Cable and Repeater Handling System

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This paper describes the development of methods and equipment for handling cable and repeaters in laying submarine cable systems and the application of these developments to C.S. "Long Lines." Both the laying process and the associated operation of assembling the system components in preparation for laying are described.

I. INTRODUCTION

The underwater portion of a modern submarine cable system is composed of three basic components; cable, repeaters and equalizers. These are delivered to dockside as individual items, and the handling of these units from this point to the time when they leave the ship on the way to the ocean bottom is the work of the cable and repeater handling system. The planning of arrangements and procedures, and the design of equipment and details to implement the following operations are included in the handling system:

(1) movement from dockside to appropriate stowage positions aboard ship,
(2) connection of components into a transmission system,
(3) cable test during loading,
(4) system test during laying,
(5) preparation of repeaters and equalizers for launching,
(6) control of cable and repeater movement during laying, and
(7) cable jointing for laying and repair.

For the performance of these operations, the following requirements were set for equipment and arrangements:

(1) cable to be handled in a fashion to avoid damage from bending, twist, abrasion and tension;
(2) repeaters stowed and handled to avoid excessive shock and extremes of temperature;
(3) stowage of cable simplified to avoid possibility of cable fouling

and permit easy checking of clearances and provide flexibility in sequence of tanking;

(4) cable and repeaters to be payed out in a steady-state continuous operation at speeds to 8 knots;

(5) minimum manpower requirements during the laying operation.

II. GENERAL SCHEME OF OPERATION

From a knowledge of the route over which the cable is to be laid, a loading plan is prepared which assigns cable sections, repeaters and equalizers to particular places in the system and particular positions on the ship. The components are then brought aboard ship in the proper order for stowage to permit laying in the correct sequence.

The cable and repeaters, which comprise a shipload, are connected together aboard ship to form a single complete circuit. This may consist of as much as 2000 nautical miles (nm) of cable, 100 repeaters and 10 equalizers if the ship is loaded to design capacity. The circuit thus formed consists of a series of "ocean blocks" 192 nm in length, each containing 10 repeaters. The ocean blocks are connected together through ocean-block equalizers which are adjusted aboard ship just prior to overboarding.

After the shipload of cable and repeaters is assembled into a complete circuit, the ends are connected to the shipboard power supply through power separation filters and the circuit is powered from end to end. Transmission measurements are then made on one block at a time from one equalizer to the next adjacent. Through measurements from end to end of the system are not possible when the cable is aboard ship, because the temperature of the cable in the ship's tanks is much higher than it is at sea bottom, and the excess loss of a complete shipload due to temperature is in the order of 200 db.

Following the shipboard transmission check and upon arrival at the cable ground, the outboard end of the cable is connected to the shore station or to the end of cable previously laid. As soon as the connection is complete, power is turned up on the system, ship-to-shore communication is established and transmission measurements are made. Cable laying is then started, and from this time until the bitter end of the cable is reached there is no interruption in power or signal transmission.

The amount of cable payed out is slightly in excess of the distance traveled over the ground, in order that there be sufficient cable length to fill bottom irregularities, the excess length being known as "slack." To measure the distance over the ground a continuous length of piano wire, called the "taut wire", is payed out. This wire is anchored to the ocean bottom and is payed out under constant tension. The speed of taut wire payout is measured and the cable payout speed adjusted to provide the slack appropriate for the bottom conditions at the point of cable touchdown. Bottom contours are measured by echo sounders, the results of the measurements being plotted on a precision depth recorder. In laying cable over a flat ocean bed or over constant, moderate slopes of less than about 4°, the cable and repeaters are payed out at top speed of 8 knots, weather and sea conditions permitting. Over rough bottom with steep slopes, ship's speed is altered as necessary to get proper coverage of the bottom.[1]

As cable is payed out, the next repeater or equalizer which is to be launched is moved from a stowage position to a launch position, where it is free to move in line with the cable along the working deck, through the cable engine and into the water. At this time a parachute is attached to the repeater body. When in the water, the parachute opens to slow the repeater descent to more nearly match the sinking rate of the cable.

As soon as a repeater is launched the next repeater is prepared for overboarding. The preparation for launching takes about 10 minutes and the time interval between repeaters or between repeaters and equalizers varies from about $\frac{3}{4}$ hour to 5 hours, depending upon cable laying speed.

While laying the system, transmission measurements are being made and communications are being carried on over the cable between ship and shore. The transmission and equalizer adjustment connections to the cable are made at the equalizer, and measurements are made between shore and the next equalizer to be launched. Approximately 3 hours before the equalizer launching a decision is made as to the optimum setting of the equalizer. It is then adjusted by means of the stepping switch. After rechecking the transmission characteristic, the transmission and stepping lead connections are removed, the lead ends are sealed and the equalizer is prepared for launching.

The process of cable laying and repeater and equalizer launching continues section-by-section and block-by-block until the end of the load is reached. The cable end is then joined to the shore end cable or is streamed on the bottom to be picked up later after the ship returns with another load of cable.

III. CABLE LAYING SYSTEM

The most significant single contribution to improved cable laying was the design and development of the linear cable engine,[2] which made it possible to pay out cable and large, heavy, rigid repeater casings with

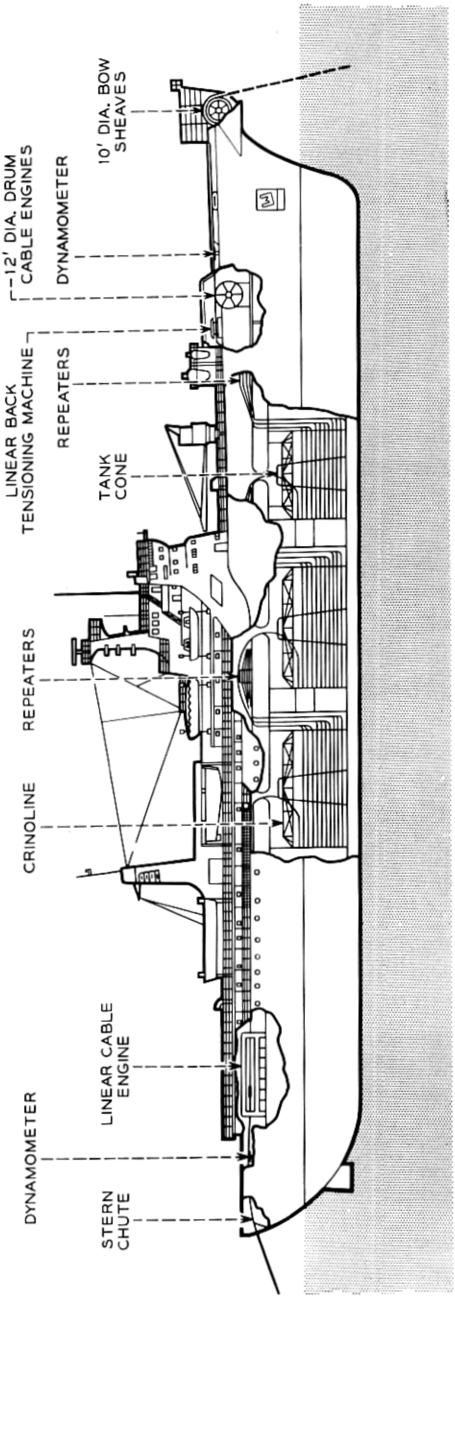

Fig. 1 — General layout of the cable laying system.

equal ease. The cable handling system exploits to the fullest extent the capabilities of the linear cable engine and provides for continuous substantially automatic, payout of cable and repeater.

The general layout of the cable laying system is shown in Fig. 1 and an individual tank arrangement is shown in Fig. 2. Cable is loaded into the cylindrical tanks in a reverse sequence from which it is to be laid. The cable is coiled as shown, in layers called "flakes," around the central core of the tank, which has the form of a truncated cone. There are three main cable tanks along the center line of the ship which hold the cable to be laid. In general, all of the cable in one tank is payed out before transferring to another; the preferred order is tanks 3–2–1. The arrangements are completely flexible, however, and practically any order can be used at a sacrifice in simplicity of stowage.

Cable is payed out from the center of the top of the tank over the smooth faired surface to the cable working deck. It moves aft along this deck to enter the repeater trough and passes through the trough to the cable engine. On passing through the cable engine it reenters the trough, continues over the dynamometer, through the stern overboarding chute and into the water. The guiding principles have been that the moving cable and repeaters travel over faired surfaces, smooth deck areas or through open troughs. Closed guides, rollers and gates are avoided, and it is unnecessary for personnel to handle or guide the moving cable or repeaters at any point in the payout process. Once payout is started the only action required by personnel is to move the repeaters from the stowed to launch position and to dress the following cable on the deck forward of the repeater in the launch position.

In Fig. 2, tank 3 is shown with a repeater in the launch position and the repeater stowage area filled with a complete complement of repeaters. Payout of the cable is aft, and a bight of cable is shown rising through the deck slot just before reaching the working deck. As the bight of cable reaches the working deck the bight is straightened out, the cable is pulled taut, and the repeater is accelerated to payout speed.

IV. CABLE TANKS

Of the seven cable tanks in the ship only the three main tanks which carry the cable to be laid are of particular interest. The other four are small tanks which hold short lengths of spare and repair cable; cable is not payed out directly from these.

The three main cable tanks are similar, differing only in diameter. Tank 1 forward is 42.5 feet in diameter, with a capacity of 31,000 cu. ft., while tanks 2 and 3 are 55 feet in diameter and have a capacity of

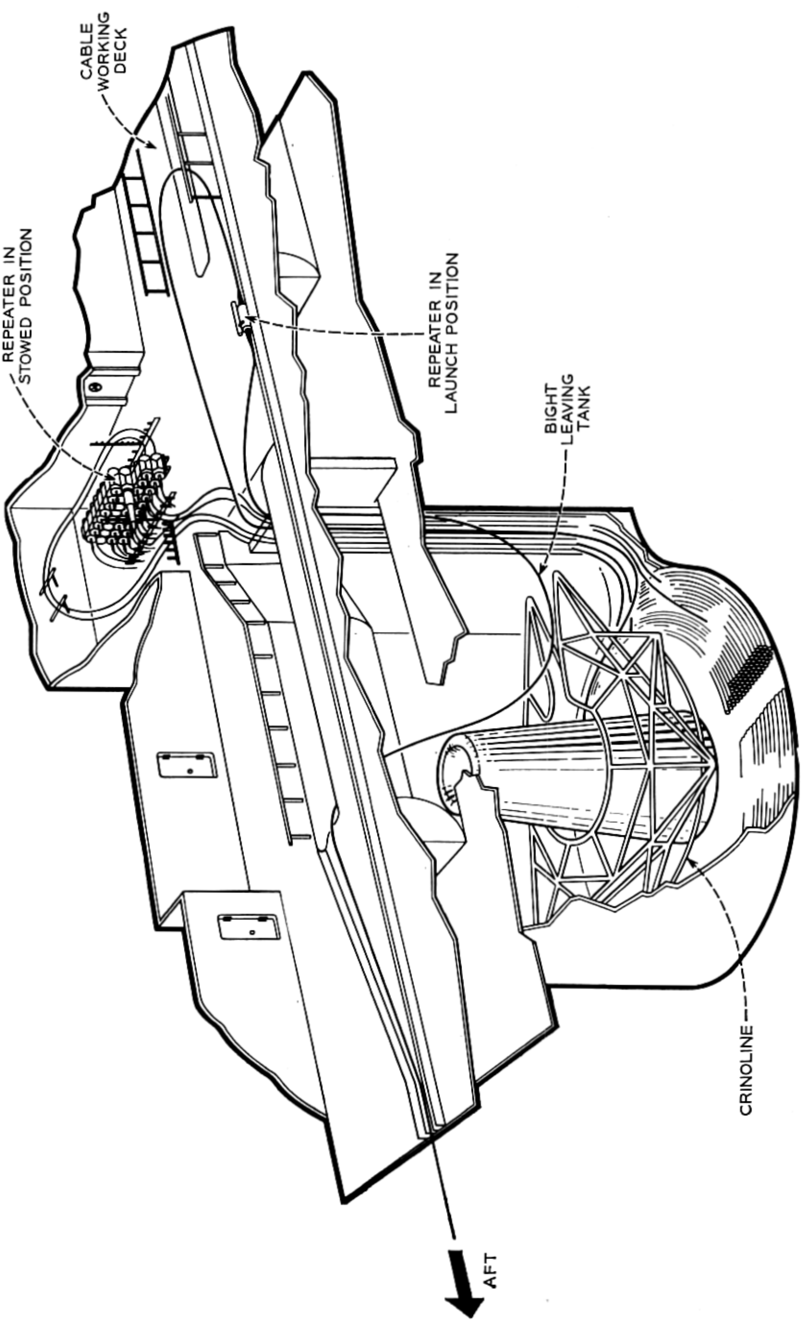

Fig. 2 — Cable and repeater stowage.

54,000 cu. ft. each. The central cones are 15 feet in diameter at the base and taper to 10 feet at the top. The coiling height of 24 feet is the same for all tanks. The total tank capacity is sufficient to contain 2000 nm of $1\frac{1}{4}$-inch diameter deep-sea armorless cable.

The cable tanks differ from previous designs in several respects, all of them pointed toward automating the cable payout. The usual tank opening, consisting of a relatively small round or rectangular central hatch, has been replaced by the long narrow slot shown, extending from the center of the tank forward to the tank wall. This slot permits the cable bights to rise freely from the tanks without danger of twisting or kinking. A nylon net is stretched taut across the entire slot opening a few inches above the deck surface, since it was recognized that an unprotected open slot would be a hazard to personnel. Cable and repeaters move freely under the net during payout. The net also serves to restrain the rising bight of cable as it is pulled out of the tank and into the trough.

The forward wall of the tank has been opened to provide a full-length vertical slot to contain the cables running from the tank to the repeater stowage area. As many as 88 cables are stowed in holders or restrainers mounted in these slots. The slots also contain small elevators or man hoists used for raising and lowering personnel and materials into the tank and as working platforms for personnel placing cables in the cable holders.

The cable holders mounted on the forward wall of the vertical slot are shown in Fig. 3. These are a series of narrow slots deep enough to hold four separate cables and wide enough to accommodate single armored cable (1.88-inch). After the cables are stowed in the holders, the slots are closed with flat strips of rubber which prevent the cable from falling out and control the rate at which the cable leaves the slot. This is particularly important to the cable entering the tank, since if too loosely held it may fall freely and form a kink, and if too heavily restrained it may be bent at too small a radius as it is pulled free. The choice of material as well as its thickness and amount of closure were all critical in a single design to control the several different cables under varying temperature conditions.

The crinoline, seen as the slotted circular pipe framework within the tank in Fig. 2, represents an important development in the automation of bight payout. The purpose of the crinoline is to restrain and control the cable as it moves around the tank during payout at high speeds. The open slot extending from the center ring to the tank wall prevents the cable from running out into the slot during normal payout but permits

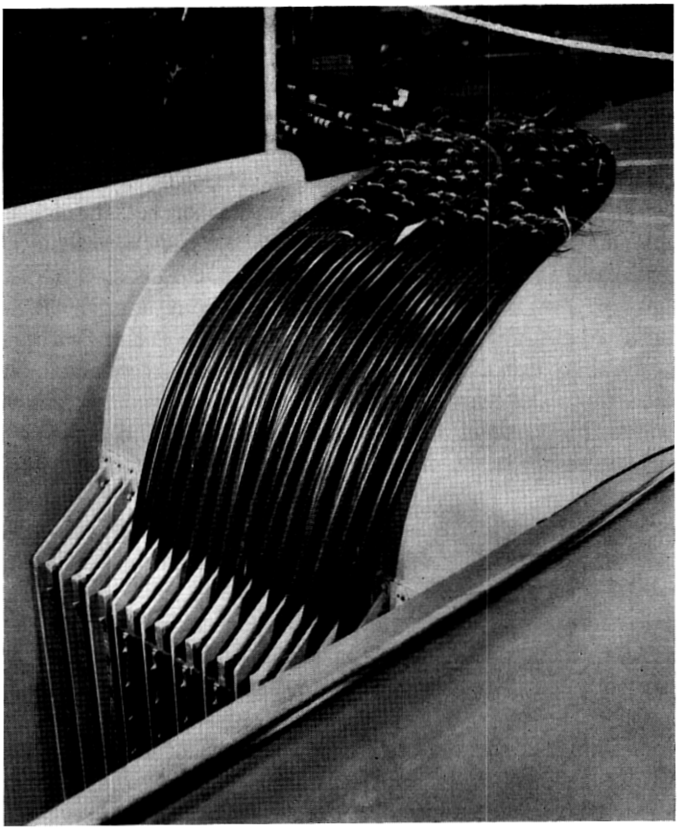

Fig. 3 — Cable holders on forward wall of vertical slot.

the bight to rise freely through the slot to the cable working deck at cable speeds as high as 8 knots. Although the crinoline working height above the top flake is not critical, a height of 6–7 feet gives the best results. Two auxiliary rings, having a diameter (17 feet) equal to the inner ring of the main crinoline, are provided above the main crinoline so that unrestrained cable lengths need not exceed 7–8 feet. The main crinoline and auxiliary rings are positioned at appropriate heights above the top cable flake by means of electrically operated hoists. The hoists are controlled from crinoline control stations at the main deck level. These stations are manned continuously during payout by personnel who can observe the cable action in the tank, adjust the crinoline height as necessary, and report any observed irregularities during the procedure.

V. REPEATER STOWAGE

The repeater stowage areas are located on the port side, forward of the tanks in which the cable is stowed. This position was chosen because it simplified the cable arrangement and the repeater handling process. The repeaters are clamped in individual rack frameworks shown in Fig. 4. These racks, which are demountable, are then bolted one to another and to a deck foundation to form a stack with as many as 44 repeaters arranged 11 wide and 4 high. Since these areas are not air-conditioned, forced-air ventilation for repeater cooling is provided through ducts opening under the repeater stacks. A nearly complete stack of repeaters is shown in Fig. 5.

At the outboard end of the repeater rack foundation a vertical frame is placed to serve as a lateral support for the repeater stack. This also serves as a mounting for power separation filters which terminate the cable and for terminations of transmission and test leads from the transmission testroom. Flexible leads connect the equalizers to measure transmission and to step the equalizer switch to adjust loss during the equalization process.

A station for auxiliary services is located in each of the repeater stowage areas. This provides electrical power, compressed air and fresh water for equipment used in the cable-to-repeater assembly procedure.

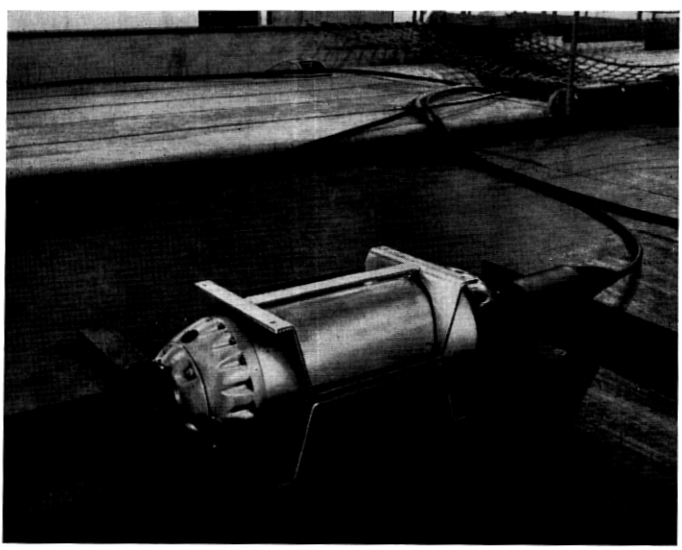

Fig. 4 — Repeater clamped in individual rack framework.

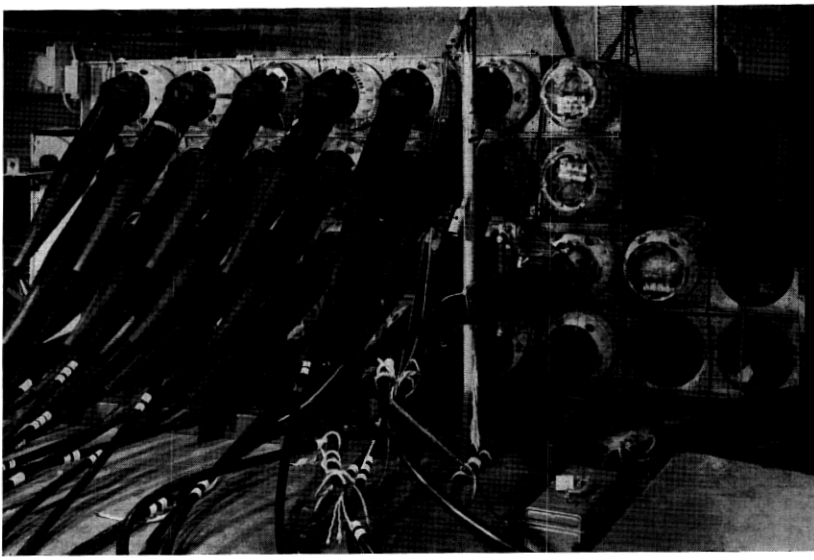

Fig. 5 — Repeater stack.

Repeaters are moved into stowage position and from the stowage area to the launch position by means of an electrically operated hoist. This hoist is driven for both rise and traverse and can reach any of the working areas at the upper deck level.

Because of the large numbers of cables which must be stowed in a repeater bay and because of the need to prevent bending below a minimum radius of 3 feet, the cable runs were carefully worked out, and supports and guides were devised to assure that the proper paths would be followed and that the cable would not be subjected to damaging conditions.

VI. CABLE WORKING AREA, REPEATER TROUGH AND OVERBOARDING CHUTE

Fig. 6 shows the cable working deck looking aft from forward of tank 2 with a central area called the "highway" raised approximately 6 inches above the deck surface. The cable during payout moves across this highway surface until it enters the repeater trough section shown to the left of the highway in the illustration. This deck has been built without sheer in order that cable lines will lie flat on the deck.

The repeater trough is rectangular in cross-section over most of its length but becomes "vee" shaped a short distance forward of the cable engine and between the cable engine and the stern chute, where it

Fig. 6 — Cable working deck looking aft from forward of cable tank 2.

again becomes rectangular. The transition from rectangle to vee forward of the cable engine is designed to rotate the parachute attached to the repeater through an angle of 25° so that it is outside the gripping surfaces as the repeater moves through the engine. The vee shape continues aft of the engine past the dynamometer (see Fig. 1), where the transition from vee to rectangular shape rotates the parachute back to its original orientation to clear the side of the stern chute.

Since the sensitivity of the dynamometer is a function of the cable angle at the dynamometer bearing surface, it is essential that this angle be constant. This is accomplished by providing a cable hold-down device in the stern chute which restrains the cable and prevents it rising off the trough bottom when the ship pitches. This hold-down is raised automatically before the repeater reaches this position.

When cable moves across broad, flat deck areas and over large-radius faired surfaces at low tension, the stiffness of the cable is sufficient to cause it to move laterally, and surface wear at these surfaces is low although no lubrication is provided. This situation exists on all surfaces over which the cable passes forward of the cable engine.

In the cable trough aft of the cable engine the cable is in contact with the trough bottom at one point and with the dynamometer at another. At these points the cable is under tension (600–7000 lbs.) and is restrained from lateral motion by the trough shape. Tests showed that under these conditions a $\frac{1}{4}$-inch thick plate of mild steel would have a life well over 10,000 nm. To further increase the life and simplify replacement, hardened steel surfaces in the form of bolted inserts are installed at these points, and cooling is provided by water flooding over the wear surfaces.

The cable and repeaters leave the ship through a stern chute instead of over a sheave as is common practice on most cable ships. The chute is advantageous in that the large radius needed ($>$3.5 feet) can be obtained in much less space and at considerably lower cost than by the use of sheaves. Several proposals were considered before the final design, shown in Fig. 7, was reached in which the ship's hull was shaped to form the sides and bottom of the chute. The structural and shaping problems were not difficult, since the intersecting surfaces are all cylindrical sections with no compound curves required. Wear in the chute after 3000 nm has been so small that it has been difficult to detect.

VII. PARACHUTE DESIGN AND OPERATION

There are two reasons for controlling the rate of descent of the repeater. The first of these has to do with the laying of bottom slack and the second concerns the protection of the repeater from excessive shock on bottoming.

Under steady-state laying conditions the configuration of the cable between the ship and ocean bottom is a straight line; it is desirable to

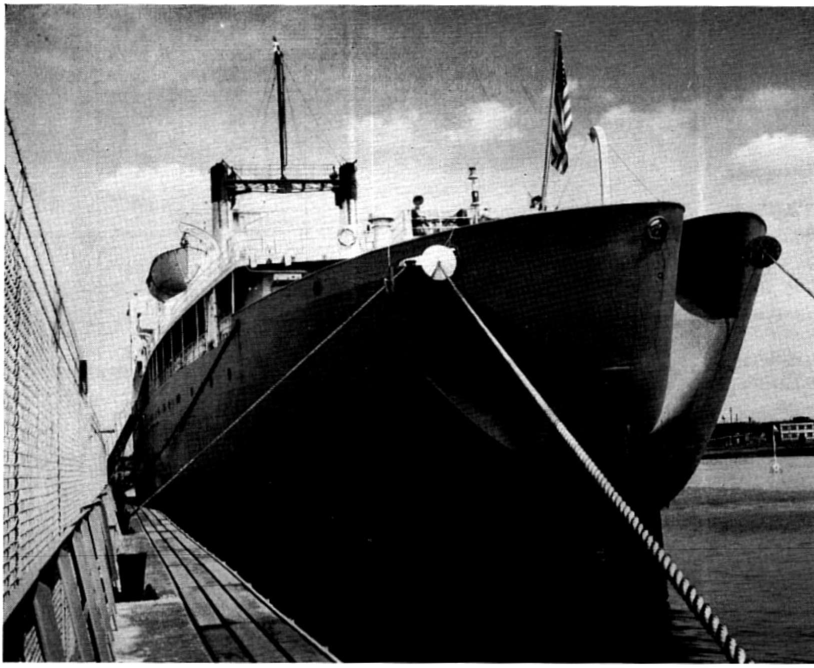

Fig. 7 — View of stern chute of C.S. *Long Lines*.

maintain this configuration to properly control the distribution of slack. The presence of the large mass of the repeater in the suspended cable destroys this condition and adversely affects slack control since the repeater sinking rate is several times that of the cable (8 k vs $\frac{3}{4}$ k).

If the cable were laid in still water the problem would be fairly simple, and substantially perfect match could be obtained between cable and repeater sinking rates. This condition never exists, however, because of the presence of ocean currents of varying and unpredictable velocities which affect the parachute drag. A compromise size was chosen which will not present excessive drag but limits the repeater bottoming speed to a safe magnitude of 2 knots.

The nylon parachute is of simple circular design, seven feet in diameter. The complete parachute mechanism consists of four parts: parachute, container, flotation bag and harness. Fig. 8 shows a repeater ready for launching with a parachute attached.

The parachute is packed in a zipper-closed pocket at the end of a cylindrical air-filled flotation bag. This flotation bag is placed in a fabric

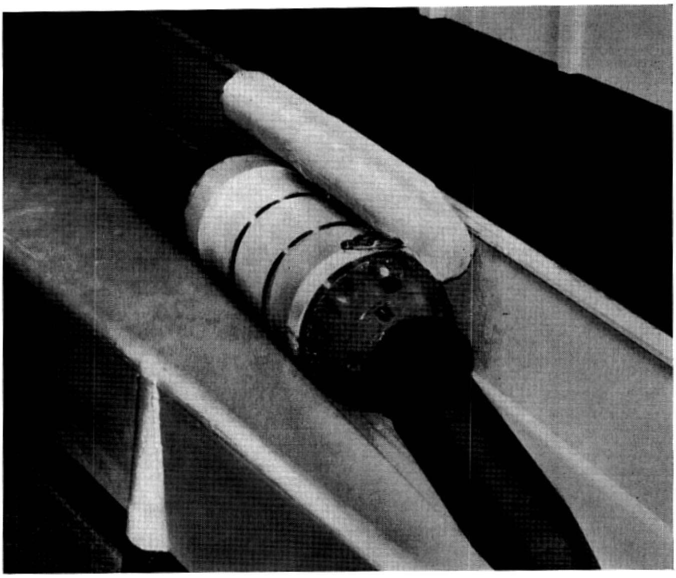

Fig. 8 — Repeater ready for launching with attached parachute.

container which is attached to the harness. The harness serves the dual purpose of fastening the parachute to the repeater and, in connection with the trough shape, positions the parachute properly during payout.

The operation is entirely automatic. When the repeater enters the water the flotation bag pops out and floats to the surface, releasing the parachute to deploy in the water. A corrosive link between the parachute shrouds and the repeater releases the parachute after about 24 hours of exposure to sea water. Several hundred parachutes have been used thus far and there has been no failure in operation.

VIII. FORE DECK

The fore deck at the boat deck level (shown in Fig. 9) is the location for all repair and recovery and buoy handling operations. It is also expected that a small amount of cable laying, particularly of shore ends, will be done over the bow.

The three large-diameter bow sheaves are housed in the faired surfaces shown in Fig. 10. The three sheaves are mounted coaxially, the outer two being grooved and the center one flat surfaced. Cable, rope and chain are ordinarily carried over the outer sheaves, and heavy, bulky gear such as cable mooring anchors and grapnels is handled over the

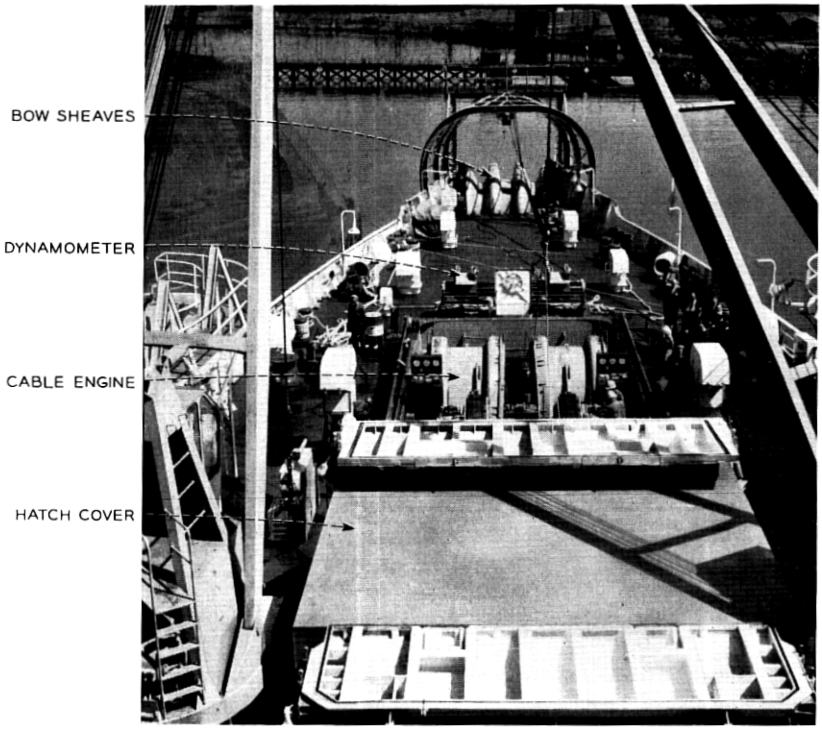

Fig. 9 — Foredeck layout of C.S. *Long Lines*.

center sheave. Two cable handling sheaves are required because during repair or splicing operations two cables are handled simultaneously. The gantry frame shown provides support for an electrically driven hoist used for moving heavy grapnels and mooring anchors over the sheaves.

A ship control station is located just aft of the bow sheaves, and the ship's operation can be handled directly from this position. Cable payout information is also repeated at the foredeck control. This includes cable tension and amount of cable picked up or payed out through the bow engines.

There are two large rectangular hatches located well forward on this deck. The first of these provides access to the two drum-type cable engines located below this hatch at the upper deck level. The after hatch opening gives access to the upper deck, and cable, rope and chain are carried through this hatch to the upper deck.

The covers for these cable working hatches are unique on a cable ship. The after cover telescopes under the forward cover, and the covers can

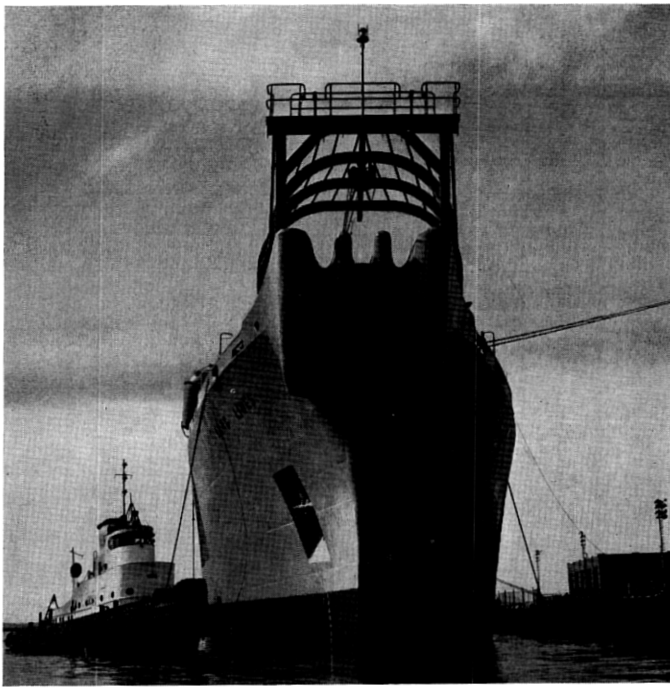

Fig. 10 — Bow sheaves of C.S. *Long Lines*.

be moved individually on longitudinal rails to open either or both of the hatches. By this means and by opening the ends of the covers, almost any degree of protection can be obtained for personnel and machinery during foul weather operations.

IX. CHESTER LABORATORY DEVELOPMENT WORK

The use of full-scale models as exemplified in the operation of "C.S. Fantastic" was an essential part of the successful development of the cable handling facilities. While scale models were useful for purposes of visualization, they were of little practical value in predicting operating characteristics, since it was impossible to scale the cable dynamically.

All of the details for handling cable and repeaters were built in prototype and subjected to exhaustive tests. Since ship's motion (pitch, roll and yaw) could not be simulated, all of the payout processes were required to operate successfully at speeds well in excess of the design objective of 8 knots to allow for possible adverse effects from this motion.

Cable payout, repeater launching, parachute positioning, crinoline operation and transfer of payout from one tank to another were accomplished successfully at speeds as high as 11.5 knots, the maximum capability of the Chester facility.

Measurements were also made of the shocks to which the repeater was subjected during acceleration from standstill to payout speeds in the launching operation. The validity of these tests was later confirmed by similar measurements aboard ship; even at payout speeds of 9.5 knots, accelerations do not exceed 19 g, well below design requirements.

It is interesting to note that many of the innovations developed at Chester have been used in cable ships other than C.S. *Long Lines.*

X. CABLE LOADING AND REPEATER JOINING

The arrangements and details for loading, although somewhat less exacting than those required for laying, are of considerable importance. It is here that the possibility of confusion and error is greatest, and extreme care must be taken to prevent locked turns and crosses which could make it impossible to get the cable out without cutting and splicing.

Insofar as possible, the cable is loaded in a single continuous length and the mechanical continuity is never broken. This is possible only to a limited extent, since two load lines are normally in operation simultaneously. It is possible, however, to load each tank with a single mechanically continuous length, and this practice is followed in general on C.S. *Long Lines.*

The individual cable sections are taken in pans to the loading dock area and placed as required at the end of the loading line. The cable is then pulled aboard ship through the load line by a linear transporter located at the forward end of the cable tank slot and fed down into the tank for coiling. On the straight runs and around curves in a vertical plane the cable moves through open troughs or over faired surfaces, but for turns in a horizontal plane, sheaves having a minimum diameter of 6 feet are used.

Coiling of cable is in a clockwise direction, beginning at the outer tank wall and working into the central cone; then it continues working from the cone outward. In the large tanks each flake contains approximately 3 nm of cable and there are about 6 flakes per section.

This is the first time that out-in, in-out coiling of cable has been successfully used. With conventional armored cable the practice has been to coil from the tank wall in to the cone and then lay out to the tank wall and resume coiling again toward the cone. Coiling from the cone outward was not successful with the armored cable because in the reverse operation of paying out there was a possibility of turns sticking, resulting in lifting an adjacent turn with high probability of forming a kink. With the out-in, in-out coiling, load factors approximately 92 per cent of theoretical (57.5 cu. ft./nm) for perfect pack have been achieved.

When the last end of a cable section is reached, it is joined to the first end of the next succeeding section by means of a coupling connector usually referred to as a "dummy repeater." The dummy repeater shown in Fig. 11 consists of two coupling covers connected together by a tie bar; the combination is equal in length to a repeater or equalizer. This dummy serves as a convenient device for positioning the cable section ends in the repeater stack while the cables to and from the tank are being

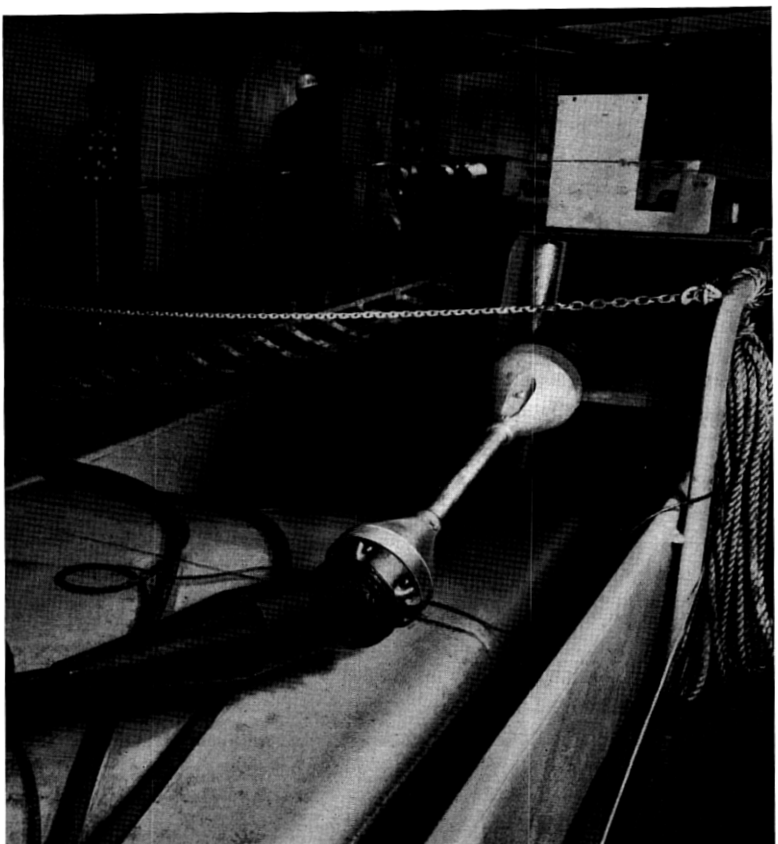

Fig. 11 — Coupling connector ("dummy repeater").

dressed into position and fastened down. In addition to furnishing a means of mechanical connection to the cable section, the coupling covers protect the coupling pigtail and provide mountings for electrical connection to the center conductor for electrical test during loading. Before the couplings are disconnected from the dummy for joining to a repeater, the cable ends are joined together by a rope tie. This tie is not removed until the process of joining the cables to the repeaters is finished and the lead position and continuity have been checked.

Coiling in the tanks is manual and crews of about 25 men per tank are used to perform this work. Loading speeds as high as 4 knots per line can be achieved, and, with allowance for down time to bring the cables from the tank to the repeater stowage area and dress them into position, an average speed of 2.5 knots per line is possible.

As soon as the first cable couplings have been placed in position at the repeater rack, a repeater is moved into place and the work of joining cable to repeaters is started. The space for the electrical and mechanical connection of cable to repeater is restricted, and the equipment designs and processes had to be carefully coordinated to work in the space available.

The joining process requires exact positioning of the coupling with respect to the repeater, preparation of pigtail ends, brazing of center conductor, overmold of conductor joint, X-ray examination of the mold, assembly of ground leads, and bolting of coupling to repeater. Mounting jigs like that shown in Fig. 12 hold the coupling in alignment with the repeater body during the joining procedure, and the jig serves in turn as a mounting for the brazer, molding machine and X-ray unit and as a bolting guide for final assembly. The illustration shows the molding machine in position.

XI. CABLE AND SYSTEM TESTS

Electrical tests of the cable during loading are rather rudimentary but will indicate any serious cable faults as soon as possible. The tests consist of dc resistance measurements made before, during and after loading; insulation resistance measurements made after loading; and pulse echo tests made after loading.

The system tests are much more comprehensive and are a measure of system transmission performance. The transmission characteristic of each block is measured and the crystal peak gain of each repeater is measured. In addition, each of the equalizers in the system is checked at every one of the 32 positions of the stepping switch.

Since the cable loss — and hence the system characteristic — varies

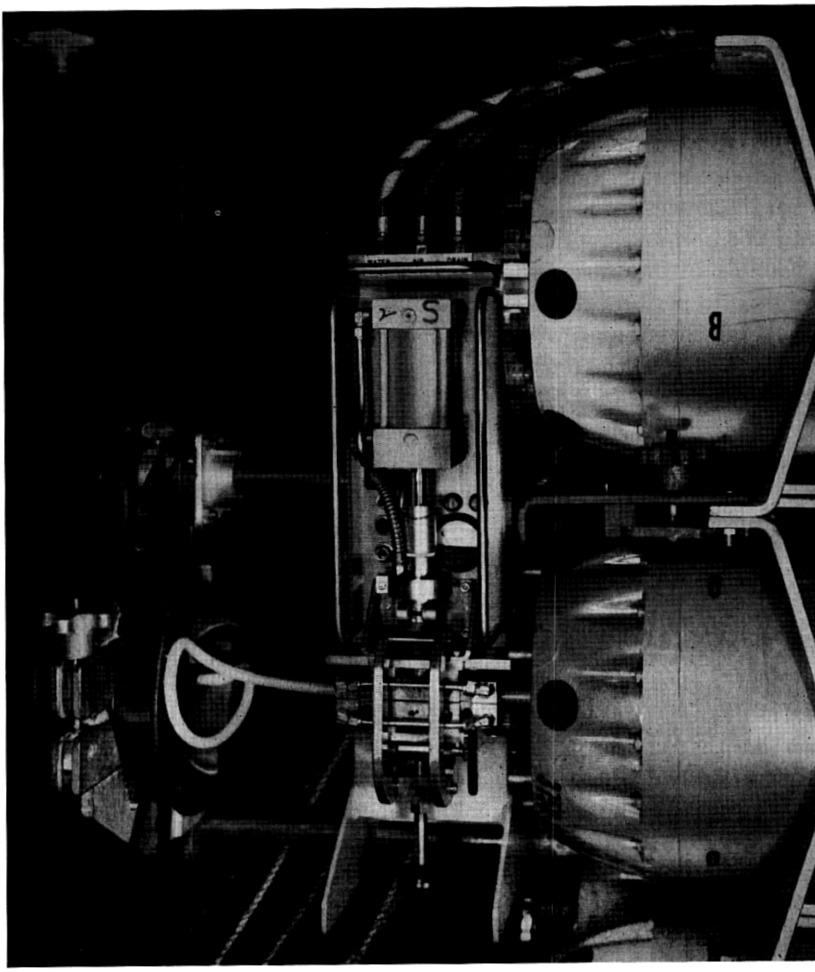

Fig. 12 — Mounting jig with molding machine in position.

with temperature, it is necessary to know the temperature of the cable at the time the transmission measurements are made. Temperature measurements are made at 15 positions in each of the repeater tanks. Three thermocouples are located in the wall of each central cone, and 12 thermocouples are placed in designated positions within the cable coils of each tank. The measurement of temperature is semiautomatic; to determine the temperature at any of the 45 positions, it is necessary only to press the appropriate button and read out the temperature directly on the meter scale.

At the conclusion of these tests, power is turned down and no further measurements are made until the initial splice is made and laying is ready to start.

XII. SPACE LOCATIONS AND ARRANGEMENTS

Efforts were made to assign spaces for cable operations for the greatest convenience and utility. Consideration was given not only to immediate requirements for equipment areas, working space and servicing needs but also to probable future requirements.

Floor plans were worked out for all of the areas directly or indirectly connected with the cable laying operation. Lighting, air-conditioning and ventilation requirements were set for all these areas.

Special attention was given to the layouts in the drum room, transmission testroom, jointing room and taut wire room, since these are the active operating areas during cable laying, and convenience and efficiency are especially important.

In the transmission testroom all equipment is furnished in duplicate so that the failure of any unit does not interrupt system operation and test. Cable payout information which is of assistance to the transmission eingineers is repeated in the test room. This information consists of cable payout speed, mileage and miles to the next repeater. Cable temperature measuring equipment is also located in this room.

Cable engine control during laying is from the cable operations center, known as the "drum room," and the layout centers around the cable engine control console. All of the payout control equipment is located here. This includes cable engine controls (both bow and stern), mileage counters of cable and taut wire, slack computers, depth sounders, precision depth recorder and ship's speed indicator. Slack computers and cable and taut wire mileage counters are furnished in duplicate.

Cable jointing, whenever possible, is carried on in the jointing room. The location on the upper deck opposite cable tank 1 was chosen, since it is the space most readily accessible for cable ends brought over the bow and through the cable hatch. The layout permits splicing operations on all types of cable without exceeding the minimum bending radius requirements.

The taut wire room houses not only the taut wire machine itself but provides for stowage of full and empty taut wire reels. Racks were designed and layout arranged so that the bulky reels, containing 140 nm of wire weighing approximately 2000 pounds, could be safely handled under rough sea conditions.

XIII. ELECTRICAL SERVICES AND COMMUNICATIONS

The factors of safety, reliability, stability and convenience determined the choice of electrical service to the working areas. Alternate power sources supply the regular and alternate test and power equipment in the transmission testroom for maximum reliability, and both steady-state and transient voltage and frequency requirements were set for the prime power sources.

Fusing and switching of all of the equipment was specified so that these were compatible with the services furnished. In areas such as the transmission testroom and electronics maintenance room where portable equipment may be used or equipment serviced, the convenience outlets are fed through isolation transformers to provide single-phase grounded service in place of the usual shipboard single-phase balanced-to-ground supply.

Coaxial circuits are installed from the switchboard bay in the transmission testroom to all of the cable working areas and, by appropriate patching at the switchboard, test and communication circuits can be set up between any of these locations.

A cable operations communication circuit connects all of the cable working areas. Operating stations consisting of microphone and loudspeaker are located at strategic locations where there is active cable movement or cable control, and announcements over this circuit are repeated at all locations.

For the purpose of safety to personnel and to cable, "safety alarm" stations are also provided at strategic locations. These stations consist of distinctively colored button switches connected to all of the cable engines and to an audible alarm. The operation of any of these switches immediately stops any operating cable engine and cable payout or pickup comes to an immediate halt. Needless to say, this circuit is used only in extreme emergencies, to stop operations when personnel are endangered or an equipment failure requires immediate or drastic action.

REFERENCES

1. Zajac, E. E., Dynamics and Kinematics of the Laying and Recovery of Submarine Cable, B.S.T.J., **36,** Sept., 1957, p. 1129.
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