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DESIGN OF TETHER TERMINATION ASSEMBLY FOR TETHERED FLOAT BREAKW--ETC(U)

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DESIGN OF TETHER TERMINATION ASSEMBLY FOR TETHERED FLOAT BREAKWATER: PRELIMINARY REPORT

by

Norman F. Johnson
Ocean Technology Department

January 1977

NAVAL UNDERSEA CENTER
SAN DIEGO, CALIFORNIA

NAVAL UNDERSEA CENTER, SAN DIEGO, CA 92132

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This report describes preliminary work undertaken to design and develop a tether termination assembly for an open-ocean tethered float breakwater. Such a termination must be able to support a float with 3,000 to 4,000 pounds (1,360 to 1,814 kg) of buoyancy and sustain flexure of the tether about its vertical axis by up to 17 degrees in any direction for an estimated 19 million cycles during five years; it must also be able to withstand the environmental conditions associated with submergence in the ocean. A survey of commercial sources revealed that terminations capable of meeting such requirements have not yet been developed.

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In preliminary experiments, however, a termination designed for mooring and towing applications was modified and tested with promising results. This termination was based on the use of a swaged socket with a slip-on boot that damped vibrations in and controlled the bending radius of the tether. Three prototype terminations for the breakwater application were then designed, one based on a ball-and-socket technique and two on the slip-on boot technique. A total of eleven of these terminations were fabricated and installed in October 1976 in the ocean off Imperial Beach, California, for long-term testing. Additional units will be fabricated and tested under controlled conditions in the laboratory.

SUMMARY

This report describes preliminary work undertaken to design and develop a tether termination assembly for an open-ocean tethered float breakwater. Such a termination must be able to support a float with 3,000 to 4,000 pounds (1,360 to 1,814 kg) of buoyancy and sustain flexure of the tether about its vertical axis by up to 17 degrees in any direction for an estimated 19 million cycles during five years; it must also be able to withstand the environmental conditions associated with submergence in the ocean. A survey of comercial sources revealed that terminations capable of meeting such requirements have not yet been developed. In preliminary experiments, however, a termination designed for mooring and towing applications was modified and tested with promising results. This termination was based on the use of a swaged socket with a slip-on boot that damped vibrations in and controlled the bending radius of the tether. Three prototype terminations for the breakwater application were then designed, one based on a ball-and-socket technique and two on the slip-on boot technique. A total of eleven of these terminations were fabricated and installed in October 1976 in the ocean off Imperial Beach, California, for long-term testing. Additional units will be fabricated and tested under controlled conditions in the laboratory.

CONTENTS

INTRODUCTION

An open-ocean tethered float breakwater (TFB) is under development for experimental evaluation at the entrance to Mission Bay in San Diego, California. A prototype section will be built and installed at a test site off Imperial Beach, California, for engineering evaluation prior to construction of the TFB for the Mission Bay experiment. This report describes the efforts of the Naval Undersea Center (NUC) to develop a tether termination assembly for use on this prototype.

The TFB is a new type of breakwater. It employs a large number of submerged floats tethered to a ballast which provides, among other functions, a space grid and sufficient weight to hold the floats at or near the water's surface (reference 1). These floats and their tethers form upside-down pendulums tuned to oscillate out of phase with water particle motion. Drag induced by the moving floats expends wave energy and thereby reduces wave height.

The function of the tether is to maintain the floats at a fixed distance above the ballast while allowing them to oscillate freely in all planes about an axis formed by a line through the base of the tether and perpendicular to the ballast (figure 1). Tether length is set according to the float chosen (reference 2). The two must form a pendulum with a natural frequency equal to that of the most significant waves which the TFB is to attenuate. Tether tensile strength is determined by the buoyancy of the float, using a suitable safety factor. Materials must be able to suffer long-term ocean abuse such as that caused by corrosion, dirt, biological fouling and shock loads.

For the purpose of this report it is important to understand that there are two scales of TFBs: marina TFBs and larger open-ocean TFBs. The primary difference, as far as tether problems are concerned, is in the size and buoyancy of the floats used. Marina TFBs use floats about 12 inches (30.5 cm) in diameter, while the open-ocean TFB floats are 3 feet (91.4 cm) or greater in diameter (5 feet or 152.4 cm in diameter in the case of the Mission Bay breakwater). Whereas the marina TFB floats provide 27 pounds (12.2 kg) of buoyancy each, the 5-foot-diameter floats provide 3,000 to 4,000 pounds (1,360 to 1,814 kg) of buoyancy, depending on construction. Suitable tether termination assemblies have been developed, tested, and are in use on marina breakwaters. Because of technical and manufacturing problems, these smaller assemblies cannot simply be scaled up for the larger TFBs. This report is concerned only with the larger tether termination assemblies.

Relatively simple, efficient methods of wire and synthetic rope terminations have long been sought by those who work in the ocean. In recent times, a number of good rope terminations have been developed which provide the full breaking strength for a given line when subjected to straight tensile loads. Premature failures of these same terminations often occur, however, when the rope termination assemblies are used in the ocean, where they experience strumming vibrations and flexing. These failures generally

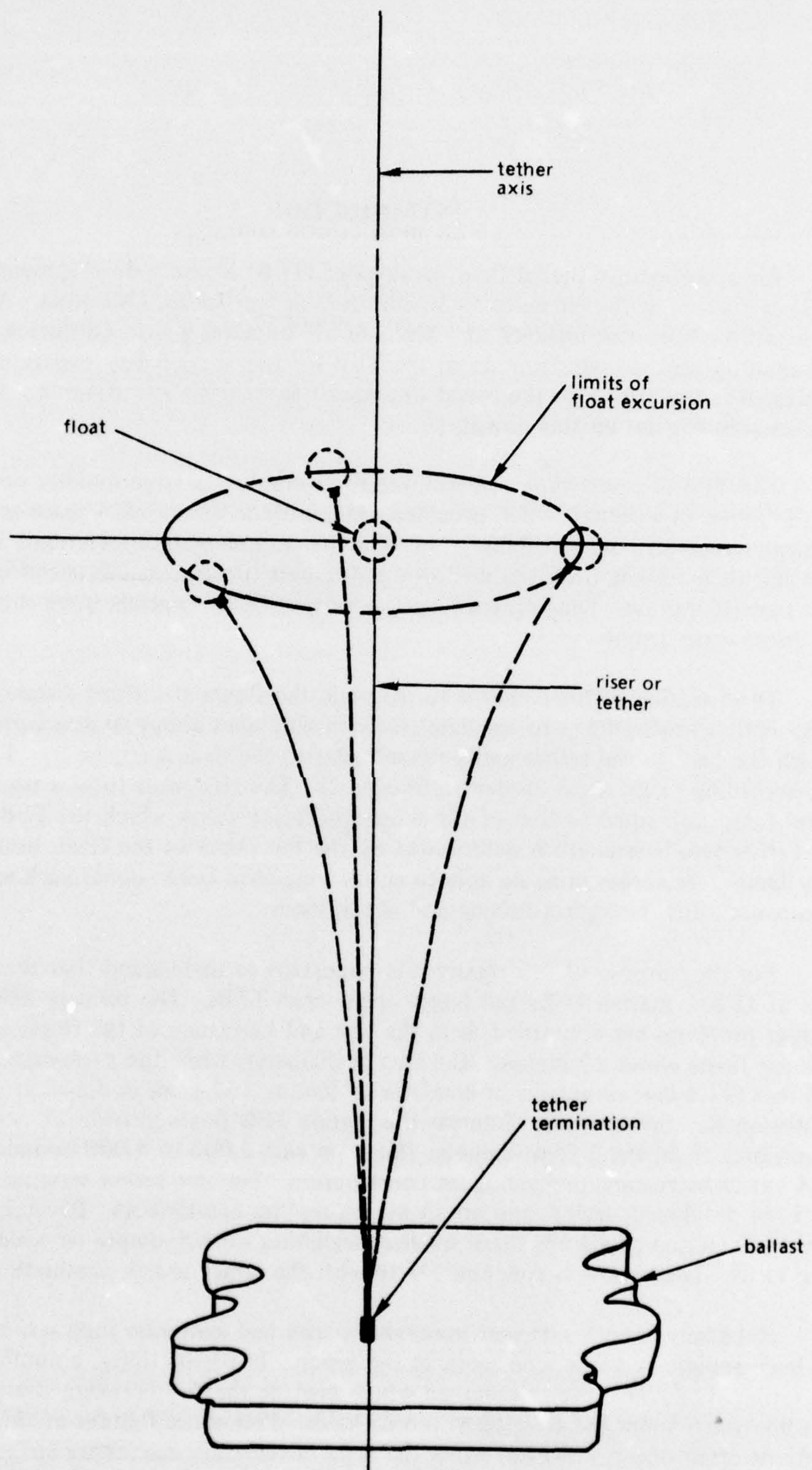

Figure 1. Tether termination assembly and associated parts.

occur due to repeated stress concentration at or near the terminations, where the strumming must be absorbed and where the sharpest flexing usually occurs.

DESIGN CONSIDERATIONS

Flexure life is judged to be the most critical consideration when attempting to design a tether termination assembly. Float movement through the water causes the tether to flex randomly in all planes about the tether axis. Best estimates indicate that over a 5-year period the tether will flex ±11 degrees about the tether axis for 18 million cycles and ±17 degrees for an additional 1 million cycles.

The tether termination assemblies for the Mission Bay TFB, as noted above, must tether submerged buoys producing 3,000 to 4,000 pounds (1,360 to 1,814 kg) of buoyancy each. In addition to the static tensile load caused by this buoyancy, environmental conditions cause tensile cycling of approximately ±10 percent about the static load. This tensile cycling occurs at the same rate as flexure, producing about 19 million cycles in a 5-year period. No severe shock loading of the tethers is anticipated, because the ballast is designed so that even under storm conditions the floats will not surface to a degree which will significantly reduce the tensile load on the tethers.

Large increases in tether length will move the spectrum of maximum wave attenuation to other than that for which a particular TFB is designed; therefore, long-term elongation (stretch and creep) must be kept within reasonable limits. Recent studies (reference 3) indicate that some lengthening of tethers will not adversely affect TFB performance. Another reason for keeping creep within limits is that loss of tensile strength of the riser is in direct proportion to the reduction of its cross sectional area. Materials like polypropylene are thus not suitable because they creep indefinitely at appreciable rates.

Uniformity of stretch and creep is also an important consideration. If stretch and creep are not uniform throughout the array of tethers used in the TFB, some of the floats will eventually be allowed to come to the surface (possibly to the point where their tethers become slack). It is necessary then to select a riser which has either no significant stretch or creep (wire rope) or one in which they are controlled by proper design and manufacture.

Although the TFB ballast is designed so that even under storm conditions the floats will not be appreciably exposed above the water's surface (allowing the tethers to become slack), experience reveals that it would be a mistake to assume that no shock loading will occur during assembly and installation. Since any appreciable shock load will destroy or severely damage a line which has a hockle, it is essential to use risers which are nontorquing. The importance of this consideration cannot be overemphasized. Torque-balanced wire ropes and synthetic lines are readily available which minimize the possibility of developing hockles should a tether suddenly become slack.

Environmental considerations which must be taken into account are marine fouling, corrosion, sand, silt, dirt, sunlight, and temperature extremes. Performance of the TFB will be degraded if biological fouling, dirt, or corrosion impedes or prevents the natural action of the tethers. Temperature extremes and sunlight, especially before and during installation of a TFB, could cause damage to tethers if materials are not correctly chosen. Cold could cause cracking of wire coatings and boots. Excessive heat could cause loss of lubricants or flow of coatings. Should a metal riser (such as a wire rope) be chosen, it must be shielded from contact with seawater by a suitable coating or plastic jacket. The sealing method must also prevent seawater from reaching the ends of the riser and wicking between the riser and its protective cover.

For ease of handling, the riser should be flexible enough to be coiled within a diameter equal to that of its associated float. To insure that it will have only minimal influence on float performance, the tether termination assembly should be kept to 10 percent or less of the dry weight of its float.

SURVEY OF COMMERCIAL SOURCES

An investigation was undertaken of approximately sixty possible sources of suitable tether termination assemblies, test data, and test facilities. These sources were contacted by telephone and letter to acquaint them with the problem and discuss possible solutions. Nine of the most promising were visited during the last two weeks of August 1975.* The purpose of the visits was twofold:

1. To familiarize the selected manufactureres and laboratories with the TFB for the purpose of obtaining tether termination assemblies or data sufficient to design assemblies that we could have confidence in.

2. To find laboratory test equipment which could be used or modified to evaluate prototype assemblies prior to placing them in the ocean for testing.

The principal finding of the visits was that little or no work had been done that was applicable to our most critical concern, that of flexing failure at the termination. Though useful data were obtained on elongation and corrosion protection, no facilities visited were judged capable of testing to our specifications without expensive modifications.

Since the desired help appeared not to be available, we concluded that it would be necessary to design and develop our own tether termination assembly. Two basic approaches to solving the flexure problem were evident. The first was to use a termination technique that eliminated entirely the flexing occurring at the junction of the riser and termination on such terminations as swaged sockets and studs. The second was to control the radius of bend of a given riser to the minimum that the riser would accommodate for the flexure cycling required.

PRELIMINARY EXPERIMENTS

Examples of conventional terminations for buoy moorings were examined. These included chains, shackles, wire and synthetic rope thimbles, open and closed swaged

**The following organizations were visited: Coast Guard Research and Development Center, Groton, Conn.; Woods Hole Oceanographic Institute, Woods Hole, Mass.; Sampson Cordage, Shirley, Mass; Columbian Rope, Kenosha, Wisc.; Preformed Line Products, Cleveland, Ohio; Battelle Laboratories, Columbus, Ohio; McWhyte Wire Rope, Kenosha, Wisc.; Wall Rope, Beverly, N.J.; and Philadelphia Resins, Montgomeryville, Pa.*

sockets, special synthetic line thimbles, potted fittings, and boots which slip over the line to absorb line vibration due to strumming and buoy motion. In each case, it was found that the particular conventional method would not stand up under the many millions of flexure cycles that the TFB tether must undergo. For instance, figure 2 shows the wear on a 3½-inch (9-cm) chain after 90 days in the North Sea when used in a single point mooring system. Shackles and terminations used in conventional systems (various thimbles and potted fittings) undergo the same type of wear.

A test was made using a piece of 1-inch (2.5-cm) chain. A bail was made out of one link, while the second was attached to a tether riser. This arrangement was cycled 9 degrees about the tether axis for 15,000 cycles under a 3,000-pound (1,360-kg) tensile load in salt water. Figure 3 shows the wear after the test. (The link has been reversed for clarity, and the underside of the mating bail looks similar to the link.) After less than 0.001 of the cycling life ocurred, the link had lost nearly 10 percent of its diameter. Considering the very light tensile load for a 1-inch chain, it was obvious that such an approach would not survive, and the test was terminated. Chain, of course, is not designed for such service, but it was hoped that by making it oversize the accelerated wear could be tolerated.

Woods Hole Oceanographic Institute has for some years used slip-on boots to extend the life of line terminations used in towing or moorings. These boots slip over the shanks of swaged sockets to absorb line vibrations as they approach the socket. It is at

Figure 2. Wear of 3½-inch (9-cm) grade-3 chain used in single-buoy mooring system in North Sea.

Figure 3. Wear of 1-inch (2.5-cm) chain and bail after 15,000 cycles under 3,000-pound (1,360-kg) tensile load.

the point where the wire rope enters the socket that failure normally occurs. Even though the Woods Hole cable termination assemblies do not undergo the strenuous flexing required of those used for TFB tethers, strumming or other line vibrations though small in magnitude are large in numbers and evidently cause gradual work hardening of the wire rope as they pass from the wire rope into the swaged socket, which has a much greater mass. The boot eliminates this area of stress concentration, it is believed, and prolongs the termination life. These particular boots are not stiff enough to control the line bending radius at the working tensions the TFB risers normally see.

It was decided to see how the boot approach might be modified to solve the TFB problem. Woods Hole personnel were requested to make up a number of the assemblies they frequently use. A 3/16-inch-diameter (0.3-cm-diameter) jacketed, torque-balanced wire rope was chosen, because at that time a 3-foot-diameter (91.4-cm-diameter) sphere offering 800 pounds (363 kg) of buoyancy was being considered for the TFB. This wire, the Woods Hole boots, and oceanographic closed swaged sockets were made up into test units and delivered to NUC. Since the boot was not able to control the bending radius of the wire to a reasonable minimum when flexing under an 800-pound tensile load, it was decided to give it some help. Figure 4 shows the molybdenum disulfide bushing and washers which were used to modify the experimental tether termination assembly. The bracket shown was made to be adjusted so that the principal plane of oscillation of the tethers would be perpendicular to the wave front. (Although the buoy moves in a more or less random fashion, its principal plane of oscillation is perpendicular to the incoming wave front.) Use of this configuration was also intended to give us a start in establishing credibility for our test program. Testing will be discussed later.

(a)

(b)

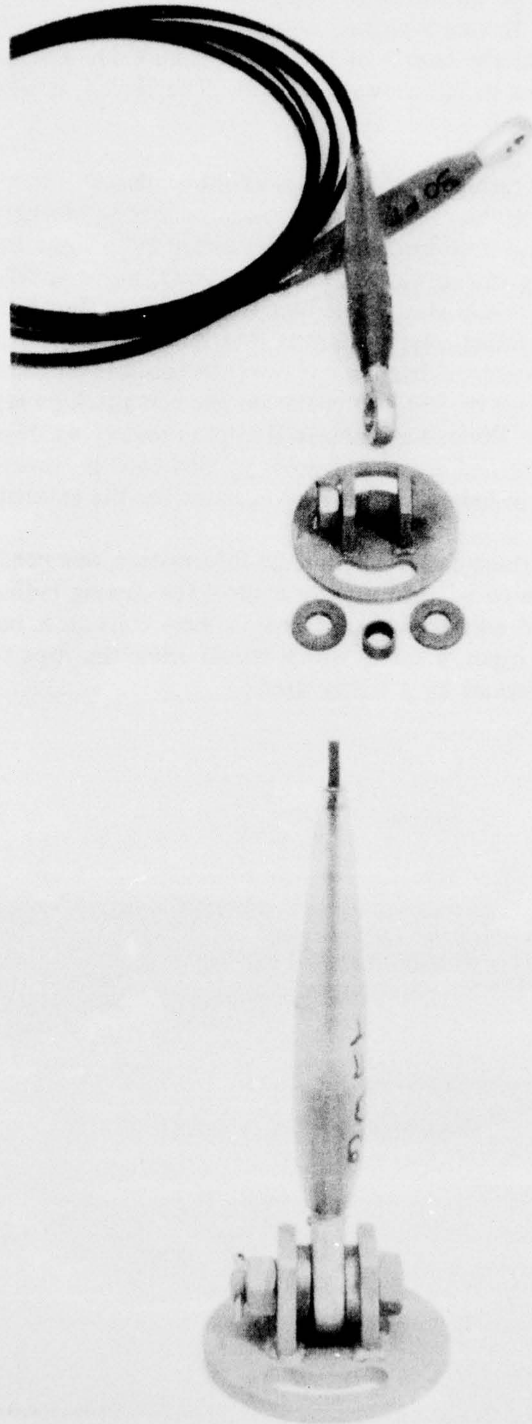

Figure 4. Lightweight experimental termination assembly. (a) Disassembled. (b) Assembled.

Four assemblies of the above configuration were tested in the laboratory under 800 pounds of tension, flexing 9 degrees about the tether axis in salt water. Failure occurred, as expected, at the mouth of the socket (figure 5). For the four assemblies, the average number of cycles to failure was 584,700. The spread, however, was from 28,000 to 1,140,000 cycles.

Twelve of these tether configurations were installed at a test site off Imperial Beach, California, in February 1976. Eight 1200-pound-buoyancy (544-kg) and four 800-pound-buoyancy (363-kg) floats were used. As of December 1976 there have been no failures. In 10 of the tethers one of the washers has worn away, but monthly inspections by divers have revealed no other visible wear. The fact that no tether termination assemblies of this configuration have failed after 9 months is encouraging, especially considering that four are under 1200 pounds of tension. It does cast doubts on the validity of our testing, however, since the average of 584,700 cycles on the test machine represents only 56 days of flexing in the ocean. Divers have observed approximately ±3 degrees of flexing perpendicular to the wave front and about 2 degrees parallel to it in waves no more than 2 to 3 feet (60.9 to 91.4 cm) in height, which may account for the anomaly.

At the time of these early experiments information was needed that could lead to the design of a boot which would properly control the flexing radius of a tether riser. Numerous synthetic and wire rope manufacturers were consulted, but none could recommend, for any of their ropes, a radius which would allow the rope to survive the millions of flexure cycles experienced by a tether riser.

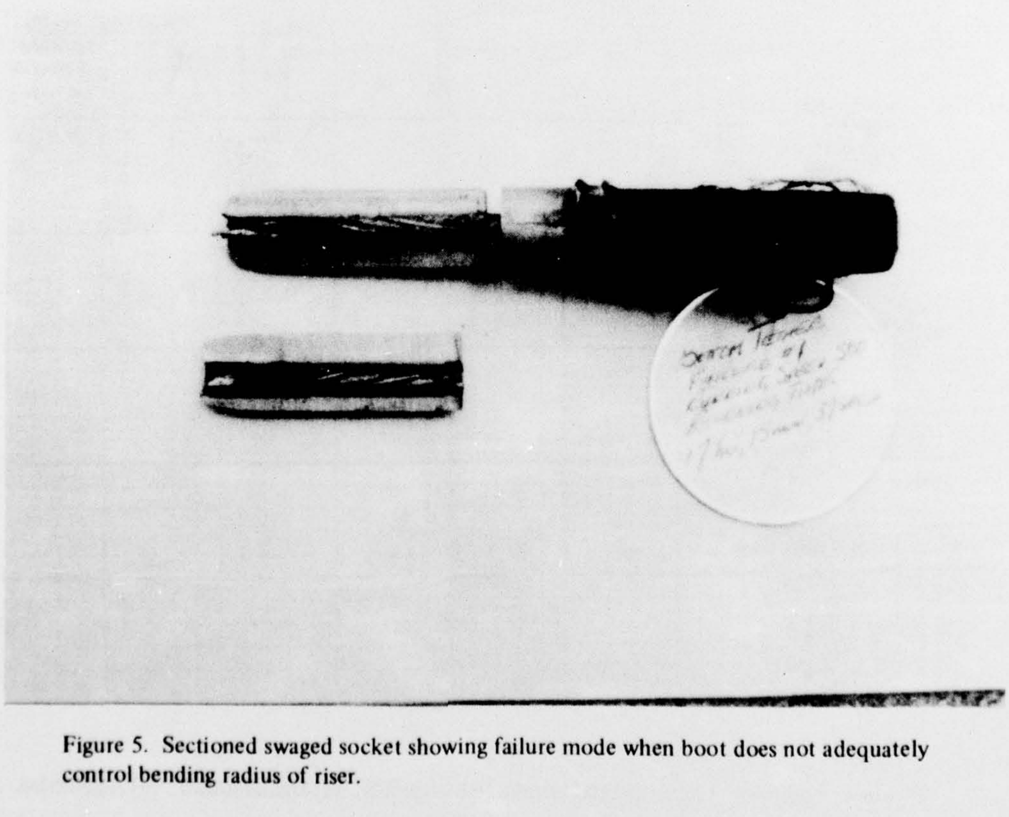

Figure 5. Sectioned swaged socket showing failure mode when boot does not adequately control bending radius of riser.

Recommendations are available for sheave diameters for running wire rope (references 4 and 5). These sources generally recommend that 20 to 40 times the rope diameter (depending on rope construction) be used for the corresponding minimum sheave diameter. Sometimes the minimum sheave diameter recommended is 400 times the diameter of the smallest wire in a given wire rope (reference 6). Sheave diameter recommendations for running synthetic ropes are about eight times the respective rope diameters (references 7 and 8), regardless of rope construction.

It is obvious that the bending or flexing action of the tether in motion on a TFB is not identical to that of a line running over a sheave, but it is the closest thing to it we have in practical operation. On one hand, the number of flexures suffered by a given portion of line running over a sheave is far below that experienced by the flexed section of a tether riser. On the other hand, the degree of bending and the crushing effect of a sheave against a line are far more punishing than the flexing experienced by a tether riser.

Mr. Peter Riggs, of Peter Riggs Services, Ltd., Boyton, England, who is the inventor and developer of the Space-Lay and Nilspin lines manufactured by the MacWhyte Company of Kenosha, Wisconsin, was consulted. His recommendation of a D:d ratio of 50:1 was the same as that being considered at NUC. The 50:1 ratio, which would establish a 12.5-inch (31.75-cm) minimum radius of curvature for a half-inch-diameter (1.25-cm) wire rope, was accepted as a starting point for initial tests.

Meanwhile, it was established that the proper bending radius of 4½ inches (11.5 cm) for the booted, 3/16-inch-diameter (0.5-cm) wire rope tether termination assembly of figure 4 was achieved when this assembly was subjected to a 172-pound (78-kg) tensile load pulled 15 degrees from its axis. A test was planned to flex the tether 9 degrees about its axis under 172 pounds of tension in salt water. The tether has to date (December 1976) undergone 22.7 million cycles with no sign that early failure may occur. Although far from being conclusive, the results so far are encouraging.

PROTOTYPE DESIGNS

Once the decision was made to use 5-foot-diameter (152.4-cm) net buoys, each offering 3,000 pounds (1,360 kg) of buoyancy, three different prototype tether termination assemblies for testing with these buoys were designed and fabricated.

Figure 6 shows an experimental termination which uses the first approach. It is a ball and socket, the ball being cast phenolic and the socket an ultra high molecular weight polyethylene. The materials were chosen for their compatability, noncorrosive characteristics, availability, toughness, and excellent abrasion resistance. The cast phenolic balls are readily available commercially in a range of sizes desirable for use in TFB terminations. Ultra high molecular weight, high density polyethylene resin with extreme abrasion resistance is now available for forming or machining the sockets. The sockets are mounted upside-down in the hope that they will be self-cleaning. Riser material is Sampson very low stretch (VLS) single-braid polyester rope 7/8 inch (2.2 cm) in diameter. The thimble on the yoke could be replaced by a swaged stud for use with wire rope as a riser. Should this configuration be chosen for use on the TFB, it is anticipated that lightweight forgings could be fashioned to replace the heavy, welded yoke and base assemblies.

(a)

(b)

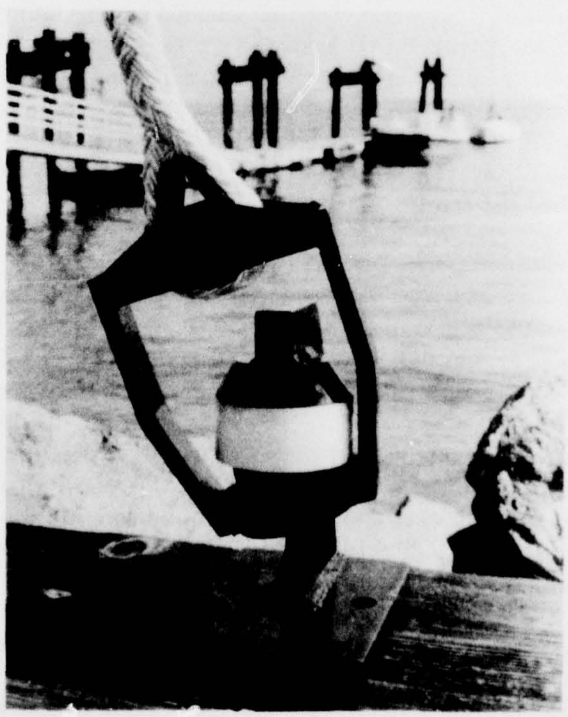

Figure 6. Prototype ball-and-socket tether termination assembly. (a) Disassembled. (b) Assembled.

A second tether termination assembly is shown in figure 7. This assembly is based on the second approach. Half-inch-diameter (1.25-cm) U.S. Steel torque-balanced Amgal polyethylene-jacketed wire rope of 3 by 19 construction is used for a riser. It is swaged into an open socket which supports all tensile loads. Length of the swage is 8 rope diameters, a figure proved over the years to be optimal for swaged sockets. The slip-on boot is designed to control flexure, so that under 4,000 pounds (1,814 kg) of tension the riser will see no curvature with less than a 12-inch (30.5-cm) radius. Also, a seal is provided by the boot so that no seawater will enter under the riser jacket. No part of the tensile loading is supported by the boot. A computer program has been developed which can be used to design boots for control of other riser diameters and working loads (reference 9).

For testing of this prototype, the socket is fastened so that the normal hinge action about its pin is totally restricted. Should this tether approach be chosen as optimal for the TFB, it is most unlikely that a swaged open socket would be used. Instead, a forging that would accommodate the tether-ballast interface would probably be employed. The open socket was used because it was available and inexpensive.

The third tether termination assembly is one that was designed by Lane Instrument Company of San Diego. Shown in figure 8, it again is an example of the second approach. Relatively new on the market, the Sampson VLS single-braid polyester used as a riser is nonhockling, easy to handle, can be spliced quickly, and has a high modulus of elasticity (less than 3 percent elongation at design load). The 7/8-inch (2.2-cm) VLS

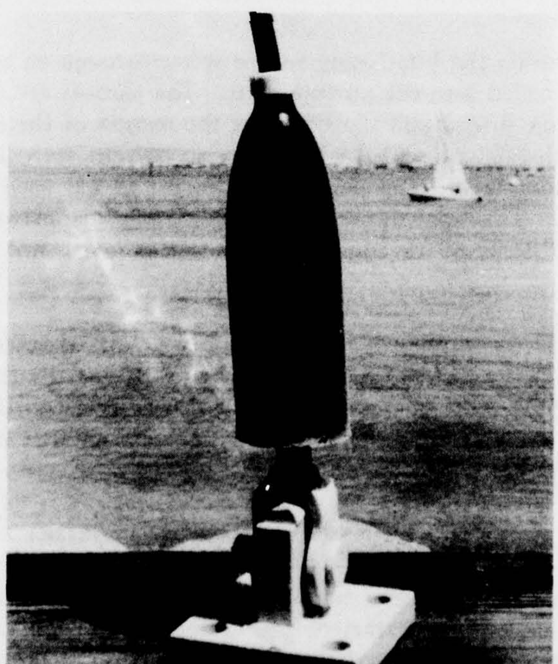

Figure 7. Prototype booted tether termination assembly for wire rope riser.

Figure 8. Prototype booted tether termination assembly for synthetic rope riser.

riser is terminated inside the boot using an eye splice through an eye bolt (figure 9), which in turn is threaded into the bottom plate. The threads are then locked with a set screw placed in a hole drilled and tapped along the margin of the eye bolt and bottom plate threads. All threads are sealed with epoxy to prevent corrosion. Boot design for this assembly was completed using the same technique as was used for the wire rope assembly described above. This boot, however, is molded in place instead of being slipped on. The bottom plate is designed for convenience in testing and is not intended to be the final configuration.

A total of eleven samples of the three above described tether termination assemblies were installed at the test site off Imperial Beach during the first week of October 1976. Testing of these three configurations will also be done on the test machine, using the procedure followed in testing the smaller tethers, except that the tension will be 3,000 pounds (1,360 kg).

QUESTIONS CONCERNING TESTING

Wire rope and synthetic line manufacturers have done considerable testing of their products to determine various characteristics. Some of the results are extremely useful. Much testing has been done to reveal elongation, abrasion resistance, strength of conventional terminations, and other characteristics.

Figure 9. Eye bolt used in synthetic rope tether termination assembly.

The most critical TFB tether problem is that of the many flexure cycles. It is true that a variety of lines have been cycled over sheaves under load for tens of thousands and even hundreds of thousands of cycles but none for the millions that the TFB risers see. To make things worse, there is some doubt that data from flexing over sheaves can be applied to tether flexure. Rope manufacturers are steadfast in their refusals to predict the life of their ropes as used in TFB tethers.

A test machine was designed and constructed to cycle tether prototypes about their axis under proper tensile loads. The geometry of the machine is such that the angle of flexure can be adjusted throughout the range which has been predicted for working tethers. A typical test cycles the tether at 500 rpm in salt water. At this rate, a test of 19 million cycles requires 26.4 days and is tremendously punishing to the test machine, especially to its bearings. Obviously, better and faster flexure test methods are needed if a tether which is both reliable and inexpensive is to be provided. Although testing is in its early stages, the performance of the lighter tethers that are installed off Imperial Beach, grossly overstressed by best estimates, gives some credibility to the argument that testing requirements are too severe. If this is true, considerable reduction in the size and cost of the tether termination assemblies may be possible.

Some sort of scaling (either up or down in material size or loads or flexing angles) is desirable to speed up testing. In order to do so and improve credibility of the tests, many questions arise, some of which must be answered:

1. Are failures rate dependent within reasonable cycling rates (say, 200-1000 rpm)?

2. What is the relationship of angle of flexure to life? Can the angle of flexure be greatly exaggerated to predict failure at lesser angles?

3. What is the relationship of radius of curvature to life? Can the radius of curvature for test specimens be made smaller to predict performance of those actually required?

4. What is the relationship of tensile load to life? Can increased tensile loads be used to predict more quickly tether life for working loads?

5. What relationship does tensile cycling (concurrent with flexure cycling) have to life?

6. How does rope construction affect life? What part do core construction, lubrication, number of strands, diameter of strands, coatings and rope stiffness contribute to tether life? Can a rope of one size or construction be used to predict more quickly the life of another?

Perhaps the most important question now is "what is really needed?" We have anticipated a flexure of 11 to 17 degrees about the tether axis but have observed only 2 to 3 degrees at our test site, though admittedly under mild weather conditions. It is believed that the prototypes installed in October 1976 have a very good chance for a 5-year life. Preliminary observations lead to a suspicion that they are overdesigned.

CONCLUSION

There is a good understanding of the long-term effects of corrosion, fouling, tensile loading, tensile cycling, elongation, and other similar factors, and by using test data and the lessons learned through experience these can be successfully controlled. Little is known which can help predict the flexure life of a specific tether termination assembly for a given set of operating requirements.

Three types of tether termination assemblies for floats with 3,000 to 4,000 pounds (1,360 to 1,814 kg) buoyancy have been designed and fabricated. Eleven units representing these three designs have been installed in the ocean off Imperial Beach, California, for test and evaluation. Preliminary tests indicate that these designs have a good chance for 5-year survival in a wave climate similar to that found along the southern California coast.

Both laboratory and ocean testing have been started, but answers to many questions are needed so that efficient and less costly tether termination assemblies can be designed. These questions can be answered only by a well planned test program.

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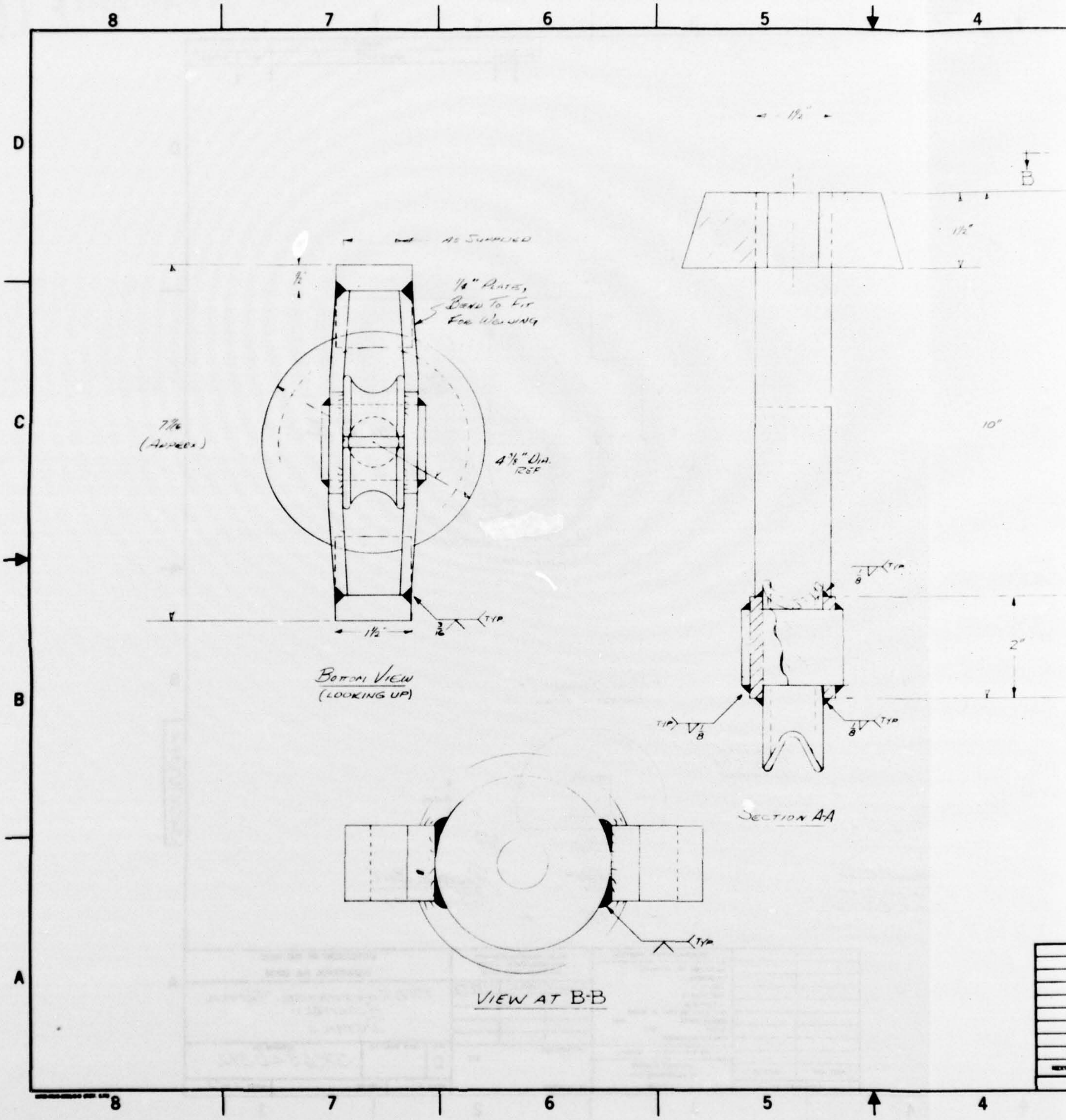
APPENDIX

ENGINEERING DRAWINGS OF BALL AND SOCKET PROTOTYPE DESIGN



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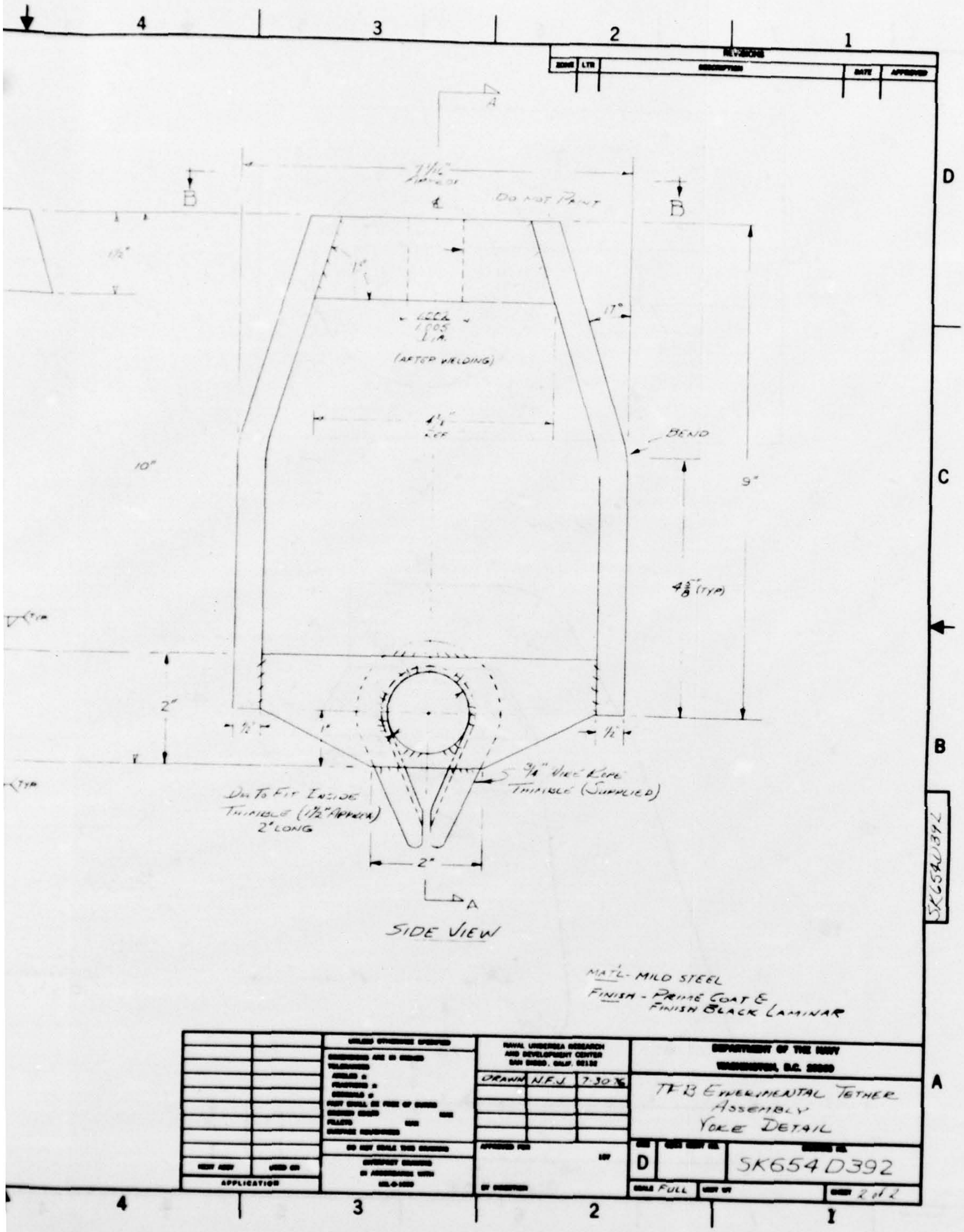
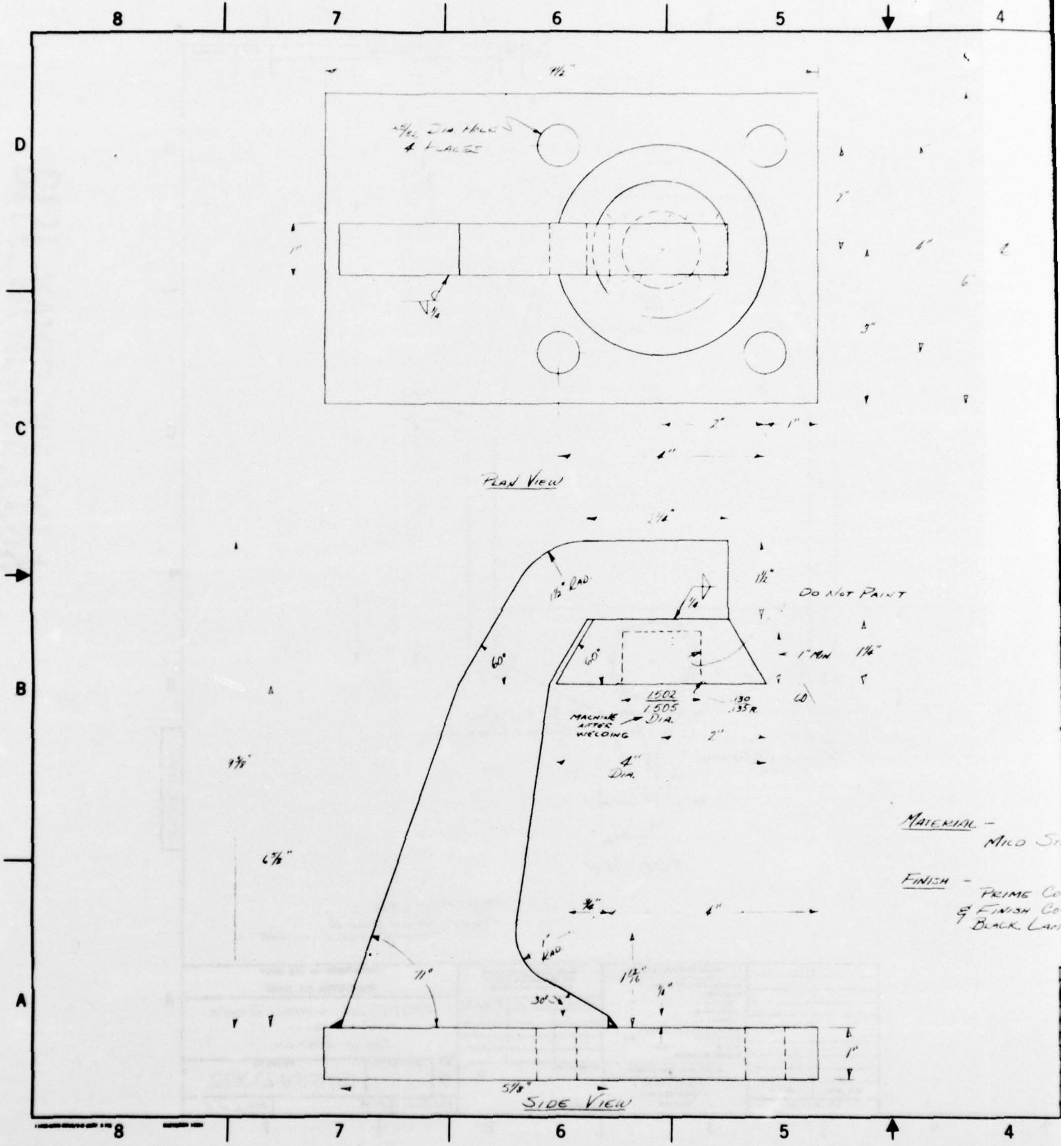
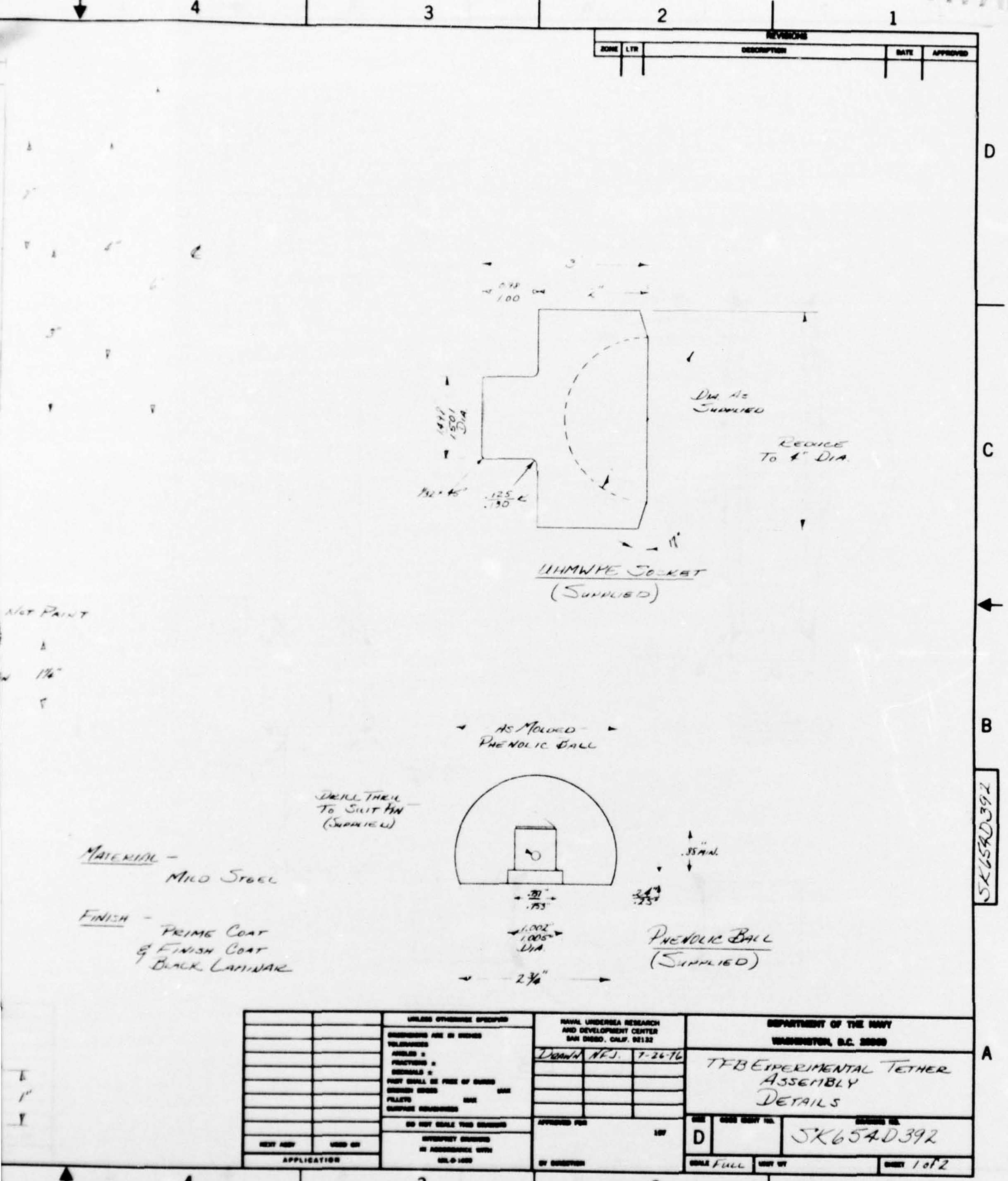

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
DO NOT PAINT
(AFTER WELDING)
BEND
SIDE VIEW
MAT'L - MILD STEEL
FINISH - PRIME COAT & FINISH BLACK LAMINAR
DEPARTMENT OF THE NAVY
WASHINGTON, D.C.
DRAWN N.F.J.
TFB EXPERIMENTAL TETHER ASSEMBLY YOKE DETAIL
SK654D392
SCALE FULL
APPLICATION

2


PLAN VIEW
SIDE VIEW
DO NOT PAINT
MACHINE AFTER WELDING
1.502
1.505
DIA.
4"
DIA.
MATERIAL -
FINISH -



UHMWPE SOCKET
(SUPPLIED)
DIA. AS SUPPLIED
REDUCE TO 4" DIA.
AS MOLDED PHENOLIC BALL
DRILL THRU TO SUIT PIN (SUPPLIED)
PHENOLIC BALL
(SUPPLIED)
MATERIAL - MILD STEEL
FINISH - PRIME COAT & FINISH COAT BLACK LAMINAR
NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER SAN DIEGO, CALIF. 92132
DRAWN NFJ. 7-26-76
DEPARTMENT OF THE NAVY
WASHINGTON, D.C.
TFB EXPERIMENTAL TETHER ASSEMBLY DETAILS
D
SK654D392
SCALE FULL
SHEET 1 of 2
APPLICATION

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