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CONCEPT FOR SEA LAUNCHING MISSILES AND TRANSPORTING LARGE BOOSTERS USING A TUBE

By

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SUMMARY

The purpose of this report is to introduce a preliminary concept of a system which will further enhance the feasibility and versatility of the sea-launch concept. The proposed system makes it possible to take almost any missile, regardless of size and type of propellant, and launch it from the sea. The system involves enclosing the missile in a reusable capsule or tube which can then be towed underwater, erected to the vertical, and the missile launched from this tube.

Some of the advantages of the tube are the following:

1. The tube provides structural strength so that the missile can be designed with an optimum mass fraction.
2. The tube provides all flotation, ballast, and work platforms. The design of the missile does not have to deviate from an optimum aerodynamic design in an attempt to build in flotation, etc.
3. Corrosion and watertight integrity problems are eliminated from the missile.
4. The tube provides a means of stabilizing the floating missile.
5. The cost of the tube is relatively low because of its simple boiler plate construction.

Besides the launching of missiles, a modified tube can also be used for transporting large boosters. In the case of solid-propellant boosters, the motor can even be cast, cured, and carried away all in the same tube.

INTRODUCTION

The idea of launching missiles from the sea was introduced some time ago and again recently as the HYDRA technique (floating the bare missile vertically in the manner of a spar buoy on the ocean's surface prior to launch).* In general, the HYDRA technique has been accepted as feasible, and the intent of this report is to introduce a preliminary concept of a system in support of sea launching. It is believed that the proposed system will further enhance the feasibility and versatility of launching missiles from the sea. In theory, the system would make it possible to take any existing or future missile of land-launch design and launch it from the sea with little or no modification.

When studying the HYDRA technique, it appeared to the author that a means of protecting the bare missile might be desirable in some cases during the handling and erecting phase. It seemed that the best method of accomplishing this would be to house the missile in a tube. The tube with the missile enclosed could be handled, erected to the vertical, and the missile launched from the tube without many of the problems associated with bare missile launches. In addition, any and all support hardware such as ballast tanks, work platforms, damping fins, trim tanks, fuel tanks, etc. could be attached to the tube to provide the needed capability. The most apparent immediate advantage over the HYDRA technique would be that not only solid but current large liquid-propellant rockets could be adapted to the concept of sea launching.

Other than preliminary conceptual work, no detailed feasibility study of this system has been made, but for the purpose of this report, and based on the preliminary work, it will be assumed that the proposed system is feasible. The design details of the tube described herein are not necessarily the final or best design for the system, but are only proposed here as one possibility.

It is interesting to note that during World War II, the Germans had plans for launching V-2's at the United States from capsules towed by submarines. It is believed that the Russians have adapted the sea-launch concept and have missiles called GOLEM I, II, and III which are launched in this manner.**

DESCRIPTION OF SYSTEM

The tube (see figure 1) consists of an internal tube to house the missile and an external tube to house the ballast tanks and other hardware. The missile is

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*U.S. Naval Missile Center. Sea Launch of Large Solid-Propellant Rocket Vehicles. Part I: Technical Aspects and Nonmilitary Applications, by J. E. Draim and C. E. Stalzer. Point Mugu, Calif., NMC, 22 Mar 1960. (NMC Technical Memorandum No. NMC-TM-60-4) UNCLASSIFIED.

**See MISSILES AND ROCKETS, 17 July 1961, p. 89.

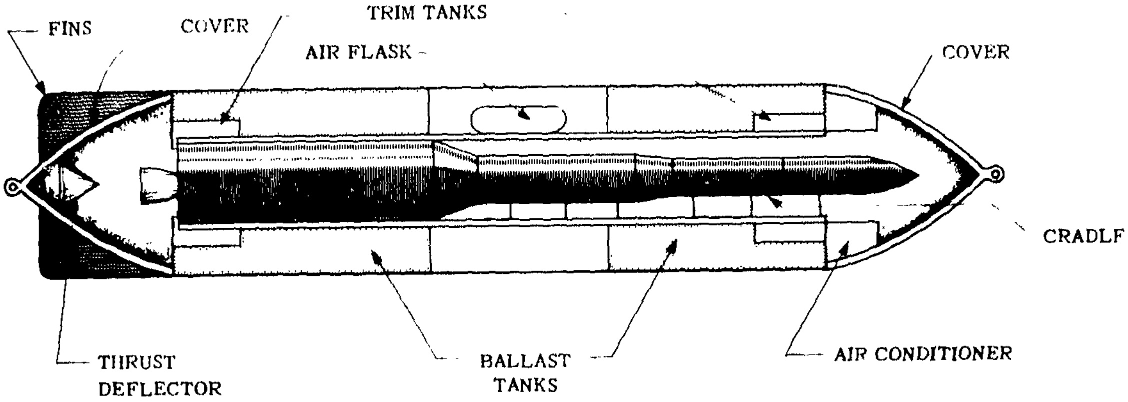

Figure 1. Tube With Missile Enclosed.

held in a full-length cradle and is supported 360 degrees, circumferentially. The surface of the cradle in contact with the missile is padded with a cushioning material. The cradle has skids that run in tracks the length of the tube.

The track (see figure 2) is enclosed in a channel which has compression springs holding down the track. Under the track is an air bladder made of a rubberized fabric which runs the length of the track. The area of the bladder is such that the weight of the missile is completely supported by the air pressure in the bladder. When the bladders are inflated, the tracks are pushed tight against the cradle and the missile "rides on air." When the missile is to be launched, the air in these bladders is released so that a sufficient amount of clearance is obtained between the missile cradle and the tube.

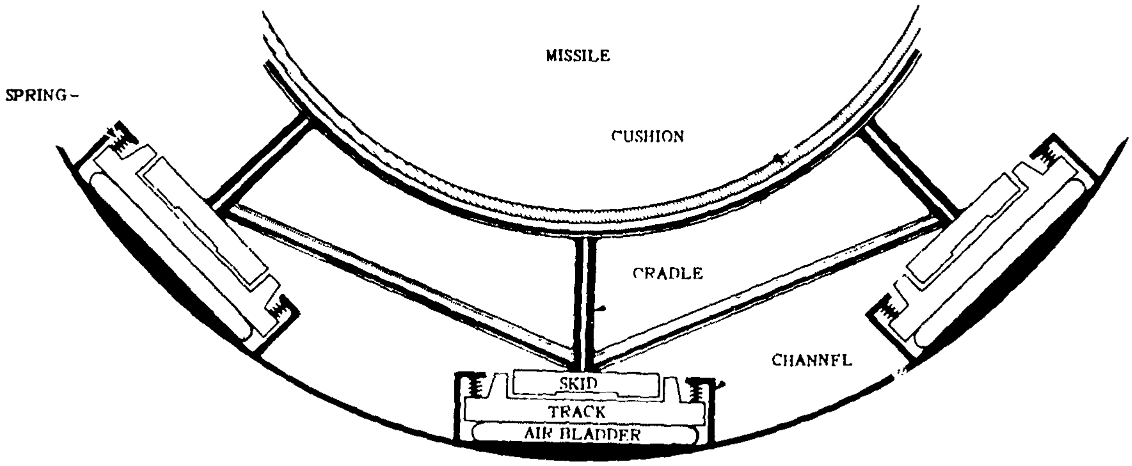

Figure 2. Cradle and Track.

As stated previously, the ballast tanks are housed between the internal and external tubes. A supply of high-pressure air is stored in a flask between the forward and aft ballast tanks. Pumps for shifting ballast are provided also.

The ballast tanks are further divided to provide trim tanks, one forward and one aft, between which ballast can be pumped fore and aft.

The inside surface of the tube is lined with an absorbent material to reduce the transmission of acoustic energy. There is a passage running the full length housed between the internal and external tubes. From the passage there are inspection hatches at all missile interstage locations for inspection of thrust vectoring alinement when the tube is surfaced in either the horizontal or vertical position. The taking on and removal of ballast is accomplished by motor-operated valves. The tube has hydrofoils or hydroplanes that are used to control the tube underwater when it has neutral buoyancy, much like a submarine. The tube is closed at the top or front end by a watertight cover which can either be hinged to the tube or removable. The aft or bottom end is closed by a watertight cover which is divided into four or more sections. The sections are hinged to the tube such that they will be pushed open by the exhaust gases of the missile.

A conical thrust deflector is housed under the aft cover, between the fins. This deflector is cooled by sea water. The framework itself is made such that it is cooled by an unlimited quantity of sea water against the same effects of the hot exhaust gases. The cooling of these parts is achieved by utilizing the Venturi effect of the high-velocity exhaust gases to draw the water up inside the members and then flow it over the outside surface with the exhaust gases.

On the outside of the tube, there are damping fins which are in planes at right angles to the longitudinal axis of the tube. These fins will open out from a folded position through spring-loaded hinges. There are several locations of these fins along the length of the tube so that the proper amount of damping is achieved to eliminate heaving of the tube in the vertical position. There could be wheels on the outside of the tube so that the tube can be moved over land if necessary.

When the tube is surfaced in the vertical position and its top cover removed, there are catwalks and platforms for the workmen to stand on while they service the payload end of the missile. All the motor-operated valves, pumps, and latches, etc., are controlled from a control panel via an umbilical cable that connects at or near the center of gravity of the tube. The displacement of the umbilical cable is such that it will have neutral buoyancy. An air-conditioning unit in the tube provides the proper climate and environment in the tube when it is hermetically sealed. The condition of the missile will be monitored continuously at the control panel.

OPERATION

Solid-Propellant Missile

This description will be for a typical MINUTEMAN or larger sized solid-propellant missile.

The tube will be placed horizontally in a drydock with the covers on both ends removed. The missile will be constructed on its cradle in a horizontal position in line with the mouth of the tube. Either the missile or the tube will be moved so that the skids on the missile cradle will fit into their respective launch tracks. During this time the air bladders under the launch tracks will have been deflated so that there will be maximum clearance between the tracks and the cradle. The missile will be slid inside the tube until it has come to rest against the supporting lip at the bottom end. Then a locking latch will snap in place securing the missile so that it cannot shift longitudinally. The air bladders then will be inflated so that the missile will be "riding on air" and held snuggly in the tube.

The covers will now be replaced at both ends of the tube. The front cover will be secured by conventional "dogs" used for watertight hatches. The sections of the aft cover will be held tightly together by a frangible or explosive band at the tip. When the tube is made watertight, it will be pressurized with an inert gas to provide additional watertight integrity, and the air conditioner started.

When the drydock is flooded, the tube will be floating on the surface much like a surfaced submarine. The tube with the missile enclosed can be towed out to deep water, and the ballast tanks flooded, causing the tube to submerge. The trim tanks will be filled enough to give the tube neutral buoyancy, and the trim ballast will be pumped either fore or aft to trim the tube horizontally. The tube can be towed either by surface ship or submarine anywhere in international waters. The hydrofoils will be used to control the attitude of the tube while being towed submerged (see figure 3).

When the launch site is reached, the tube will be surfaced vertically by blowing all ballast from the forward ballast tanks. As the forward ballast tanks empty, the tube will rise into a vertical attitude, much like a spar buoy. The damping fins will be sprung open from their folded position and will lock into place. By transferring trim ballast, the metacentric height can be varied to give the pitch amplitude and frequency that is most compatible with the size and frequency of the ocean waves so as to result in the least amount of motion. The tube should now be in a very stable condition, with negligible heave or pitch. The top cover will be opened and the technicians will go below to inspect the thrust vector control and to work on the payload high above and unaffected by the sea. Just before launch, the air bladders will be deflated and the missile locking latch released. The upper sections of the missile's cradle will now be removed also.

When the missile is ready for launch, the workmen will return to the mother ship which will withdraw to a safe distance, and the launch button pushed (see figure 4). When the first stage ignites, the bottom cover will be pushed open by the exhaust gases and the missile should behave much like it was HYDRA launched. The force acting on the thrust deflector will hold the tube at the same relative depth while the missile lifts up and clears the tube. After the missile

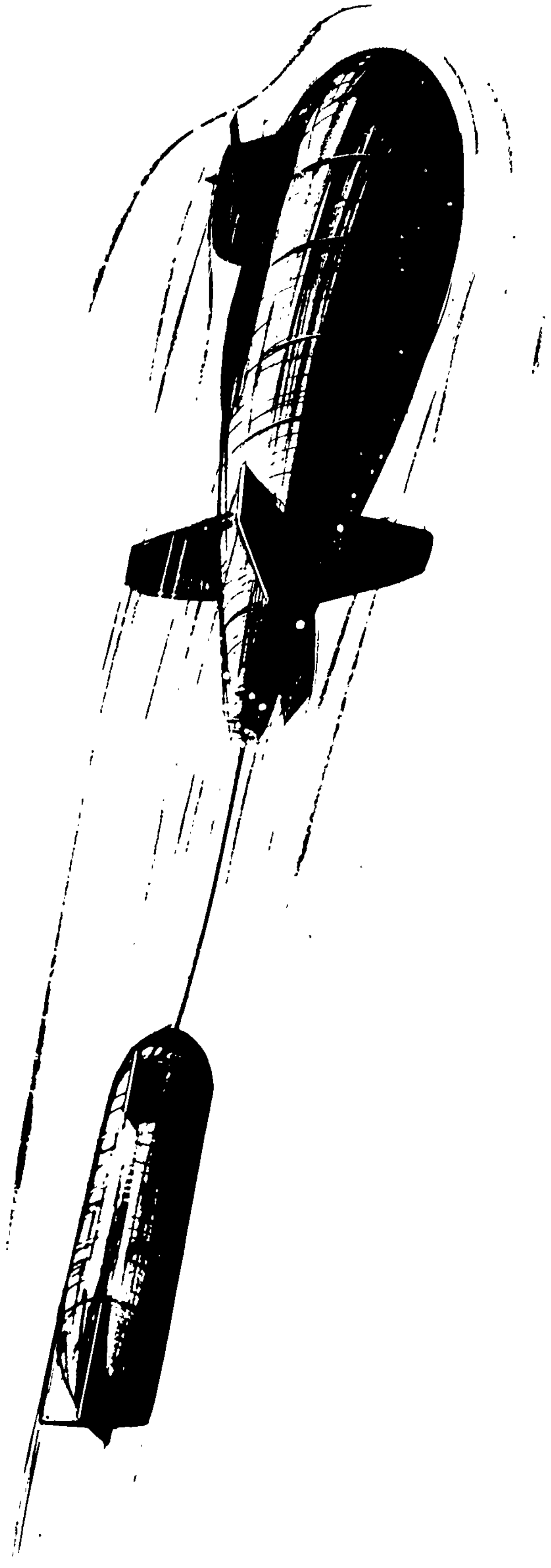

Figure 3. Tube Being Towed Underwater.

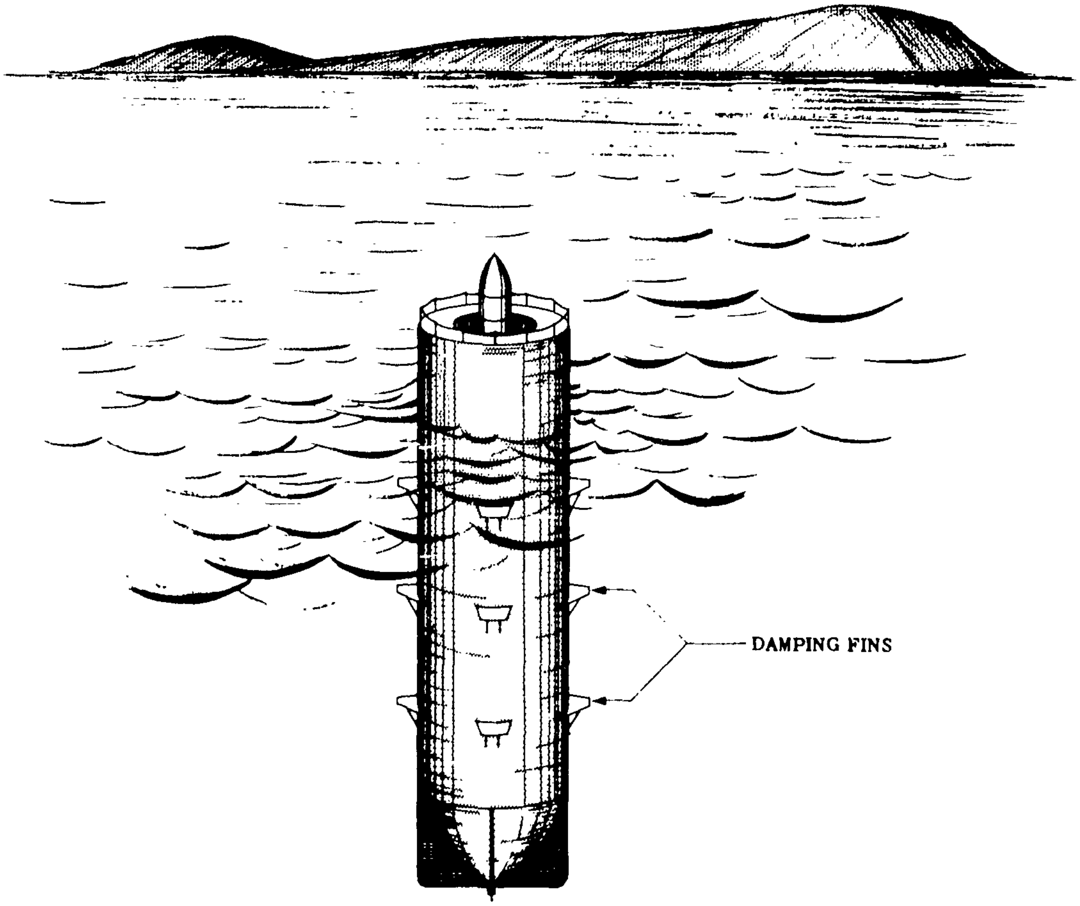

Figure 4. Missile Ready for Launch From Tube.

has left, the water will rush in from the bottom and fill the space previously occupied by the missile. The weight of the water taken on will be approximately the same as the weight of the missile so that the tube will continually float at approximately the same relative depth before, during, and after launch.

If for some reason the launch is cancelled, the same procedure in reverse order will be used to "button up" the tube and the missile can be returned to port. If for some reason the missile must be disposed of at sea, the tube can be inverted and the missile "deep sixed."

After the missile has been launched, the top and bottom covers will be secured and the tube returned to port. When the tube is returned it will be conditioned for reuse at a relatively low cost.

Liquid-Propellant Missile

The following description will be for a typical large liquid-propellant missile.

The operation of the tube will be the same for liquid- as for solid-propellant missiles except that a method of keeping the tube in position is needed while the engines are being brought up to full thrust. The method proposed will be to hold the missile in the tube and to neutralize the effective thrust so that the tube will have no tendency to move.

A variable thrust deflector could be used that would provide the thrust neutralization; that is, the initial thrust would be deflected at right angles to the longitudinal axis of the tube. When the motors reach full thrust, the thrust deflector would be varied to a position such that the force on the deflector would be decreased to a value equal to that of the weight of the missile. At this same instant, the "hold-down" mechanism would release the missile from the tube, and from then on, the operation of the tube and missile would be the same as for the solid-propellant missiles.

ALTERNATE DESIGN FOR NOVA-CLASS MISSILES

When the size of a missile becomes too great for housing in a cylindrical tube, an alternate method can be used for constructing the tube. The tube will be a structure that is fabricated from tubular members, welded together (see figure 5). The displacement of the tubular members will be such that they will provide sufficient buoyancy to float the structure with a missile enclosed. The ballast will be taken on by flooding the aft portion of the structure, thus causing the tube to go into the vertical position. The tube could be made watertight as long as size permits.

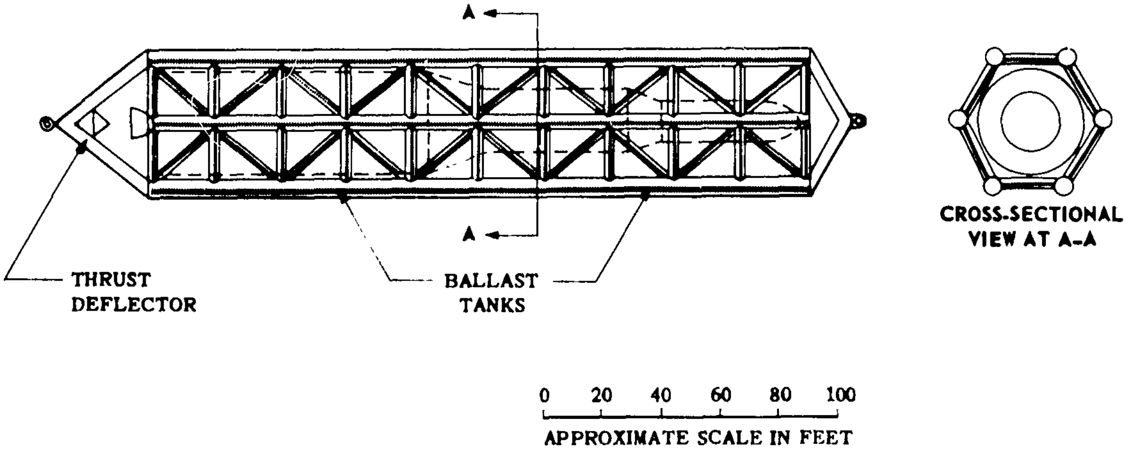

Figure 5. Tube for Transporting and Launching Large Missiles.

In cross section, the tube can be as many sided as desired, depending on the cross-sectional shape of the missile. If the first stage is a cluster of four motors, then the tube will be four sided, etc. All the operating features of this type of tube will be the same as in the previously described cylindrical tube.

ADVANTAGES OF TUBE

The advantages of the tube are as follows:

1. The tube will supply all the structural strength required to withstand all handling, towing, and erecting loads, both static and dynamic. Thus it is unnecessary to design a missile with other than an optimum mass fraction.
2. The tube will make it unnecessary to attach flotation and ballast to a missile and will do away with the problems of detaching these from the missile during launch. Also, it will not be necessary to deviate from an optimum aerodynamic design in an attempt to build in flotation.
3. The tube will continuously keep the missile in an ideal environment and will do away with the problems of corrosion and the need for missile watertight integrity.
4. The tube will provide a means for inspecting the thrust vectoring hardware and will provide a platform for working on the payload. This will eliminate the need for a floating platform or an attachable and detachable one. By providing a means of inspecting the thrust vectoring hardware just prior to launch, the existing methods of thrust vectoring can still be used.
5. The tube will provide a means for damping the heaving motion when in the vertical position by the use of damping fins or plates on the outside of the tube.
6. The tube will provide a means for damping the pitching motion when in the vertical position. By shifting ballast between the trim tanks, the metacentric height can be varied according to the existing sea state to provide an optimum pitch amplitude and frequency.
7. The tube will make it possible to launch almost any missile, whether it uses solid or liquid propellant, by the sea-launch technique.
8. The cost of a tube will be relatively small compared to the cost of large gantries, because of its simple boiler plate construction.
9. Most of the inherent advantages of launching a bare missile are retained.

DISADVANTAGES OF TUBE

1. The tube would probably be destroyed if there was a malfunction of the booster during launch.

2. The tube requires engineering development similar to that required for the silos of MINUTEMAN and TITAN to overcome a possible acoustics problem.
3. The tube would require development to eliminate the problems, if any, caused by the motion of the tube relative to the missile.
4. Each new missile design would require a new tube design.

OTHER USES FOR TUBES

Transporting Large Boosters

One of the major problems faced by large missile manufacturers is that of transporting the large boosters to the site of final missile assembly and launch. Because of their size, large boosters must be transported by water. The only method being used today, as is the case with the SATURN booster, is the use of a barge to carry the booster to the nearest landing and then to use conventional land transport methods from there to the final destination.

The SATURN booster had a special barge with air conditioning to keep the booster in an ideal climate while being transported from Huntsville, Alabama to Cape Canaveral, Florida. Unfortunately, the locks in the Tennessee River failed, blocking the passage of the barge. The only solution was to transfer the booster over land to another barge downstream of the locks and then to continue the journey from there.

One approach to the problem worthy of serious consideration, would be to design a tube for the specific purpose of transporting such large boosters. With wheels, such a tube could be made amphibious, thus allowing it to be towed right from the manufacturing plant into the water. The sealed tube can provide the proper air-conditioned environment for the booster while being towed underwater to its destination. The fact that it can be towed underwater not only provides a soft ride for the booster, but it also provides a measure of "privacy." If the missile is to be land launched, the booster can be towed right up to the launch pad. If, on the other hand, it is to be sea launched, the booster will be towed into the drydock for missile assembly as described previously. Thus, by the use of the transporting tube, the booster will arrive at its destination still sealed in its special atmosphere and as well preserved as the day it left the plant. This method of transporting would be especially suited for carrying boosters to far-off locations such as equatorial launch sites.

Cast, Cure, and Carry Away

Still another use for a tube would be for making and handling of giant solid-propellant boosters. (One manufacturer of solid boosters has proposed the use of floating caissons to handle his large boosters because no other method would be practical.)

The empty motor case would be placed in the tube, and the tube erected vertically in the drydock (see figure 6). The motor grain would be cast while the case is still in the tube. Then the tube would be sealed and heat provided inside the insulated tube for curing the grain. Upon completion of curing and inspection, the drydock would be flooded, and the sealed tube with the booster motor inside, would be towed away to its destination.

Thus by the use of the tube, the booster would be cast, cured, and carried away without the need of even handling the booster itself. The curing process could even be carried out to completion while the motor is being towed to its destination, thus allowing two time-consuming operations to be carried out simultaneously.

CONCLUSIONS

Any size of missile, both solid and liquid propellant, can be sea launched from a relatively simple shipyard-built tube that is reusable. The tube concept appears to provide many, if not all, of the answers to the problems (both present and anticipated) of sea launching. The tube provides a great measure of reliability along with relative simplicity and versatility, by allowing the missile to be carried in a container that not only is used to protect it, but is used to transport it and launch it all in one.

It is felt that the technique of tube launching can be perfected quite easily because its relative simplicity and versatility will lend themselves well towards a short development program. Some of the experience gained in the HYDRA project, along with other programs of launching missiles from tubes and silos, should further guide the way through a rapid development program. The concept is presented as a means of furthering the national space effort, even though it is not a new concept by any means to our competitors for outer space.

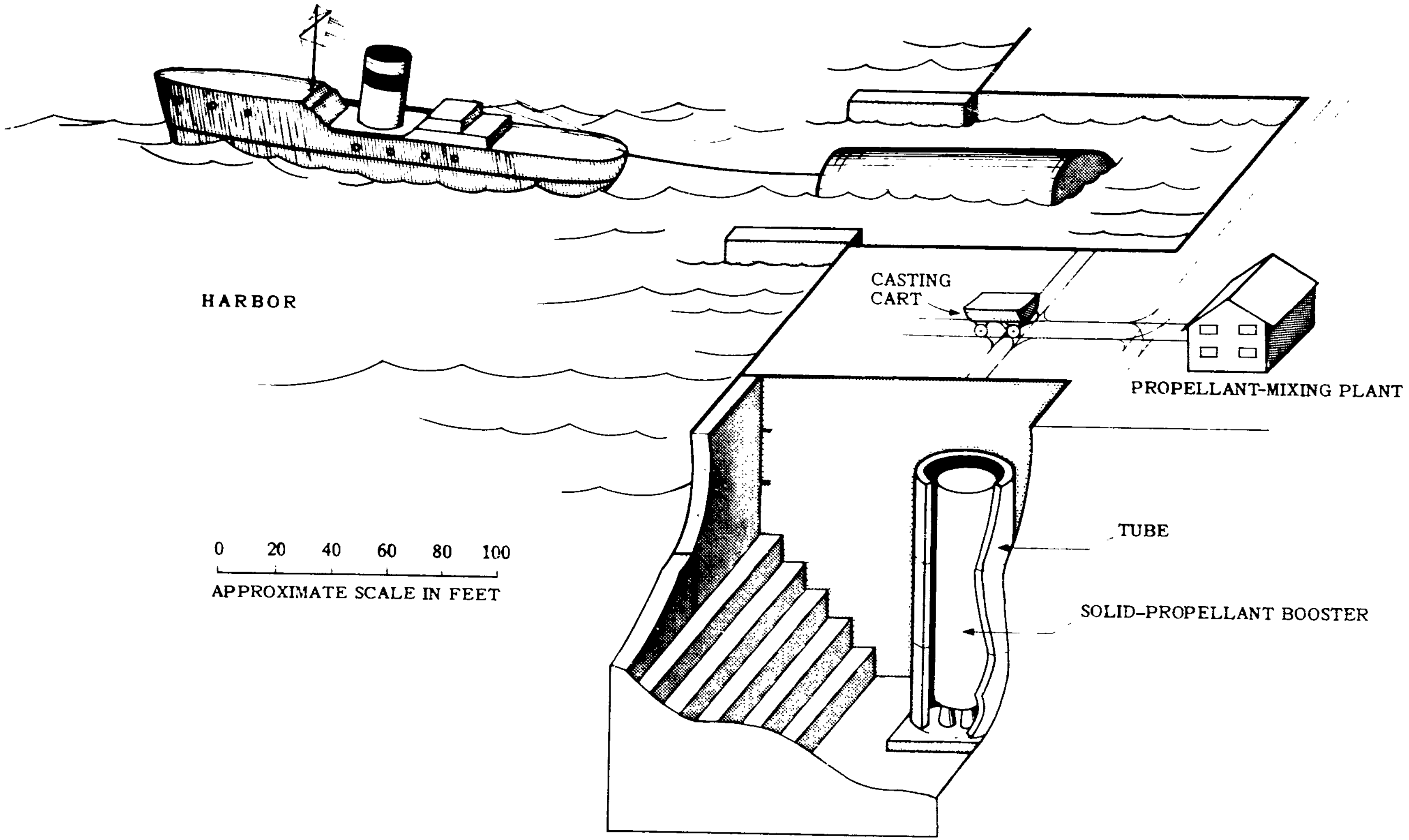

Figure 6. Facility for Casting, Curing, and Carrying Away Boosters.