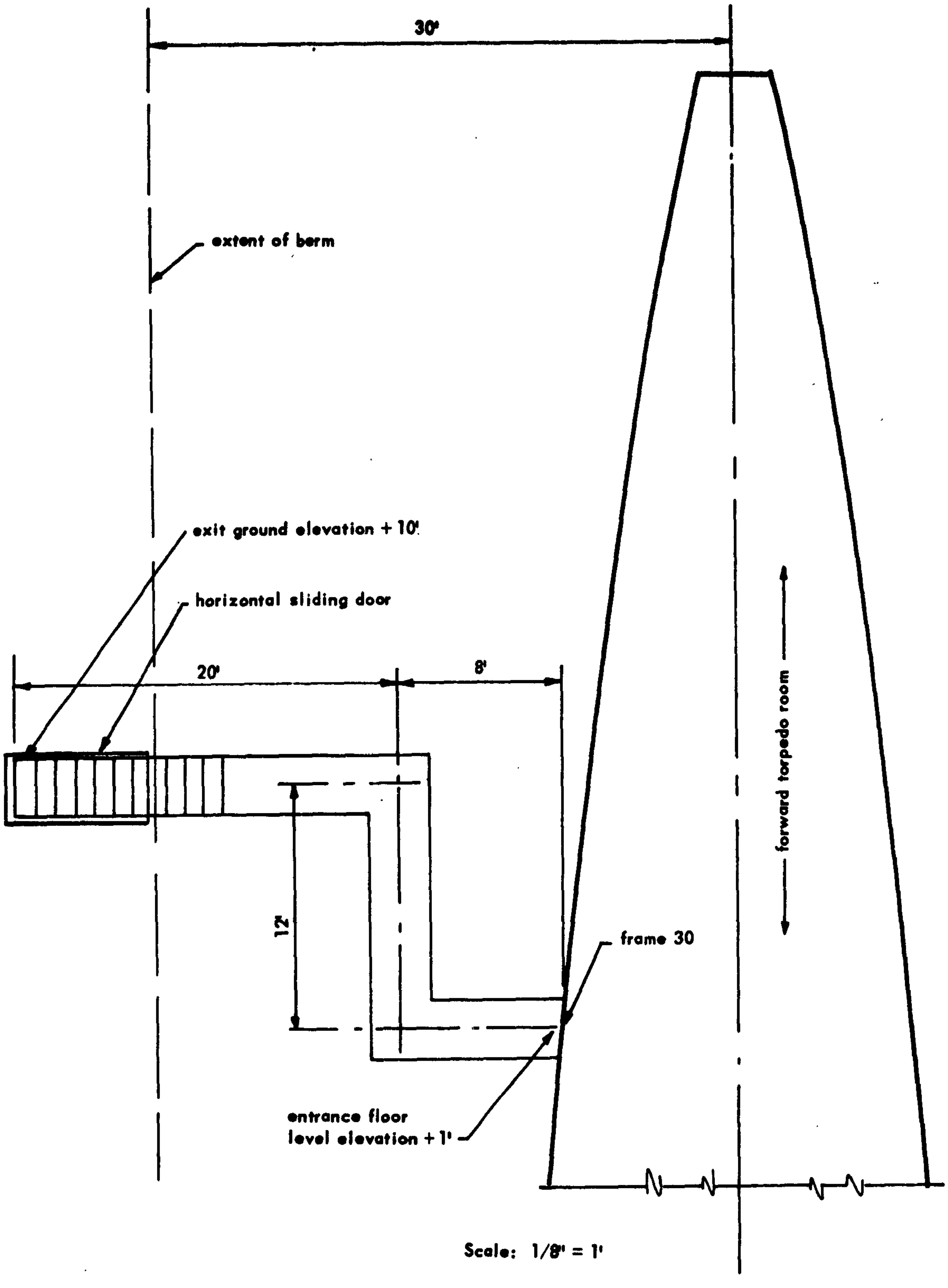

Figure 5. Shelter entrance design.

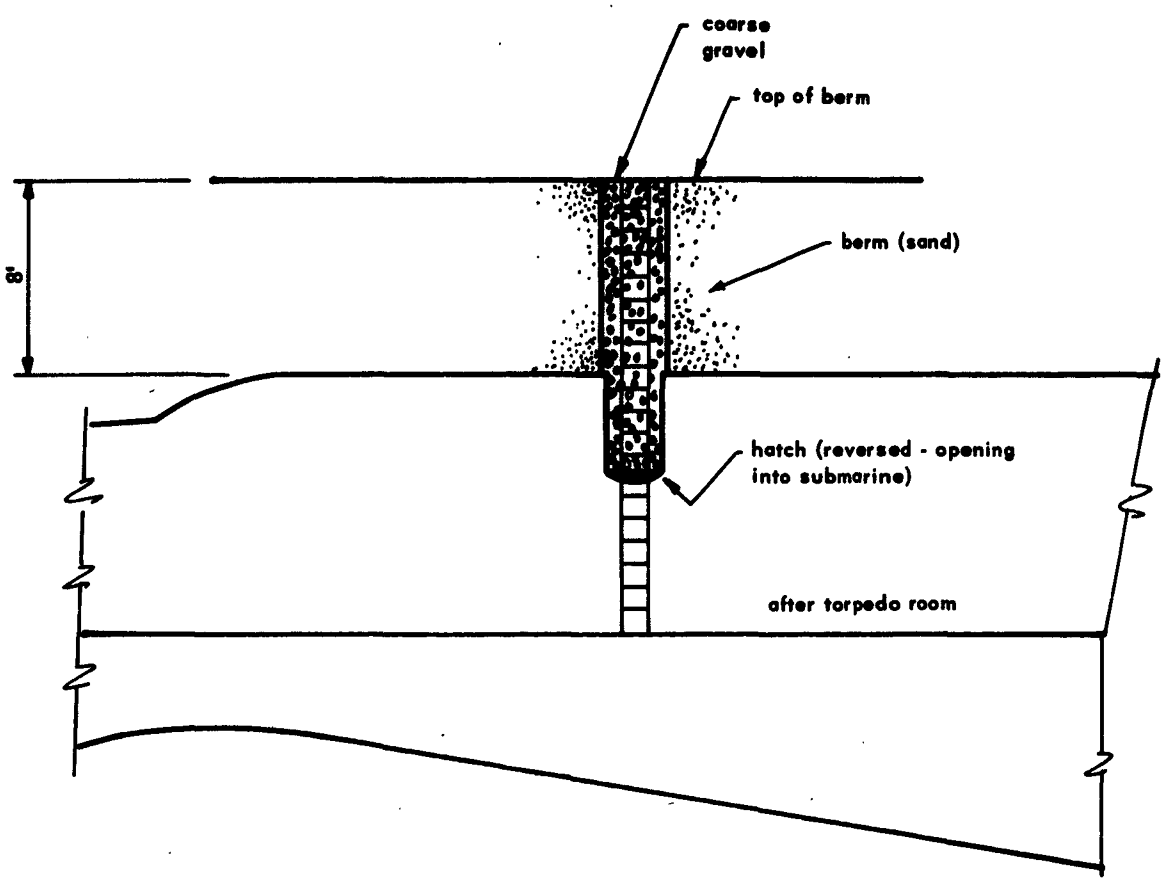

Figure 6. Emergency exit arrangement.

Most of the present electrical equipment aboard the SS-212 class submarines requires direct current. Some submarines of this class have wiring for lighting that is adaptable to either alternating or direct current.

The submarine should not only be capable of utilizing external power, but it should also be able to generate its own emergency power. This could be done in either of two ways. One would be to convert exterior utility power to dc and to use the existing emergency facilities aboard the submarine; the other would be to use exterior ac utility power and to install emergency ac power-generating equipment. In the latter case it would be necessary to rewire the submarine for ac service.

It is estimated that the cost of the first alternative would exceed that of the second and that the first alternative would be in general less desirable. The existing emergency power generator on the SS-212 class submarine is rated at 300 kilowatts; it is not desirable to use this size generator when the power demand is only 30 kilowatts.

Thus, external power would be received in the form of four-wire, 120/208-volt, 60-cycle utility service. A 30-kilowatt, four-wire, 120/208-volt, 3-phase, 60-cycle diesel generator would be installed, preferably in the engine room. A normal ship's fuel tank would be used for fuel storage. The water supply for generator cooling is discussed under Air Conditioning. A main distribution panel with transfer switch would be installed and all wiring would be newly installed except in those cases where existing wiring is suitable for ac use.

The cost of making electrical modifications is estimated at $11,000.

Ventilation and Air Conditioning

The proposed ventilation and air conditioning arrangements are shown in Figure 7.

Ventilation. The submarine has an air supply and exhaust system that includes fans driven by dc motors. The capacity of the system is more than adequate but modifications would be required at the intake and exhaust ports. These openings are located near the conning tower and are protected by a steel shroud. It would be necessary to cut away the shroud and existing hoods, add ductwork to grade, and provide two blast closure valves that would withstand at least 130 pounds per square inch. The supply duct would also require a filter unit similar to the Army Chemical Corps M10. As the electrical system would be ac, the present dc motors must be replaced by ac motors. The air supply requirement is assumed to be 5 cubic feet per minute per person (750 cfm total); as no leakage is expected, the exhaust requirement is the same.

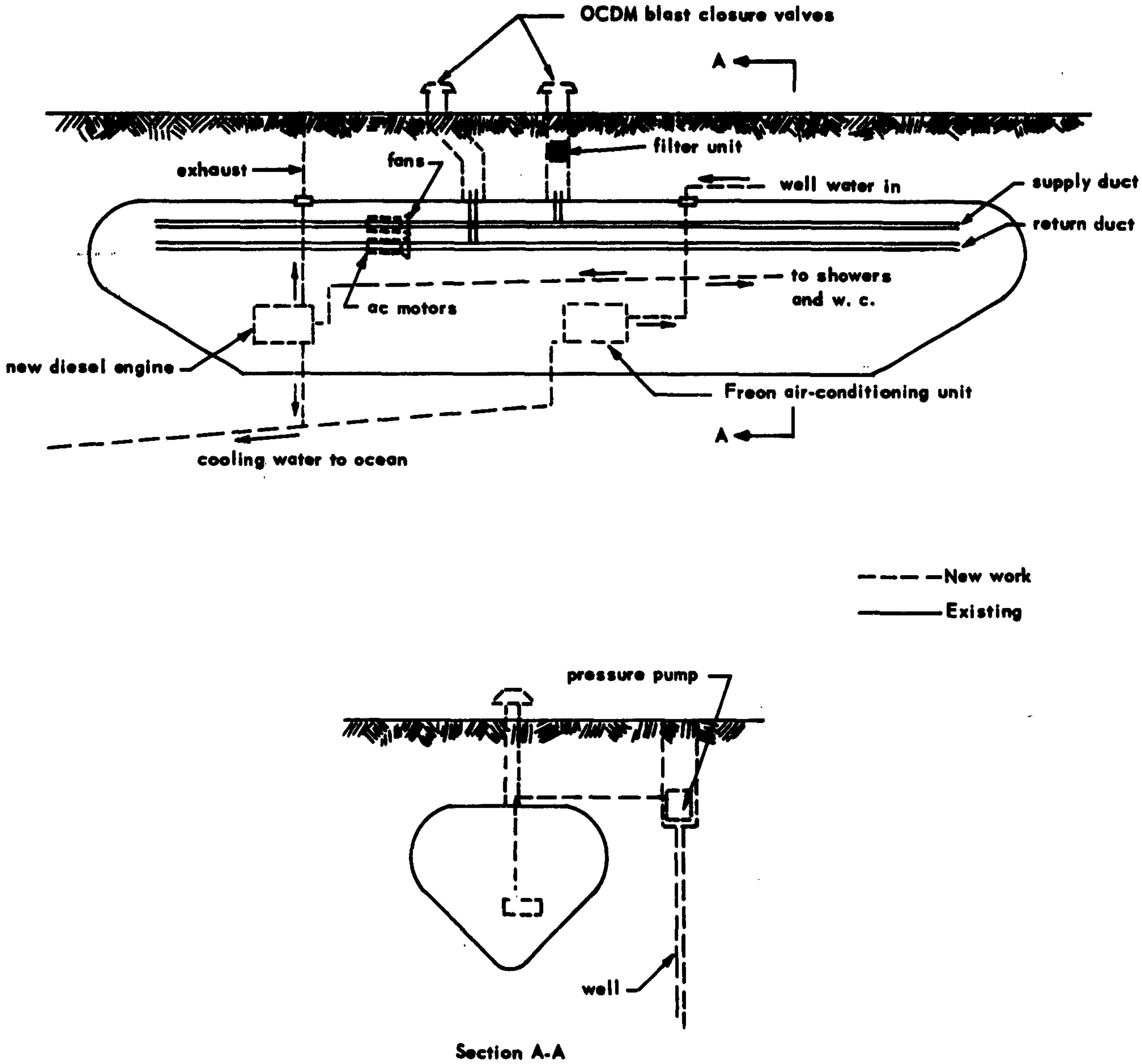

Figure 7. Ventilation and air-conditioning arrangement.

It would be necessary to provide a special exhaust for the stand-by diesel generator unit. This exhaust would run directly upward to the ground surface. As use of the diesel generator would not be necessary prior to an attack, a blast closure device could be replaced by a simple yet positive closure of the exhaust duct. This closure would have to be internally located so that the diesel generator could be put into operation without having to leave the submarine.

The estimated total cost for ventilation equipment and conversion is $7,500.

Air Conditioning. The present cooling equipment for the air-conditioning system on an SS-212 class submarine is located in the ship's hold, with a heat exchanger in the main supply duct. It is assumed that this air-conditioning system, if it has not been removed from the salvaged submarine, would probably not be in working condition and that a new unit would be required. An inspection of the old unit should be made, however, to determine if it would be less expensive to overhaul it. It would also be necessary to provide cooling water for the air-conditioning system as well as for the emergency diesel power-supply unit.

Contributions to the heat load that would be imposed on the air-conditioning system would be from inherent heat in the outside air and from inhabitants, interior motors, lights and cooking equipment. Some heat, however, would be lost through the walls of the submarine. The internal heat contribution would be approximately 146,000 Btu per hour. A contribution of 24,000 Btu per hour is gained from the outside air if an exterior design condition of 90 F dry bulb and 50 percent relative humidity and an allowable interior design condition of 85 F dry bulb and 50 percent relative humidity is assumed. Heat lost to the soil is difficult to predict, but based on basement losses estimated by the American Society of Heating, Refrigeration and Air-Conditioning Engineers, the loss would be approximately 20,000 Btu per hour.

A summation of the heat gains and losses indicates a final cooling load of 150,000 Btu per hour. This load requires 12-1/2 tons of air-conditioning equipment, for which the cost would be $4,000.

The total amount of cooling water required for the air conditioner would be approximately 390,000 gallons. The emergency diesel generator unit would require an additional 150,000 gallons. A total of 540,000 gallons would have to be supplied in 14 days, which gives a rate of 27 gallons per minute. The most convenient means of water supply would be a shallow well under the submarine, which would in most cases draw brackish but radiologically uncontaminated water. The cost to drill the well and provide a pressure pump is estimated at $1,500.

Corrosion Prevention

In many instances the pressure hull of a submarine is protected with a vinyl coating that would prevent corrosion. In all probability the outer hull would not be as well protected, but as this hull does not contribute to the structural integrity of the vessel its protection is not vital. For this study, protection of the pressure hull only is considered; the outer skin would be allowed to corrode.

The simplest means of protecting the pressure hull when there is no vinyl coating is the inclusion of a weak ammonia solution (1,750 ppm) in salt water in the various ballast and fuel tanks. It would be desirable to fill all except sanitary tanks with this solution. A small amount in the tanks used for sanitary purposes would allow a reduced, though acceptable amount of protection.

The combined capacity of the submarine tanks is 250,000 gallons; one and one-half tons of ammonia would be required for the desired solution. The cost for this protection, which would be effective for 20 years or more, would be $300.

Other Habitability Facilities

Berthing. The berthing capacity of SS-212 class submarines varies between 75 and 85; the capacity of the USS SUNFISH was 77. Certain compartments could be modified at varying expense to allow more space for berthing. A survey was made of the SUNFISH to determine where additional berthing facilities might be located. The results of this survey are indicated in Tables V and VI. Table V includes the cost estimate for modifications of the various compartments to provide for the indicated number of additional bunks, with the cost per bunk.

A cost of $400 or more per additional bunk is considered excessive. Table V indicates the berthing capacity (138) when the more costly modifications are not made. The cost for an additional bunk frame and installation is taken as $10; this figure is also reflected in column 5 of Table VI.

The modifications necessary to enlarge the berthing capacity to 138 would cost $7,510. The overload capacity of the submarine would be at least twice this figure, inasmuch as it is possible to sleep in shifts.

Storage Space. The existing submarine facilities are more than adequate for storage of clothing, medical equipment and supplies, and other items. Additional space is available in the compartments in which submarine batteries had been stored.

Table V. Cost Analysis for Expanded Berthing Capacity

Space	Equipment or Fitting to be Removed	Present Berthing Capacity	Expanded Berthing Capacity	Additional Bunks Provided	Cost to Remove Equipment	Cost per Additional Bunk	Comments
Forward Torpedo Room	Torpedo skids and brackets Work berches Torpedo rollers and brackets	14	32	18	$2,000	$111	All but one skid on USS SUNFISH already removed.
Officers' Quarters	None	13	17	4	0	0	Bulkhead removal would allow somewhat greater capacity.
Control Room	Master gyro Chart table Auxiliary gyro Steering stand Indicator panels and diving control Electrical control panel Fathometer	0	12	12	4,000	333	The auxiliary switchboard should remain if this circuitry is to be used.
Conning Tower	Fire-control equipment Periscope hoists	0	6	6	3,000	500	
Radio Room		0	0	0	0	0	Only one TBL transmitter remained on SUNFISH. Space is adequate for a command communications center.
Crew's Mess Hall	Mess tables	0	12	12	300	25	This envisions shelter messing to be buffet style. No cooking equipment remained on SUNFISH.
Crew's Quarters		36	42	6	0	0	Bunks on SUNFISH had been removed.
Forward Machine Compartment	Fittings adjacent to passageway	0	9	9	600	67	
Aft Machine Compartment		0	0	0	0	0	Cost to remove main engine - $29,000.
Maneuvering Room	Lathe Work bench	0	4	4	3,000	750	Cost to clear cubicle would be prohibitive.
Aft Torpedo Room	Work table Pyro firing gear and attached diaphragm Torpedo rollers and skids	14	19	5	2,000	400	
	Totals	77	153	76	$14,900		

Table VI. Proposed Changes to Increase Berthing Capacity

Space	Present Capacity	Expanded Capacity	Additional Bunks	Cost to Prepare Space	Cost for Bunks and Installation
Forward Torpedo Room	14	32	18	$2,000	$180
Officers' Quarters	13	17	4	0	40
Control Room	0	12	12	4,000	120
Crew's Mess Hall	0	12	12	300	120
Crew's Quarters	36	42	6	0	60
Forward Machine Compartment	0	9	9	600	90
After Torpedo Room	14	14	0	0	0
Totals	77	138	61	$6,900	$610

Total Cost $7,510

Fresh Water. It is proposed that four of the existing ship's fresh-water tanks be used for water storage; they hold in excess of 4,000 gallons. For a design capacity of 150 persons, this allows more that two gallons per person per day, whereas half a gallon has proven adequate.[8] It would be necessary to install two small hand pumps at a cost of $50.

Sanitation. The existing toilet facilities include four water closets, which are considered adequate for 150 men. The sanitary tanks installed on the submarine have a capacity of 815 gallons; this capacity, however, would be inadequate, as no overboard discharge is anticipated. The capacity of the sanitary tanks may be suitably increased to 4,923 gallons by allowing an opening to adjacent variable or lube oil tanks. Chemicals would be used in these tanks, and venting would be accomplished through the main exhaust stack.

The remodeling of sanitation facilities would cost approximately $260.

Decontamination. Present suitable decontamination facilities consist of one shower in the vicinity of the entrance. The well used to supply water to the air-conditioning system could serve this facility also. Though brackish, the water would be suitable for showers.

Food Preparation. The range and other food-preparation equipment aboard the SUNFISH had been removed. It is anticipated that dry emergency rations would be used and that there would be no demand for cooking facilities other than two small hot plates for heating water.

SUMMARY

1. Location. The best way of moving the submarine to its location is the beach-slip method. For maximum economy the shelter location is limited to nearly ideal beach sites along oceans, or in areas adjacent to rivers or inlets.

2. Additions. Certain additions are necessary for the submarine to serve as a shelter. They include exterior ventilation ductwork, two blast closure valves, a shallow well, concrete foundation support, an entrance structure, a blast-resistant exterior door, a corrosion-protecting solution, and an emergency ac generator.

3. Modifications. A number of modifications to the submarine are necessary. They include conversion of the electrical system from dc to ac, renewal or overhaul of the air-conditioning unit, provision of a doorway in the side of the submarine, removal of a portion of the superstructure, and removal of much interior equipment for additional berthing space.

The best method of modifying the superstructure is to strip it to the top of the pressure hull (Method 1). It is less expensive and entails a lower sand overburden than the other method considered.

4. Berthing. After modification, the number of bunks in the submarine would be 138. With only 50 percent of the occupants asleep at one time, the capacity of the submarine becomes 276.

5. Shock Resistance. In its modified state an SS-212 submarine hulk could withstand at least 133.5-psi overpressure. For short-duration blast loadings from smaller weapons, the overpressure resistance would probably be twice that figure.

CONCLUSIONS

It is possible to utilize a buried submarine as a personnel shelter.

The estimate for modification and emplacement of an obsolete submarine hulk as a personnel shelter is approximately $60,000 (Table VII), or a cost of $220 per occupant. This figure compares favorably with the costs for current construction of underground shelters.

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Contributions to this report were made as follows:

A. M. Brown - Electrical

C. V. Brouillette - Corrosion

C. A. Dittus - Sanitation and Water Supply

J. M. Stephenson - Ventilation and Air Conditioning

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Table VII. Final Cost Summary

DESCRIPTION	METHOD 1 Breakdown	METHOD 1 Summation	METHOD 2 Breakdown	METHOD 2 Summation
1. Submarine Movement				
a. Tow costs	$ 1,000		$ 1,000	
b. Movement into slip	500		500	
		$ 1,500		$ 1,500
2. Submarine Emplacement				
a. Site preparation	$13,250		$13,250	
b. Backfilling	960		1,500	
		$14,210		$14,750
3. Submarine Modifications and Additions				
a. Superstructure	$ 1,000		$ 800	
b. Outer skin support - concrete	1,000		1,000	
c. Entrance	10,000		10,000	
d. Emergency exit	150		150	
e. Electrical	11,000		11,000	
f. Ventilation	7,600		7,600	
g. Air conditioning and well	5,500		5,500	
h. Corrosion	300		300	
i. Berthing	7,510		7,510	
j. Fresh water	50		50	
k. Sanitation	260		260	
		$44,370		$44,170
	Total	$60,080		$60,420

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