TM no. M-42-77-1

TECHNICAL MEMORANDUM

title: Use of the CEL 100K Propellant Anchor in Hard Coral to Provide Pulling Reactions for Toppling the Argus Island Tower

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INTRODUCTION

The Argus Island Tower was a four-legged tower structure used by the Navy for oceanographic research. It was installed circa 1960 in approximately 190 feet of water, 22 miles south of Bermuda. A secure foundation was obtained by drilling and grouting the tubular steel legs into the hard coral seafloor, and filling them with concrete to a level slightly above the seafloor. After its installation, it was used effectively by its owner, NAVELEX, for several years.

The tower is shown in Figure 1 as it was just prior to the installation of the first propellant anchor. Because of a lack of requirements for current or future use and a considerable maintenance expense, it was decided in 1975 to remove the tower. The most economical method was determined to be cutting the legs near the point where they entered the seafloor and pulling the tower over on its side. The approximately 100-foot-wide base would provide more than adequate clearance for present and foreseen ships to pass over the tower wreck.

Management of the toppling operation was the responsibility of the Navy's Supervisor of Diving and Salvage (NAVSEA Code OOC--SUPSALV). Propellant anchors were selected to provide a reliable anchorage for pulling reactions in the hard coral seafloor. Although these anchors presently are in the process of being service approved for Navy use, only R&D prototype hardware was available. The Navy's Civil Engineering Laboratory (CEL) recommended the use of the CEL/SUPSALV 100K Propellant Anchor System as having adequate capacity and being suitable for deployment from the available support vessel, an ARS salvage vessel. CEL and NAVSEA personnel jointly designed propellant anchor mooring and pulling hookups. CEL also provided services to prepare the system for shipment and deployment, managed procurement of needed expendables, and provided a technical representative during anchor installation to operate the anchor and to ensure that safe procedures were used in relation to anchor ordnance.

ANCHOR SYSTEM DESCRIPTION

The CEL/SUPSALV 100K Propellant Anchor System was developed for the Navy's Supervisor of Diving and Salvage to provide salvage anchoring capability at sites where the seafloor was not suitable for drag-burial anchors (True and Taylor, 1976). In addition, it was desired that the anchor system be capable of operating in unconsolidated sediments so that a single system could be carried aboard a salvage vessel (ARS, ATF, or ATS) for use at any site. The anchor system (Figure 2) consists of a launch vehicle, a safe-and-arm (S/A) firing device, a propellant cartridge, a projectile assembly, and lines.

Launch Vehicle

The launch vehicle consists of a gun mounted atop a quadropod frame with a square base. It measures about 8 feet (2.4 m) by 8 feet (2.4 m) by 12 feet (3.7 m) high and weighs about 12,000 pounds (5,500 kg) bare.

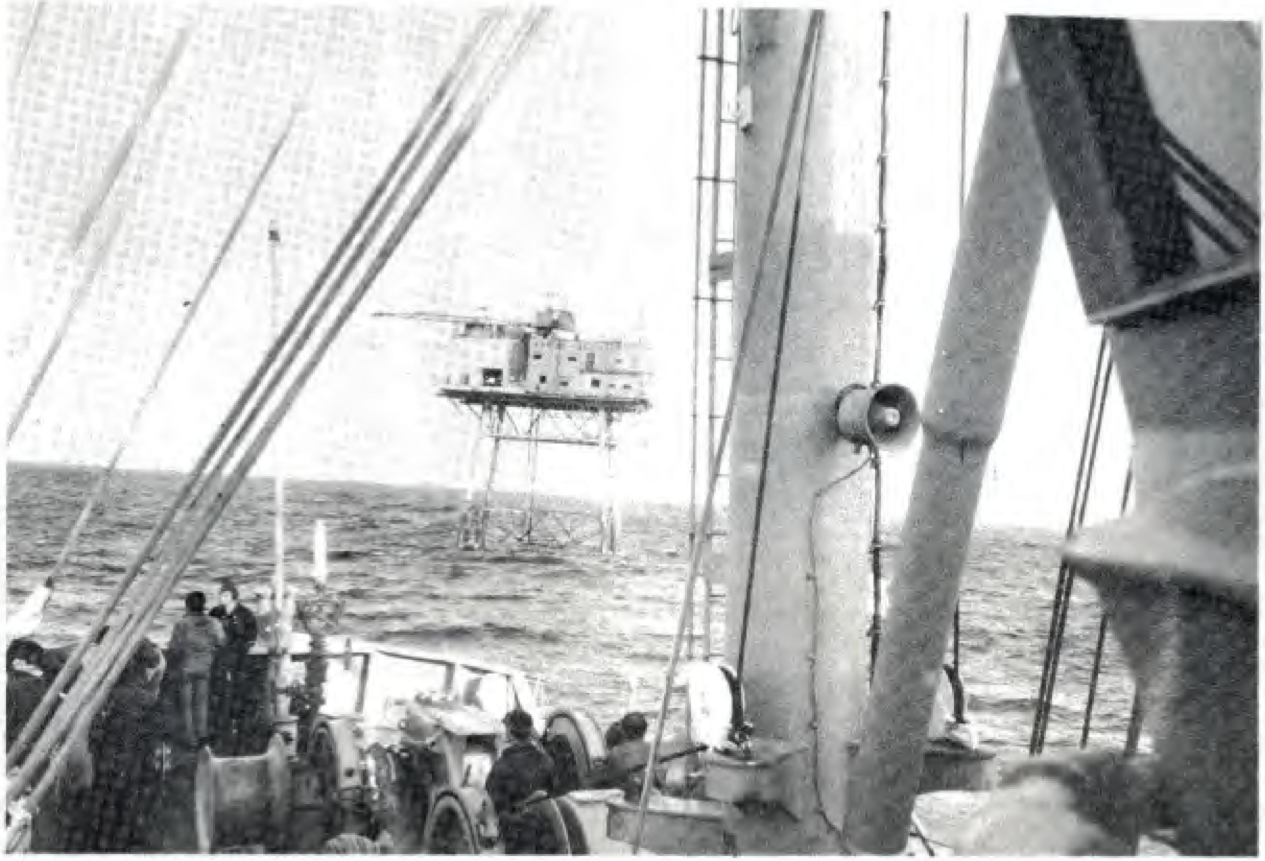

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Figure 1. Argus Island Tower from USS ESCAPE (ARS-6) in April 1976, prior to toppling operations.

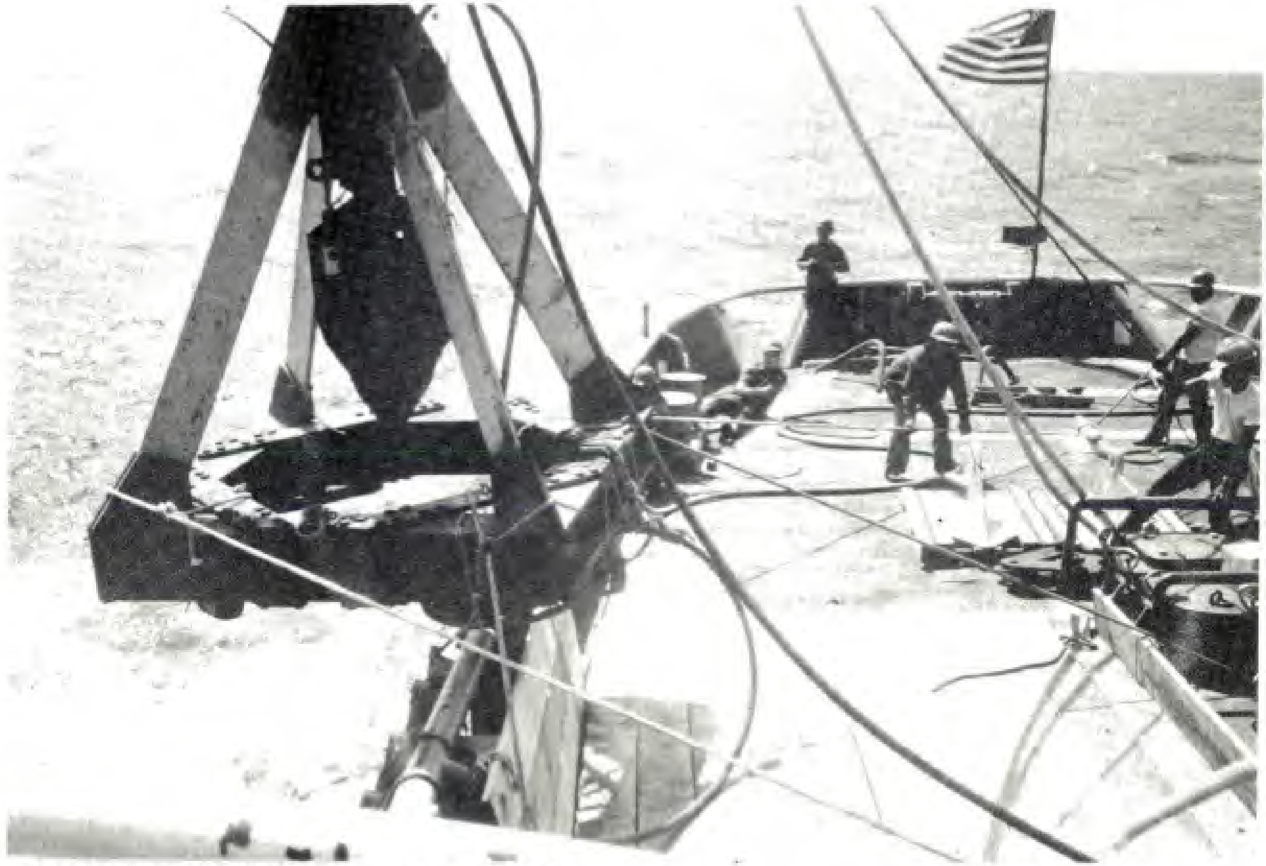

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Figure 2. The CEL/SUPSALV 100K Propellant Anchor System being deployed from the USS ESCAPE (ARS-6).

The gun barrel is a steel forging having the following dimensions:

Item	Dimension, in. (mm)
Inside diameter	10 (254)
Outside diameter	17 (432)
Overall length	42 (1,067)
Internal travel	36 (915)
Breech diameter (internal upset)	6 (152)

It is designed to operate with a peak pressure of 35 ksi (240 MPa). A breech block is fitted to the breech and screwed in over the propellant cartridge to contain the propellant gases during firing. The outside of the gun barrel is fitted with four double padeyes for pin connection to the quadrapod legs. These legs are bolted to the ends of four beam sections that form a square base. The beams support the vehicle and serve as drag surfaces to limit recoil. They must withstand a distributed reaction during firing, peaking at about 2 million pounds (9 MN). Diagonal bracing is attached across the corners of the base to provide the strength required to sustain the large outward loading produced by the propellant gases that escape the gun barrel shortly after firing. A circular drag plate is attached to the gun barrel atop the leg padeyes. Tie rods are fitted to this plate to secure the projectile assembly before firing. Drawings are given in Appendix A.

Firing Assembly

Included in the firing assembly are a reuseable safe-and-arm (S/A) device and the propellant cartridge. The S/A device effectively makes the system safe while on deck, arms at a preselected depth, and then causes the system to fire. This device, shown in Figure 3, is screwed into the top of the breech block and contains a firing pin that is driven downward to detonate the propellant charge. An electric current, which must be at least 0.3 ampere at 24 volts, actuates solenoid valves, releasing gas pressure. The gas breaks a 400-psi (2,800) kPa) shear disk and drives the firing pin downward with an energy in excess of 500 inch-ounces (3.5J).* A safety lockout plunger prevents firing pin motion unless the plunger is moved in line by a preselected level of hydrostatic pressure. Normally, a separate electrical line is extended to the sea surface to provide actuation, although an on-vehicle battery pack coupled to a touchdown or acoustic trigger could be employed.

The propellant cartridge consists of a cartridge base, capable of containing the gun barrel pressure, a plastic tube and foam plastic plug to contain the charge, and a standard M-58 primer. Firing occurs when the firing pin in the S/A device strikes the percussion cap at the rear (top) of the primer. A peak force of about 2.8 million pounds (12 MN)

*M-58 primer detonation requires between 60 and 160 inch-ounces (0.4 to 1.1J).

Figure 3. Safe-and-arm device.

is generated during firing to act downward on the projectile assembly and simultaneously upward on the launch vehicle.

Projectile Assembly

The projectile assembly (Figure 4) includes the piston and the anchor projectile, or "fluke." The dimensions of the flukes are given below:

Dimension	Value for Coral/Sand Fluke	Sand/Clay Fluke
Length, ft (m)	5.5 (1.66)	6.7 (2.04)
Width, ft (m)	2.7 (0.81)	3.3 (1.02)
Thickness, in. (mm)	1.0 (25)	1.0 (25)
Weight, lb (kg)	900 (408)	1,250 (567)
Area, ft^2 (m^2)	12.5 (1.15)	21.5 (1.99)

The dimensions of the piston are given below:

Dimension	Value for Piston
Length, in (mm)	34.5 (876)
Outside diameter, in (mm)	10.0 (254)
Inside diameter, in (mm)	5.4 (127)
Hollow length, in (mm)	25.5 (638)
Weight, lb (kg)	700 (320)

The piston is hollow, to accommodate the cartridge; the lower end is fitted with an eye for connection to the piston retrieval line and retainers to maintain proper alignment during firing. It bears against the rear of the projectile with a peak force during firing of about 2 million pounds (9 MN).

The projectile fits below and is driven by the piston. It may be designed for hard coral or other rock, soft coral, dense sand, or softer unconsolidated sediments. For all but the hardest rock, projectiles are constructed from 1-inch-thick (25 mm) high-strength steel plate. The basic design is a flat anchor plate with a backbone plate to provide strength during installation and service and an eccentric point of attachment to force keying (rotation toward the horizontal).

The projectile assembly is secured in the launch vehicle by tie rods. The lower ends of these tie rods are attached by shear pins through small holes in the rear of the anchor and backbone plates, and the upper ends extend through holes in the barrel drag plate and are secured by nuts atop the drag plate.

Lines are connected to the projectile and piston and are faked in figure-8 loops around timber pads on the bottom of the launch vehicle to allow rapid payout as the projectile assembly is launched downward. The main anchor load line is faked on the side of the launch vehicle base adjacent to the eye in the projectile, secured to the acceleration-activated release mechanism on the side of the base, and extended outward toward the intended direction of major loading (if loading will have a

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Figure 4. Projectile assembly installed in launcher with anchor load line attached and secured to eliminate end play.

lateral as well as an upward component). The piston retrieval line is faked on the opposite side of the launch vehicle base, over its first 40 feet or so; the remainder may be lightly secured to the launch vehicle or extended to the sea surface. The lengths of these lines may be adjusted to fit the water depth, the mooring design, and the connections to be completed after firing by divers or by remote mating devices. Typical characteristics of these lines are given below.

Line Characteristic	Value for Anchor Load Line	Value for Piston Retrieval Line
Material	Improved Plow Steel	Extra Improved Steel
Coating	Galvanized	None
Construction	6 x 36 Right Regular Lay With Independent Wire Rope Core	6 x 25 Right Regular Lay With Independent Wire Rope Core
Diameter, in (mm)	1.75 (44)	1.00 (25)
Breaking Strength, lb (kN)	230,000 (1020)	108,000 (480)

The use of the piston retrieval line is optional, depending upon the relative costs of piston expenditure versus piston retrieval. In the Argus operation, pistons were not retrieved, and the cost of expended pistons was reduced by using a modified piston design in which the retrieval line eye was deleted.

Costs

The expendables for each anchor installation have a total cost of about $4,000. In addition, the provision of management, component selection, procurement, monitoring, shipping, and on-site technical representative services, and system preservation and storage after use typically costs about $2K per shot when at least six shots are made in a single operation. The costs incurred in the Argus operation are in agreement with these typical figures for the system. They should be expected to be about the same in future similar operations. Costs associated with the installation vessel and crew are not included in these figures.

ARGUS ISLAND SITE CHARACTERISTICS

The site was located in 190 feet of water, about 25 miles south of Bermuda. This site borders on the Gulf Stream, and has peak currents of one to two knots. The seafloor was reported to be hard coral, having an unconfined compressive strength in the range of 5,000 to 10,000 psi (Young, 1975, and Mascisco, 1976). Such competent coral is typical of the high nutrient, open-ocean environmental conditions at the site.

This material is substantially more competent than the corals that had been encountered by CEL during previous anchor installations but is softer and more porous than some materials in which ballistic embedment anchors had been tested successfully. Consequently, the standard coral fluke used with the 100K Anchor System was judged to be the appropriate fluke; i.e., the one that would be small enough to achieve the needed penetration (at least 5 feet) and large enough to develop the needed holding capacity (at least 50 tons).

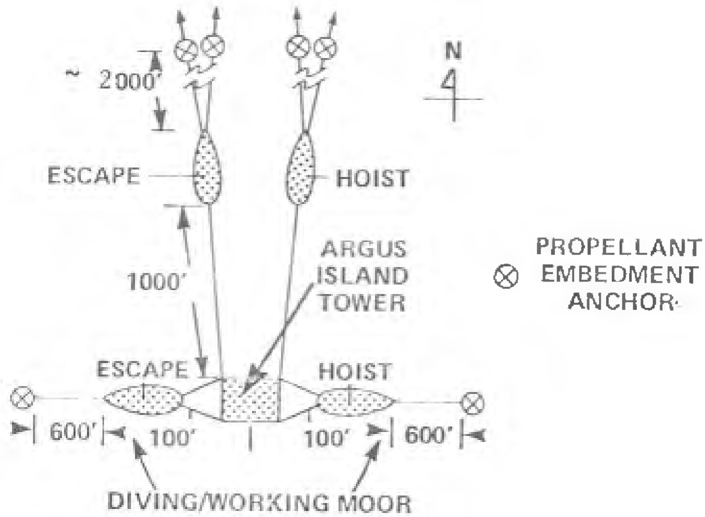
ANCHOR PLACEMENT AND HOOKUP

Operational plans involved toppling the tower toward the north. Pulling lines from two vessels were connected to loops of chain passed around the two northernmost tower legs. Each vessel was held in place during pulling by two anchors. The remaining two anchors were placed one on either side of the tower for use in mooring the vessels during diver work and rigging prior to the actual toppling operation.

The anchors were emplaced as shown in Figure 5. Pendants of 1-5/8 inch fibercore wire rope, 600 feet in length were used as the main anchor lines. A hard spliced eye in the end of the line was connected to the fluke with a 2-inch anchor-type (straight) round pin high-strength shackle with a rated safe working load of 35 tons, with a manufacturer's advertised safety factor of six against breaking. The anchor lines were extended with several additional pendants to permit the pulling vessels to assume their desired positions as shown in Figure 5. Two anchor lines were fed through the bow rollers on each pulling vessel. Each line was connected to a set of beach gear purchase tackle which was secured to an eye on the deck of the vessel with a tensiometer. The 2-inch-diameter wire rope towing cable carried on an aft winch on each vessel was used as the pulling wire. This cable was fed over a stern roller and connected to the chain on the tower leg. During pulling, the pulling wire was secured at the winch and the heavy pulling forces were generated by the beach gear tackle. The tensiometers were used to monitor pulling forces so that the anchors could be loaded equally and forces on the anchor lines, as well as the total force on each pulling line, could be held at the desired level.

ANCHOR INSTALLATION OPERATIONS

Procedures for using the anchor system are given in Appendix B. For the Argus operation, the handling of the anchor launcher during the assembly and loading of the fluke and the deployment of the system necessitated careful planning and execution to fit the needed load handling into the capabilities of the equipment that was available in the installation vessel.



(After Hall, 1976)

Figure 5. Anchor placement and hookup.

The USS ESCAPE (ARS-6) was the installation vessel, and also accompanied the USS HOIST as a pulling vessel. The boom crane located just forward of the aft work deck on the ESCAPE was used to handle and deploy the anchor system. This crane has a rated capacity of 8 tons, and had recently been proof loaded statically to 16 tons; it was assessed as adequate to handle the 7-ton anchor system in sea states up through 3.

Installing the piston and fluke in the anchor system is most easily done with the launcher laying on its side. In order to tilt the launcher from an upright to a side-down position, two lines were used on the crane boom. In addition to the main wire regularly used on the boom, a synthetic line was rigged to a block located near the sheave supporting the regular line on the boom; this synthetic line was fed down along the boom, through another block, and to a deck capstan. When the regular line and the special line were worked together, the launcher was laid down and righted without difficulty in calm seas. With the careful use of four tag lines, one to each corner of the launcher, the same handling was done without difficulty in sea state 3 conditions. Also, a timber layer was installed on deck and a timber bumper was lashed to the side rail to protect the ship from being scraped or marred. These measures (Figure 2) proved effective and highly desirable for their intended purpose during the handling and deployment of the heavy anchor system.

After the assembled system was set upright, the propellant was loaded and the breech block and safe-and-arm (S/A) firing device were secured. A safety line was installed on the S/A device to be used in the case of a misfire; this line was placed so that, if pulled, it would unscrew the S/A device two turns. (By this action, the S/A would be retracted from the primer sufficiently (a) to prevent the firing pin from striking the primer, and (b) to permit water to enter the propellant chamber upon repeated deep submergence, wetting the propellant and primer.) Then, with the ship's towing wire connected to the lowering eye, the assembled system was raised and put over the side with the regular boom line, lowered so as to transfer the load to the towing wire, disconnected from the boom line, and lowered to the seafloor with the towing wire. Deployment is shown in Figure 2. During lowering, the anchor load line was payed out from a point near the bow of the ship with enough tension maintained to prevent any spinning of the launcher, but not so much as to cause the launcher to tilt. A set line tension at the launcher of about 500 pounds was needed; this meant that a larger line tension was needed at the payout location, that increased according to the weight of line payed out (about 4-1/2 pounds per foot, submerged).

When the system was on the seafloor, as indicated by a slackened lowering cable, and in an upright position, it was fired by energizing the S/A device through the firing cable with a battery. The firing cable contained a wire to the level indicator that was checked for continuity to show an upright position.

After the firing, the launcher was retrieved with the lowering line. The anchor load line, which previously had been passed up through a roller sheave near the bow of the vessel, was retained to moor the vessel momentarily and then was tensioned to proof load the installed anchor.

ANCHOR SYSTEM PERFORMANCE

The anchor system performed well, except for two problems, which are discussed later in this section. Gun pressures were close to predictions, and embedment depths were as expected for the seafloor material that was encountered. Details are given in Appendix C.

Predictions of gun performance were made prior to the operation for the various pistons and projectiles used. These predictions were plotted as shown in Figures 6 and 7 for use in the field in determining the charge weight required for the available combinations of chamber volume and total projectile weight (combined weights of piston, fluke, shackle, eye with thimble, and 4 feet of wire rope). Copper ball crush gages were used in the field on the first five shots to check predictions and to provide a basis for modifying predictions in the field if necessary.

Gun performance is detailed in Table 1. As shown, predictions were within 1,500 psi of measured peak pressures. This is considered good, but will be improved slightly in the future by adjusting some of the parameters used to characterize the propellant when making predictions. Measured pressures may be compared with the prediction curves in Figures 6 and 7. The projectile velocities corresponding to these measured pressure data points are improved estimates of the projectile velocities actually occurring.

System maintenance was routine. Timber foot pads required occasional replacement. Sealing surfaces in the gun muzzle and breech required normal cleaning and greasing. S/A devices (two were used, alternately) also required normal maintenance, and performed well. The level indicators in the S/A devices performed well, and proved valuable in preventing misdirected firings on two occasions.

The first system problem that occurred was really not in an integral part of the system itself, but in the connection between the fluke and the main load line. An old-design fluke was used that had an undersize eye, necessitating the use of a smaller shackle. Calculations indicated that the 25-ton screw pin shackle that was used would have sufficient strength, and indeed a nearly identical shackle had been used successfully on the previous anchor. However, the shackle failed during firing, probably because of its weakness at the threaded position of the pin, in combination with a snap loading created when an initial end play in the connection was snapped taut during firing. The end play problem was solved in subsequent shots by rigging pretensioning line from the eye in the fluke end of the anchor load line to a hole in the edge of the upper drag plate on the launcher. Pretensioning the connection with a force of 100 pounds and using higher strength shackles resulted in no connection failures in subsequent shots.

The only other system problem that occurred during anchor installations involved the seal between the S/A device and the cartridge base. A misaligned cartridge tube prevented proper seating of the cartridge base when the breech block was tightened with the normal torque of 20 foot pounds. When the system was lowered into the water, the pressure apparently forced the cartridge base away from the S/A device, breaking the seal and permitting water to enter. The back-pressure created by

Table I. Anchor Gun Performance

working moors

bow pulling moors

Shot No.	Piston a/	Fluke b/	Chamber Volume in^3 (m^3)	Projectile Weight c/ lb (kg)	Charge Weight lb (kg)	Peak Pressure k lb/in^2 (MPa) Predicted	Measured
1	S	TFC	873 (.0143)	1610 (730)	13 (5.9)	26.4 (182)	26.4 (182)
2	E	TFC	676 (.0111)	1560 (707)	12 (5.4)	28.1 (194)	25.9 (172) downhaul broke
3	E	EEC	676 (.0111)	1450 (658)	12½ (5.7)	28.6 (197)	26.9 (185)
4	E	EEC	676 (.0111)	1450 (658)	13¼ (6.0)	31.6 (218)	29.9 (206)
5	E	EEC	676 (.0111)	1450 (658)	13¼ (6.0)	31.6 (218)	29.1 (201)
6	E	ICC	676 (.0111)	1460 (663)	13 (5.9)	30.6 (211)	--
7	S	EEC	873 (.0111)	1500 (680)	14 (6.4)	28.4 (196)	-- misfired relowered

a/ Pistons:

Designation	Description
S	SUPSALV type; retrievable
E	New type; expendable

b/ Flukes:

Designation	Description
TFC	Three-finned coral
ICC	Integral clevis coral
EEC	Elongated eye coral

c/ Includes weights of piston, fluke, shackle, eye with thimble, and 4 feet of wire rope.

piston extraction loads?

which anchors were measured under load?

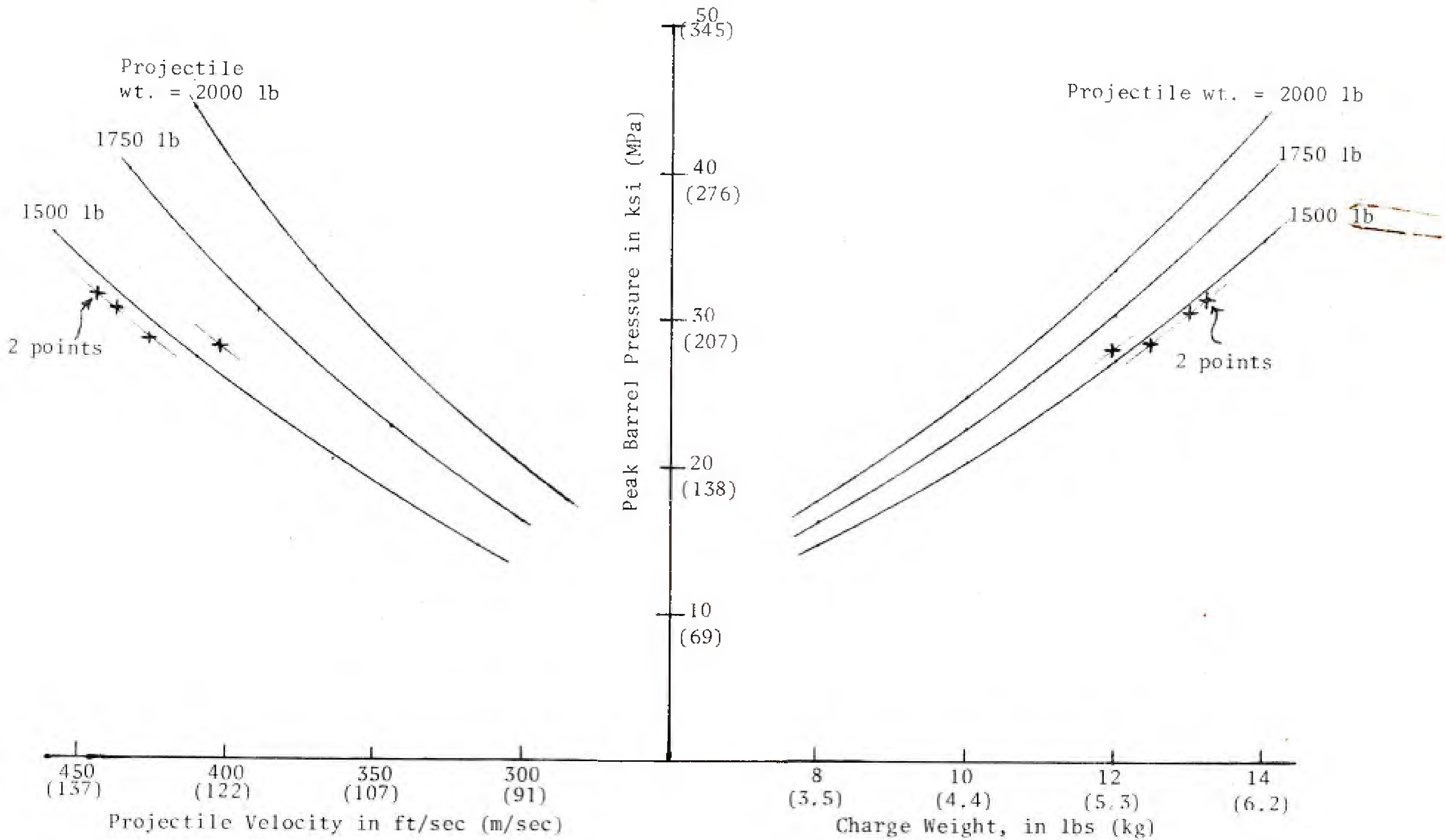


Figure 6. Anchor gun performance predictions for expendable piston

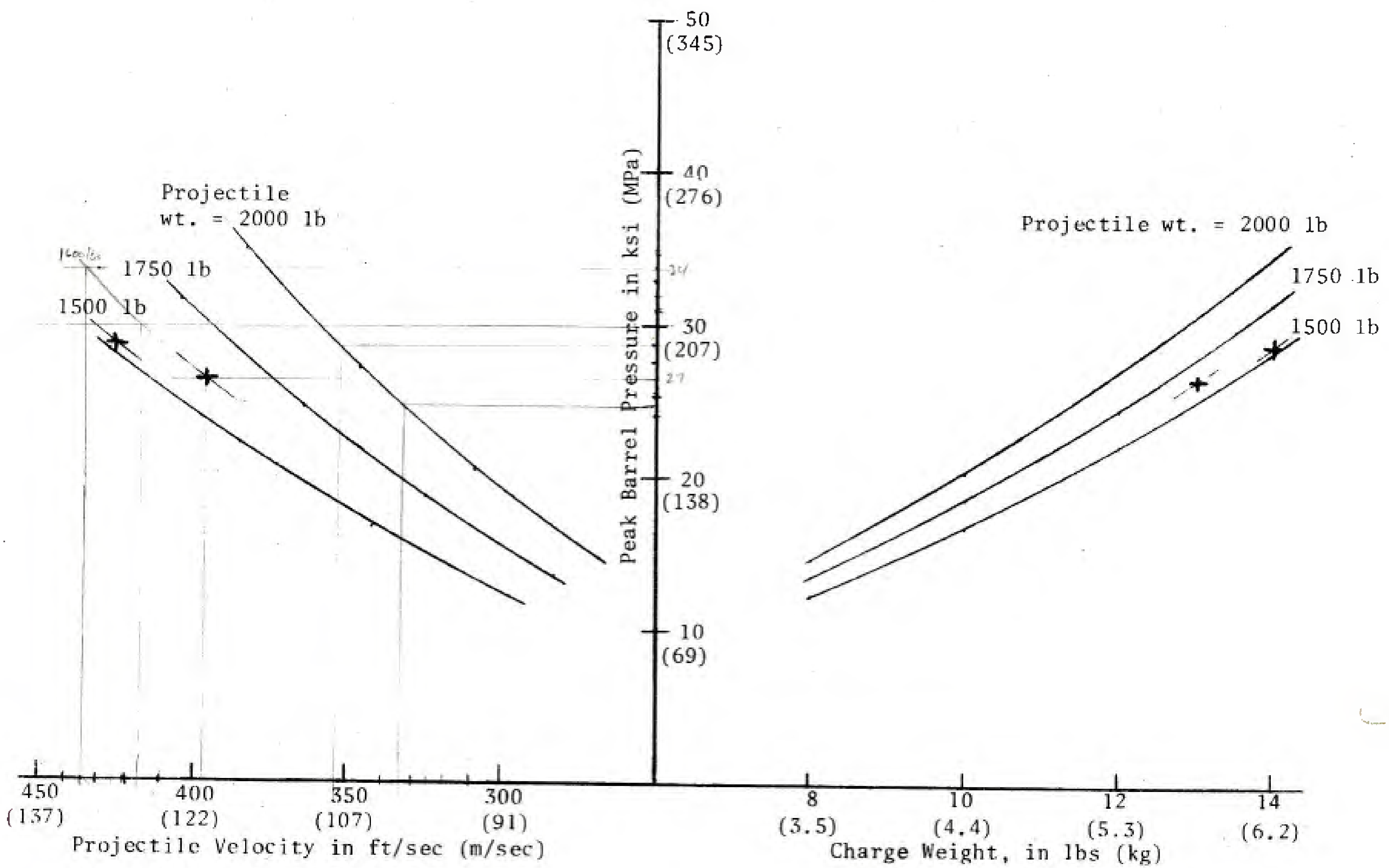


Figure 7. Anchor gun performance predictions for SUPSALV piston

the intruding water apparently allowed the depth-sensing safety plunger in the S/A device to return to an out-of-line position. After the system failed to fire and safety procedures were carried out, the problem was remedied, a higher torque (200 ft-lb) was used in tightening the breech block, the system was redeployed and successfully fired. (A change in cartridge and breech block design is being made to eliminate this problem completely.)

SUSTAINED ANCHOR LOADS

Each of the two anchors installed near the tower, designated as mooring anchors, were used for several days to moor an ARS during diving and rigging operations. The ARS assumed a fore-and-aft moor; the bow was anchored with the embedment anchor and the stern was pulled toward the tower with a heavy wire. Weather conditions were mild, so that loads on the mooring anchors (not measured) probably were substantially less than loads on the pulling anchors.

The four "pulling" anchors were hooked up for pulling as described in a previous section. After initial attempts at toppling the tower were unsuccessful, additional explosives were detonated inside the legs at points near the seafloor, and moderate pulling toppled the tower. It was during the initial attempts, however, that anchor loading was highest. Each pulling anchor was loaded to a mean load of 110,000 pounds, with maximum recorded oscillations of plus or minus 15,000 pounds, over a period of about 30 minutes. The failure of a used towing wire, and later of a section of large synthetic line, further attested to the high loading level (each of these lines was carrying load from an ARS to the tower, and each ARS was anchored with two embedment anchors).

After pulling was completed, an inspection of one of the anchors showed no significant kinking or chafing. Although it is not likely that such a line would survive for a long time in a semi-permanent or permanent installation in which the loading direction was changed frequently, the use of unprotected wire rope is apparently satisfactory for the duration of a typical salvage operation.

FUTURE EMBEDMENT ANCHORING CAPABILITIES

The operation of installing ballistic embedment anchors from the ARS salvage/towing vessel, although demonstrated to be reasonably straightforward, should be improved to reduce the time and effort of pre-cruise ship preparation, system handling, and deployment.

The present system, with its large launcher, could be modified to facilitate handling. The approach that is envisioned involves the use of receiver units mounted on the deck of the ship that would receive and hold trunions attached to the base of the launcher. The receiver/trunion joint would permit the tilting of the launcher without the use of taglines. Based upon the experience gained during the Argus operation, it is doubtful that the benefits would justify the cost, unless many anchor installations from a particular vessel were anticipated.

A new launcher is being constructed (True and Stern, 1976) that will provide greater handling ease and more rapid installation, as well as anchor performance that slightly exceeds that of the present launcher. This new launcher has a touchdown-firing configuration; that is, (a) its reaction mass is largely water contained within a hemispherical tub connected to the gun, (b) it has no base, so it is not suited to placement and waiting prior to firing, and (c) it is fired by the upward motion of its touchdown probe, relative to the gun, when the probe contacts the seafloor during lowering. A cradle mounted on the deployment vessel's deck is used for launcher stowage and system assembly during an operation. The cradle and system may be stowed elsewhere during cruising, requiring a space about 6 feet by 6 feet in plan and 4 feet in height. The single line normally used with the boom crane is quite adequate for system assembly and deployment; flukes and pistons are designed to be installed easily in the system with the aid of a vertical lift and light taglines, and the total system weight is less than 7,000 pounds. Cradle weight is less than 2,000 pounds.

SUMMARY

Ballistic embedment anchors were used effectively to moor vessels during diving and rigging operations and to provide reactions during heavy salvage pulling. Anchor installation was accomplished smoothly, within the capabilities of the ARS assigned as the installation vessel, as a result of careful planning of the handling of the large anchor system. Two difficulties occurred with the system itself, one with an anchor line connection that failed during firing and the other with the firing action within the system; these difficulties pointed up needed improvements that are being made. The use of the reported system in near future salvage-type operations probably would be conducted in a very similar manner. A touchdown-firing launcher will soon be available that is smaller, lighter, and easier and faster in its handling and deployment; this new configuration is more suitable for carrying on salvage vessels for semi-routine use.

CONCLUSIONS

1. The 100K bottom-sitting ballistic embedment anchor system used in the Argus Tower toppling is an effective means of providing large anchors in hard coral in a water depth of 200 feet. It is expected to be equally effective throughout its design depth range of 30 to 500 feet.

2. Anchors can be installed with this system from an ARS salvage vessel, or a vessel having similar or better load handling equipment and deck space. Installation can be done smoothly under conditions up to sea state 3 with careful handling and the proper use of taglines to control pendulation. Timber pads and bumpers are highly desirable for protecting

the vessel's deck and side rail.

3. The shackle connecting the fluke to the main anchor load line must be a new, high-strength, round pin or safety type of adequate size (35-ton safe working load), and must be pretensioned with a force of at least 100 pounds to eliminate end play, in order to ensure that failure will not occur during firing.

4. With the present system, particular care must be taken to ensure that a good seal is obtained between the S/A device and the cartridge base. The breech block must be tightened with a torque of about 200 foot-pounds to ensure proper seating.

5. The level indicator installed as a special modification in the S/A device proved essential in preventing misdirected firings on two occasions. It must be made a regular part of this bottom-sitting anchor system for future use when there is any chance that the installation site will be uneven, as is common when coral and coral heads are encountered.

6. The cost of providing propellant anchors was about $6,000 per shot, excluding the cost of the work vessel and crew. This cost should remain about the same in future similar operations.

7. The 100K system having a touchdown-firing launcher that will soon be available should be considered for incorporation into salvage fleet assets. This new system will be designed to eliminate the problems encountered in the reported operation and will reduce ship preparation and system handling efforts and times considerably.

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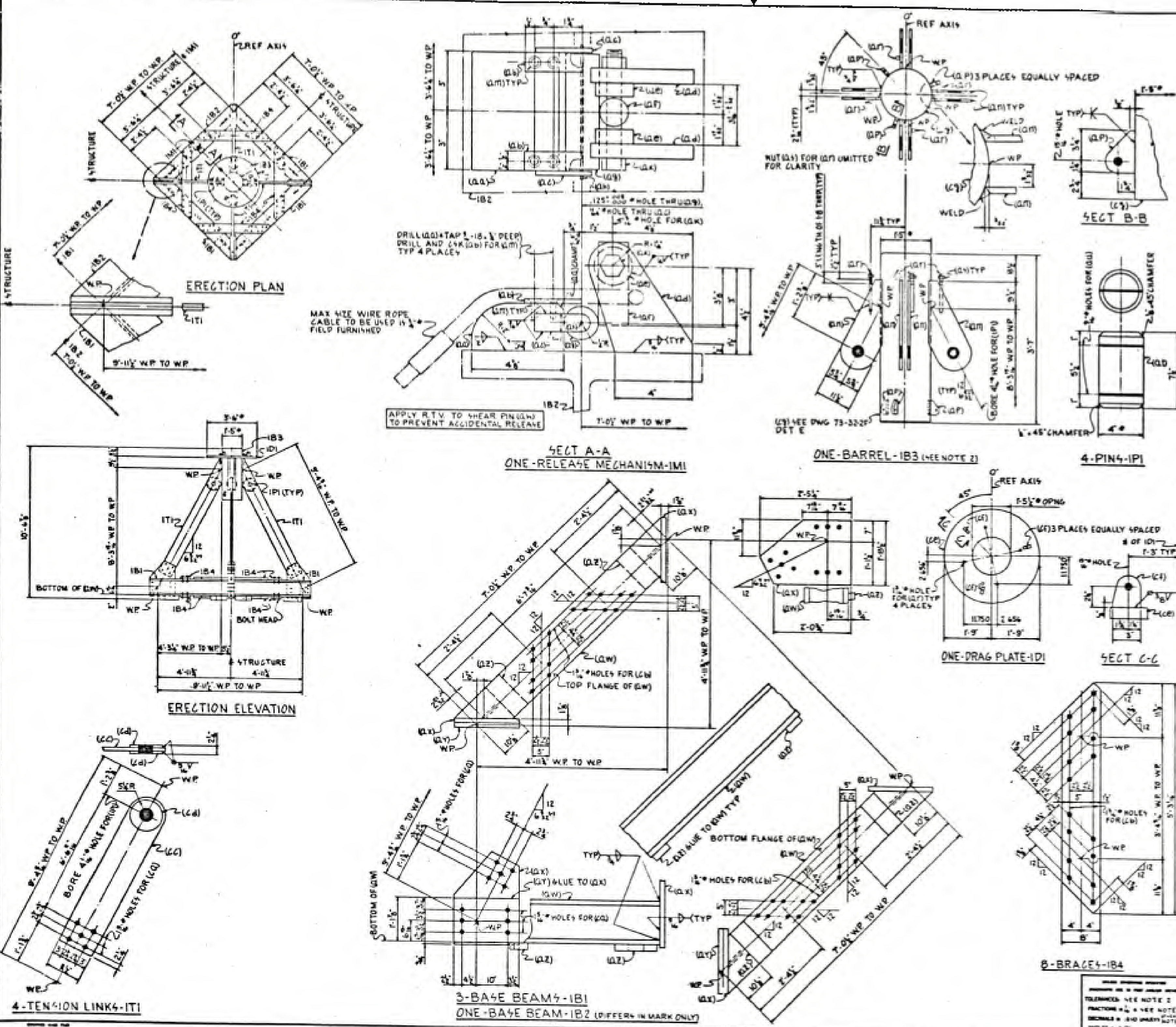
5. Young, C., personal communication, December 1975.

Appendix A

ANCHOR SYSTEM DRAWINGS



NOTES

1. TOLERANCE FOR CENTER TO CENTER OF HOLE SPACING ±1/16". TOLERANCE FOR WORKING POINT TO WORKING POINT ±1/8".
2. FOR BARREL FABRICATION DETAILS OF (G3) SEE DWG 73-32-2F, DET E. TOLERANCES FOR (G3) ONLY ARE AS SHOWN ON 73-32-2F. THE FOLLOWING PIECES (GT)(GP)(GR)(GS) TO BE ADDED AS PER THIS DWG.
3. THE FOLLOWING WELDING RODS ARE TO BE USED:
   E11018 - AISI 4140 TO AISI 4140
   E11018 - ASTM A514 TO ASTM A572 OR A36
   E7018 - ASTM A572 TO ASTM A36
4. THE FOLLOWING PROCEDURE SHALL BE USED IN THE WELDING OF 1B3:
   A. SAND BLAST ALL MATING SURFACES TO WHITE METAL.
   B. PREHEAT (G3)(GR)(GP)(GT) TO 350°F(±25°F) PRIOR TO WELDING AND HOLD THIS TEMPERATURE UNTIL ALL WELDING IS COMPLETED.
   C. AFTER ALL WELDING IS COMPLETED, ALLOW ASSEMBLY TO COOL IN STILL AIR.
   D. STRESS RELIEVE ASSEMBLY. HEAT TO 1200°F(±50°F). HOLD AT 1200°F (±50°F) FOR 4 HOURS. FURNACE COOL AT 50°F/HR TO 700°F. AIR COOL FROM 700°F TO ROOM TEMPERATURE.

MARK	NO. REQD	SIZE	FT	IN	REMARKS
	8	BAR 6 × 1¼	5	3⅛	ASTM A514, GRADE B
					8-BRACES-1B4
GF	3	BAR 3 × 1	0	3½	ASTM A36
GE	ONE	R 1¼ × 42	3	6	ASTM A514, GRADE B
					ONE-DRAG PLATE-1D1
Gd	8	BAR 10½"	0	0½	ASTM A514, GRADE B
GC	4	R 1¼ × 11½	7	8⅛	ASTM A514, GRADE B
					4-TENSION LINKS-1T1
Gb	128	BOLT 1⅛	0	4½	ASTM A490 W/NUT (NO SUBSTITUTES)
GG	44	BOLT 1¼	0	5½	ASTM A490 W/NUT (NO SUBSTITUTES)
GZ	8	BAR 6 × 2	1	0½	PVC TYPE II
GY	4	R 1¼ × 13⅝	1	8½	PVC TYP II
GX	8	R 1¼ × 20½	2	5⅛	ASTM A514, GRADE B
GW	4	W12 × 161	7	7⅛	ASTM A572, GRADE 50
					3-BASE BEAMS-1B1 ONE-BASE BEAM-1B2 (DIFFER MK ONLY)
GU	8	COTTER PIN ½"	0	6	STEEL
GT	4	BAR 4"	0	7½	AISI 4140, LEADED, MINIMUM F_{yield} = 55,000 psi
					4-PINS-1P1
GS	4	1-8 HEX NUT			ASTM A325
GR	4	BAR 1"	1	0	AISI 4140 ANNEALED, SEE NOTE 4, THRD ONE END
GP	3	BAR 3 × 1	0	4½	AISI 4140, ANNEALED, SEE NOTE 4
GT	8	R 1 × 11½	2	4⅝	AISI 4140, ANNEALED, SEE NOTE 4
G3	ONE	17.00" × 43.00" FORGED BILLET AISI 4140, ANNEALED, SEE NOTE 4			
					ONE-BARREL-1B3
GM	4	⅝-18 × ¾ LG SOCKET FLAT HD MACHINE SCREW, STEEL			
GK	ONE	BOLT ¾"	0	5½	ASTM A325 WITH HEX NUT
GH	ONE	ROD ⅛"	0	7	ACRYLIC
Gg	ONE	BAR 1½"	0	1⅝	ASTM A36
Gf	ONE	BAR 1½"	0	4⅝	ASTM A572, GRADE 50
Ge	2	BAR 2"	0	10½	ASTM A36
Gd	2	BAR 5½ × ¼	0	5½	ASTM A36
Gc	2	BAR 1 × ¼	0	3	ASTM A36
Gb	2	BAR 1 × ¼	0	3	ASTM A36, DRILL & CSK FOR (GM)
GA	ONE	BAR 2½ × 4⅝	0	6	ASTM A36, DRILL & TAP FOR (GM)
					ONE-RELEASE MECHANISM-1M1

BILL OF MATERIAL

TOLERANCES: SEE NOTE 1
FRACTIONS ± 1/16 SEE NOTE 1
DECIMALS ± .010 UNLESS OTHERWISE NOTED
ANGLES ± 30'

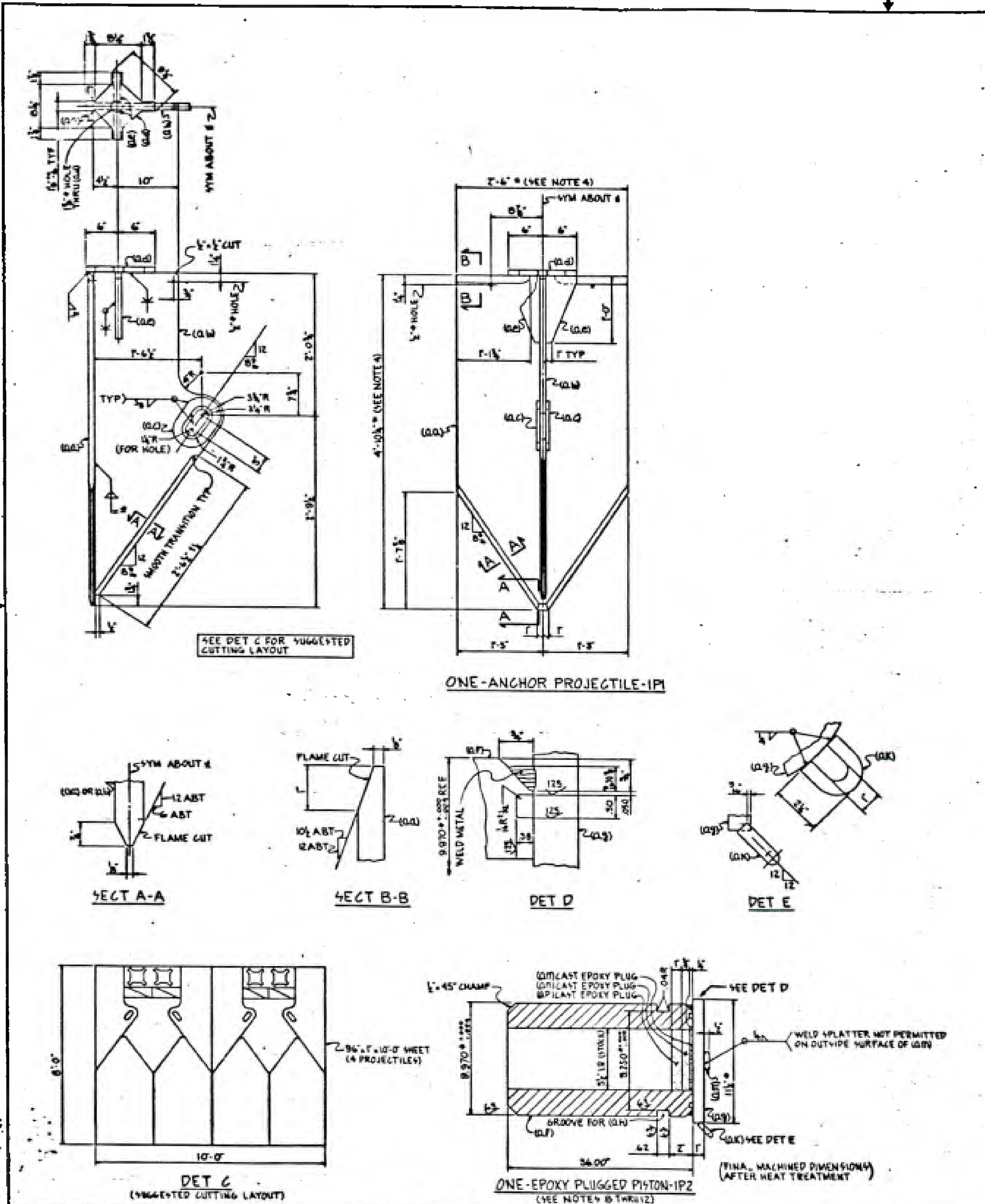
PROJ NO. 54-004
NCEL DWG NO. 73-32-1F

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA

EMBEDMENT ANCHOR
LAUNCH VEHICLE
ERECTION PLAN & DETAILS

SIZE F | CODE IDENT NO 80081 | SCALE NONE | SHEET 1 OF 1

271-18 REV1



NOTES

FOR 1P1

1. ALL STRUCTURAL STEEL SHALL CONFORM TO ASTM SPEC A514, GRADE B, H OR F, OF MOST RECENT ISSUE UNLESS OTHERWISE NOTED.
2. WELDING ROD USED SHALL BE AWS A5.5 E110-18M.
3. WELDING SHALL BE DONE ACCORDING TO SPECIFIED PROCEDURES WITH THE FOLLOWING MAXIMUM HEAT INPUTS:

STEEL TYPE	ASTM DESIGNATION	MAX HEAT INPUT (JOULES/INCH) FOR FILLET WELDS	OTHER WELDS
T-1	A514 GRADE F	216,000	175,000
T-1 TYPE A OR B	A514 GRADE B OR H	138,000	110,300

NOTE: IF TWO DIFFERENT TYPES ARE WELDED TOGETHER LOWER VALUES ARE TO BE USED.

4. TOLERANCE FOR DIMENSIONS WITH AN ASTERISK (*) ±¼" TO ALLOW FOR CUTTING (SEE DET C).

FOR APPURTENANCES

5. CHARGE WEIGHTS TO BE USED WITH THIS PISTON AND FLUKE:

CARTRIDGE TUBE THICKNESS (INCHES)	WEIGHT (POUNDS) OF .058 M6 (5-38)		
[illegible]	15.0		
[illegible]	14.8		
[illegible]	14.6		
[illegible]	14.4		

6. CONNECTOR IS ROUND PIN CHAIN SHACKLE, 35 TON SAFE WORKING LOAD, HIGH STRENGTH TYPE (BREAKING LOAD AT LEAST SIX TIMES SAFE WORKING LOAD). WASHER, 2⅛" I.D., 4½" O.D. × ¾" THICK IS FIELD WELDED TO PIN AFTER CONNECTION IS ASSEMBLED.
7. ANCHOR LOAD LINE TYPICALLY IS 1⅝, 6×36 GALVANIZED IMPROVED PLOW STEEL WIRE ROPE WITH FIBER CORE. OTHER, STRONGER AND/OR MORE RUGGED LINES MAY BE USED FOR LONG-TERM SERVICE. POURED SOCKETS SHOULD BE MADE UP WITH TIN RATHER THAN ZINC.

FOR 1P2

8. HEAT TREAT PISTON BARREL (PART (af)) BEFORE FINAL MACHINING AND WELDING TO APPROXIMATELY 340 BRINELL (OR ROCKWELL C30-38) HARDNESS.
9. USE E8018-M (LOW HYDROGEN) WELDING RODS.
10. PREHEAT TUBING (af) TO 350°F ±25°F BEFORE WELDING.
11. USE WELD PROCEDURES ON C.E.L. DWG. SK1275 WITH MAX. HEAT INPUT OF 90,000 JOULES/INCH.
12. EPOXY PLUG TO BE CAST IN THREE LAYERS, ⅓" RIGID, ⅓" RIGID, 1" FLEXIBLE — BEFORE PRESERVATIVE OIL IS APPLIED.

BILL OF MATERIAL

MARK	NO. REQ'D	SIZE	LENGTH FT	LENGTH IN	REMARKS
a.p		EPOXY, QUANTITY AS REQUIRED (FLEXIBLE)			
a.n		EPOXY, QUANTITY AS REQUIRED (RIGID)			
a.m	ONE	TUBE 1½ OD	0	0½	1" I.D., AISI 1015 OR 1018, COLD DRAWN SEAMLESS
a.k	ONE	WELDLESS END LINK ⅝" STOCK, CUT AS SHOWN, SEE DET E			
a.h	ONE	O-RING, 10" OD, ⅜ I.D. ½ HIGH, PARKER 8012-0925, BUNA N			
a.g	ONE	℞ 1 × 11½	0	1½	ASTM A514 GRADE B, H OR F
a.f	ONE	TUBE 10" OD	3	0¼	ORDERED LG. BILLET
		ONE-EPOXY PLUGGED PISTON-1P2 (SEE NOTES 8 THRU 12)			
a.e	2	BAR 5½ × 1	1	0	
a.d	ONE	℞ 1 × 9⅛	0	9⅛	
a.c	2	BAR 6½ × ⅝	0	9½	
a.b	ONE	℞ 1 × 22¼	4	8½	
a.a	ONE	℞ 1 × 30	4	10¼	
		ONE-ANCHOR PROJECTILE-1P1 (SEE NOTES 1 THRU 4)			

EXPERIMENTAL MODEL DWG.

TOLERANCES: FRACTIONS ± 1/16 (SEE NOTE 4); DECIMALS ± .XX ±.02, .XXX ±.005; ANGLES ± —

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA

P.O.L. TANKER MOORING SYSTEM
PROPELLANT EMBEDMENT ANCHOR
ANCHOR PROJECTILE

MODEL DWG NO 76-1-1F

SIZE F — CODE IDENT NO 80091 — SCALE NONE — SHEET 1 OF 1

Appendix B

DEPLOYMENT INSTRUCTIONS

This appendix contains instructions for the deployment of the CEL/SUPSALV 100K Propellant Anchor, together with relevant figures, and an anchor preparation checkoff list. Most of these procedures should continue to be applicable in future usage of the system. The recent provision of a releasing feature on the tie rods that secure the anchor fluke has eliminated the need for unscrewing the safe-and-arm device in case of misfire; simplified procedures incorporating this new feature will be provided when needed.

Deployment of CEL/SUPSALV 100K Propellant Anchor

1. A marker buoy normally is set for reference in locating the exact desired point of embedment. The effects of currents and winds (different for the buoy and the anchor) should be accounted for.

2. The anchor launch vehicle is tilted to a near-horizontal position and laid on its side on the deck of the installation vessel. This is most easily accomplished with two lines. One, attached to the side of the launch vehicle base, may be of a fixed length. This length is adjusted to put the end of the line about six feet above deck so that the launch vehicle will be tilted past its balance point before contacting the deck when the other line, attached to the main lowering padeye located atop the launch vehicle, is lowered. As an alternative, a fixed length line may be connected from the boom to the lifting eye on the anchor, and the boom's powered hook may be used to lift the side of the launch vehicle base as the boom is slowly lowered to permit the launcher to tilt without ever raising it more than a few inches off of the workboat deck (Figure 1).

3. Seals are placed on a clean piston and lubricated. The piston is positioned at the gun muzzle with a crane, and is slid into the gun barrel as the crane line is lowered slowly about 6 inches. A tagline should be attached to the piston end to restrain the piston from going too rapidly into the barrel, so that the seals can pass into the barrel without damage (Figure 2).

4. A vacuum is applied to the gun barrel through a special breech adaptor (made from a modified cartridge base) in order to check the piston seals. The seals should hold a vacuum without change for at least 15 minutes.

5. A clean fluke is positioned ahead of the bottom end of the piston with its eye directed to one side, by using a crane. The three tie rods are positioned over the shear pin holes in the fluke, and shear pins are inserted, with the aid of a hammer. The tie rod nuts are tightened using a moderate torque (about 30 ft.-lbs.). Then, the crane line can be released. Placement of the fluke should be initiated as soon as it appears from the vacuum check that the piston seals are functioning properly.

6. An anchor load cable is flaked around the two corner timbers on the side toward the fluke eye, making a vertical figure - eight. The following lengths of cable should be used, depending upon anticipated fluke penetration during firing:

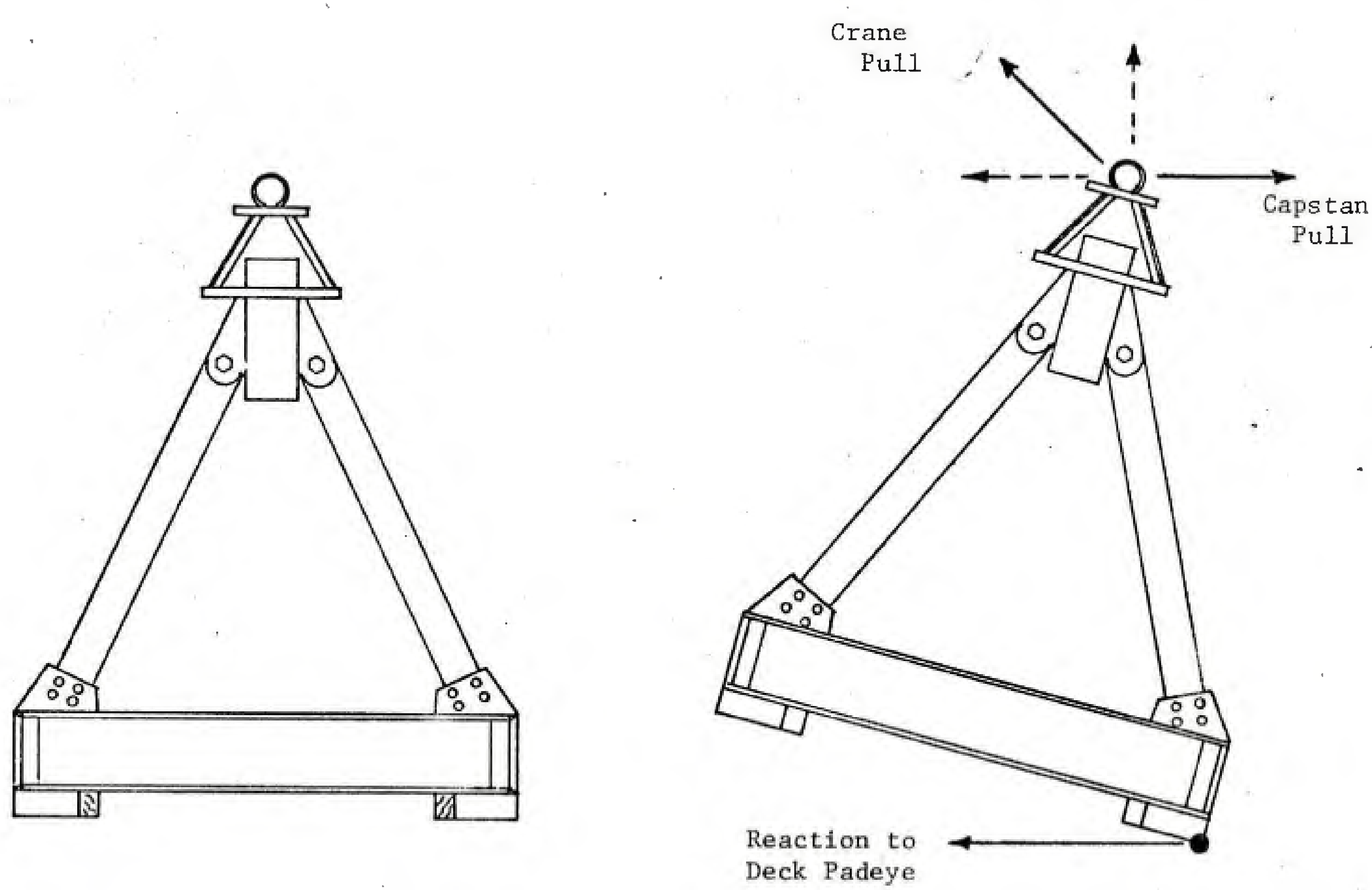


Figure I. Tilting Launch Vehicle.

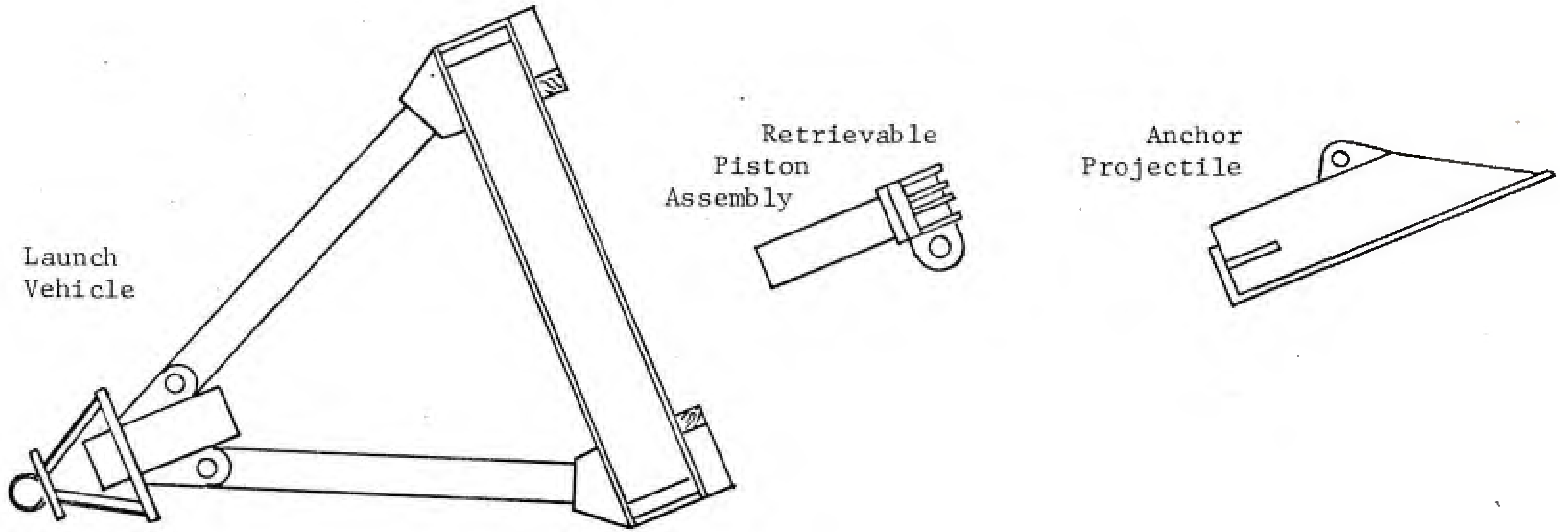


Figure 2. Loading Piston and Projectile.

Anticipated Penetration to Tip (ft.)	Cable Length (ft.)	No. Loops Flaked
0 - 12	19	1
12 - 24	31	2
24 - 36	43	3
36 - 48	55	4

These lengths are subject to field modification, plus or minus a few feet, depending on cable stiffness. Flaking is begun by attaching the cable, at the required distance from the end, to the underside of the launch vehicle in the center of the base beam adjacent to the fluke eye, with the end to be connected to the fluke directed inward. The required loops are secured, one by one, using 1/4 to 3/8-inch-diameter manila rope passed around the topside of the base beams. The end of the cable is then passed through the center of the launch vehicle base, up toward the gun barrel, and then back down to connect to the fluke eye. The initial attachment of the cable at the measured point should be reinforced by forming a choke stopper around the cable with a section of 3/4 to 1-inch rope about 10 feet long and securing the free end of the rope in the inertial release mechanism located atop the base beam used for flaking. This stopper should be strong enough to withstand the tension applied to the anchor load line during deployment for the purpose of orienting the anchor in a desired direction (Figure 3).

7. The anchor load cable is connected to the fluke eye by a shackle and/or pin (different versions may be provided). The preferred method of completion is the welding of a washer to the end of the large fluke pin and/or the shackle pin, with no welding between the pin and its hole; this ensures that welds will not be loaded directly by firing or anchoring forces, thus maximizing the reliability and longevity of the connection.

8. The assembled anchor system is set upright by reversing the tilting procedure; that is, the main lifting eye is raised, causing the line connected to the base beam to come taut when the launch vehicle angle is approximately 30 degrees above the horizontal before the balance point has been reached; then the main eye is further raised until the launch vehicle is vertical; the base beam line becomes slack and is disconnected, and the launch vehicle is lowered to stand upright on deck.

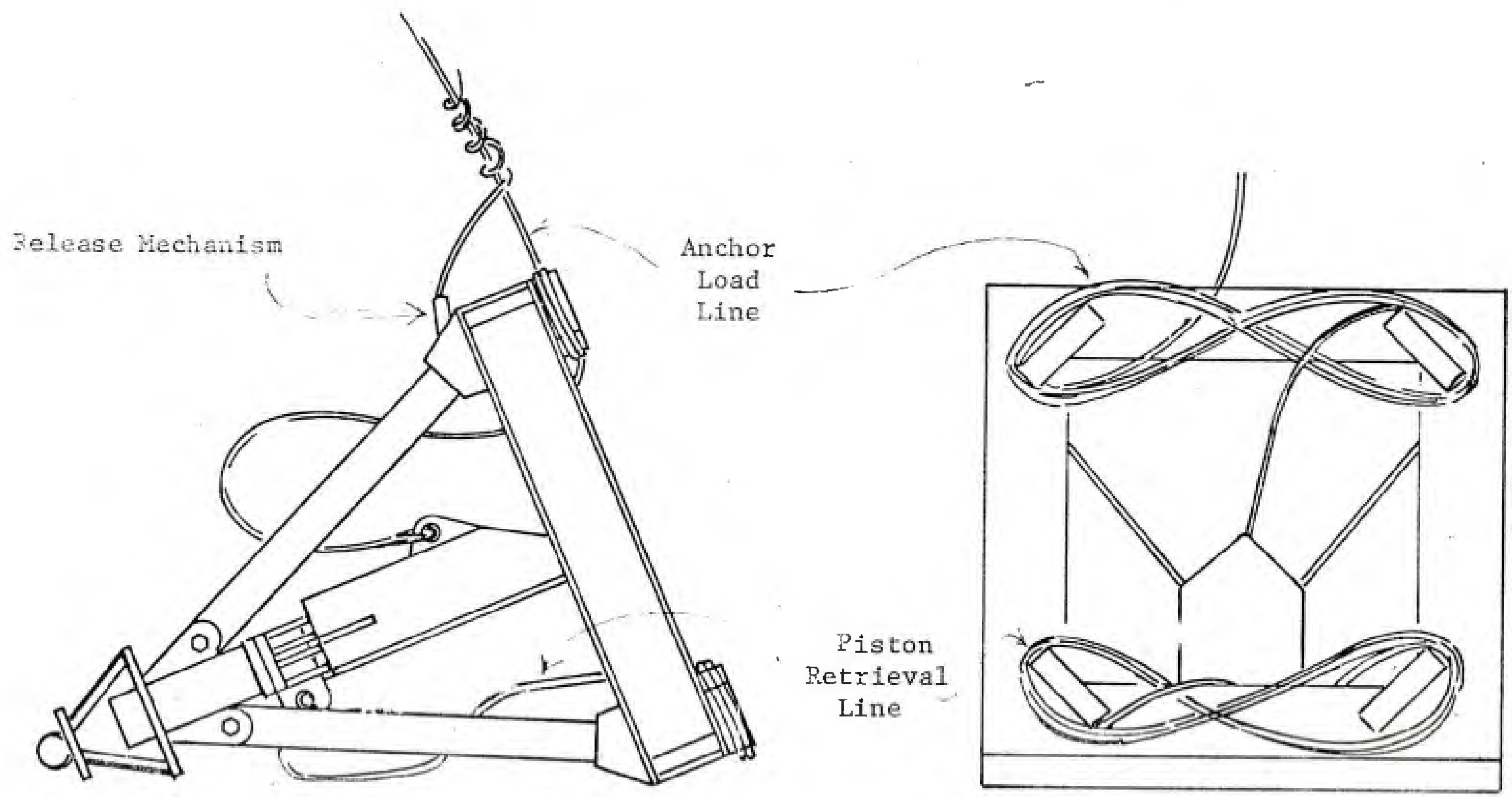


Figure 3. Securing Wire Rope.

9. A step ladder is lashed to the launch vehicle. The vacuum test fitting is removed from the breech, and sealing surfaces are checked and greased.

10. The immediate area is cleared and a no-smoking condition is imposed. The propellant cartridge is carried to the anchor and handed up the step ladder to the loader, who places it into the breech. The breech block is then screwed into place. Finally, the S/A device is screwed into place. The loader should make a final check of the S/A device's hydrostatic lock for smoothness of operation and of its electrical circuits for continuity. The electrical firing cable is attached, and the entire circuit is checked at the boatward end of the cable for continuity (Figure 4).

11. A safety line (1/4 to 3/8-inch-diameter rope) is attached to the S/A so as to unscrew it two turns when tensioned, to be used in case of misfire; this line is lashed to one of the lifting eye supports with a slipknot; its length is adjusted so a grappling loop at its end dangles a few feet below the slipknot.

12. The anchor may be placed in its desired location, with the load line extending in its intended direction , either from a stationary mooring or during a slow pass over the installation point. In either case, a reference buoy is desirable. If the seafloor is hard and uneven such that there is a chance that the anchor will not come to rest vertically on the first lowering, then the stationary mooring method is preferred, as the anchor should be retrieved and checked before firing if it has been dragged on its side during a slow pass approach (Figure 5).

13. The anchor is lifted and lowered into the water after position is established (in the slow pass approach "position" is that suitable for beginning the pass). For slow-pass deployment, the anchor should be held far enough off of the seafloor to preclude snagging prior to reaching the installation point; this height will depend upon topography along the approach path. When it has been verified that the anchor location and orientation are those desired, the anchor is lowered to the seafloor.

14. The electrical circuit is checked for continuity. The level indicators are checked to verify that the system is standing upright. If these checks are positive, the anchor is fired by energizing the firing circuit with a battery on the work boat deck. A tilted anchor requires lifting and a second placement on the seafloor, at a short distance from the first attempt, if convenient. If the anchor has been dragged when tilted, it should be raised to check for readiness of lines, etc. If an electrical discontinuity is indicated, the anchor should be retrieved and the problem resolved (Figure 6).

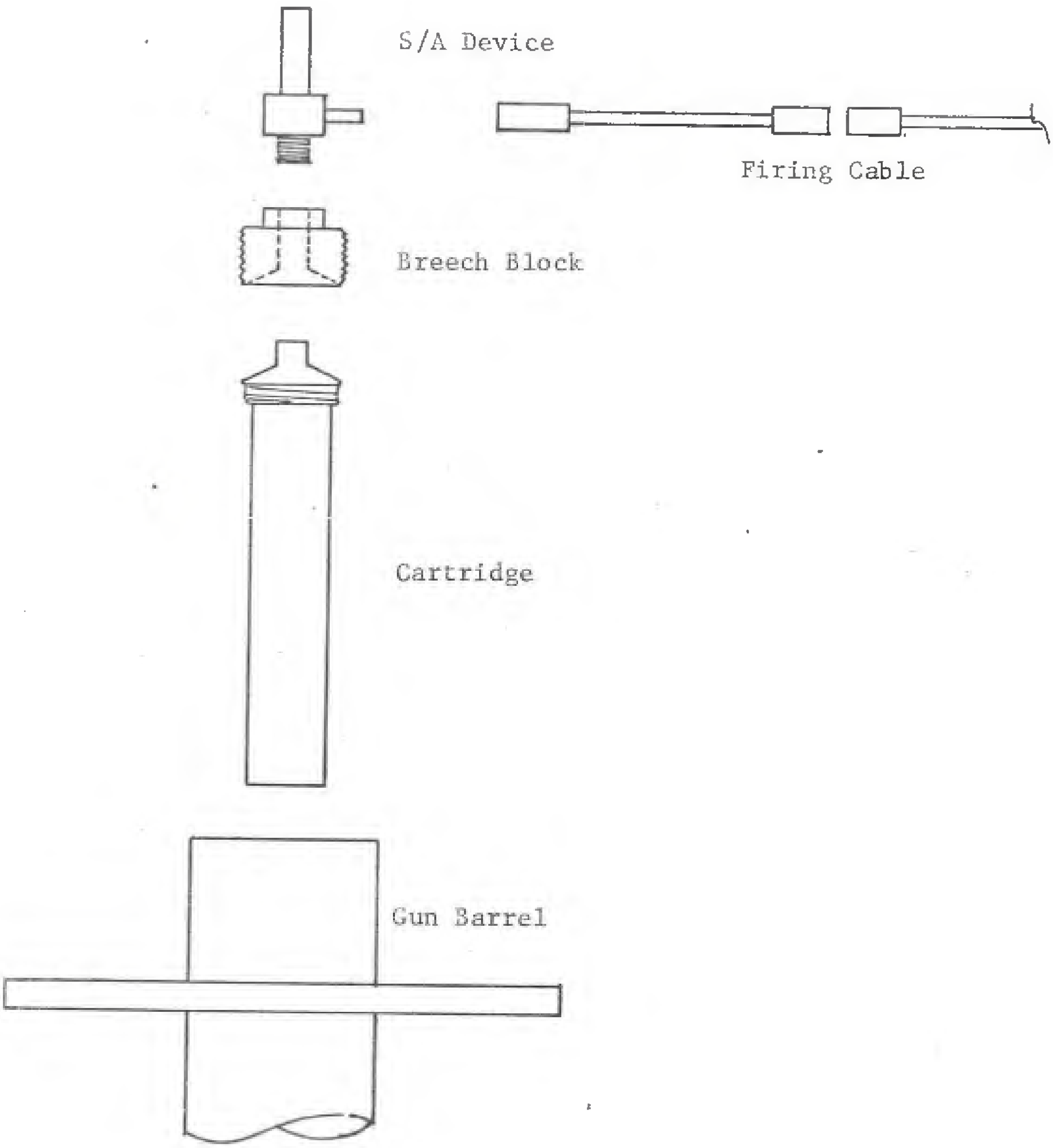


Figure 4. Loading Ordnance.

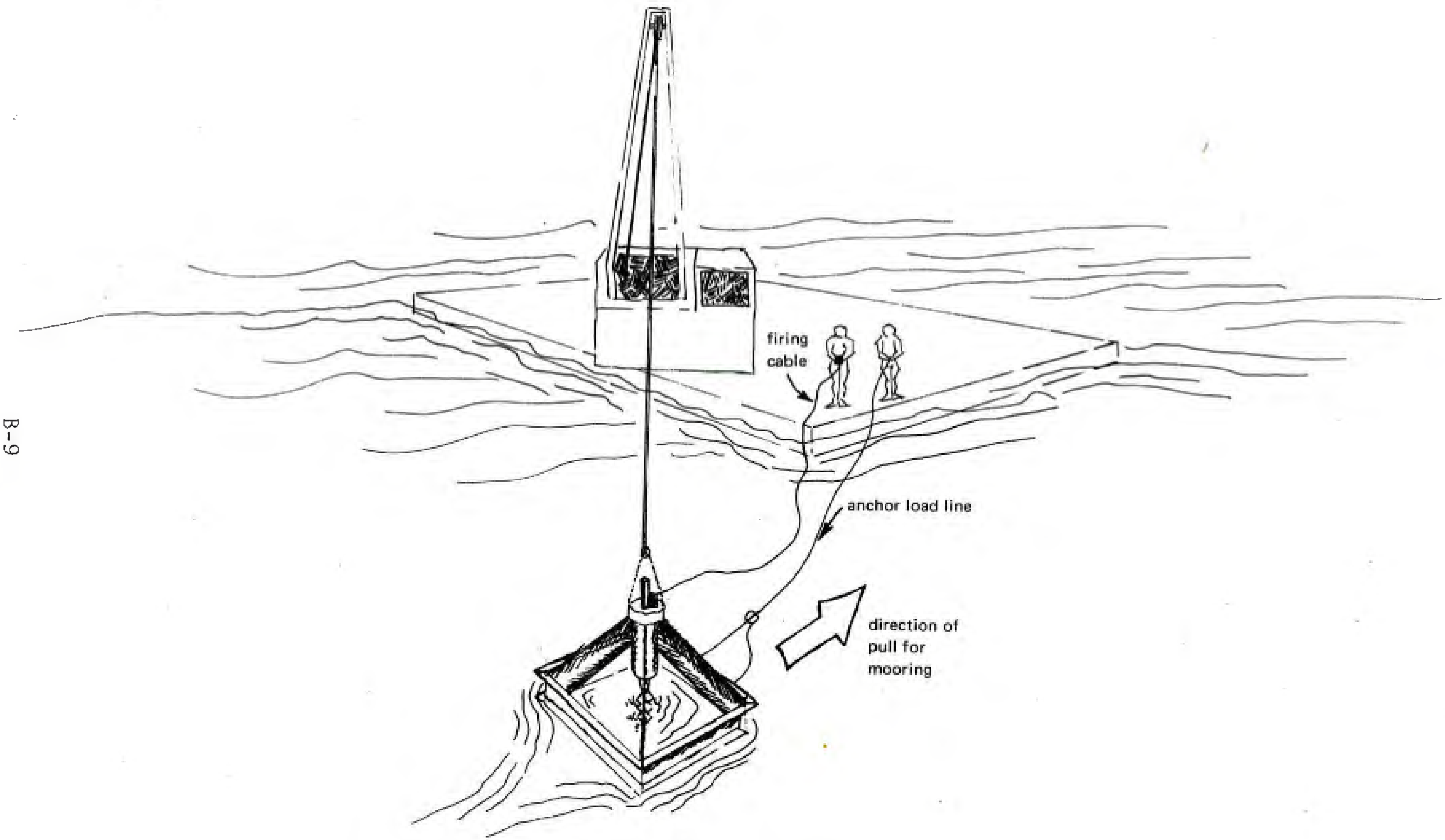


Figure 5. Deploying anchor system.

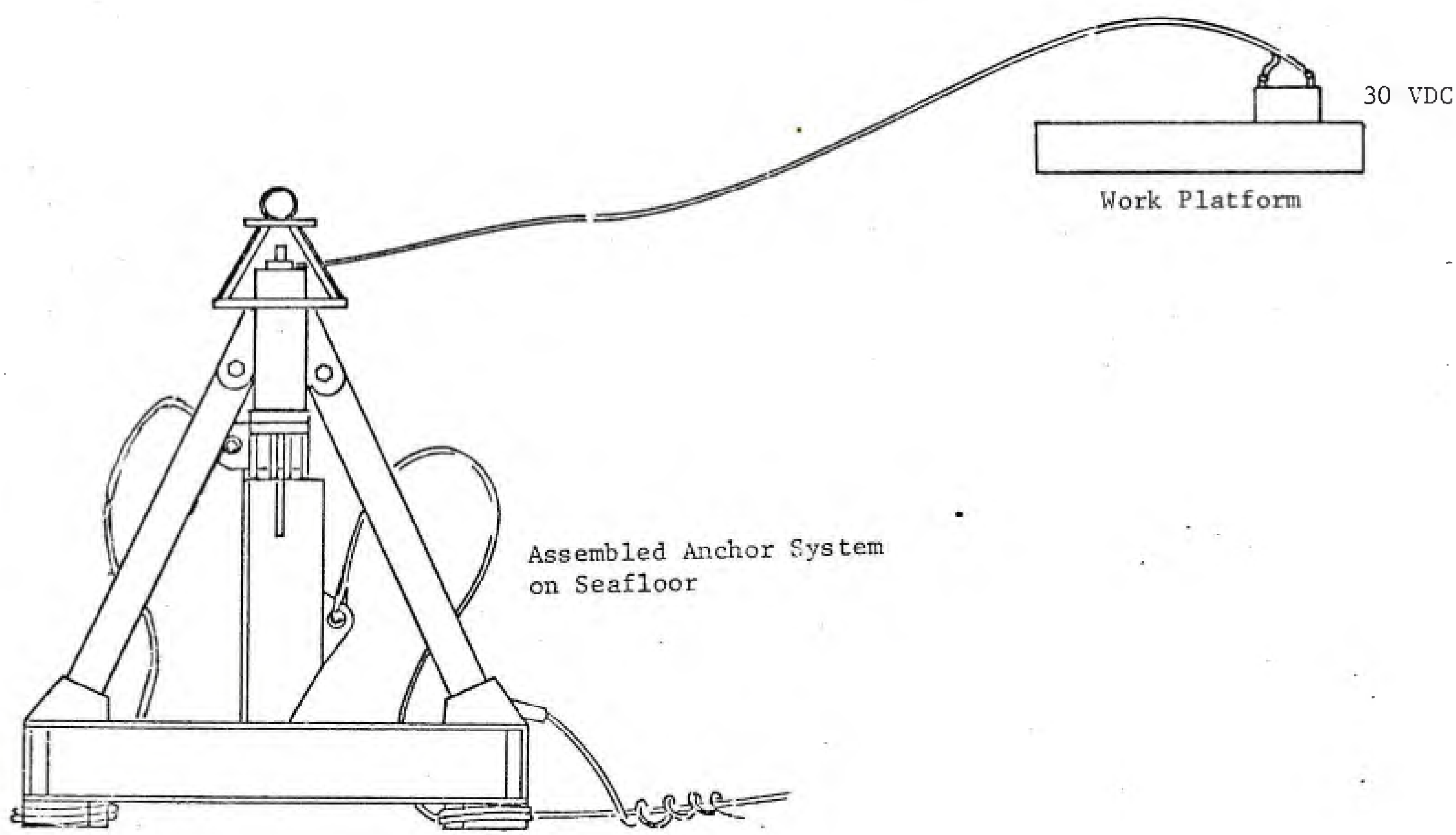


Figure 6. Hookup for Firing.

15. Upon firing, a shock will be heard aboard the work boat, and a large bubbly cloud will appear on the sea surface soon after. The launch vehicle should be retrieved without delay. The anchor load line may be loaded to set and, if desired, to proof test the anchor. The launch vehicle is recovered and laid on its side on deck for reuse (Figure 7).

16. If the anchor does not fire, emergency disarming procedures will be begun. These procedures are outlined in detail in an annex. Briefly, they involve the following steps:

    a. A 30-minute waiting period is imposed.

    b. After 30 minutes have elapsed, the anchor is raised to within 5 feet of the sea surface for inspection of the S/A device. If the hydrostatic plunger is in its out position, the anchor is safe and is retrieved for removal of the S/A for trouble-shooting.

    c. If the plunger is in-line, the firing pin must be assumed to have moved. The S/A is unscrewed two turns and the anchor is returned to the seafloor. A safety line should be pre-rigged to unscrew the S/A when pulled. Alternatively, EOD divers may be needed to unscrew the S/A.

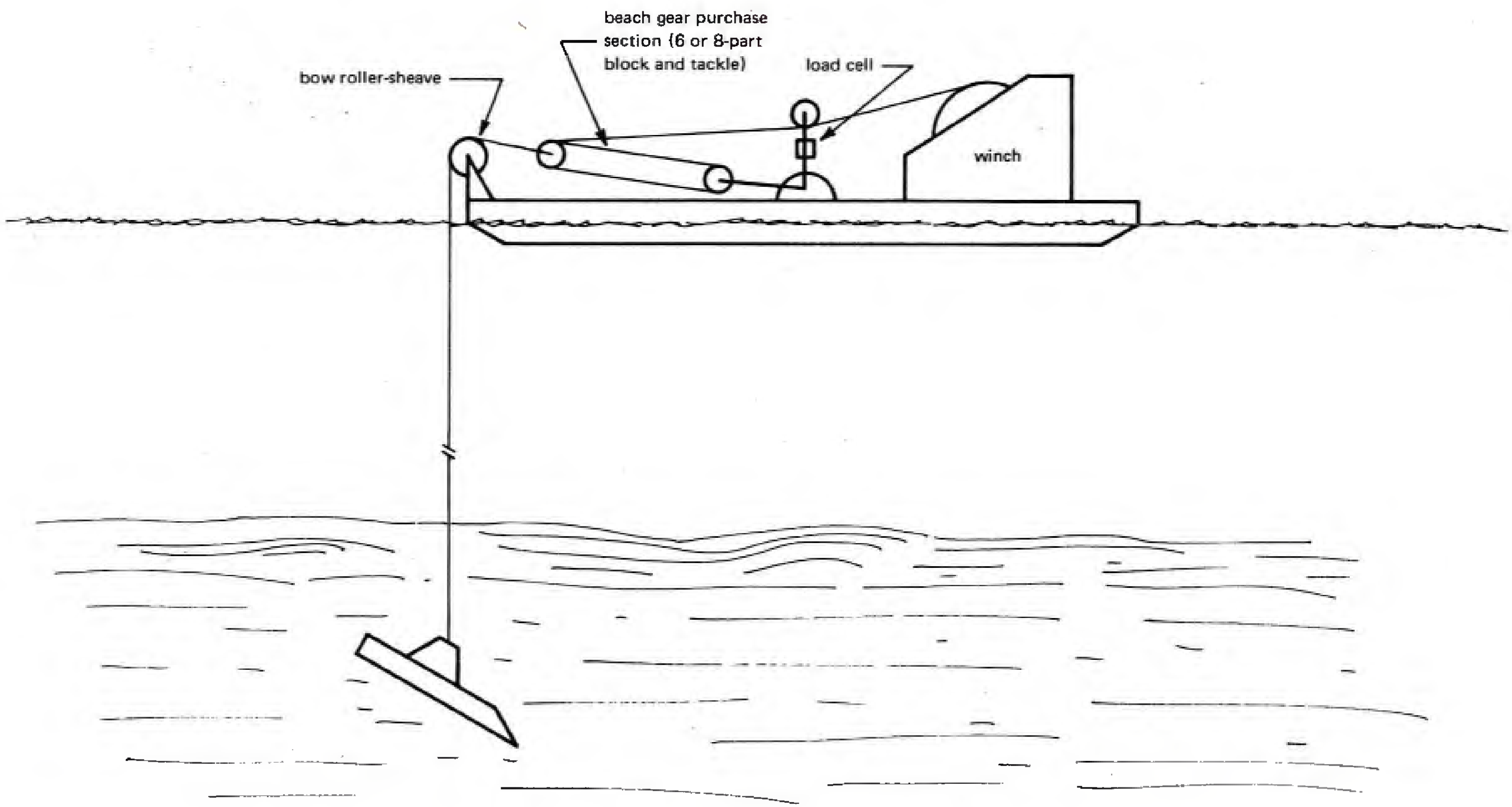


Figure 7. Applying large vertical loads for piston retrieval and proof-testing propellant-embedment anchors.

Deployment of CEL/SUPSALV 100K Propellant Anchor

ANNEX: EMERGENCY DISARMING IN CASE OF MISFIRE

1. General Precautions. In the event of an ordnance system malfunction, observe the following disarming and recovery procedures:

1.1 Check continuity of the firing circuit. If continuity is satisfactory, activate the firing control.

1.2 If the anchor does not fire after the second attempt, proceed as follows:

WARNING

Under no circumstances is the anchor to be removed from the water until the propulsion system is rendered safe.

1.3 Without explosive ordnance disposal (EOD) personnel aboard, the person in charge must verify the safe status.

1.4 When EOD divers are available they are responsible for determining the safe status of the anchor.

1.5 Misfired ordnance should not be returned to the magazine.

1.6 Misfired ordnance is the responsibility of EOD personnel when they are on board.

1.7 Misfired ordnance shall be dumped overboard only in an emergency and, if possible, at a water depth greater than 300 feet.

1.8 After it is determined that the anchor has failed to fire, leave it on the seafloor for 30 minutes.

2. Disarming the Anchor. After 30 minutes, bring the anchor to the water surface for a visual inspection.

2.1 Arming Plunger In-Line; Safety Line Used

2.1.1 If the in-line/out-of-line device is in-line and the safety line is intact, lower the anchor to 15 feet.

2.1.2 With the anchor at 15 feet, pull the safety line, verifying proper unscrewing visually if possible.

2.1.3 If necessary, raise anchor to water surface to verify unscrewing.

2.1.4 Lower anchor to 100 feet, or in shallower water raise and lower repeatedly so that the total distance lowered is at least 100 feet, pausing each time for several minutes to allow water to enter the chamber through the samll passageways around the S/A.

2.1.5 The anchor will now be in a disarmed state.

2.1.6 EOD divers are responsible for the disposition of the used ordnance.

2.2 Arming Plunger In-Line; Safety Line Not Used or Inoperative

2.2.1 If the in-line/out-of-line device is in-line, lower the anchor to 15 feet.

2.2.2 With the anchor at 15 feet, notify the cognizant area EOD diving team that they are required to disarm the anchor.

2.2.3 Underwater disarming will proceed in the following manner if sea conditions permit:

(a) Lower a weighted line 20 to 30 feet away from the anchor line, preferably down current from the anchor line, to the depth of the anchor.

(b) The EOD divers will swim down the line, approach the anchor from the side and inspect it.

(c) EOD divers will remove the S/A from the anchor and return it to the surface for inspection.

2.2.4 The anchor will now be in a disarmed state.

2.2.5 EOD divers are responsible for the disposition of the used ordnance.

2.3 Arming Plunger Out-of-Line

2.3.1 If the device can be seen and it is out-of-line, personnel designated by the person in charge will replace the safety pin in the in-line/out-of-line device.

2.3.2 Disconnect the electrical lead to the S&A.

2.3.3 The anchor will now be in a disarmed state.

2.3.4 Bring the anchor on board and disassemble the remaining ordnance.

ANCHOR PREPARATION CHECKOFF LIST

	Checkoff for Each Deployment
A. Anchor Assembly	
1. Tilt launcher to lay on its side	
2. Check timber pads and retainer plate safety lines	
3. Place seal on cleaned piston	
4. Grease seal/insert piston into gun barrel	
5. Conduct vacuum check	
6. Lift cleaned fluke into position	
7. Insert shear pins & tighten tie rods	
8. Install tie rod retainer line	
9. Flake & secure anchor load line	
10. Secure line to release mechanism	
11. Secure line end to fluke (weld)	
12. Draw anchor line eye toward launcher top drag plate with light line	
13. Set assembled system upright	
14. Check shackle and anchor line eye for alignment and taughtness	
B. S/A Assembly	
1. Charge cannister/valve assy. to 1100 psi	
2. Measure zero shrinkage when disconnecting	
3. Check for leaks in solvent	
4. Clear firing pin & plunger passages	
5. Clean & grease plunger with seal	
6. Install plunger & keeper pin	
7. Clean & grease firing pin & seals	
8. Install firing pin & work with plunger	
9. Install shear disk w/o-ring	
10. Install & snug down shear disk nut/seal	
11. Install cannister/valve assy. & connect	
12. Clean & grease cover seals & surfaces	

ANCHOR PREPARATION CHECKOFF LIST

B. S/A Assembly (continued) — Checkoff for each Deployment

13. Install cover--notice piston effect ______
14. Clean & check base o-ring & threads ______
15. Check for electrical continuity & leaks ______

C. Cartridge Assembly

1. Epoxy tube to cartridge base ______
1a. (Optional) Install peak pressure recorder ______
2. Clean & grease grooves & install seals ______
3. Install primer and cap protector ______
4. Install propellant & wadding ______

D. Loading

1. Lash step ladder to assembled system ______
2. Check tie rod adjustments ______
3. Remove vacuum check fitting & check breech ______
4. Obtain permission to load (area clear and smoking prohibited) ______
5. Bring cartridge to gun barrel ______
6. Check & grease seals & surfaces ______
7. Install cartridge & remove protector ______
8. Install & snug down breech block ______
9. Check & grease S/A seal ______
10. Screw in S/A ______

E. Electrical Hookup

1. Clean & grease cable & attach to S/A ______
2. Check circuit for continuity & leaks ______
3. Secure loose cable to prevent damage ______

F. Final Safety Precautions

1. Install Emergency unscrewing line ______
2. Check S/A plunger--out and free ______
3. Check firing circuit continuity ______

G. Deployment

1. Mark anchor load line for penetration ____ | ____
2. Check firing circuit periodically ____ | ____
3. Watch lines to prevent tangles, etc. ____ | ____
4. Man electrical cable and tape to lowering line ____ | ____
5. Control load line to orient anchor ____ | ____

H. Firing

1. Check circuitry upon bottom contact ____ | ____
2. Fire by energizing circuit w/24-30 vdc ____ | ____
3. Retrieve launcher ____ | ____
4. Use load line as desired ____ | ____

I. Emergency Disarming

1. If no fire, wait 30 minutes ____ | ____
2. Raise system to ~5 ft to inspect plunger ____ | ____
3. If plunger is out, return to deck and troubleshoot S/A ____ | ____
4. If plunger is in, pull line to unscrew S/A two turns, lower to bottom hard, and repeat several times; divers remove cartridge. ____ | ____

Appendix C

PROPELLANT ANCHOR INSTALLATION LOG
ARGUS ISLAND TOWER TOPPLING
APRIL - MAY 1976

Shot 1: 29 April, 1400

Loading: 13 lb propellant, three-finned arrowhead fluke, SUPSALV piston.

Performance: Peak pressure was 26.4 Ksi. Deployment in the sea-state 3 condition required careful handling with several tag lines, but went well. Launcher sat level on seafloor and was fired. Embedment was apparently satisfactory. One timber foot pad was lost; two are being replaced for the next shot.

Proof Load: 170 K lb @ 60 to 70 degrees above the horizontal by surge motion of the ship while the anchor line was connected to beach gear tackle (measured with tenisometer).

Shot 2: 30 April, 0925

Loading: 12 lb propellant, three-finned arrowhead fluke, new-type expendable piston.

Performance: Peak pressure was 25.9 Ksi. Deployment was especially easy in the calm sea (sea-state 1). The launcher came to rest on its side initially, was raised 10 feet and lowered to set upright, and was fired. One timber foot pad and its retainer plate were lost--stronger safety lines will be used in subsequent shots, with more line slack to permit some plate movement without line breakage and loss of the plate. The shackle that connects the fluke to the anchor line failed in its pin; hence the fluke and piston were lost, whereas the line was retrieved and reused. Possible causes, in order of descending probability, are:

(a) faulty shackle;

(b) the 25-ton-rated shackle, screw pin type, with a probable safety factor of 5 on breakage, failed at 250,000 lbs, or possibly less because of shock loading of the pin at the notch created by the threads on one end of the pin;

(c) the anchor load line wire rope, with some twist, left about one-half inch end play at the shackle, causing impact (shock) loading during firing when the line fitting came taut;

(d) a failure of the epoxy seal plug in the expendable piston caused piston failure, leading to shackle failure.

It was decided to use higher-strength shackles exclusively in subsequent shots, and to ensure that no slack would be left in the fluke line connection by using additional tightening of the lashing line between the connection and the top drag plate on the launcher and by driving a wooden wedge into the space between the shackle and the fluke eye.

Proof Load: None

Shot 3: 30 April, 1355

Loading: 12½ lb propellant, new elongated-eye coral fluke, expendable piston.

Performance: Peak pressure was 26.9 Ksi. Deployment went smoothly. The launcher sat on its side initially; it was raised about 10 feet, the anchor line (handled from the forward part of the ship) was slackened somewhat, and upon lowering it sat upright and was fired. Embedment was apparently satisfactory.

Proof Load: Approx. 120 K lbs.

Note: Proper performance indicates that the expendable piston is functioning as designed, and that the steps taken to prevent another connection failure after Shot # 2 are sufficient.

Shot 4: 1 May, 0950

Loading: 13¼ lb propellant, elongated eye coral fluke, expendable piston

Performance: Peak pressure was 29.9 Ksi. Deployment went smoothly, the system sat upright on the seafloor and was fired, and embedment was apparently satisfactory. However, a loop in the anchor load line caught on the line release mechanism during retrieval of the launcher, as evidenced by marks made by the line on the mechanism, causing the load on the retrieval line to jump momentarily from 10.5 K lb (the weight of the launcher in water) to about 30 K lbs.

Proof Load: 25 to 50 K lbs (estimated) on capstan, indicating anchor and line are in satisfactory condition.

Shot 5: 1 May, 1430

Loading: 13½ lb propellant, elongated eye coral fluke, expendable piston.

Performance: Peak pressure was 29.1 Ksi. Deployment went smoothly, the system sat upright on the seafloor and was fired, and embedment was apparently satisfactory.

Proof Load: 80 to 120 K lbs (estimated) on capstan.

Shot 6: 2 May, 0910

Loading: 13 lb propellant, integral clevis coral fluke, expendable piston.

Performance: Peak pressure was not measured. Deployment went smoothly, the system sat upright on the seafloor and was fired, and embedment was apparently satisfactory. The expendable piston performed as designed even though the bearing surface between the piston and the fluke was uneven because of superfluous welding beads.

Proof Load: 100 to 140 K lbs (estimated) on capstan during surge motion of ship.

Shot 7: 2 May, 1730

Loading: 14 lb propellant, elongated eye fluke, SUPSALV piston.

Performance: Peak pressure was not measured. Deployment to the seafloor went smoothly. However, the system failed to fire. After carrying out prescribed safety delays, it was found that the hydrostatically actuated plunger was in a safe position. The S/A device and breech were removed with the system held along side the ship, suspended from the towing wire over a side rail roller. Water had leaked into the gun chamber, apparently through a seal that was not seated properly because of a slight misalignment of the cartridge. The water was removed, the charge replaced, the seals checked, and the breech replaced and tightened with a torque of about 200 ft - lb (instead of the normal 20 ft - lb) to force the cartridge base to seat properly. Another S/A was installed and the system was redeployed from its side rail position, sat upright on the seafloor, and was fired. Embedment was apparently satisfactory, although unusually large distortion of tie rods (slight distortion is normal) indicated an excessive peak pressure, and hence the probability that a small leak still existed (a small amount of water would reduce chamber volume and hence increase peak pressure, but would not necessarily prevent firing).

Proof Load: Approx 100 K lbs (estimated) on capstan.