TECHNICAL BULLETIN

U.S. ARMY
TOWING MANUAL

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U.S. ARMY TOWING MANUAL

REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS

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CHAPTER 1

GENERAL

Section I. INTRODUCTION

1-1. PURPOSE.

Clearly, the primary mission of the Army is defense rather than commercial ocean towing or rescue salvage. It should be emphasized that U.S. Army ships are not designed to be in the commercial ocean towing or salvage business.

Section II. GENERAL INFORMATION

1-2. TYPES OF TOWING

The Navy recognizes several distinct types of towing which will be briefly listed here and discussed in more detail in the following paragraphs. These include:

a. Harbor or inshore towing-both barge towing and docking (berthing)

b. Ocean or offshore towing, which subdivides services into point-to-point scheduled or fixed- scenario towing, and general multi-scenario, special project towing

c. Salvage work, including combat salvage, domestic/CONUS towing, and rescue towing

d Tow-and-be-towed or emergency ship-to-ship towing.

1-2.1 HARBOR WORK. Harbor towing and base support, which includes berthing, is the province of what is referred to as "yard tugs." The Navy has had three classes of yard tugs: YTLs, YTMs and YTBs. The larger YTBs currently have as much as 2,000 shaft horsepower and are similar to commercial harbor tugs performing similar types of services. They are employed at major naval bases, overseas operating bases, ammunition depots, submarine bases, and in shipyards. In addition to berthing services, these tugs perform standby and safety escort duty. Of particular interest is the specially designed fender system on YTBs and YTMs configured for servicing submarines.

1-2.2 OCEAN AND OFFSHORE TOWING. The development of these activities within the Navy also depended to a large degree on the Navy's operations during WWII and thereafter.

1-2.2.1 Point-to-Point Towing. From WWII until the 1960s, point-to-point towing was performed by Auxiliary lugs, Fleet Tugs, Rescue Salvage Ships, and civilian-manned, government-owned tugs of the MARAD V-4 type. The ATAs were generally home- ported in each naval district in the continental U.S., Alaska and Hawaii, as well as at selected overseas bases. They were used for coastwise towing of various kinds of floating equipment (barges, pile drivers, dredges, etc.).

1-2.2.2 General Multi-Scenario Towing and Special Ocean Engineering Projects. General multi-scenario towing and special ocean engineering projects include the following types of missions:

a. Fleet or Task Force standby duty and rescue towing services-Generally assigned to the Fleet Tug (ATF) and now to the Rescue Salvage Ship (ARS) and the Salvage Tug (ATS) Classes. The MSC-operated Fleet Tugs (T-ATF) also perform these tasks.

b. Submarine Rescue and Escort-The primary mission of the ASR Class is rescuing submarine personnel. ASRs are capable of supporting deep sea (helium/oxygen) diving and are configured for quick mooring in water depths up to 1,000 feet. ASRs, with the exception of ASR 21 Class, are fitted with automatic towing machines and are fully capable of rescue towing.

c. Convoy Escort-Another type of rescue duty was performed by the tugs which escorted the convoys. This duty was originally assigned to older, commercially built and operated tugs, but later in WWII the Rescue Tug (ATR) was as- signed for this service. Today the T-ATF Class performs this function.

d. Ice Convoy and Arctic Rescue Towing-These were the missions of the Icebreakers (AGB Class). Until the mid-1960s, the Navy-operated AGBs were distinguished as the largest and most powerful tugs operated anywhere in the world. The Icebreakers (designated WAGB) were transferred to the U.S. Coast Guard in the 1960s; the older ones have since been decommissioned. Few, if any, of the remaining WAGB Class retain a specialized towing machine.

e. Special Projects Towing-Navy tugs often become involved with unusual tows or ocean engineering tasks. Some of the towing operations include: target services, submersible towing, array movements and classified operations In the area of ocean engineering, the tug may serve as a diving platform, establish moors, or perform a variety of deepwater tasks including remotely-operated vehicle support and deepwater recovery.

1-2.3 SALVAGE TOWING. Salvage vessels have been designed primarily for salvage work and only secondarily for towing. They have relatively large afterdecks. Below decks, they are equipped with good shop facilities, diving support equipment, limited off-ship firefighting systems, and large quantities of beach gear and other salvage supplies.

1-2.3.1 Combat Salvage and Towing. Ships playing this role include Fleet Tugs (T-ATF) when out- fitted, Rescue Salvage Ships (ARS), and Salvage Tugs (ATS) when they escort amphibious landing forces and battle groups. Their job is to tow ships or landing craft that are damaged, afire or disabled or beached and (if beached) likely to broach The tugs also stand by to tow away disabled vessels from the bombardment group, as well as transport and supply ships laying off the beachhead. In the case of amphibious landings, these rescue tugs and salvage ships can be subject to enemy fire from ashore. During World War II, the ARSs were originally intended to extract stranded ships by means of beach gear transferred to, and operated from, the stranded ship. They essentially were salvage support ships. The ARSs of the early years of WWII even lacked towing machines. Later, automatic towing machines were diverted from the ATA program and installed on the ARSs, thus adding towing to their capabilities. The current ARS 50 Class and ATS 1 Class are designed from the keel up to support combat salvage and towing missions.

1-2.3.2 Rescue Towing. The mission of rescue towing encompasses saving a stricken ship at sea or towing a disabled ship from the scene of a successful salvage to a safe refuge.

1-2.4 TOW-AND-BE-TOWED. Another kind of towing worthy of note is emergency towing accomplished not by tugs but by other ships, often of the same class. This is referred to as "tow-and-be-towed" or "emergency ship-to-ship towing." As early as the 1929 edition of the Navy General Specifications for Building Ships, a provision was made for accomplish- mg this type of towing. The Ships' Characteristics Board requires that every ship in the Navy be capable of and equipped to "tow-and-be-towed.'"

Generally, this means that the ship is capable of towing one of its own or a similar type in an emergency, with each ship providing half the towline. Tow-and-be-towed operations for NATO Navies are covered in ATP 43 (Ref. 7) and are further discussed in Section 4-10 The commercial equivalent is the optional towing capability stimulated by the International Maritime Organization (IMO) and other organizations as described in Appendix K.

1-3 TOWING SYSTEM DEVELOPMENT

Towing systems include various components of which the towing vessel or tug is most prominent However, the tug must have other items to make up the connection to the towed vessel. This section will look first at towing vessel developments and then at the towline connection system of hawsers, connecting elements, winches and towing machines.

1-3.1 TOWING VESSELS-OCEAN TUGS AND RESCUE SALVAGE SHIPS. These tugs and salvage/rescue types of ships are the only U.S Navy oceangoing ships whose primary mission is towing. Thus, they are the only types that are considered to be purpose-built for towing and for which towing activities have significantly influenced the design.

Most of the Navy purpose-built towing ships in use today are carryovers and replacements or successors to similar ships used or developed during WWII. Table 2-1 begins with a listing of these WWII ship classes and continues through their successors that are currently in use in the Navy Some of the differences between the WWII-vintage and the more modern ships lie in increased horsepower and bollard or towline pull, hawser size, provisions for use of synthetic fiber hawsers, and, of major importance, vastly improved onboard equipment and accommodations. The latter classes are summarized below-

a. ATF 76 Class-The ATF Class consists of large ocean tugs of the UTE Class and were excellent all-purpose ships. Their long-range, high horse- power and excellent seakeeping characteristics made them particularly suitable for operations in combat zones They also are excellent for towing large vessels, including dry-docks. They have off-ship firefighting and salvage facilities, and are equipped for ship rescue, emergency damage control, and ship repair. A limited number of this ship class remain in service.

b. ASR 7 Class-These ships were originally designed and equipped primarily for rescuing crews from sunken, disabled submarines They are now equipped for towing special arrays and the NR-1 research submarine. Those currently in Navy service can support surface-supplied he- hum/oxygen diving to a depth of 300 feet and can quickly moor in water depths up to 1,000 feet. They are currently equipped with AAJ 250/260 towing machines.

c. ARS 6 and ARS 38 Class-These ships of the ESCAPE and BOLSTER Classes are steel vessels designed for Navy offshore salvage work in overseas areas. They carry a large amount of salvage gear and supplies, and are intended to be stationed just outside the immediate combat zone until required for rescue or salvage. They have, until recently, been the backbone of the Navy salvage forces They are excellent long- distance towing vessels and are equipped with AAJ 250 towing machines

d. ATA Class-This class of tugs was designed for major towing operations at sea, and they had relatively long endurance. Their intended mission was major towing operations outside combat areas and Fleet support operations in peace- time They could, therefore, stand by just outside a combat or operational area and be in position to take the tow from an ATF that might be towing a disabled vessel to a repair base or safe haven. Although not intended for it, the ATAs per- formed some firefighting and salvage duties

e. ATS 1 Class-The three ships of this class are excellent towing and salvage ships. These English-built ships have two 3,000 foot, 2l/4-inch main towing hawsers in- stalled on a Stothert and Pitt automatic towing machine which was built under license by Almon A Johnson, Inc. The

TABLE 1-1. U.S. Navy Open-Ocean Salvage Towing Ships.

Ship Class	First Commiss.	SHP Drive*	Main Towing Winch	Wire Rope Hawser Dia X L	Traction Winch and Synthetic Hawser Size
ATF 76	May 1942	3000 S-DE	AAJ 222 SPEC	2" x 2100'	--
ASR 7	Apr 1943	3000 S-DE	AAJ 260 SPEC	2" x 2100'	--
ARS 6	Nov 1943	3000 T-DE	AAJ 250 SPEC	2" x 2100'	--
ATA 120/170**	Jul 1944	1500 S-DE	AAJ 222	2" x 2100'	--
ARS 38	May 1945	3000 T-DE	AAJ 250 SPEC	2" x 2100'	--
ATS 1	Jan 1971	6000 T-CPP	STOTHERT and PITT (AAJ Design)	24 " x 3000'	--
T-ATF 166	Jun 1979	7200 T-CPP	SMATCO	24" x 2500'	Lake Shore up to 15" circumference
ARS 50	Nov 1985	4200 T-CPP	AAJ 322/400	21/"x3000'	AAJ 400upto14" circumference

* Propulsion Code
S-DE Single screw, diesel-electric
T-DE Twin screw, diesel-electric
T-CPP Twin screw, controllable pitch propeller

** The ATAs are no longer in commission

NOTE

All the main towing machine installations by Almon A Johnson and Stothert and Pitt have an automatic payout and reclaim feature The SMATCO winch on the T-ATF does not include this feature ship class also has a 5,000-foot, 1-inch auxiliary hawser.

f. T-ATF 166 Class-This ship was conceived and specified to replace the Auxiliary Ocean Tugs (ATA) and Fleet Tugs (ATF) for routine towing, and it also was intended to serve as a salvage tender, hence, it has a large afterdeck, much as an offshore supply vessel. Although not normally carried, various suites of special equipment can be installed on board the T-ATF for support of such services as: air and mixed gas diving, beach- gear operations, off-ship firefighting and oil spill recovery response This class is capable in rescue towing applications, but has limited salvage capabilities. The class is not equipped with an automatic towing machine; rather, it is equipped with a single-drum, diesel-driven winch-one which is relatively common to the offshore oil industry. This 7,200 horsepower tug class carries a 2,500-foot, 2/4-inch wire rope tow hawser At the time that the T-ATF was being specified and designed, it was thought that nylon rope would be utilized for various towing missions. To sup- port this, the T-ATF was also given a traction winch which can handle synthetic hawsers up to 15 inches in circumference.

g. ARS 50 Class-These four ships are an upgrade of the ARS 38 Class. The automatic towing machine on board the ARS 50 Class is a Series 322 double-drum machine built by Almon A. Johnson, Inc. This double-drum automatic towing machine stores 2/4-inch diameter towing hawsers, 3,000 feet long The ARS 50 Class ships also have Series 400 traction winch capability for handling synthetic line up to 14 inches in circumference. The traction winch also is useful for mooring and ocean engineering operations.

1-3.2 TOWLINE SYSTEM. After the tug, the next elements in the towing system are the hawser and an attachment such as a post, bitt or hook. Through time, this combination has developed into a winch or towing machine. The towing system also may include a chain pendant, wire-rope pendant and/or spring pendant as part of the tension-member portion of the system. These elements are connected by shackles, links or other connecting devices The towing system must not only serve as the tensile load-carrying link between tug and tow, but also withstand dynamic peak loads, often called "shock" loads. Traditionally, there have been three ways of coping with these peak loads in a towline:

a Using a fully automatic towing machine

b. Using a deep catenary as a spring

c. Inserting a spring or stretcher into the towline.

These items and techniques are discussed briefly in the following paragraphs.

1-3.2.1 Main Towing Hawser. The main towing hawser generally has been a wire rope, especially when used with any of the peak load-reducing systems mentioned above. One can, however, utilize a fiber line hawser of either natural or synthetic fiber. Such a hawser has enough elasticity of its own to act as a spring and dampen the peak loads. In this connection, refer to Paragraph 2-6 2 and Appendix C for conditions allowing use of synthetic fiber hawser.

The U S. Navy, along with all other ocean towing organizations, relied on past experience and empirical rules of thumb for designing and utilizing tow- lines which depended upon the catenary or upon the automatic towing machine for shock mitigation However, when attempts were made to use nylon line (pendants or complete hawsers) as the peak load mitigation system, the Navy began to experience problems. It appeared that the source of some of the problems was a lack of understanding that nylon has lower strength when wet than when dry. Additionally, there has also been a realization that the Safe Working Load and Factors of Safety for the use of nylon in the marine environment have not been adequately defined

The resolution of the towline design problem is now seen to require not only improved knowledge of the characteristics of nylon and other synthetic fibers, but also better basic engineering tools and a better understanding of the towline system itself as well as its response to the marine environment

Towards this end, the U.S. Navy has instituted the Synthetic Fiber Rope Safety Program. The final out- come of this effort should provide sound decisions on the use of synthetic lines in towline systems (e.g., wet versus dry strengths, nylon versus polyester or other synthetics, all-synthetic towlines, and Safe Working Loads and Factors of Safety for synthetics). In fact, a major value of the research effort will be the provision of a stronger engineering base for the design of any towline system.

In the meantime, the U.S. Navy does not approve the routine use of synthetic towing hawsers for open- ocean towing See Paragraph 2-6.2 and the introductory paragraphs of Appendix C. Refer to the current edition of the U.S. Navy Salvage Manual for guide- lines on use of synthetic lines in salvage.

1-3.2.2 Bitts, Padeyes and Hooks. Initially, the connection of the tow hawser to the tug was simply to belay the natural-fiber manila line to bitts at the stern of the tug Later, wire rope began to be used for hawsers and metal came to be a more prominent part of both the ship's structure and its fittings. Then padeyes were installed, to which eyes in the tug end of the hawser could be secured The padeyes eventually evolved into towing hooks over which thimbled eyes of both fiber and wire rope could be hooked. When wire rope came into use, the hooks began to be equipped with heavy springs to help replace some of the natural elasticity that was lost in the change from fiber line to wire rope.

1-3.2.3 Winches and Towing Machines. Although wire rope was somewhat easier to handle than was wet manila line of equal strength, it still could not be faked out on the deck as a manila hawser could be when hauled in Powered winches were a natural evolution, providing the in-haul and storage features for wire rope hawsers and for the attachment point formerly provided by the bitts and hook. The winch soon became the standard equipment for the hard- point, m-haul, and stowage functions for most ocean tugs Winches have since developed along two paths. On one path, a control system was added which would pay out the towline when the tensile load on it exceeded a set value; then, as the tensile load decreased, the control would haul in the hawser. These actions tend to smooth out the peak loads and maintain a more nearly constant tensile load on the towline system.

The other path of winch evolution was the development of a multi-sheave traction winch for use with very long synthetic fiber hawsers. Rather than stowing the hawser on a drum which serves as both hard-point and stowage, the traction winch, with assistance, feeds the hawser into a stowage bin. Some traction winches are now equipped with automatic controls which pay out hawser to relieve high tensile loads However, the control generally does not provide for automatic reclaim on the traction winches. Traction winches for wire hawsers are also found on some larger commercial ships. Appendix L contains more detailed information on towing machines, towing winches and traction winches.

1-3.2.4 Catenary. When the change was made from manila to wire rope for towing hawsers, the catenary became the primary means of relieving the peak dynamic tension loads. The weight of a wire-rope towing hawser, either alone or in combination with a short segment of chain cable at the tow end of the towline, causes a catenary in the towline between the tug and the tow. Variations in the towline tensile load tend to be smoothed out in the catenary. Temporary decrease of the distance between tug and tow, or a decrease in tension, is absorbed by a deepening catenary depth. An increase in the separation between tug and tow causes the catenary to decrease, and the hawser tension to increase. Thus, the wire catenary tends to act as a spring, softening the tug-tow interaction.

1-3.2.5 Chain Pendants and Bridles. The short length of chain used to increase the catenary as mentioned in the above paragraph also serves another purpose: that of providing a rugged, chafing- resistant attachment point for the hawser at the tow end. Chain, like other marine tension members, has evolved over the years. The Boston Naval Shipyard led U.S Navy chain development and manufacture for many years. Two major developments and manufacturing responsibilities at the Shipyard were die lock chain and the Navy detachable link. With the deactivation of the Boston Naval Shipyard in 1972, this capability was lost to the Navy, although similar products were commercially manufactured until the mid-1980s. See Appendix D for a complete discussion of chain.

1-3.2.6 Spring. In towing, a spring absorbs shocks due to dynamic loading of the towing system. It is a rope made of material exhibiting elastic behavior It is for this reason that, for the last 25 years, the ocean towing industry has been interested in nylon line and, more recently, other synthetic fiber lines as well. Nylon replaced manila in hawsers and spring pendants because of its superior elasticity and because, strength-for-strength, it was smaller, lighter, and easier to handle. Nylon line has other beneficial properties, which include its resistance to mildew and rotting, a serious problem in natural fiber lines. How- ever, nylon exhibited certain disadvantages, including susceptibility to damage from ultraviolet light, loss of strength when wet and a perplexing history of unexplained failures. Use of nylon in towing currently is restricted. Recently, other synthetic materials have attracted increased interest. See Appendix C for more information on fiber lines

SECTION III. SAFETY SUMMARY

This Safety Summary contains all specific WARNINGS and CAUTIONS appearing elsewhere in this manual. Should situations arise that are not covered by the general and specific safety precautions, the Commanding Officer or other authority will issue orders, as deemed necessary, to cover the situation.

1-4 GUIDELINES

Extensive guidelines for safety can be found in the OPNAV 5100 Series instruction manual, "Navy Safety Precautions." Personnel required to perform towing operations must be thoroughly trained and equipped not only to perform routine duties but also to react appropriately to unusual or non-routine situations.

The officers and crew of vessels likely to be involved in towing operations should continuously conduct safety indoctrination lectures and exercises aimed at reducing hazards and at reacting appropriately to unusual circumstances with professional under- standing of their duties and the proper use of safety equipment

1-4.1 PRECAUTIONS

The WARNINGS and CAUTIONS contained in this manual and listed below are referenced by page number. In addition, the following general precautions are offered as part of this Safety Summary:

a. All personnel responsible for towing should read and comprehend this manual.

b. Observe all warnings, cautions and notes listed in this manual.

c. Follow operational procedures. Observe operating parameters of all equipment.

WARNINGS

Do not confuse pelican hook with chain stopper. (Page 2-30)

In no case should the stud of a common chain link be removed to provide a connecting point to a chain. (Page 2-33)

The tow wire will be under tension when released, creating an extremely hazardous condition. All nonessential personnel must evacuate the area to prevent serious injury. (Page 2-34)

Wire rope stretches far less under load than most natural and synthetic fiber lines and thus has a smaller zone of danger to bystanders from loose ends "snapping back" in the event that it fails under high loads. The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path. (Page 2-35)

Old-style stoppers with smooth covers are condemned and should not be used. These old models were made of cast metal and are subject to explosive brittle fracture upon impact. Serious injury to personnel may result from flying fragments. (Page 2-35)

The Stern Rollers and Norman Pins onboard the ARS 50 Class ships will drop when a load of 50,000 pounds or more is applied to mid-barrel height. The resulting uncontrolled sweeping of the towline may injure personnel or damage equipment. (Page 2-44)

Substitution of materials can be dangerous as well as detrimental to the tow. Substitutions shall not be made unless there is a complete knowledge of the material being substituted. Material substitutes frequently introduce a new and unpredictable weak link. Substitution of a stronger material may change the location of the weak link and relocate the potential failure point in the rig to a position that is hazardous to personnel. (Page 3-14)

Use the applicable safety precautions for entering voids and unventilated spaces. Failure to do so may result in injury or death to personnel. (Page 3-15)

Carefully adhere to safety requirements when entering closed spaces. See NSTM 631. (Page 3-29)

Rockets should be used only where no explosive fuels, deck cargo or other flammable objects are exposed. All uses of line throwing guns, rockets or heaving lines should be accompanied by verbal warnings and sound warnings to take cover. Failure to do so may result in injury or death to personnel. (Page 3-15)

Do not use screw-pin shackles in ocean towing. (Page 3-43)

Most casualties in passing a tow occur because the ships do not maintain a steady course or speed, or because the towing ship releases the tow before the other ship is ready to accept the
strain. (Page 4-3)

Always remain with a target sled until it is recovered or righted and towed to port; it be- comes a hazard to navigation if it is left to drift. (Page 4-4)

Do not allow the tow hawser to drag on the bottom. (Page 5-9)

Cotter keys are not used in towing, despite MIILS-24214A (SHIPS) drawings. (Page 5-29)

If time and the situation permit, a detailed analysis of the padeye and connection shall be made in order to avoid unexpected failure of either. (Page 5-31)

Wire rope stretches under load far less than most natural and synthetic fiber lines and thus has a smaller zone of danger to bystanders from loose ends "snapping back" in the event that it fails under high loads. The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path. (Page B-l)

It is extremely important that wire rope used in critical or potentially dangerous applications such as towing be properly maintained. (Page B-7)

When using a termination on the tow hawser of less than 100 percent efficiency, the base strength to which the factors of safety are applied must be adjusted accordingly. (Page B-11)

The failure of synthetic fiber lines under high tensile loads can be extremely dangerous. Stay out of bights and areas through which the end of a failed line may whip. (Page C-1)

Surging of synthetic line under tension can cause sufficient frictional heat at the contact surfaces to result in melting the surface of the line. The melting point of polypropylene line, for instance, is 320°F to 340°F, while the softening point is around 300 F. Comparable temperatures for nylon and polyester are only moderately higher. These temperatures are quite quickly produced when a line is surged on a winch or capstan.
(Page C-5)

The major special precaution to be taken in the use of synthetic lines that are heavily loaded is to be constantly alert to the danger of line snap- back if it fails. Personnel must remain clear of the areas through which the ends of a failed line may whip or snap. This is vital since the end of the broken line can travel at speeds up to 500 mph. (Page C-5)

Several factors affect line behavior, such as line condition and specific application. The tensile loads are tabulated for new line in good condition. Normal working loads are not applicable when the line is subject to dynamic loading. (Page C-7)

Never pass a stopper on a tension member that is under a strain greater than the safe working load of the stopper, or on a tension member that might be subjected to a heavier loading condition while the stopper is in place. (Page E-1)

CAUTIONS

The craft listed in Table 2-1 are representative of vessels requiring special consideration. Evaluation of stability characteristics, material condition of the hull, equipment on board, operational requirements and other applicable considerations must be made on any craft before towing. Only under extreme emergency situations should open-ocean towing be attempted when the tow is not considered seaworthy. (Page 2-1)

River and harbor dredges generally have little or no compartmentation and machinery occupies most of the below deck space throughout. Additionally, they tend to have a very low freeboard. Whether towed with or without a riding crew, dredges should be given extra attention from departure to destination and should be towed with caution. (Page 2-3)

When towing alongside, keep all lines taut until ready for streaming the tow. This will prevent the tow from pounding alongside the tug and ensure effective control of the tow. (Page 2-23)

Chain smaller than about 31/4 will require a pear-shaped link or an anchor shackle to connect to the standard Smit Bracket. Check dimensions carefully! (Page 2-32)

The large and small Smit Brackets are sized to accept the standard end like of 3-inch and 2-inch chain, respectively. They will directly accept the common link of considerably larger chains. Check dimensions carefully in designing the tow connection! (Page 2-33)

The towing ship should reduce the tension on the towing assembly by either slowing down or stopping prior to cutting or otherwise releasing a towline. (Page 2-34)

A carpenter stopper should not be used unless it is specially designed for the lay, helix, number of strands and diameter of the specific wire rope. The stopper and wire rope should both be clean and free from sand or other abrasives. (Page 3-35)

When towing "on the dog'" there is no hawser quick-release capability. (Page 2-38)

Whenever the surface of a caprail becomes rough, steps should be taken to repair or replace it in order to protect the hawser. Caprails should be kept clear of all appurtenances. (Page 2-44)

Shackles and other fittings frequently come with cotter pins which should be replaced with locking bolts with two jam nuts. (Page 2-51)

Special forged shackles, when used with chain stoppers and carpenter stoppers, utilize care- fully machined screw pins and are permissible in towing. Such pins must remain accessible for inspection and service while in use. (Page 2-52)

Whenever a poured socket is installed on a wire rope, the condition of the lubricant in the portion of the rope near the socket should be checked and new lubricant applied to dry areas. (Page 2-52)

Swaging is acceptable only on IWRC (Independent Wire Rope Core) wire rope. It is not to be used on fiber core rope. (Page 2-52)

Do not allow main reduction gears to rotate unless they are properly lubricated. This requires full lube oil pressure. (Page 3-6)

Many barges and barge-like vessels tend to be more susceptible to damage and deterioration than conventional ship-type vessels. They should therefore be inspected for hull strength prior to towing. (Page 3-8)

Do not use temporary lashings or other make-shift measures to lock the rudder of a towed ship. Lock the rudder amidships for towing. (Page 3-8)

A screw-pin shackle shall not be used as a replacement for a safety shackle in towing A safety shackle will deform under load and still hold, while a screw-pin shackle's pin can work itself out of the shackle. (Page 3-14)

When picking up a tow, the Conning Officer on the tug should be cautious when increasing speed and should maintain an even strain on the towing gear. If a readout is not available on the bridge, tow hawser tension information should be provided to the Conning Officer by the Towing Watch. (Page 3-16)

Good judgment is required in the use of a weak link. When operational requirements dictate maximum strength, such as a tow along a lee shore, an intentional weak link may jeopardize the mission. (Page 5-35)

Batteries should be protected from electrical grounding by mounting them on non-conductive bases or with non-conductive liners in the box. (Page 5-37)

Great care should be taken when the rope is removed from the shipping package since it can be permanently damaged by improper unreeling or uncoiling. Kinks and hockles, see figure B-3, may occur with careless uncoiling. (Page B-3)

Sudden application of a load to wire rope by rapid acceleration causes stress much greater than the weight or resistance of the tow. Avoid such strain on the rope by employing gradual acceleration. (Page B-5)

In general, one should wear gloves when handling wire rope except when it is moving under load. The gloves, if snagged, can drag the hands into dangerous locations. (Page B-7)

New synthetic hawsers should not be subjected to heavy strain prior to breaking them in. Limit the towing loads applied to a new hawser until it has been cycled up to its working load. (Page C-2)

A common method of uncoiling wire rope by rolling the coil along the deck is not recommended for fiber lines because of the potential for abrading or cutting the outer fibers, and also because the coil will collapse when the bands are removed. (Page C-3)

The potential for catastrophe, resulting from the failure of a heavily-loaded synthetic line and the sensitivity of the line to damage from rough surfaces, indicates another major precaution. That is, when towing either alongside or stern-to- bow, with a synthetic hawser, try to keep your line completely outboard. This can be done by shackling into a double synthetic line strap of equal size and type as your line or into a wire rope or chain pendant. This is particularly important on the towed end, as the conditions of those chocks, bitts, etc. are unknown. Barges usually have very rough chocks caused by previous repetitive use of wire rope or chain. (Page C-5)

Synthetic lines may slip when eased out under heavy loads since their coefficient of friction is below that of manila. This may cause injury to personnel who have not been thoroughly instructed in these lines' peculiarities. Take two or three turns on a bitt before you "figure 8" the line; this provides closer control. Stand well clear of the bitts. (Page C-6)

Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration set up by the hydrodynamic actions on the towline. (Page D-5)

Care should be exercised when alongside in a seaway. The motions of the tug and tow may be sufficient to part the mooring lines, resulting in damage and causing the tug to lose control of the tow. (Page 3-16)

Small increments of rudder angle are recommended when changing course under tow. This will ensure that the tug maintains control of the tow and prevents the tow from ranging up the tug. Never permit the tow to pass forward of the tug's beam, as the tug or tow hawser may be severely damaged. (Page 3-20)

Use of vertical rollers may put tug in irons, which would seriously limit the tug's maneuver- ability. (Page 3-22)

A hogging strap may be necessary to prevent the towline from jumping the stern rollers when towing a high-bowed ship at short stay. A hogging strap may be subject to excessive vertical loads. Care should be taken not to part the strap. Failure of a hogging strap may result in the loss of tug control or ranging up by the tow. (Page 3-23)

Running before the sea and wind can cause difficulty in steering and in keeping the tow astern or in the desired position. The tug may be pooped or the tow may tend to overtake the tug. The over- taking will reduce the tension in the towline and cause an increase in the catenary which may also cause the towline to snag on the bottom or bring the tug and tow to collision. The recommended course of action is to head into the weather and maintain steerageway, increase hawser scope and, as long as there is enough searoom, tolerate a negative speed over the ground. There is no reason to slip the tow unless the towing ship is in danger of grounding. (Page 3-26)

Under more strenuous sea conditions, dynamic hawser tensions, when towing down wind, can be significantly higher than when heading into wind and seas at the same speed and power. Turning into the wind and seas, and slowing to maintain steerageway are appropriate under such conditions. (Page 3-27)

Do not permit the disconnect pendant or bridle to drag on the bottom, as considerable additional resistance will result and maneuvering will be seriously disrupted. (Page 3-30)

Approaching at too small an angle in the lee of the larger vessel is not recommended. (Page 3-32)

Riding crews normally consist of a minimum crew and can be expected to perform only minimal emergency functions on board. (Page 3-35)

When towing under unfavorable conditions or inclement weather and at short stay, danger exists of being overridden. In such a situation, particular care is advised in setting an underway material condition so that watertight doors, hatches and other openings are secured. (Page 3-35)

The mooring loads of the tug and tow may be greater than the holding power or strength of the tug's ground tackle. A dragging anchor or failure of the ground tackle is possible, resulting in loss of control of the tug and tow. (Page 3-37)

Releasing the hawser under tension, or even its own weight, can be hazardous. (Page 3-37)

In operating the Liverpool Bridle, limit the tension to the safe working load of the bridle's 15/8-inch wire rope pendant. (Page 3-39)

Except in an emergency, backing down with a tow is not recommended. If a collision with another ship is imminent and backing down appears necessary, it may be attempted. (Page 3-39)

If the target is made up bow-to-stern, it will reverse direction and swing into position when slipped, unless there is too much way on the ship. Too much way on will cause the target to be towed stern first. Ensure that the target does, in fact, tow bow first as the target has a tendency to stream aft without reversing itself and will end up by straddling the towline in a stern-first position. (Page 4-21)

The strain on the towline will be severe if the towed ship contacts heavy ice. Take special pre- cautions to prevent the chain bridle, chain pendants and hawser from chafing. An automatic towing machine makes this easier. Avoid towing on the bitts; they may be torn out by the sudden increases in tension if ice is encountered when towing at short scope. (Page 4-6)

Every retractable item forward of the tow fair- lead, or flounder plate if used, must be retracted by the submarine crew to preclude damage to the submarine itself and to prevent parting of the tow hawser. (Page 4-7)

The submarine's designed towing rig was intended for intra-harbor towing and is not generally acceptable for open-ocean towing. (Page 4-8)

Few deck fittings on submarines are not designed for loads that are commonly considered in the design of surface ships. Care must be exercised to ensure that the safe load capacity of fittings, such as the bullnose fairlead, cleats and padeyes, is not exceeded. Particular attention must be paid to the loads which may develop when the submarine yaws. (Page 4-9)

Obtain technical advice prior to any welding to a submarine's pressure hull. (Page 4-9)

Due to the severe sheering tendencies of most submarines, employing active steering of the tow, as directed by the towing vessel, can be helpful. (Page 4-10)

Because of the great difference in strength between Grade A and Grade B shackles, pay particular attention to the presence or absence of the HS mark, indicating a high strength shackle. The user must be sure that proper shackles are used in the system. (Page 5-29)

Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration set up by the hydrodynamic actions on the towline. (Page 5-29)

Never weld on forged steel shackles. The welding process can weaken the shackle. (Page 5-29)

Never weld detachable links. The welding process can weaken the links. (Page 5-29)

CHAPTER 2

ELEMENTS OF TOWING-SHIPS AND HARDWARE

SECTION I

2-1 INTRODUCTION

This chapter introduces the technology and equipment involved in towing operations. Included are brief discussions of the tows, towing ships and towing systems involved in the operation. Detailed data on operations and on the design and selection of towing systems and components are contained in subsequent chapters and the appendices. Through- out this manual the terms "tug" and "towing ship" are used interchangeably.

SECTION II

2-2 TOWS

2-2.1 TYPES OF VESSELS. The types of vessels which may require towing include the following:

a. All Navy combatant ships-ranging in size from small patrol boats to large aircraft carriers
b. Non-combatant vessels-ranging from targets to large fleet oilers and other supply ships.
c. Non-ship vessels-ranging from small barges to large floating dry-docks

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CAUTION

The craft listed in Table 2-1 are representative of vessels requiring special consideration. Evaluation of stability characteristics, material condition of the hull, equipment on board, operational requirements and other applicable considerations must be made on any craft before towing. Only under extreme emergency situations should open-ocean towing be attempted when the tow is not considered seaworthy.

Hulls not considered seaworthy for open ocean tows should be transported as deck cargo or on board a floating dock, submersible vessel or LSD-type ship. Table 2-1 provides a partial list of tows which are not recommended for open ocean towing, along with supporting rationale as to why they do not qualify

2-2.2 TOWING SERVICES. The conditions under which towing must be attempted depend to a large degree upon the principal missions of the Navy at the particular time. Wartime towing can be essentially worldwide and will often include combat zones as well as the supply routes to these zones. The weather environment can range from tropical to polar and local specific weather conditions can range from dead calm to tropical cyclones or Arctic ice storms. Towing can also vary from routine, well-planned activities to time-critical emergencies such as rescue or salvage towing.

2-2.2.1 Routine Towing. Routine Navy towing includes a wide variety of activities such as harbor work and many classes of offshore or open ocean towing. The vessels towed in routine point-to-point ocean tows include barges, special work craft and ships of various classes being towed to repair bases or to reserve fleet areas. Included in the routine-tow category are target towing and other special projects such as towing oceanographic instrumentation plat- forms and R&D operations.

2-2.2.2 Emergency Towing. Navy emergency towing consists almost entirely of escort, rescue and salvage missions Much of this towing is performed by ships that have been specifically designed and built for such duty. However, nearly every class of U.S Navy ship can tow and be towed in an emergency. See Chapter 3 for data on "Tow and be Towed." Ships not specifically equipped for towing can make use of anchor chains, wire straps, mooring lines or necessary combinations of these items. A proper catenary will ensure some spring in a wire towline; slow speed will minimize dynamic loads developed between the towing ship and the tow Therefore, the towing

TABLE 2-1. U.S. Navy Craft Not Recommended for Open-Ocean Tows.

CRAFT CLASSIFICATION	REASONS FOR NON-RECOMMENDATION
LCU, YCU Landing Craft LCM8, LCM6 Landing Craft YFU, YFB, LWT	Low freeboard. Light construction of bow door locking mechanism. Structure can be strengthened to reduce risk.
YFNG, YFNX Lighter, YNG Gate Craft, YSR Sludge Removal Craft	All have deck-mounted equipment which requires installing special protection before towing.
YM Dredge, YPD Pile Driver, YD Crane LSMR	All tend to be top-heavy (have high center of gravity) and may also have poor watertight integrity. Topside high weights may require removal and stowage prior to open-ocean towing to attain adequate stability. All require special preparations
YSD (formerly Seaplace Derrick)	Low freeboard and high weights reduce sea-keeping ability. Weights may require removal and stowage to improve stability at sea.
YTL Small Harbor Tug PTF Patrol Boat	Hulls considered too small for open-ocean tows. Should be trans ported as deck cargo.
Mini-ATC, LCPL MK2, MK3, MK4, MK5 personnel boats	Low freeboard. Light construction with poor watertight compartmentation and weak to no attachment points for towing.
MK1, MK2 65’ utility boats, MK4 50’ utility boat, MK3, MK4 40'	Low freeboard. Deck mounted equipment.

should keep its speed low to minimize strain and surging and yet maintain steerage.

2-2.3 MANNED VS. UNMANNED TOWS. Approval to man a tow must come from the Fleet Commanders-in-Chief (CINCs). The Navy command requesting the tow should make the manned/ unmanned recommendation with the following considerations. The first consideration is the lives of the personnel; second is the value of the tow. The value of the tow can be either its replacement cost, value of its safe and timely delivery or cost of the consequences of loss from a tactical, strategic or public-relations standpoint. Safety considerations in making the manned/unmanned decision must be made on the basis of the crew's influence on the tow's safety rather than the tow's influence on crew convenience.

2-2.3.1 Manned Tows. Rescue tows should be manned if possible in order to have personnel on board to make the tow connection and to respond to changes in the tow's material condition or to respond to fires, flooding, chafing of the hawser or bridle, loss of the towline or other such emergencies. The presence of the riding crew can add immeasurably to the general safety of the tow. When a tow is manned, it must be adequately supplied and equipped to sup- port the riding crew.

2-2.3.2 Unmanned Tows. Barges, floating derricks, ocean dredges, pontoons, crane barges, pile drivers, dry-docks, caissons and yard and service craft can be towed without a riding crew. Under normal conditions, after carefully securing for sea, many point-to- point tows are undertaken without a riding crew.

CAUTION

River and harbor dredges generally have little or no compartmentation and machinery occupies most of the below deck space throughout. Additionally, they tend to have a very low freeboard. Whether towed with or without a riding crew, dredges should be given extra attention from departure to destination and should be towed with extreme caution (Page-2-3).

To be considered seaworthy, a towed vessel must have adequate watertight integrity, structural soundness and intact stability Officers-m-charge must consider the impact on stability of the free-surface effects of cargo or liquid ballast

The tow's hull design may require taking numerous steps in preparing to tow. Examples include cranes, pile drivers, dredges, dump scows or other equipment designed for operation in sheltered waters. These measures may include removing high weights, securing booms, dredge ladders and other deck structures, adding or removing ballast or adjusting trim; stiffening the hull and performing other functions. Wherever possible, heavy, welded brackets should be used to secure heavy movable objects and a tow should always be secured for the worst sea conditions. Expect large angles of roll and pitch and secure all heavy objects accordingly.

2-2.4 REQUIREMENTS PLACED ON THE TUG. The primary requirement placed on the tug is to provide a power plant that the tow does not have available, due either to its construction or to a casualty or other failure of its own main power plant. Secondary requirements include such functions as steering for maneuverability, navigation and communications, security, damage control and fire protection. In addition, the tug may have to supply all the rigging for the towing system. The degree of service required from the tug will depend upon the circumstances.

While underway, the tug and tow will be subject to both steady and dynamic loads Care must be taken in planning the tow by selecting the proper gear and deciding on the route and departure date to avoid adverse weather conditions which may subject the towing systems to loads that exceed the safe working load of any component within the towing system. A tug must request Optimum Track Ship Routing (OTSR) for each long ocean tow.

Navy design criteria for safe mooring loads are based upon specific conditions of winds, waves and cur- rents. In contrast to this situation, safe working loads for towing depend much more upon the towing operation and upon the general category of towing: inshore barges, rescue towing in combat or storm conditions. In the routine, inshore barge type of tow, safe loads are more easily defined and the design can be based primarily upon normal operating conditions For ocean towing, the design must consider loads associated with extreme weather or survival conditions, rather than those characterizing normal operations. Chapter 5 contains detailed discussions of towline tension, towing resistance and factors of safety for towing system design.

SECTION III. TUGS

2-3.1 TYPES OF TUGS. Most U.S. Navy ships can tow man emergency, but only properly designed and outfitted tugs make good towing ships. Characteristically, a tug's superstructure is set forward, allowing the towing point to be close to the ship's pivot point. The towline, secured well forward of the rudder and propellers, is allowed to sweep the rail without limiting the maneuverability of the tug. In addition to a clear fantail area, characteristics of a good tug include the following:

a. High horsepower
b. Slow speed
c. Large-diameter propeller(s)
d. Large-area rudder(s)
e. Towing machine
f. Power capstans
g. Towing points

2-3.1.1 Yard or Harbor Tugs. The U.S. Navy operates the YTB (large yard tug), YTM (medium yard tug), and YTL (small yard tug) These tugs are used primarily in sheltered waters including harbors. On occasion, however, YTMs and YTBs can be used in open-ocean towing. In addition, the U.S. Army and U.S. Coast Guard operate a large number of similar tugs and yard craft.

Harbor tugs are classified by shaft horsepower (shp)

YTL-small-400 SHP and under

YTM-medium-400 to 1,000 SHP

YTB-large-1,000 to 2,000 SHP or greater.

The design of harbor tugs and the equipment they employ varies. The typical harbor tug is a single- screw, deep-draft vessel equipped with a capstan aft, H-bitts forward and aft, towing hawsers and additional lines for handling ships or barges in restricted waters. The harbor tugs may also be equipped with fenders, very limited firefighting equipment and deck equipment to support harbor operations.

2-3.1.2 Ocean Tugs. The Navy's ocean tugs are designed to be far more versatile than harbor tugs, not only in terms of horsepower and range capabilities, but also in terms of the services they can provide to their tows. Designing purpose-built tugs has not been the primary goal of Navy design practices in the past; most Navy ocean tugs are multipurpose-built In addition to their power, range and endurance capabilities, the ocean tugs have the capability to work and survive in heavy weather independently of other auxiliary or support ships. They also are used in stranding and other salvage operations. Ocean tugs should have automatic towing machines and load-sensing systems. An automatic towing machine's feedback and load response provide the capability of reducing dynamic loads and, if necessary, rapidly releasing the towline.

Table 2-2 lists the various classes of towing ships operated by the U.S. Navy. These ships are capable of long-range tows and other missions. The T-ATF is a multipurpose, long-range, high-horsepower, sea- worthy tug. It can conduct long-distance tows, and when augmented with additional crew and equipment, operate in support of firefighting, diving and salvage missions. The ARS 50 is a salvage tug with a double-drum towing machine. It carries a crew and equipment sufficient to handle independent salvage, diving, damage control and firefighting capabilities in time of war

The ARS 38 (Rescue and Salvage) and ATS (Towing Salvage) Classes have similar capabilities and sufficient personnel to perform ocean towing.

Although they have somewhat lower propulsion power than other classes, the ASR (Submarine Rescue) Class ships, with the exception of the ASR 21 and ASR 22, are equipped with towing machines. They are capable of rescue as well as routine towing. See Figures 2-1 through 2-6 for information regarding major specifications and visual appearance of the various Navy ocean tugs.

2-3.2 TUG DESIGN CONSIDERATIONS. The specific items to be considered in the design of an ocean tug are dependent upon the missions and services that it will be called upon to perform In general, a Navy ocean tug is a very versatile ship, but its design involves many compromises. The services that the tug may be required to furnish to its tow can cover a very wide spectrum of needs. For long ocean tows, the tug can be called upon to provide complete logistic support for the tow and the riding crew, if it is manned During rescue salvage towing operations the tug may also be required to serve as a supply base and shop for repairs, rigging and damage control. Trade-offs and compromises must be made in terms of mission and operational factors by choosing among the many sub-items listed. Appendix J provides data on features and compromises in an ocean tug.

2-3.3 TUG POWERING AND BOLLARD PULL. The design of the main propulsion power plant must be a compromise among the needs for high free- running speeds for reaching the scene of a casualty, good economy with high towline pull for long- distance tows at reasonable towing speeds and high bollard pull. The latter is necessary for such activities as holding a distressed ship to prevent it from grounding, and for refloating stranded ships. In the absence of a good automatic towing machine or other accurate means of measuring the towline tension, as knowledge of the tug's available towline pull and bollard pull is required for controlling the tension Chapter 5 presents the methodology for estimating towline pull and bollard pull

2-3.4 FENDERS. Fenders are energy-absorbing materials or devices that protect both the tug and the tow Standard fenders currently in use generally are either molded rubber or specially-designed, foam- filled and pneumatic-type devices. These are discussed in the following paragraphs and illustrated m Figures 2-7 and 2-8.

2-3.4.1 Subsurface Fenders. Tugs working along-side submarines should have subsurface fenders

2-3.4.2 Modern Pneumatic And Foam Fenders. Modern fendering is an important part of towing operations when alongside evolutions are required, either in harbors or at sea Three types of fenders are available They are high-pressure (5 to 7 psi) pneumatic, low-pressure (1 psi) pneumatic and closed-cell foam covered with urethane elastomer In the following list, the first six features are most significant Important characteristics include.

(Text continued on page 2-15)

Characteristics	**Navy ARS 7**	**Navy ATF 76**	**Navy ATS 1**	**Navy ARS 6**	**Navy ARS 38**	**Navy ARS 50**
Length (ft)	251.5	205	282.7	213.5	213.5	255.0
Beam (ft)	43	38.5	50	39	43	52
Draft (ft)	19 5	15.5	18.0	13	16	17.5
Displacement (Full-Load LT)	2400	1675	3117	1750	1900	3282
Cruising Range (nm @ kts)	8400/10.0	10000/15.0	10000/13.0	9400/12.5	9400/12.5	8000/8.0
Speed, Max Sustained (kts)	14.9	15.5	16.0	14.8	14 5	15.0
Shaft Horsepower	3000	3000	6000	3000	3000	4200
Propulsion, Main	Diesel-elec	Diesel-elec	4 Diesel	4 diesel-elec	4 diesel-elec	4 diesel
and Screws	1 screw	1 screw	1 screw	2 screws	2 screws	2 screws
	2 engines-	2 engines-	2 engines-	2 engines-	2 engines-	2 engines-
Fuel Consumption (gal/day)	2100 GPD (est)	2000 GPD	3000 GPD	2300 GPD	2300 GPD	2100 GPD (est)
at Normal Cruising Speed	4 engines-	3 engines-	4 engines-	4 engines-	4 engines-	4 engines-
Fuel Consumption (gal/day)	4100 (est)	3400 GPD	4200 GPD	3500-4000 GPD	3500-4000 GPD	4100 GPD (est)
with all Engines		4 engines- 4100 GPD				
Complement	95	85	102 + 20 tran.	85		94 + 16 tran
Bow Thruster9	No	No	Yes	No		Yes

Characteristics	MSC T-ATF (166 Class)	USCG Icebreaker (Polar Class)	USCG Cutter (Reliance Class)
Length (ft)	225	185	210 5
Beam (ft)	42	78	34
Draft (ft)	15	28	10.5
Displacement (Full-Load LT)	2260	6000	1000
Cruising Range (nm @ kts)	10000/13.0	24000/13.5	6100/14.0
Speed, Max Sustained (kts)	15.0	18	18.0
Shaft Horsepower	7200	75000	5000
Propulsion, Main	2 diesel	3 gas turbine	2 diesel
and Screws	2 screws	6 diesel 3 screws	2 screws
Fuel Consumption (gal/day) at Normal Cruising Speed	1 engine- 4149 (est)	3 engines- 1500 GPD 6 engines- 35,600 w/turbines- 130,000	1 engine- 1080 GPD
Fuel Consumption (gal/day) with all Engines	2 engines- 8300 (est)	4 engines- 14,000 GPD	2 engines- 2160 GPD
Complement	20 + 20 tran.	155 + 10 tran.	61
Bow Thruster9	Yes	No	No

These ships are fitted for salvage and towing. They are also equipped with compressed air diving equipment.

Length (ft)	213.5	Shaft Horsepower	3000
Beam (ft)	39 (ARS 6) 43 (ARS 38)	Cruising Range (nm)	9400 @ 12.5 kt
Draft (ft)	13 (ARS 6) 16 (ARS 38)	Fuel Consumption (Gal/day)	2 engines-2300 4 engines-3500 to 4000
Displacement, Full Load (LT)	1750 (ARS 6) 1900 (ARS 38)	Complement	85 crew (ARS 6) 96 crew (ARS 38)
Propulsion, Main	4 diesel-electric, 2 screws	Towing Machine	Almon A Johnson, Inc. automatic towing machine,
Maximum Sustained Speed (kts)	14.8 (ARS 6) 14.5 (ARS 38)		Series 250 "Special" 2-inch wire

FIGURE 2-1. ARS 6/38 Class Salvage Ship.

These ships are designed with modernized salvage and towing capability. They are also equipped with off-ship firefighting improvements.

Length (ft)	255	Fuel Consumption (Gal/day)	2 engines-2100 4 engines-4200
Beam (ft)	52	Complement	94 crew 16 transients
Draft (ft)	17 5		
Displacement, Full Load (LT)	3282	Towing Machine	Almon A. Johnson, Inc. automatic towing machine, Series 322 (double-drum) 2 1/4-inch wire, 3000 ft (will accept 21/2-inch wire) and 14-inch traction winch, Series 400
Propulsion, Main	4 diesel 2 screws		
Maximum Sustained Speed (kts)	15		
Shaft Horsepower	4200	Bow Thruster	1 @ 500 HP
Cruising Range (nm)	8000 @ 8 kt		

FIGURE 2-2. ARS 50 Class Salvage Ship.

These are large tug-type ships equipped with heavy air compressors and rescue chambers for submarine salvage and rescue operations. They are also fitted for helium-oxygen diving equipment.

Length (ft)	251.1	Cruising Range (nm)	8400 @ 10 kt
Beam (ft)	43	Fuel Consumption (Gal/day)	2 engines-2100 4 engines-4100
Draft (ft)	19.5	Complement	95 crew
Displacement, Full Load (LT)	2400	Towing Machine	Almon A. Johnson, Inc. automatic towing machine, Series 260 2-inch wire
Propulsion, Main	diesel-electric, 1 screw		
Maximum Sustained Speed (kts)	14.9		
Shaft Horsepower	3000		

FIGURE 2-3. ASR 7 Class Submarine Rescue Ship

These tugs are designed specifically for salvage operations; they are capable of (1) ocean towing, (2) supporting diver operations, (3) lifting submerged objects weighing as much as 600,000 pounds by static tidal lift or 300,000 pounds by dynamic lift, (4) fighting ship fires, and (5) performing general salvage operations.

Length (ft)	282.7	Cruising Range (nm)	10,000 @ 13 kt
Beam (ft)	50	Fuel Consumption	2 engines-3000 4 engines-4200
Draft (ft)	18.0	Complement	102 crew 20 transients
Displacement, Full Load (LT)	3117		
Propulsion, Main	4 geared diesels, 2 screws	Towing Machine	Stothert & Pitt (Almon A. Johnson, Inc.-licensed), automatic towing machine, 2 drums, 2 1/4-inch wire, 3000 ft. each (will accept 21/2-inch wire)
Maximum Sustained Speed (kts)	16		
Shaft Horsepower	6000	Bow Thruster	1 @ 350 HP

FIGURE 2-4. ATS 1 Class Salvage Tug.

This class of tug has augmented the ATF 76 Class They have a large working space aft for VERTREP (replenishment by helicopter), and they can be readily outfitted for specialized salvage and ocean engineering missions.

Length (ft)	225	Shaft Horsepower	7200
Beam (ft)	42	Cruising Range (nm)	10,000 @ 13 kt
Draft (ft)	15	Fuel Consumption	1 engine-4149 2 engines-8300
Displacement, Full Load (LT)	2260	Complement	17 crew 4 Navy communicators 20 transients
Propulsion, Main	2 diesel, 2 screws Controllable, reversible pitch in Kort nozzles	Towing Machine)	SMATCO 2500 ft. 2 1/4-inch wire winch (15-inch Lake Shore, Inc. traction winch
Maximum Sustained Speed (kts)	15	Bow Thruster	1 @ 300 HP

FIGURE 2-5. T-ATF 166 Class Fleet Tug.

These are large ocean tugs.

Length (ft)	205	Shaft Horsepower	3000
Beam (ft)	38.5	Cruising Range (nm)	10,000 @ 15 kt
Draft (ft)	15.5	Fuel Consumption (Gal/day)	2 engines-2000 3 engines-3400 4 engines-4100
Displacement, Full Load (LT)	1675	Complement	85 crew
Propulsion, Main	diesel-electric, 1 screw	Towing Machine	Almon A Johnson, Inc. automatic towing machine, Series 222 2-inch wire
Maximum Sustained Speed (kts)	15.5		

FIGURE 2-6. ATF 76 Class Fleet Tug.

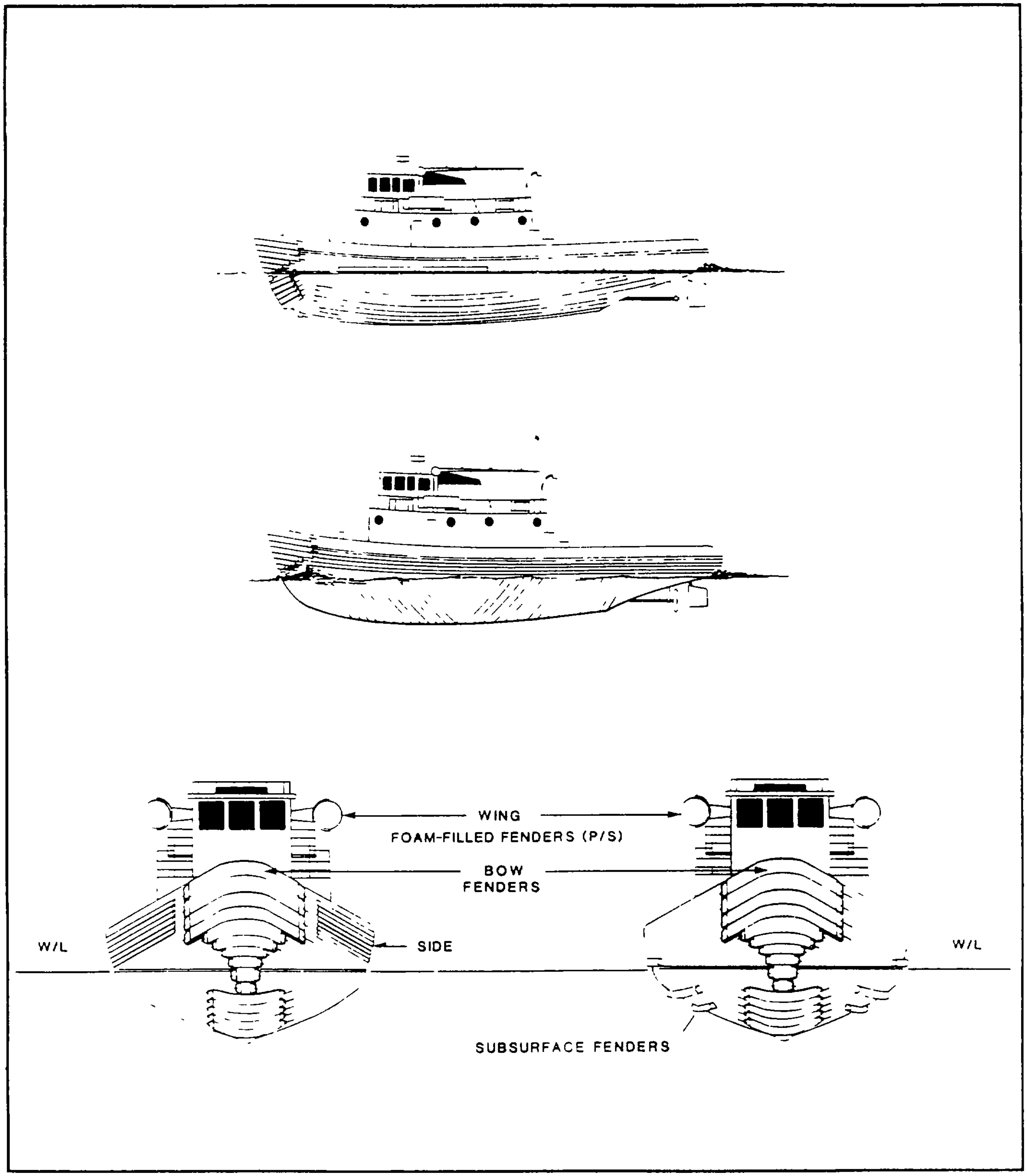


Figure 2-7. Typical Rubber Fenders.

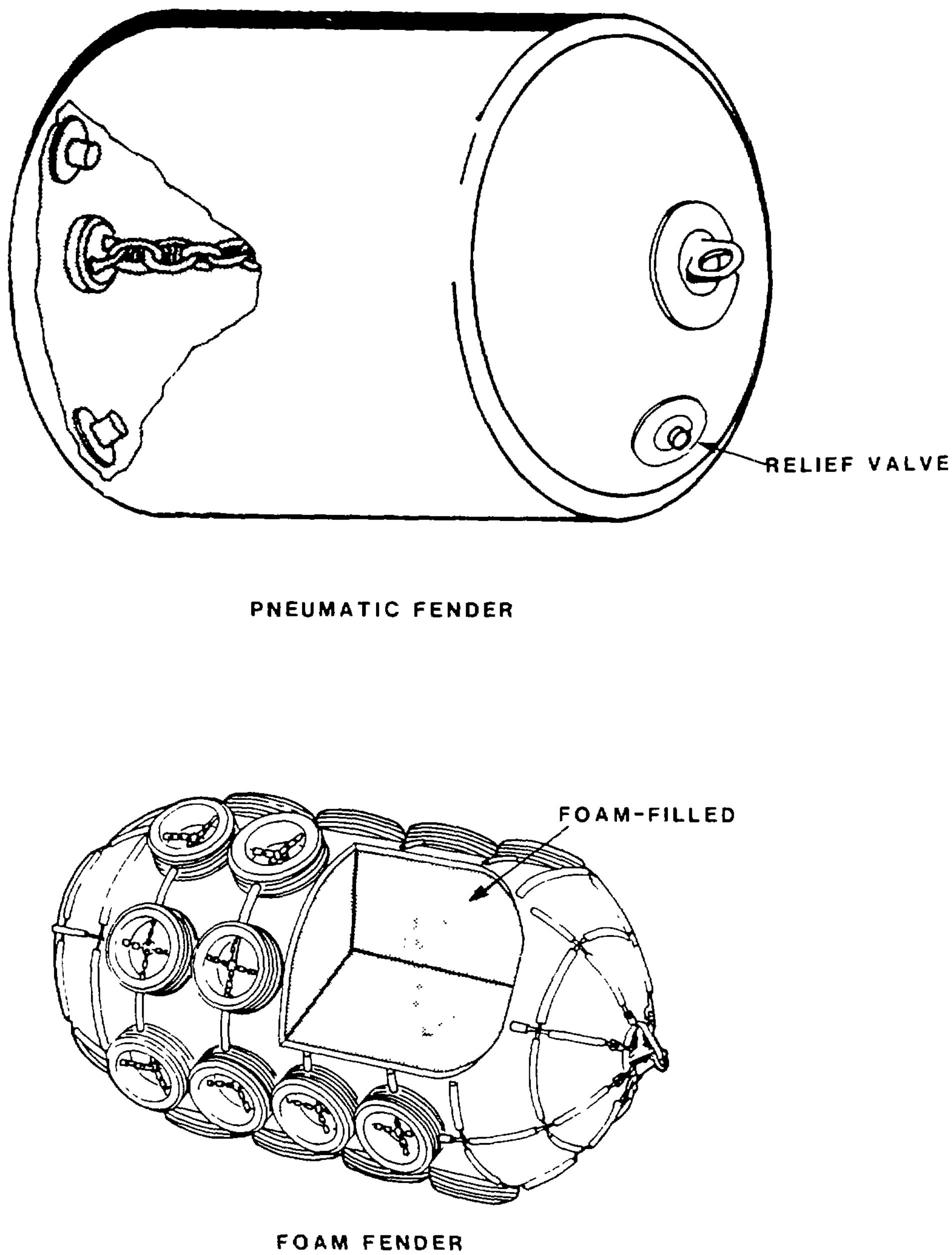


Figure 2-8. Pneumatic and Foam Fenders.

(Text continued from page 2-5)

a. Energy absorption
b. Durability
c. Handling characteristics
d. Ease of storage aboard ship
e. Ease of maintenance when not in use
f. Required support equipment
g. Weight
h. Size
1. Standoff distance
j. End fittings
k. Time required for deployment and recovery
l. Capability of being used if damaged

Low-pressure and high-pressure pneumatic fenders have similar characteristics. However, because they are filled with air they must be larger than foam-filled fenders to absorb the same amount of energy. On the other hand, equal capacity and quality foam-filled fenders will likely be more expensive and heavier than pneumatic fenders.

2-3.4.3 Operating Problems. In addition to the larger size of pneumatic fenders, other attending disadvantages are the extra equipment needed to pressurize them and to check the internal pressure. Patch kits and special slings to support the fender's mid-section when being deployed and retrieved are also necessary for the low-pressure types. All pneumatic fenders have safety valves. When these valves relieve under high fender loads, the fenders lose nearly all their energy absorption capability. There- fore, foam filled fenders are recommended when there is a choice.

One major operating problem, with side fenders especially, arises when either the tug or the tow has a low freeboard relative to the other ship When the heaving or rolling motions of the two ships get out-of-step, the fender can be rolled upward between the two ships and pop out onto the deck of the one with the lower freeboard.

When the freeboards are more nearly equal, the out- of-step motions of the two ships can create a great deal of frictional heating on the surfaces of the fenders. It is often necessary to spray seawater onto the rubbing surfaces to help lubricate them and keep them cool

Care must also be exercised in the fore and aft placement of the fenders to ensure that they do not bear against relatively large areas of side plating that are not well supported by internal framing and longitudinal structural members. This is especially important in quartering seas when swells will cause the two ships to pivot about the bow or stern and then slam the sides together at the other end.

SECTION IV

2-4 TOWLINE CONNECTION

The towline connection between the tug and the tow is a complete system composed of many components. Although the tow hawser has often been considered to be the "towline" or "towline connection, " it rarely is. In reality, it is only one of the components in the complete towing connection system illustrated in Figure 2-9. The towline connection system extends from the attachment point on the towed vessel to the tug's attachment point. It includes the attachment points, the connecting components and end terminations of the ropes, chains and other tension components that make up the various pendants, hawsers, etc. Each of these components is defined and discussed briefly in the following paragraphs and more fully in succeeding sections of this manual.

24.1 ATTACHMENT POINT IN THE TOW. The attachment point on the tow may be a hard point specifically intended for towing, such as a

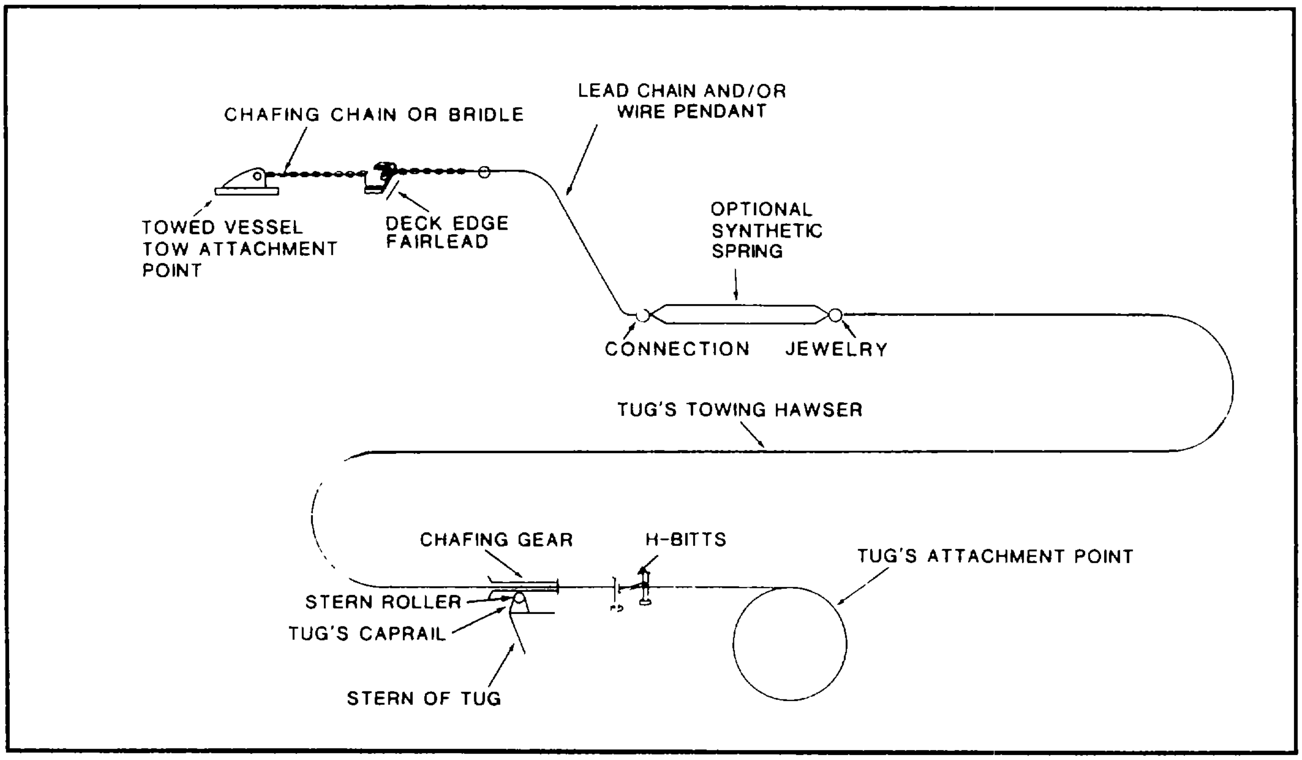


FIGURE 2-9. Typical Towline Connection Components.

deck padeye, chain stopper or specialized towing bracket. Sometimes the attachment will use fittings or gear intended for other purposes, such as SPM fittings, bitts, anchor chain holding fittings or the tow's anchor chain itself. Sometimes, for planned tows, a new attachment point will be installed. At the other extreme, for an emergency tow, a completely ad-hoc connection, such as a heavy chain wrapped around a strong foundation may be used. Each of these attachment methods is discussed more thoroughly in subsequent sections of this manual.

2-4.2 CHOCKS AND FAIRLEADS. Most tows make the towline connection on deck. Exceptions are situations involving towing from the tow's anchor chain through the hawsepipe and craft, usually barges, fitted with deck edge towing padeyes. Whether using a bridle arrangement or a single-point connection, the point at which the towline (or bridle legs) crosses the deck edge requires careful attention to protect the towline as well as the towed ship's structure. These points must be robust and include a generous radius. They include bullnoses, closed chocks and roller chocks. See Figure 2-10. Planned tows often will involve installation of a special fair- lead, because the radii of chocks and other fittings designed for mooring are much less than desirable for towing. Emergency tows generally must make do with whatever is available, remembering that extra towline chafing and structural damage to the tow are probable. In this case, the towline component crossing the deck edge will usually be a chain, heavier in size then otherwise would be required for strength alone.

2-4.3 CONNECTING HARDWARE OR JEWELRY. These items include shackles, plate shackles, joining links, detachable links, bridle flounder plates and specially-sized and arranged lengths of chain. This hardware is

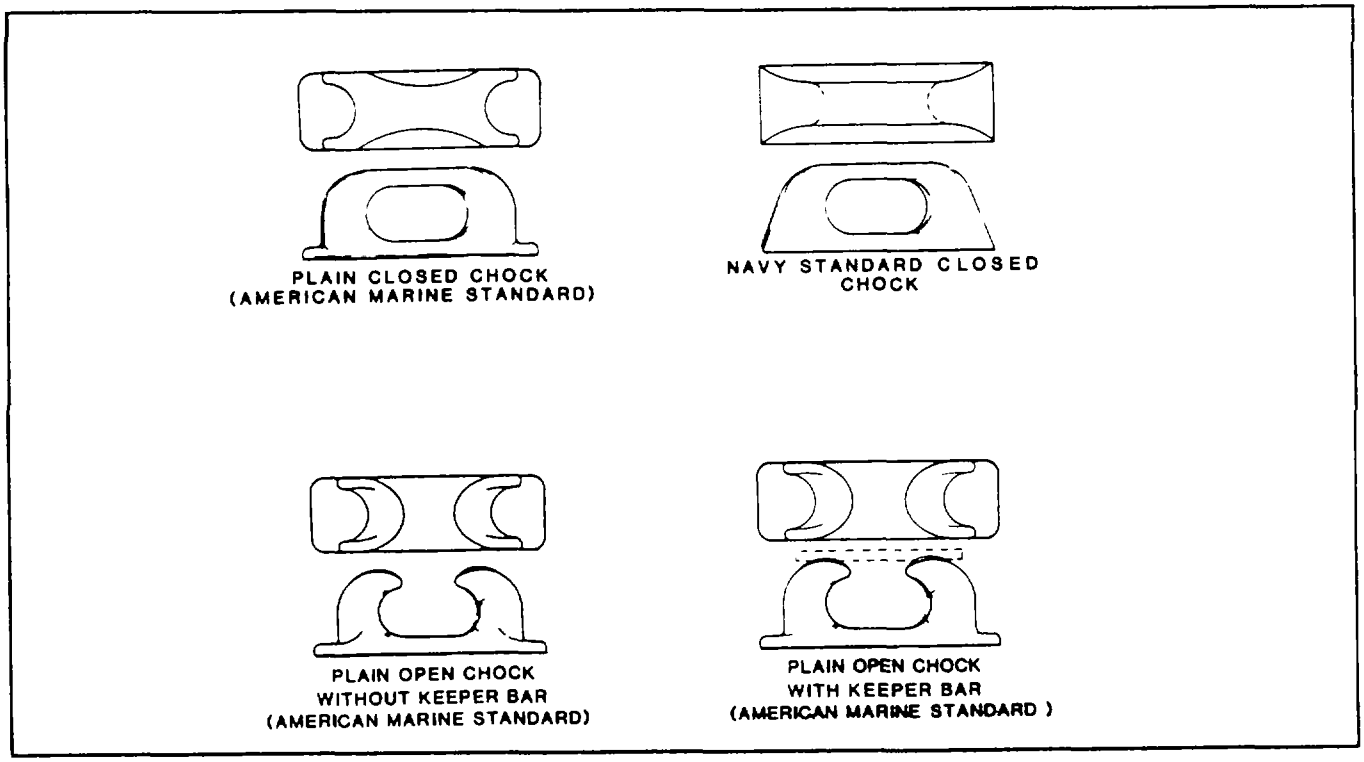


FIGURE 2-10. Types of Chocks.

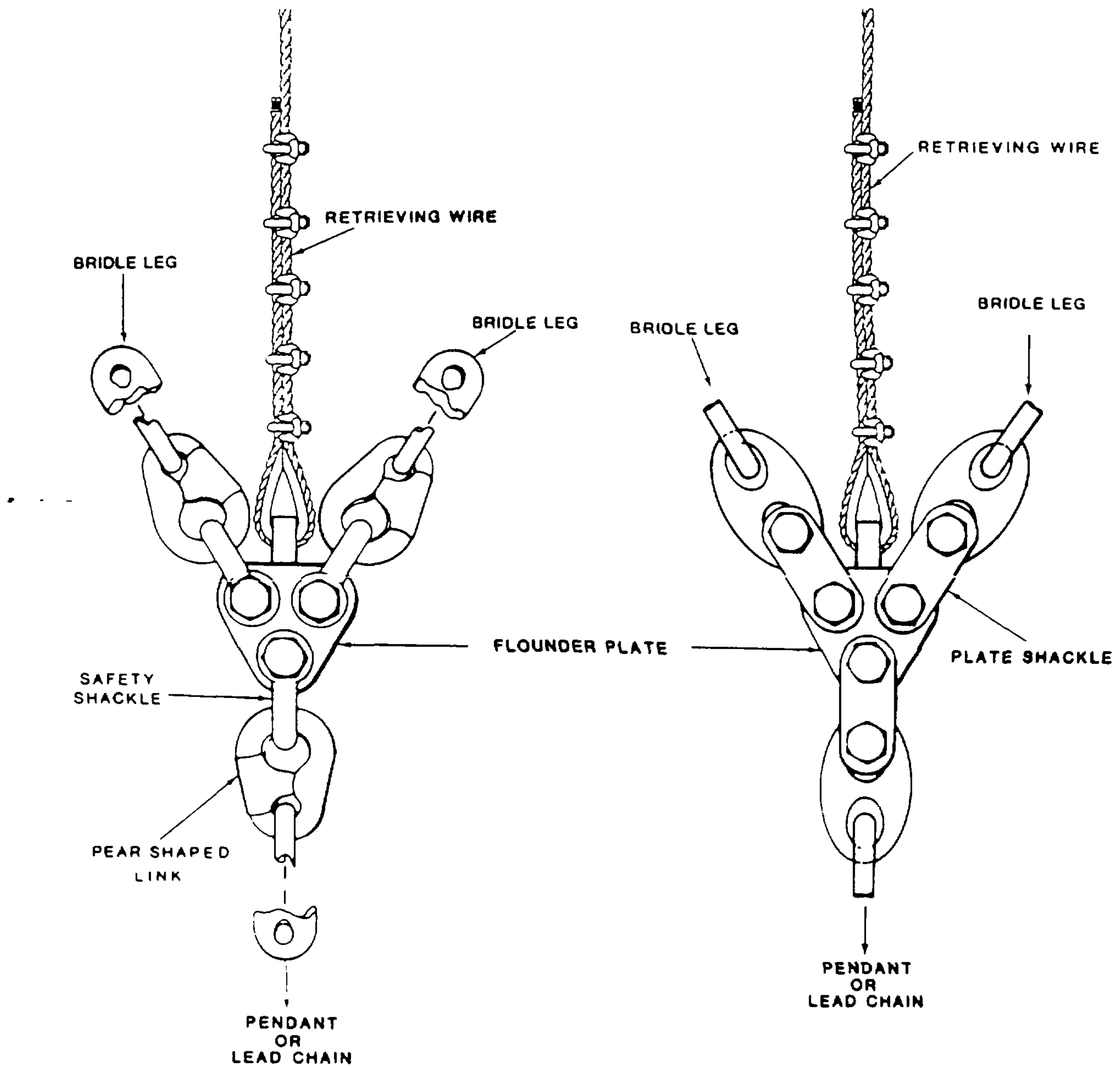
used to connect the various portions of the towline system to each other and to the tow.

2-4.4 BRIDLES, CHAFING CHAIN AND PENDANTS. The towline component located at the tow's deck edge usually is a chain, because of its superior resistance to chafing. It may be in the form of either a single element or a two-legged bridle. See Figure 2-11. Sometimes a heavy wire is used for short tows or emergency situations, but special care is required to minimize chafing of the wire and damage to the structure from the wire's extremely hard material. If the hard point is a considerable distance from the fairlead, a fairly short length of chain, sufficient to ride in the fairlead, may be used to save weight and sometimes to simplify the final connection to the tow, such as when using bitts as the hard point.

2-4.5 LEAD CHAIN AND WIRE PENDANT. A lead chain or wire pendant usually is inserted out-board of the chafing chain or chafing pendant. In the case of a lead chain, it may be the same size as, or simply an extension of, the chafing chain. A chain extending forward from the apex of a towing bridle also is a lead chain. The purpose of the lead chain is to add weight to the end of the towline system. This improves the spring in the system by increasing the towline's catenary. Sometimes the chafing/lead chain is the tow's anchor chain, which can be veered to the desired total length.

A wire pendant often is used in addition to, or in lieu of, the lead chain. It sometimes is called a "towing pendant." Its purpose is to facilitate the final connection between the towing ship's hawser and the chafing, or lead chain. The pendant may be up to 300 feet long to permit connection/disconnection on board the tug, while maintaining a safe standoff under heavy weather conditions.

2-4.6 SYNTHETIC SPRING. A synthetic spring sometimes is inserted between the towing pendant and the towing ship's hawser for dynamic load mitigation. Most frequently seen in commercial towing, the spring usually is



NOTE

SEE APPENDIX I FOR ADDITIONAL EXAMPLES OF BRIDLE AND SIZES OF COMPONENTS

FIGURE 2-11. Chain Bridles Using Plate Shackles and Safety Shackles.

a length of synthetic fiber rope, spliced together, arranged into a grommet. See Figure 5-14 and Paragraph 5-5.2.4.

2-4.7 TOW HAWSER. The tow hawser is the primary tensile element of the towline. The tow hawser normally is a wire rope, however, in an emergency, a synthetic towline may be used. At both the tow end and tug end, if the towing vessel does not have a towing machine or winch, the hawser is equipped with an end fitting such as a socket, thimble or spliced eye. When the tow hawser is part of a tug's equipment, it is stowed on the drum of the towing machine, or in the case of synthetic line, in a bin below deck. When the tow hawser is part of the towed vessel's equipment, it may be stowed on a storage drum, reel or brackets, or faked down in a tub, ready for use.

2-4.8 TUG STERN ARRANGEMENT. The stern of a tug is designed to minimize chafing of, and damage to, the tug structure from the hawser. Caprail radius is generous and free from unintended obstructions to the hawser's sweep from side to side as the tug maneuvers in restricted waters. While towing under steady-state conditions at sea, most tugs have a system to restrain the tow hawser sweep, such as vertical stern rollers or Norman pins. In any case, chafing gear usually is used to reduce wear on both the hawser and the tug's structure. Hawser wear also is minimized by frequent short adjustments in scope to spread the stress point along a length of the hawser.

2-4.9 ATTACHMENT POINTS ON THE TUG. The towline attachment point on U.S. Navy tugs is the towing machine or traction winch. For wire hawsers, the winch attachment point also serves for hawser storage. The traction machine pays out, retrieves and holds the hawser, while storage is provided by a separate bin or storeroom. Some older and/or smaller tugs do not have towing machinery described above and may secure the hawser to a towing hook, padeye or bitts

All U S. Navy towing ships have H-bitts which serve two purposes. They serve to fairlead the hawser to towing machinery and can serve as an anchor point for holding the hawser with a stopper when required. Use of the H-bitts for holding the hawser is not frequent and is usually restricted to de-beaching operations or isolating the towing machinery from hawser tension

2-4.10 RETRIEVAL PENDANT. As shown in Figure 2-11, the retrieval pendant is a wire rope led from the deck of the tow to the end of the pendant or flounder plate, to facilitate bringing the tow gear back onto the foredeck of the tow so it will not drag the seafloor or foul the ship's appendages when the tow is disconnected. The retrieval pendant often is handled on the deck of the tow by a hand-powered winch; it must be capable of being handled by the riding crew or by a boarding party put aboard the tow. The wire's strength must be sufficient to lift the flounder plate, bridle and/or pendant, it is not intended to be exposed to towing loads.

24.11 SECONDARY TOWLINE. A secondary or emergency towline is often rigged, especially if the tow has great value or is carrying hazardous cargo. See Figure 2-12. The secondary towline is intended for emergency, short-term use. It may be of lesser strength than the primary towline, and is often made up with synthetic rope. Rigging methods will vary depending on whether the tow is manned or unmanned. The secondary system usually is faked down on deck, rigged with a heavy messenger led outboard of the ship's structure, terminated by a lighter floating pendant with a marker buoy trailing astern of the tow. The entire system is rigged so that the tug merely recovers the trailing messenger and heaves the outboard end of the secondary towline aboard the tug for connection to the tug's hawser.

In all cases, the secondary towline will be already connected to an appropriate hard point on the tow and provided with necessary chafing protection.

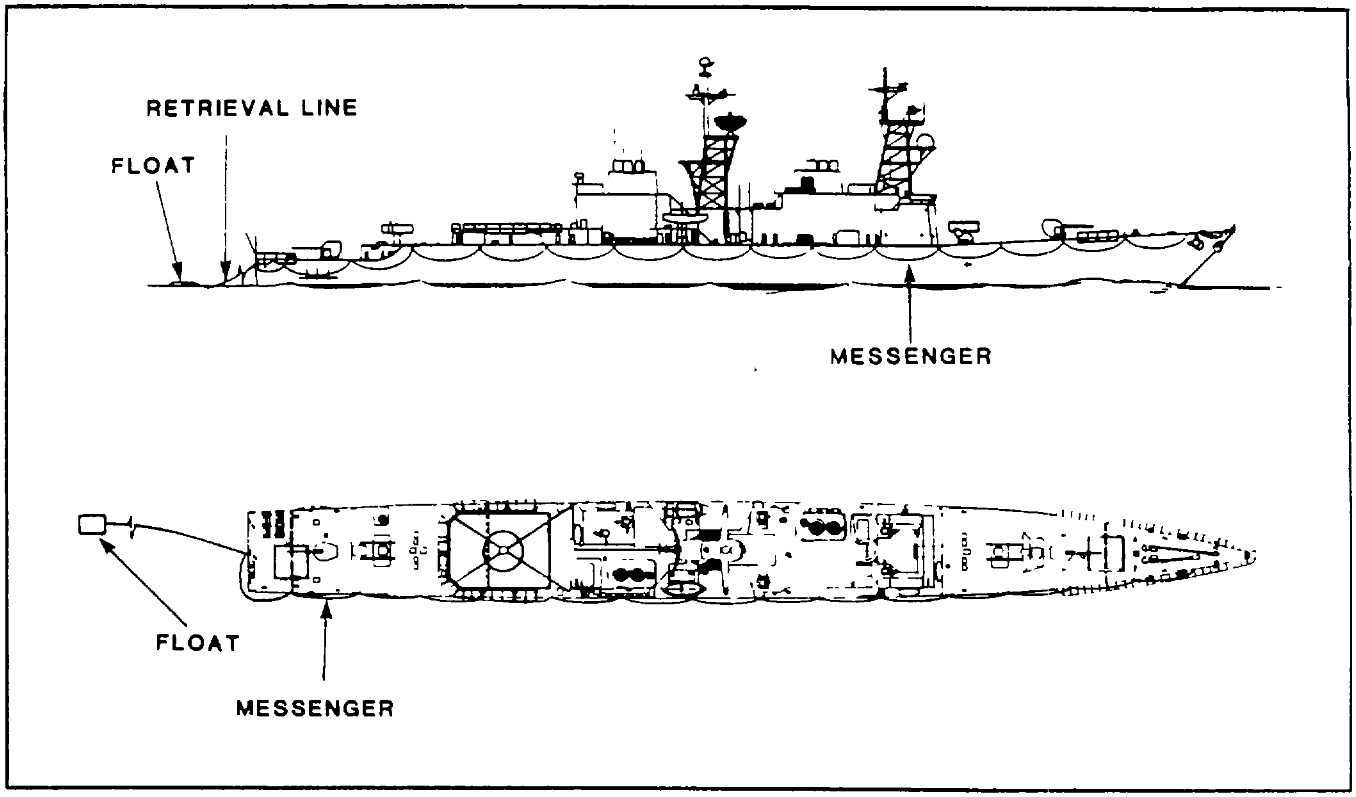


FIGURE 2-12. Secondary Towline System.

2-5 ARRANGEMENTS FOR TOW

Towing rigs can be made up in various configurations. See Figures 2-13 and 2-14 for the two principal types. Although most Navy tows are simple, single-tug, single-unit operations, some tows are considerably more complex, consisting of a single tug with multiple towed units. Occasionally the displacement of the towed unit is such that it requires utilization of more than one tug. The use of tugs and their connection to the tows vary

2-5.1 SINGLE TUG, SINGLE TOW. There are three common variations of this configuration: the single hawser with pendant, single hawser with bridle and towing alongside. The latter is used only in protected waters. A fourth variation, pushing in the notch, is also a recognized method, but is not used by the Navy.

a. Pendant or Single Leg Rig. The pendant rig is the simplest and most straightforward rig and generally is used for open ocean towing of ships with fine bows, sonar domes, bulbous bows or when the tow is most stable in this configuration. All of the components are linked in a series. A distinguishing element of the pendant rig is the deployment of a single chafing pendant to a single attachment point on the towed vessel. The pendant rig is usually used for emergency towing. Outboard of the tow's fairlead, the chafing pendant usually is connected via a reaching chain and/or a towing pendant to the tug's hawser. The advantage of the pendant rig is its ease of connection. There is little, if any, likelihood of the pendant fouling on the cutwater or outer outboard structure

b. Bridle Rig. The bridle rig is characterized by a two-legged bridle instead of the single pendant on the towed vessel. The length of each bridle leg should be approximately

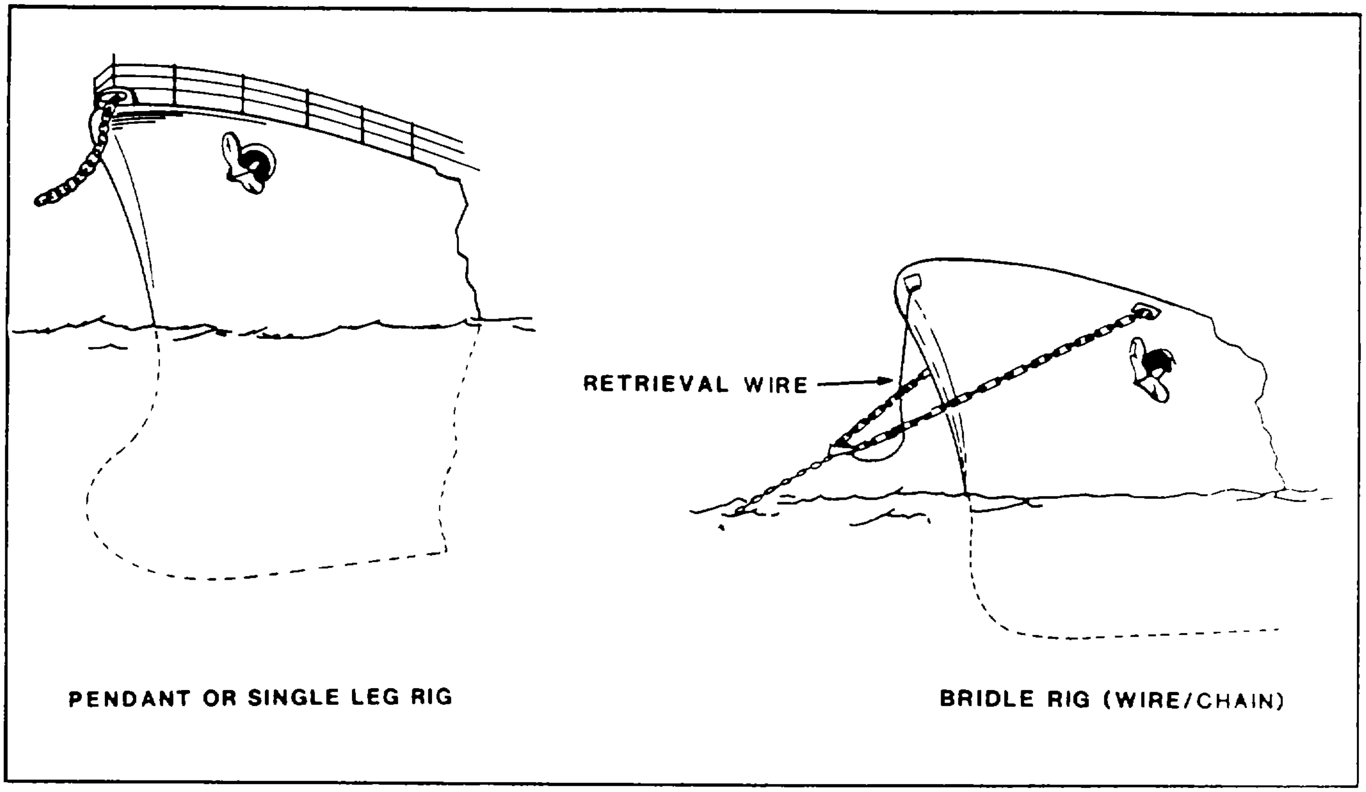


FIGURE 2-13. Towing Rigs.

equal to the beam of the towed vessel. The fitting at the apex usually is a flounder plate with the two bridle legs connected at its base and the apex usually connected to the lead chain and/or towing pendant, which in turn is connected to the tow hawser The bridle rig places more and heavier rigging outboard of the towed vessel than does the pendant rig. This can lead to rigging problems on the deck of the tow. Furthermore, the bridle rig, by definition, uses two off-centerline fairleads. As a consequence, if the tow does not track the tug directly astern, there may be an off-center dynamic load This load, while tending to be self-correcting, unbalances the loads on each bridle leg. Therefore, each bridle leg must be of full towline strength. Finally, a critical problem of the bridle rig occurs when turning, or when the tow sheers off to the side of the tug's track, and the bridle leg on the far side can ride against the cutwater of the tow, causing damage to Itself as well as to the tow In many cases, the foredeck arrangement, hydrodynamic characteristics or need to tow the vessel backwards does not permit the use of a bridle rig. For example, aircraft carriers and LSTs have forecastle arrangements that require using a pendant rig. Ships with large bulbous bows or sonar domes tow more favorably on a pendant rig, and a damaged ship may require towing it stern first. Bridle rigs are commonly used on ships with blunt bows, such as barges.

c. Towing Alongside. Towing alongside or "towing on the hip" is illustrated in Figure 2-15. In congested waters, towing alongside offers excellent control, however, it is not recommended for the open ocean because of motion between the tug and tow in a seaway. When complex maneuvering is required, consider having harbor tugs to do the job or assist during difficult phases of the maneuvers.

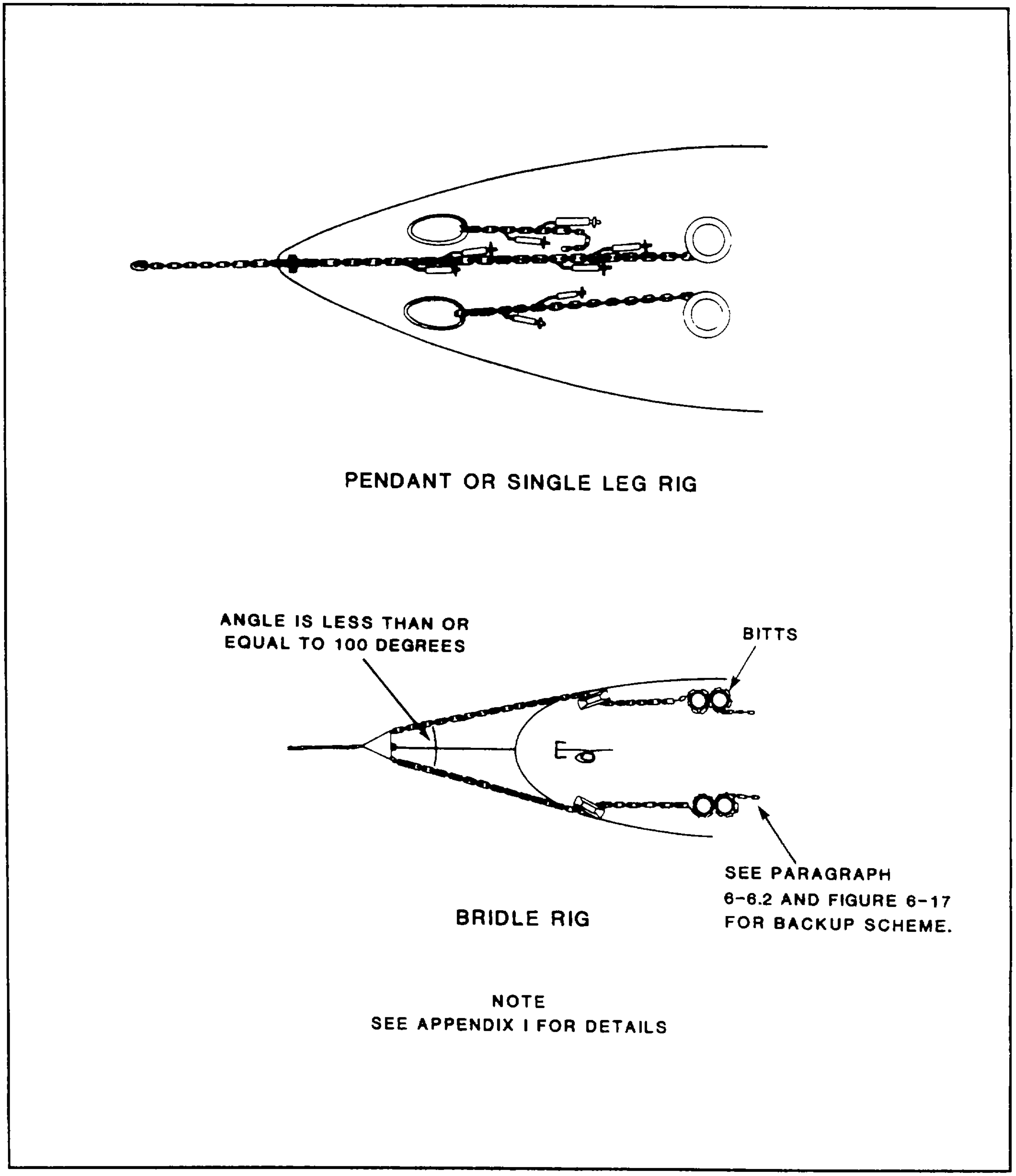


FIGURE 2-14. Towing Rigs (Plan View).

FIGURE 2-15. Towing Alongside.

For towing alongside, the tug generally secures to one side of the tow with her own stern well aft of the stern of the tow to increase the control effectiveness of her propellers and rudder.

CAUTION

When towing alongside, keep all lines taut until ready for streaming the tow. This will prevent the tow from pounding alongside the tug and ensure effective control of the tow.

2-5.2 SINGLE TUG, MULTIPLE UNIT TOW. Single tug, multiple unit tows consist of one tug and several tows; the connection and makeup of the tows can be varied. In current U.S. Navy practice four versions are used. The Christmas Tree rig and the Honolulu rig are used for open-ocean towing. The Tandem rig, when the tows are close-coupled, usually is used only in congested waters where good control is required The fourth type, the Nested rig, is restricted to protected waters.

a. Christmas Tree Rig. The Christmas Tree rig requires a review of water depths and bottom conditions prior to its use. The catenary of the towline from tug to first tow and subsequent connecting wires must be deep enough to ensure that the undesired passes safely below the bow of the leading tow(s) It is important to have adequate water depth to prevent grounding the towline. With the assistance of harbor tugs, it is feasible to break out one of the tows without disrupting the remainder.

Harbor tug assistance usually is required to break up the Christmas Tree rig before entering port. Although a strong rig, it is difficult to make up and disconnect and does not facilitate getting all elements in step Figure 3-16 illustrates this rig.

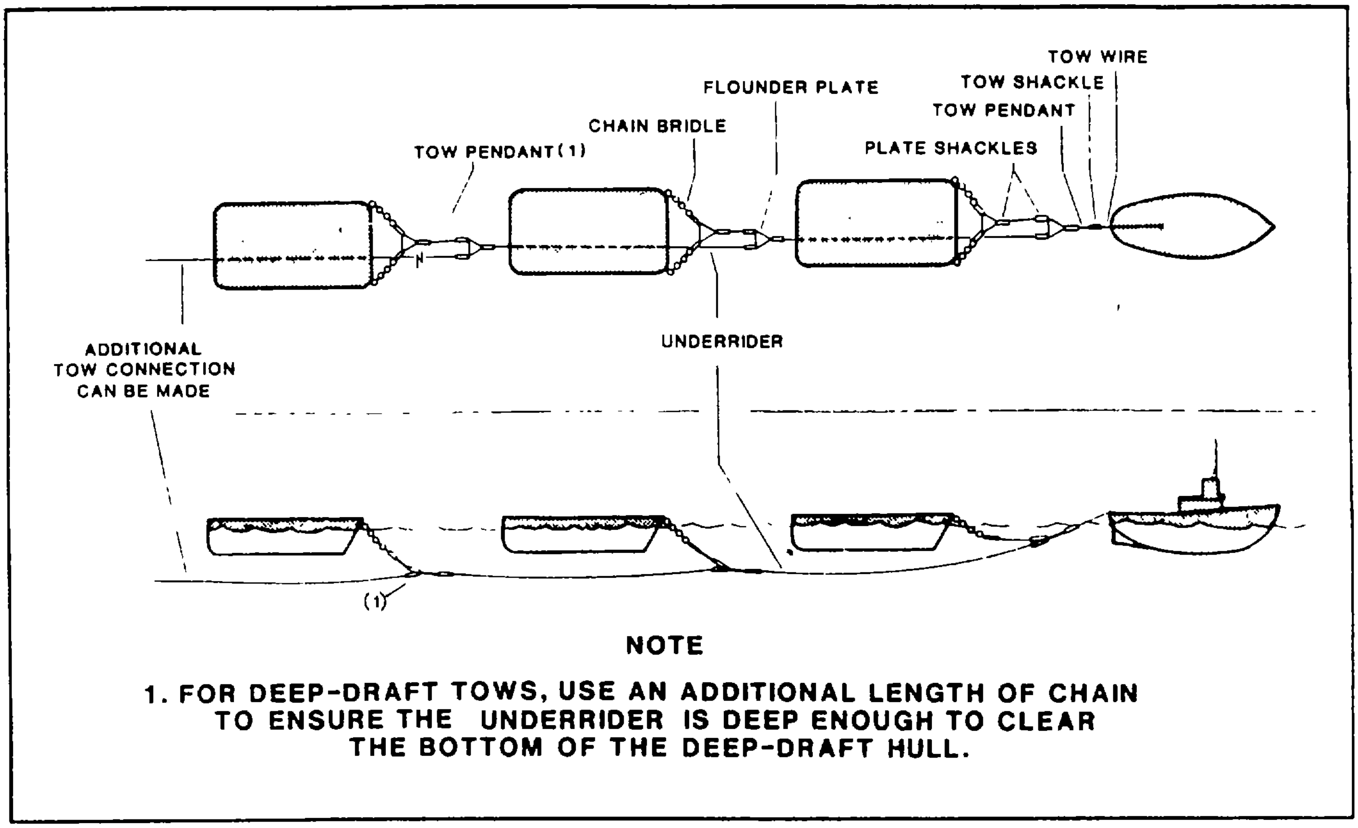


FIGURE 2-16. Christmas Tree Rig.

b. Honolulu Rig. The Honolulu rig was developed for inter-island towing, where individual units of multiple tows were delivered to or picked up from different ports. The first tow streamed is connected to the main tow wire and streamed farthest aft. Additional tows are connected with auxiliary tow wires to quarter bitts or auxiliary drums. The Honolulu rig allows independent connection of the two tows, disconnecting and control are readily workable, and it is relatively uncomplicated to get both tows in step with the tug Figure 2-17 depicts the Honolulu rig.

c. Tandem Rig. The Tandem rig, shown in Figure 2-18, connects the tug to the first tow. The first tow is connected to the second, and so on, as additional tows are added. The intermediate towline, connecting the first tow to the second, must allow a proper catenary depth so that surging action is minimized between tug and first tow and between first and second tow In this type of rig, it is difficult to keep all elements in step. This is the least desirable of the single tug/multiple tow arrangements as it lacks the flexibility and control of the Christmas Tree or Honolulu rigs for break-up upon entering port.

d. Nested Rig. A Nested rig tow employs multiple tows secured alongside each other so that they may be towed as a single unit This rig is to be used only in protected waters. See Figure 2-19.

2-5.3 MULTIPLE TUGS, SINGLE TOW. It may be desirable to use more than one tug for a single tow. Greater power, increased towing speed and better control may be obtained in a multiple tug tow. This method is generally used to tow large ships, deepdraft large-displacement dry-docks, deep-draft barges or battle casualties.

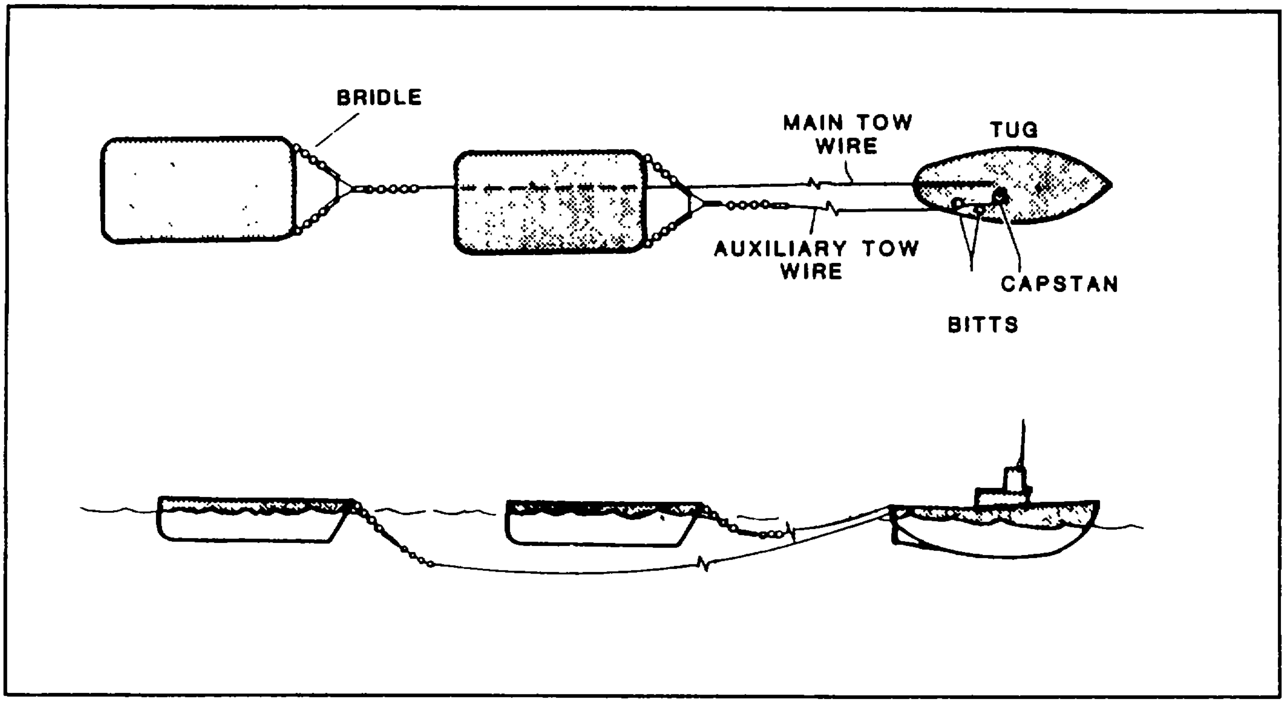


Figure 2-17. Honolulu Rig.

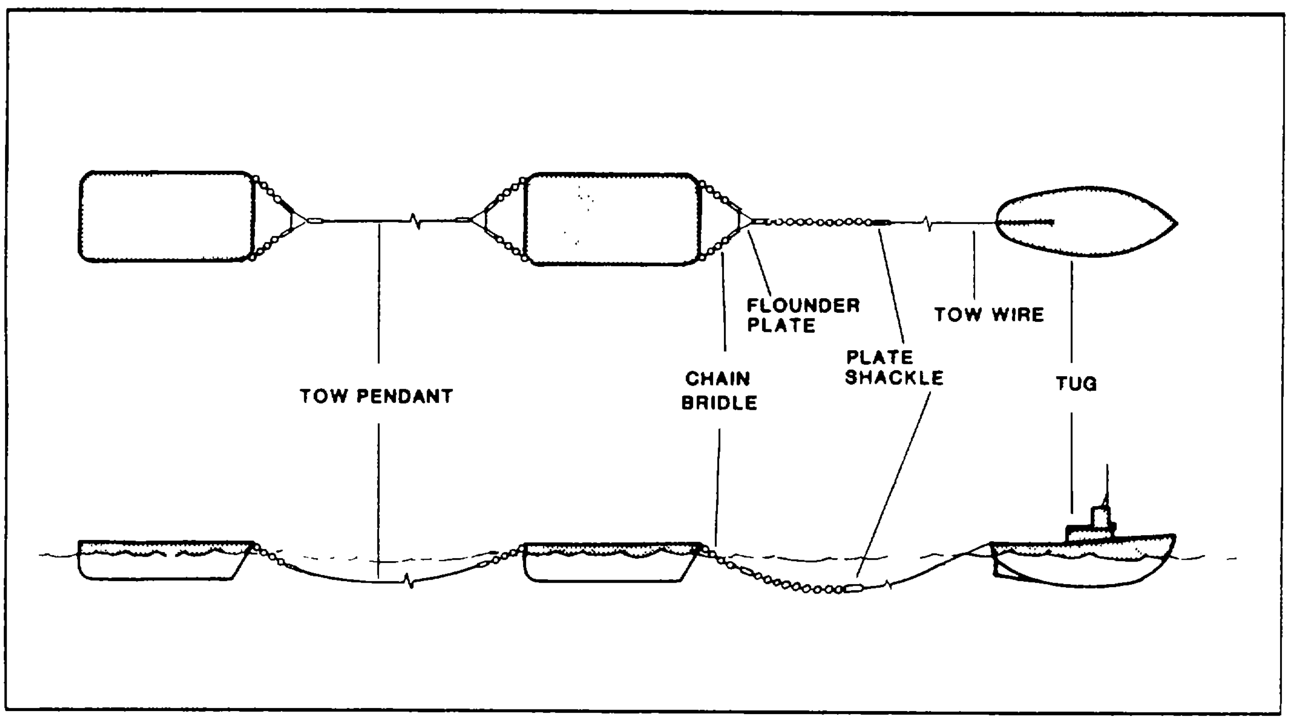


FIGURE 2-18. Tandem Rig.

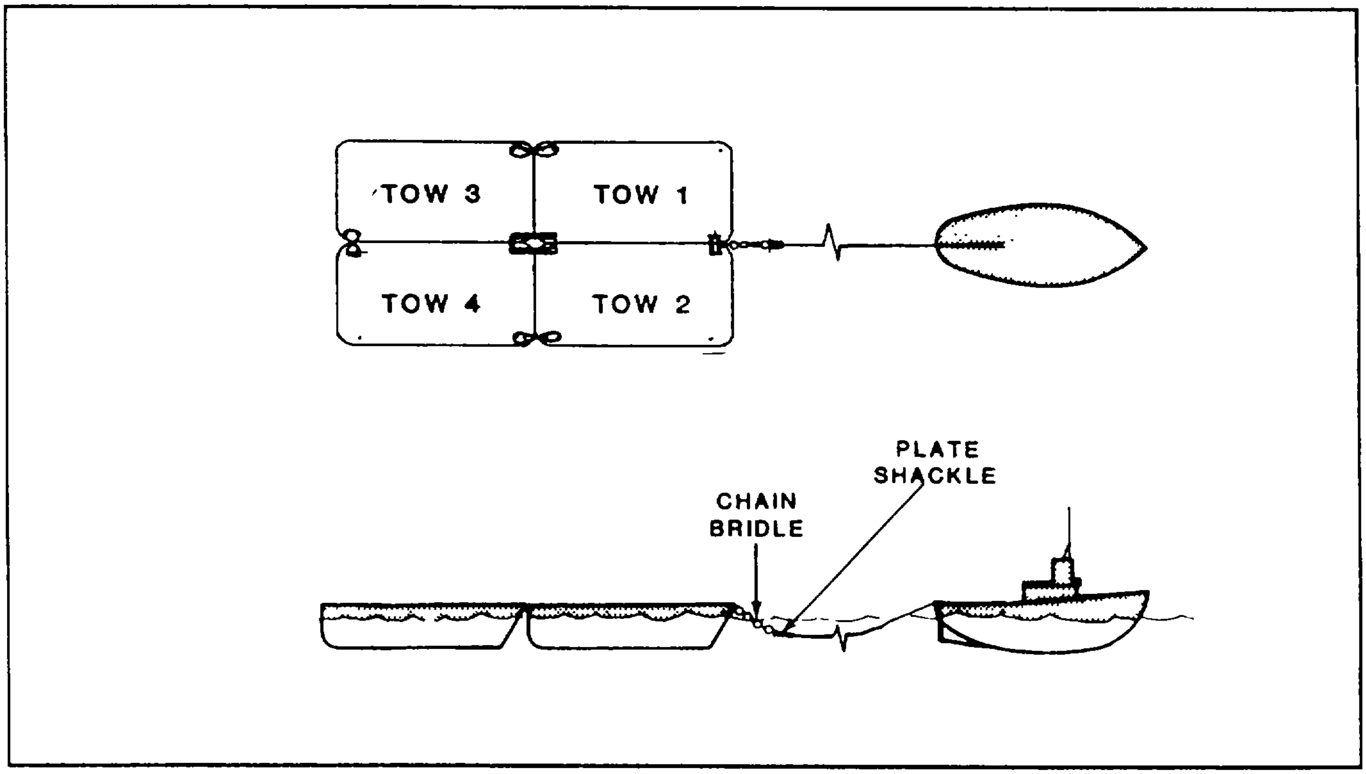


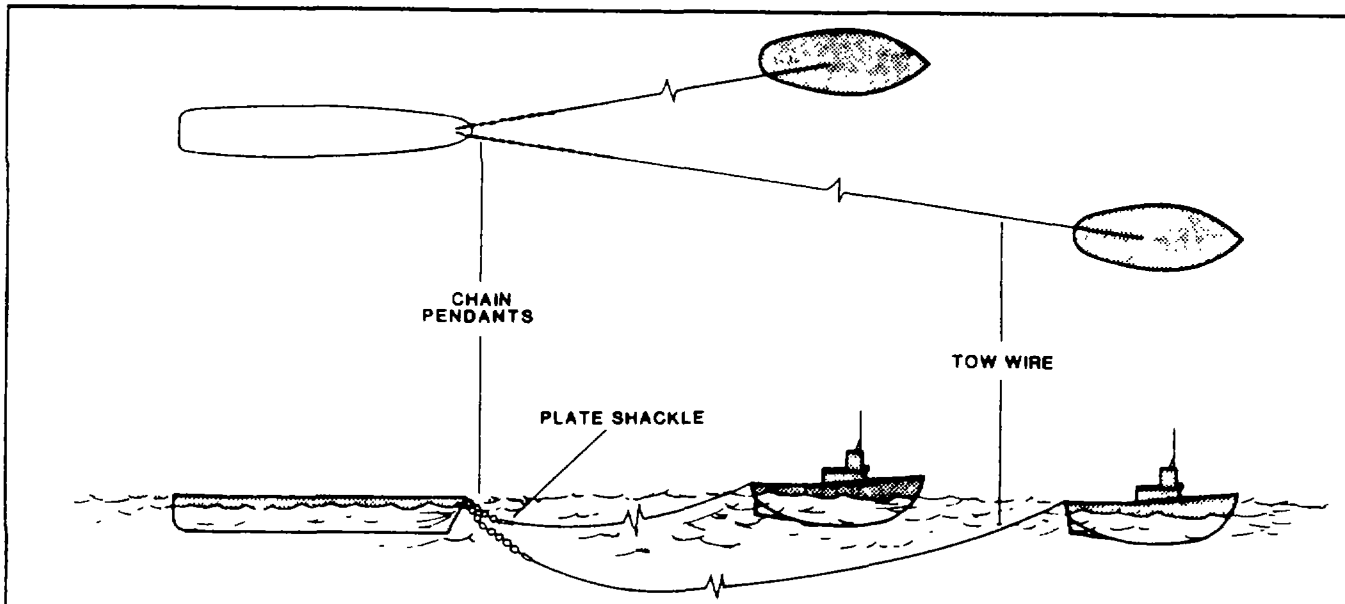
FIGURE 2-19. Nested Rig in Protected Waters.

a. Side-by side. Figure 2-20 shows side-by-side tugs towing a single tow. Each towline should have its own connector and chafing fairlead. There is no universally preferred method of two tug towline arrangement. Most operators prefer to tow "side-by-side," with equal hawser scopes; this avoids the risk of sweeping over the other's towline. A few operators prefer different scopes to minimize the risk of tug collision. In such cases, the more powerful tug is designated lead tug, with a longer hawser scope. The lead tug may use a longer lead chain to increase the catenary depth. This reduces the chance of interference, should the following tug suffer some untoward event that results in its crossing the lead tug's towline

b. Stern Steering Tug. At times when a tug has a tow at short scope in restricted waters, steering assistance is needed. This assistance can be provided by another tug, astern of the tow. Usually, the steering tug's main effect is to restrain the movement of the tow, primarily in yaw. Use of U.S. Navy towing ships for this function is rare and normally restricted to harbor tugs. Use of steering tugs varies widely, depending upon local practice, tug design and pilot preference. No attempt is made herein to provide information on steering tug connections.

2-5.4 MANAGEMENT OF TOW LOADS.

Management of tow loads involves design of the towing system before commencing the tow, adjustment of the hawser scope during the tow and modification of course and speed to reduce dynamic effects of wind and sea conditions. Each of these functions is discussed in detail in Chapter 5.



NOTE

THE SIDE-BY-SIDE TOWING ARRANGEMENT SHOWN HERE, WITH THE TUGS TOWING ON UNEQUAL TOWLINE SCOPES, IS NOT NECESSARILY PREFERRED OVER AN ARRANGEMENT WHERE THE TUGS USE EQUAL TOWLINE SCOPES. SEE PARAGRAPH 3-5.3.

FIGURE 2-20. Two-Tug Tows.

SECTION V

2-5.5 TOWLINE ATTACHMENT.

2-5.5.1 Basic Tow Attachment Points. The means of attaching the towline connecting system on board the tow is of vital importance, and must be given careful consideration from the standpoints of both seamanship/rigging and basic engineering mechanics. If the deck fittings on the tow are there for the specific purpose of towing, operators may assume that the appropriate engineering was performed. However, in every case, the material condition of the fittings and structures should be carefully inspected. Some commercial ship designs do not provide for being towed, or the tow attachment is located somewhere other than originally designed. In this case, the activity preparing the tow must arrange for engineering assistance to ensure a safe connection. The most important point to consider in such a situation is the need for an integrated attachment point and fairlead system. The fairlead serves to do just as its name implies-to lead the towline fair to the attachment point. Pay attention to both the attachment point and the fairlead. Chafing is a frequent cause of towline failure. Another common failure of the attachment system involves gross structural failure of either the attachment point or fair-lead. This problem is especially relevant when towing mine craft, vessels constructed of wood, aluminum or fiberglass and non-oceangoing craft.

The most frequent means of attaching a towline is by means of a padeye. Three distinct types of devices collectively are referred to as padeyes. Personnel rigging the connection must understand design features. The three types of padeyes found in towing are as follows

a. Horizontal padeye

b. Vertical, free-standing padeye

c. Towing bracket.

2-5.5.2 Horizontal Padeye. Figure 2-21 shows two different styles of horizontal padeyes. Their distinctive feature is that the pin held in the eye of the horizontal padeye has a vertical axis. Therefore, the towline is free to sweep in the horizontal plane. Motion of the towline in the vertical plane at the horizontal padeye should be prevented. Two types of horizontal padeyes in use today are described below:

a As shown in Figure 2-21, the integral-pin type comes with its own pin, the female threads for which are in the base plate of the padeye. A locking device prevents pin rotation. An advantage of this style padeye is that it has a lower profile, so the moment arm of the towing load is correspondingly lower to the deck. This allows for lower loading moments and eases the design of the structure. Additionally, the integral-pin padeye facilitates pinning an open or end link of a chafing chain directly to the padeye, requiring no additional connection jewelry.

b The shackle-style padeye is found on the forecastle of most Navy vessels, where it is the standard fitting for attaching chain stoppers to the forecastle deck. See Figure 2-22 for a U.S. Navy chain stopper. When used with low-profile padeyes (depicted in Figure 2-21), often there is insufficient space to accommodate the bolt of a safety shackle. Navy chain stoppers are therefore provided with a specially-forged, screw-pin shackle with carefully-controlled threads and other dimensions. This is one of the rare cases where use of screw-pin shackles is appropriate in towing. Chain stoppers and padeyes are designed for only 60 percent of the anchor chain's breaking strength. This must be considered when using them.

2-5.5.3 Vertical Free-Standing Padeye. The vertical free-standing padeye comes in two basic designs as shown in Figure 2-23. The difference is in the shape of the eyehole itself. This depends on whether the padeye is intended to accept the pin of a connecting shackle. The eye of a shackle-pin type padeye is a cylindrical hole through the plate In the dipped- shackle style, the hole is elongated and the bearing area of the hole is rounded so that the bow of the shackle can properly bear against the end of the slot In this case, the shackle's pin is presented to the chafing pendant.

Either style of vertical free-standing padeye is less resistant to lateral loads than the horizontal padeye. Except for a bridle tow, the free-standing padeye must be used with a towing fairlead strong enough to withstand the breaking strength of the towline, to minimize the risk of tripping the padeye.

The width of the shackle-pin type padeye plate should occupy 75 to 80 percent of the jaw width of the shackle, to prevent it from racking and creating loads which tend to open the jaw of the shackle.

The vertical free-standing padeye may have a higher attachment point than the horizontal padeye. This makes for larger loading moments on the structure itself and on the attachment system to the ship deck or frame structure. This in itself is not a disadvantage, so long as the design is proper and those who rig the system understand it.

2-5.5.4 Towing Bracket. The Smit Towing Bracket is shown in Figure 2-24. The bracket consists of two vertical plates, similar to a pair of free-standing padeyes, with an elliptical pin fitted between them. The pin is fitted with a keeper key or locking pin, and can be released in an emergency. The principal advantage of the Smit Towing Bracket is the ease of breaking the tow connection, even under significant load. This is accomplished by removing the locking pin and driving the striking bar

(Text continued on page 2-33)

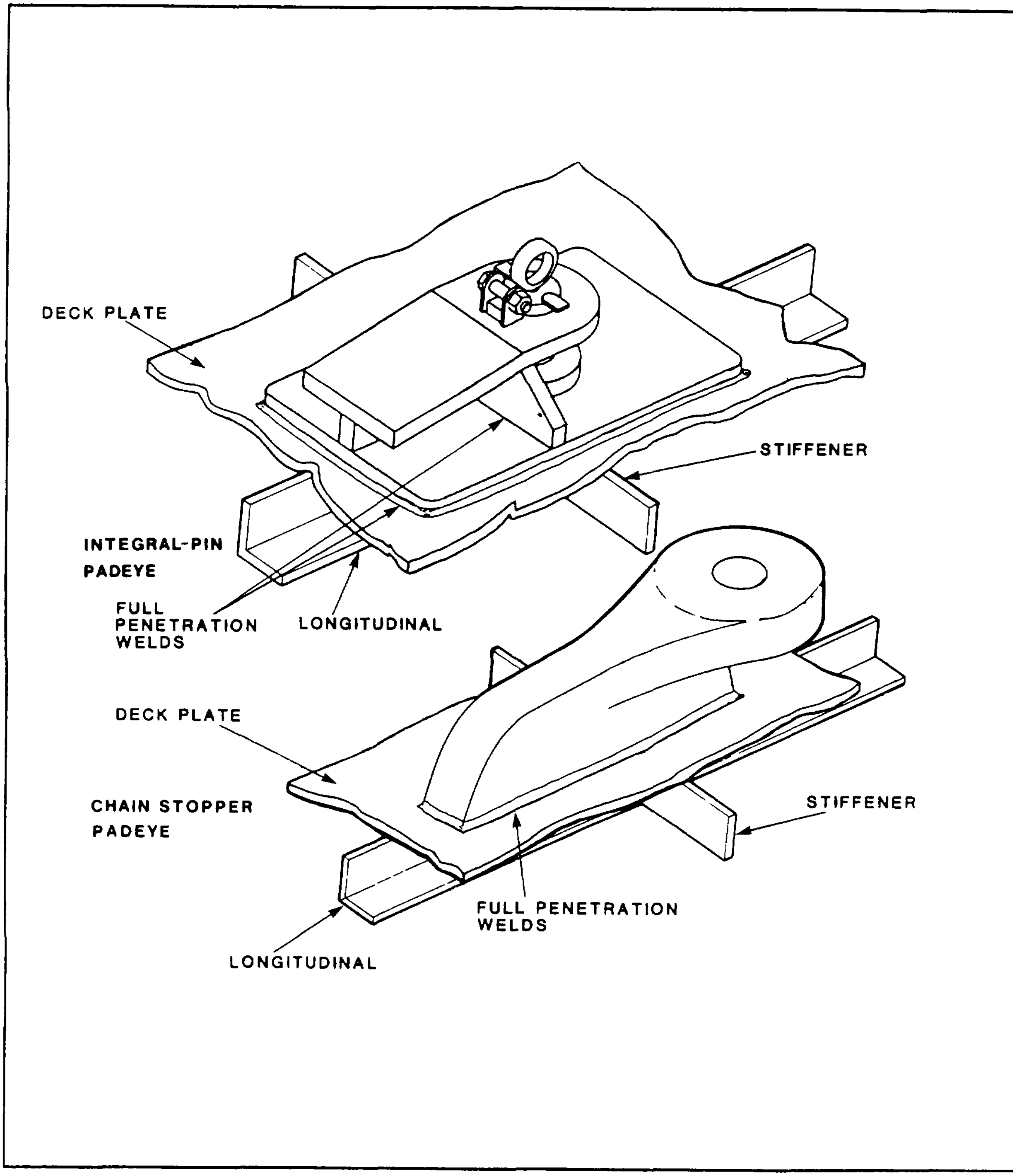
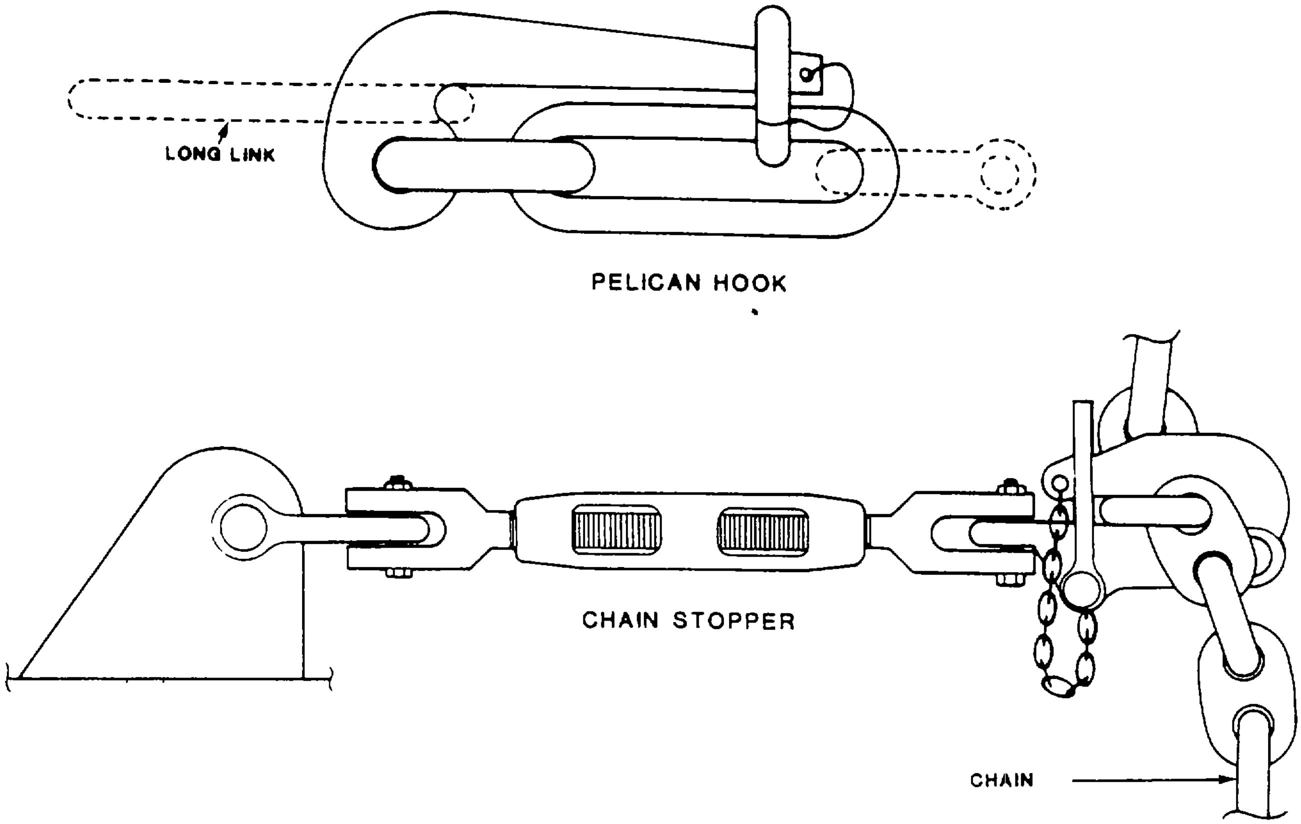


FIGURE 2-21. Horizontal Padeyes.



WARNING

DO NOT CONFUSE PELICAN HOOK WITH CHAIN STOPPER.

FIGURE 2-22. Pelican Hook and Chain Stopper.

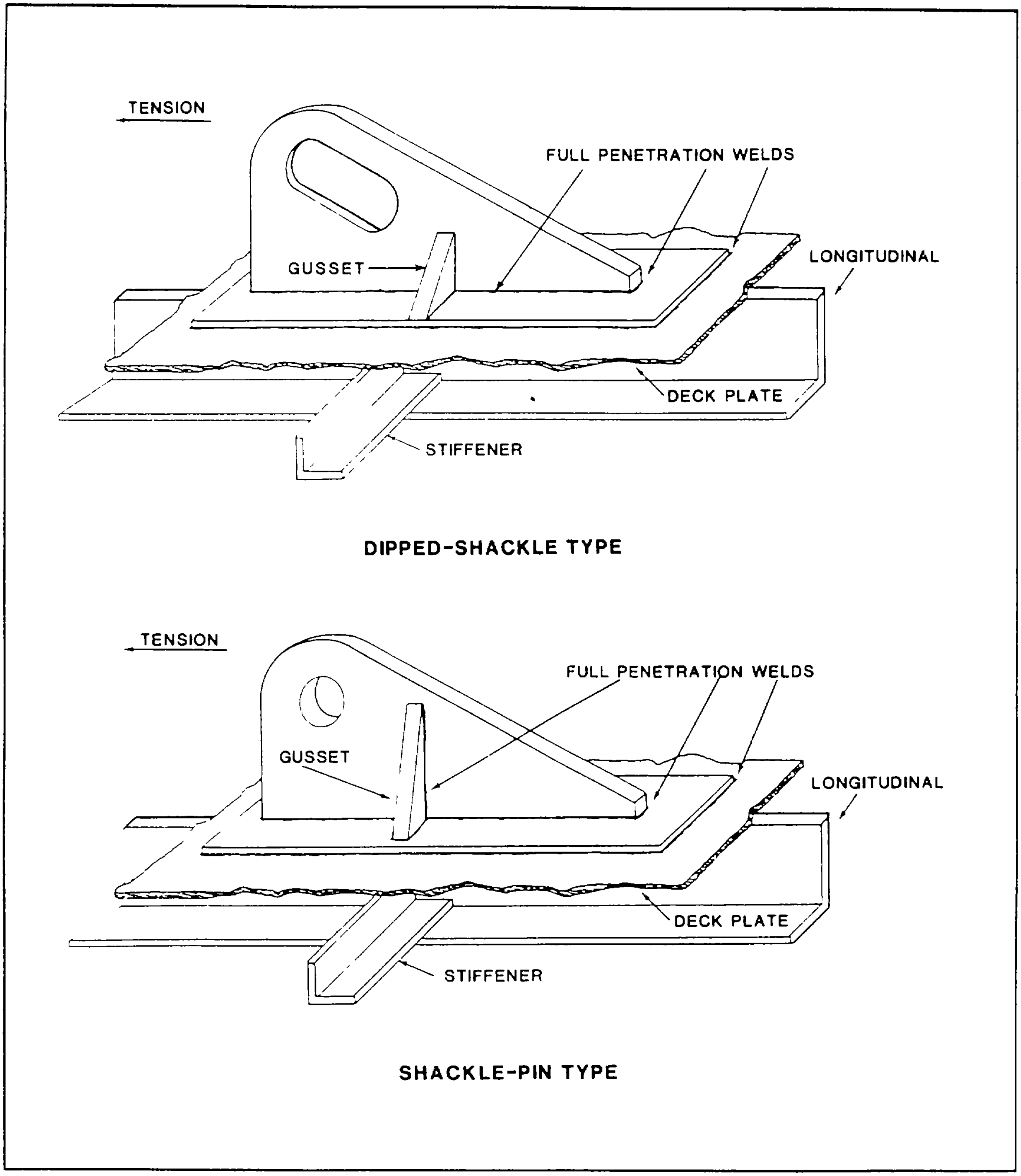
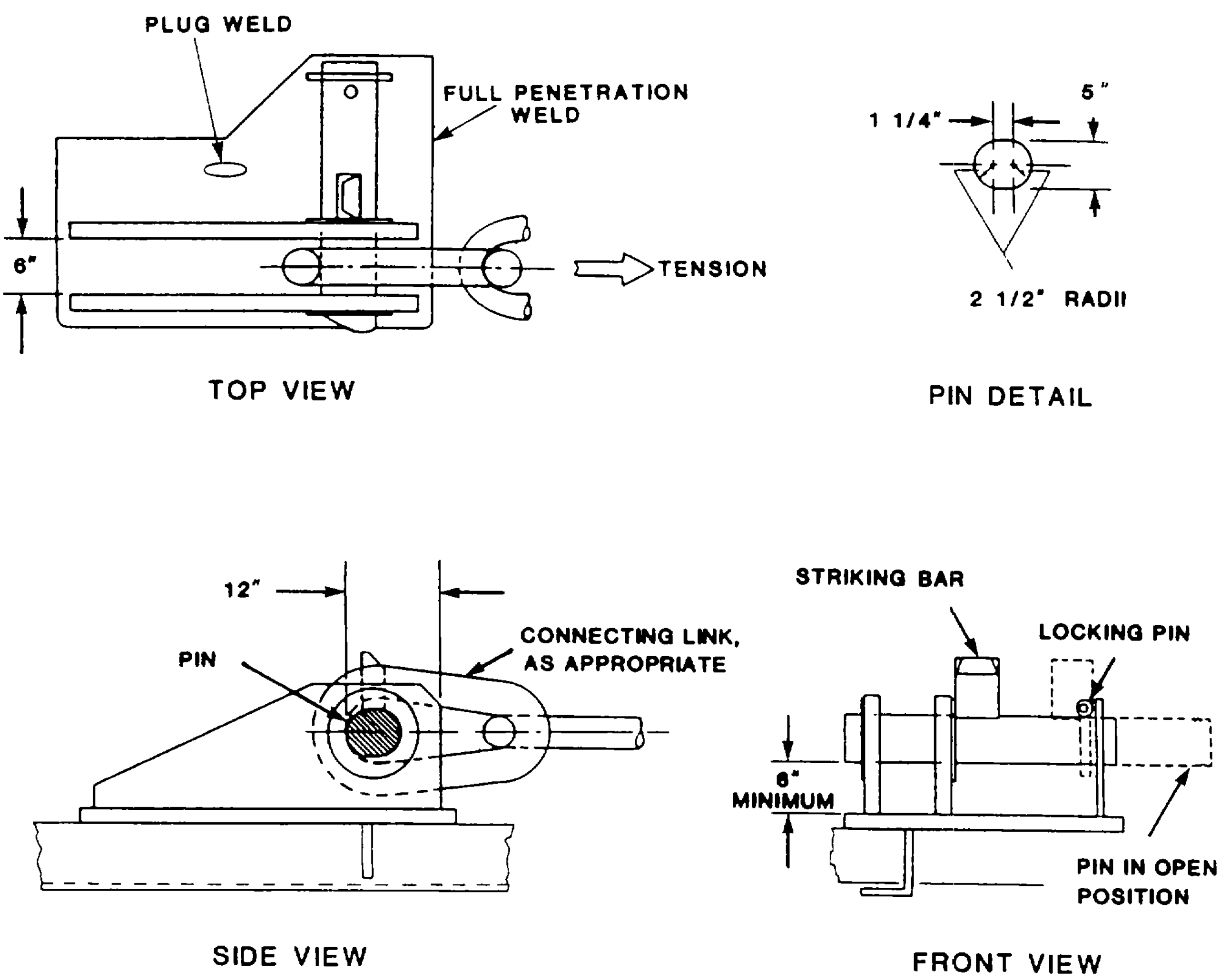


FIGURE 2-23. Vertical Free-Standing Padeye.



CAUTION

CHAIN SMALLER THAN ABOUT 3 1/4" WILL REQUIRE A PEAR-SHAPED LINK OR AN ANCHOR SHACKLE TO CONNECT TO THE STANDARD SMIT BRACKET. CHECK DIMENSIONS CAREFULLY!

NOTE

LARGER SIZE SHOWN HERE

FIGURE 2-24. Smit Towing Bracket.

(Text continued from page 2-28)

to port with a sledge, allowing the main pin to slide out of the pear-shaped link. The design uses no shackle. This style towing attachment, like the vertical free-standing padeye, is susceptible to tripping loads and is dependent upon the fairlead chock.

CAUTION

The large and small Smit Brackets are sized to accept the standard end link of 3-inch and 2-inch chain, respectively. They will directly accept the common link of considerably larger chains. Check dimensions carefully in designing the tow connection!

The standard Smit Bracket design is manufactured in two standard sizes. The larger size, whose dimensions are shown in Figure 2-24, will accept the standard end link of a 3-inch chain. Smaller chains will require a large safety anchor shackle or the pear-shaped link depicted in Figure 5-3. This link may be found aboard the ship outfitted with such a towing bracket.

The smaller standard size Smit Bracket is designed to accept the end link of 2-inch chain, or the common link of 23/4-mch chain.

Sometimes the Smit Bracket design is adapted to other dimensions. In all cases, the dimensions must be checked carefully to ensure that properly-sized jewelry is available to make the connection.

2-5.6 SPECIAL ATTACHMENTS. When there is no convenient attachment system on the towed vessel, other means must be devised for the attachment. This is particularly important in the case of rescue towing, when time and shoreside support will not be available for installing padeyes and fairleads. One alternative is to make use of the towed ship's anchor chain

WARNING

In no case should the stud of a common chain link be removed to provide a connecting point to a chain.

The usual method of using the towed ship's anchor chain is to stop off the anchor and break the chain. Ensure that the inboard section will not be pulled down into the chain locker due to its own weight. The bitter end of the chain can then be connected directly to the towing pendant brought through an appropriate deck edge chock. The anchor chain then can be veered to provide chafing protection and any desired additional catenary to the towline system, for improved dynamic load mitigation In this case, the ship's chain stopper system may not align ideally with the fleet angle of the chain, but in most cases it will be sufficient for towing purposes.

Other methods using the tow's anchor chain involve suspending the anchor from a wire strap or cutting it loose completely, and towing through the hawsepipe. The rigging involved will be complex and perhaps hazardous. Further, this method often results in the chain bearing against a sharp forward or upper outer lip of the hawsepipe, which may consist of a much smaller radius than would be ideal for chain.

Another attachment point can involve passing a chain around a gun mount or foundation of a deck machinery installation, or rigging a wire rope strap with a large eye on one end around bitts. See Figure 2-25. When using bitts for towing, refer to Paragraph 5-6.2. However the attachment point is effected, it may also be necessary to cut through the bulwark or to remove other fittings from the deck in order to provide a clean sweep for the towing pendant. When rigging a special attachment for towing, the twin problems of attachment point and fairlead must be solved For additional discussion of attachments, see Section 5-6 of this manual

2-5.7 QUICK DISCONNECT SYSTEM.
Most routine point-to-point tows are securely

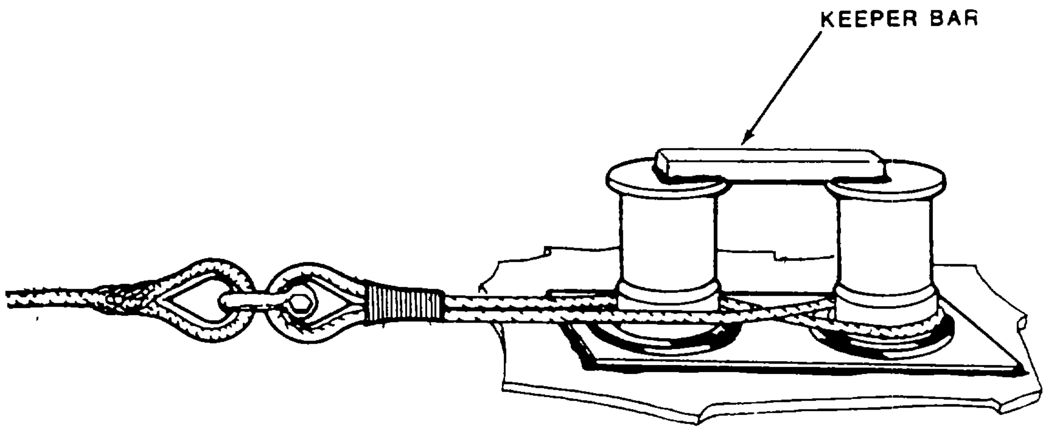


FIGURE 2-25. Strap for Emergency Tow.

rigged with no provision for quick release, other than shipping the tow wire from the towing ship. However, in towing damaged ships, especially those with no deck power available, it may be desirable to provide for a quick release of the tow pendant or bridle to facilitate breakup of the tow. Even if the tow hawser has already been disconnected, the weight of the chafing pendant or bridle legs will be significant, and must be considered in selecting the means of disconnecting.

WARNING

The tow wire will be under tension when released, creating an extremely hazardous condition. All non-essential personnel must evacuate the area to prevent serious injury.

CAUTION

The towing ship should reduce the tension on the towing assembly by either slowing down or stop-ping prior to cutting or otherwise releasing a towline.

In case of a damaged ship, the tow pendant or bridle legs, if chain, should be securely held by multiple chain stoppers, each bearing equal tension. If the pendant or bridle legs are wire, then provision should be made for cutting with an oxy-acetylene torch, a cable cutter or any similar device. As cutting is extremely hazardous, precautions should be taken to prevent whipping, and the wire should be seized on both sides of the intended cut.

If releasing the tow assembly from the tow is not feasible, then slipping the wire from the tow winch may be accomplished by either the payout mechanism, slipping on the brake or free-spooling. If time permits, free-spooling should be avoided and the wire slipped under the control of the payout system.

2-5.7.1 Cutting Gear. Most Naval ships are equipped with oxy-acetylene cutting equipment. Additionally, some tugs and most salvage ships are equipped with hydraulic cutters.

WARNING

Wire rope stretches far less under load than most natural and synthetic fiber lines and thus has a smaller zone of danger to bystanders from loose ends "snapping back" in the event that it fails under high loads. The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path.

For cutting chain, the oxy-acetylene equipment probably is the most satisfactory. For cutting wire, hydraulic cable cutters may be better. Personnel safety is paramount in cutting any member of the tow assembly, therefore, every effort should be made to reduce the tension. This is particularly true for cutting wire and synthetic lines. The greater the distance between the person doing the cutting and the cutting point, the greater the safety factor. Securing the cutting torch to a boat hook is a prudent measure. Seizing a wire hawser on both sides of the intended cut also is good practice. Cutting a synthetic line with an ax is hazardous and should not be done under tension. The use of stoppers to control snap-back decreases the hazards involved when cutting any chain, wire or synthetic line.

2-5.7.2 Chain Stopper. A chain stopper sometimes is employed as a quick-release device. In towing applications, the stopper usually is connected to a deck pad by means of chain shackles. It is used to hold a towing pendant on deck during the hookup and breaking of a tow. Stoppers are nominally rated to hold a minimum of 60 percent of the breaking strength of the chain or wire for which they have been designed. This must be considered in their use. See Figure 2-22. It is important not to confuse chain stoppers with pelican hooks, the latter being significantly weaker than chain stoppers of the same nominal size, and unable to grasp the chain in the desired manner.

2-5.7.3 Carpenter Stoppers. Carpenter stoppers are used where it is necessary to develop a grip on a wire rope and to hold it to the breaking strength of the wire. Advantages of the carpenter stopper include its quick application and release, ability to develop full tension without damage to the wire, and low maintenance requirements. See Figure 2-26.

WARNING

Old-style stoppers with smooth covers are condemned and should not be used. These old models were made of cast metal and are subject to explosive brittle fracture upon impact. Serious injury to personnel may result from flying fragments.

CAUTION

A carpenter stopper should not be used unless it is specially designed for the lay, helix, number of strands and diameter of the specific wire rope. The stopper and wire rope should both be clean and free from sand or other abrasives.

Three types of carpenter stoppers have been used in the U.S. Navy: the "old WWII style," the "improved 1948 style," and the "modified-improved 1968 style." Only the last one listed shall be used. It can be identified by four heavy ribs on the hinged cover and will have a Boston Naval Shipyard test date of 1968 to 1973 or be manufactured by Baldt after 1973.

2-5.7.4 Chafing Gear. Included in the category of chafing gear are materials such as mats, battens,

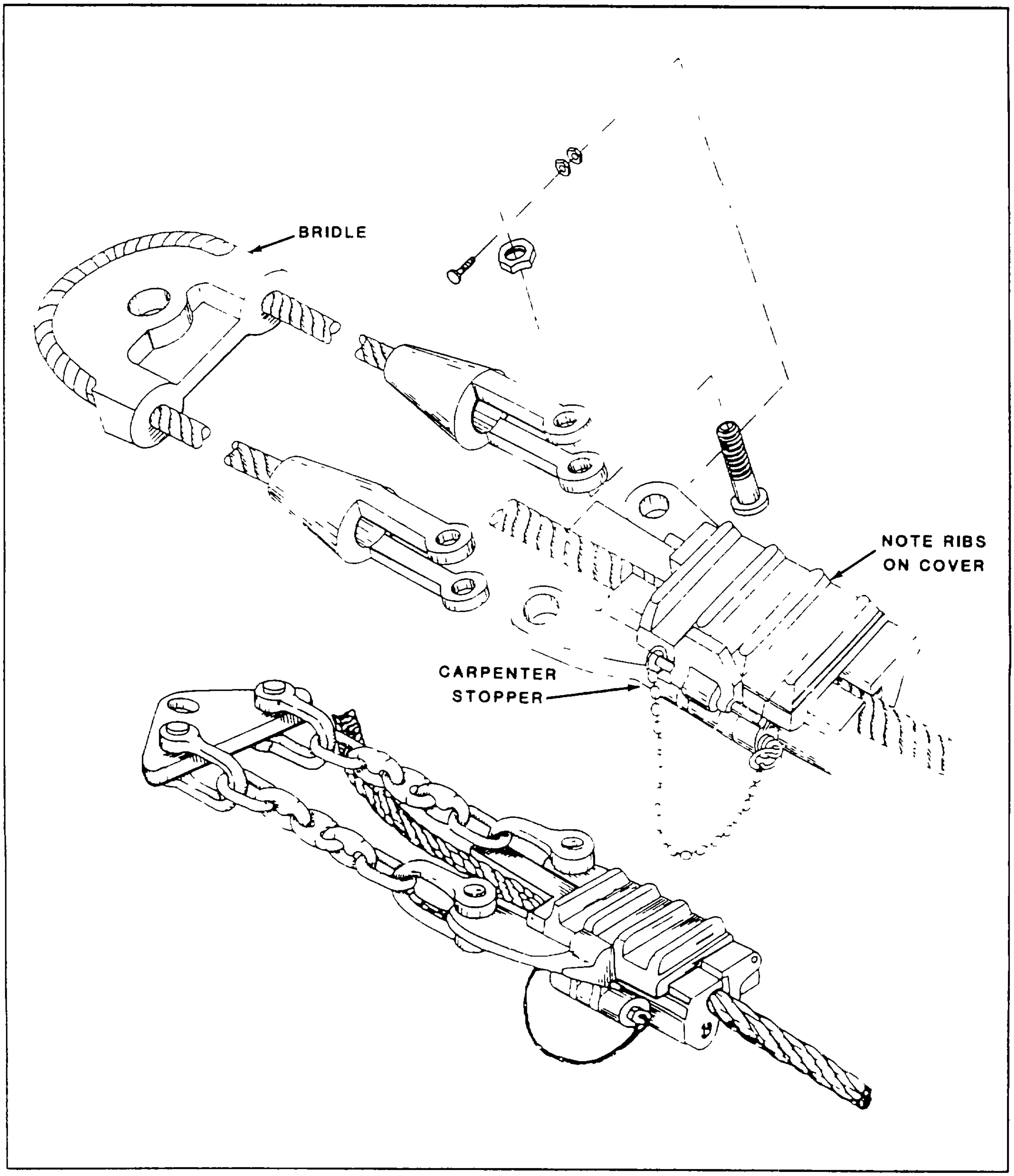


FIGURE 2-26. Carpenter Stopper.

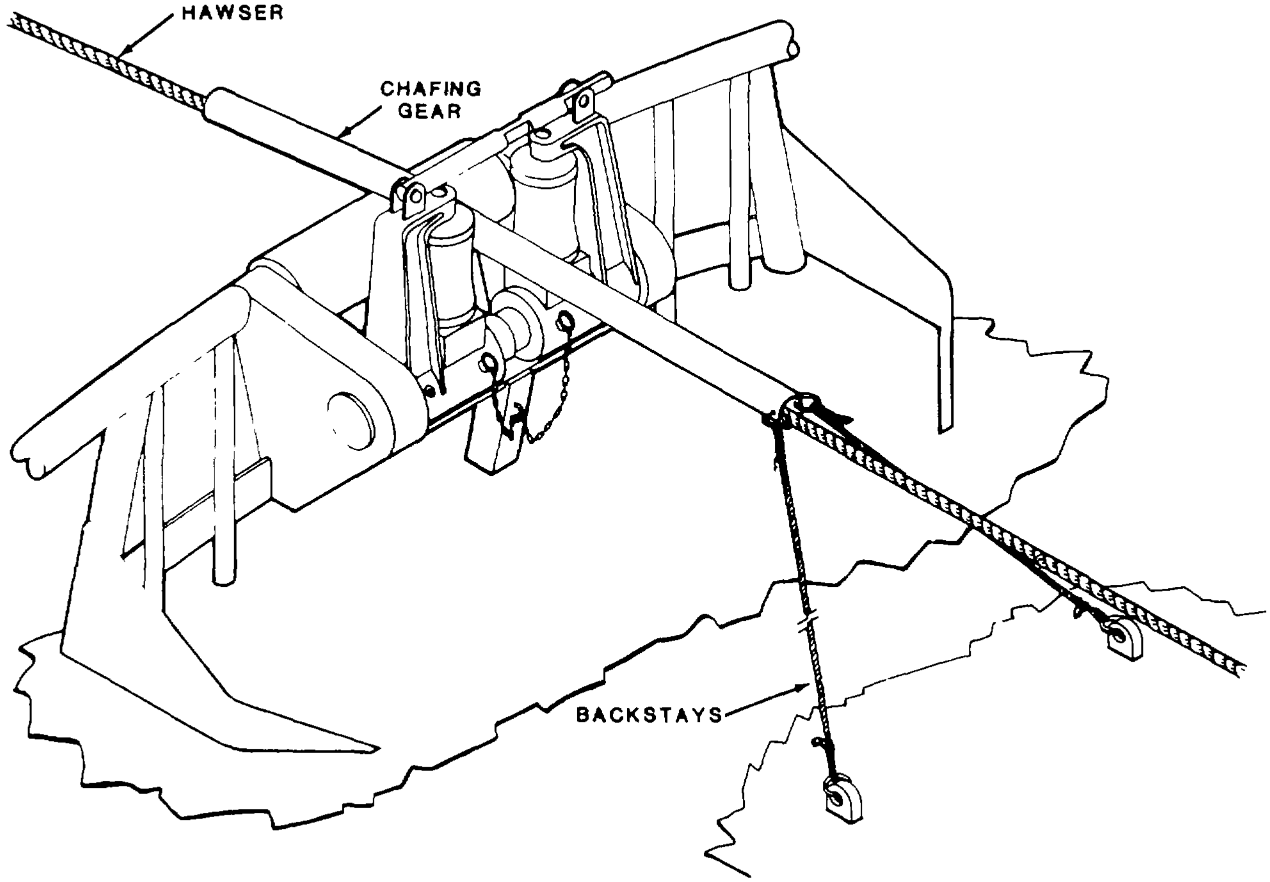


FIGURE 2-27. Chafing Gear.

strips of leather, canvas, worming, parceling, rounding and serving. These materials are all used to lessen or prevent chafing of the towline. See Figure 2-27

2-5.7.5 Capstans And Gypsy Heads. Capstans rotate on vertical shafts and are used for line-handling, but they are not used as towing machines The prime mover of a capstan often is located below deck to permit the capstan to be mounted so that the line travels relatively close to deck level. A Gypsy head, which is similar to a capstan, rotates on a horizontal shaft and is usually powered as an auxiliary of a winch Gypsy heads, like capstans, are used for line-handling, but not for towing. See Figure 2-28.

2-5.8 ATTACHMENT SYSTEM ON TUG.

2-5.8.1 Towing Machines. A towing machine is the "main battery" of a towing ship. It has a power driven drum which serves as both the hard point of the attachment system and stowage for that portion of the towing hawser that is not in use. The powered drum provides a variable length of wire towline. Most U S Navy towing machines have an automatic control system that senses the towline tensile load and provides an automatic payout and reclaiming capability which relieves the dynamic loads on the tow during the tow. Towing machines have a free-spooling feature which serves as a quick-disconnect system for the towing hawser. See Figure 2-29

Most towing machines and winches have a "dog" system that positively holds the drum against towing loads.

CAUTION

When towing "on the dog," there is no hawser quick-release capability.

When towing "on the dog", the towing machine must be started up, engaged and the hawser heaved in slightly in order to release the dog. Therefore, when towing on the dog, there is no quick-release capability.

2-5.8.2 SMATCO Winch. All U S. Navy towing ships have automatic towing machines, except the T-ATF’s, which use a SMATCO winch. The SMATCO winch, shown in Figure 2-30, does not have automatic control features. Towing usually is performed with the diesel engine power plant shut down and the winch drum restrained by either a brake or dog. As always, when towing on the dog, there is no quick- disconnect feature. To release the drum for free spooling, or routine payout, the diesel engine must be started and the clutch engaged to heave the hawser in slightly, to allow the dog to be released. The process is similar to the dog-releasing procedure for automatic machines, but may take considerably longer to execute

2-5.8.3 Traction Winches. When the synthetic fiber line towing hawser was introduced in Navy towing, the multi-sheave traction type winch was introduced to provide the hard point for attachment, as well as payout and heave-in features for changing the towline scope. Figures 2-29 and 2-31 show typical multi-sheave traction winches. These winches also provide part of the function of transporting the hawser to its stowage bins located below decks. The transport and back tensioning is provided by a power block. Traction winches are installed on the T-ATF 166 Class Fleet hag and on the ARS 50 Class Rescue Salvage Ship. The T-ATF traction winch has no automatic features, whereas the ARS 50 traction winch has an automatic payout feature only. This feature provides peak tension relief in addition to that provided by the spring in the synthetic hawser, an automatic reclaim feature is not installed. When operating in the automatic mode, periodic heave-in, under manual control, may be required to maintain the desired towline scope.

(Text continued on page 2-42.)

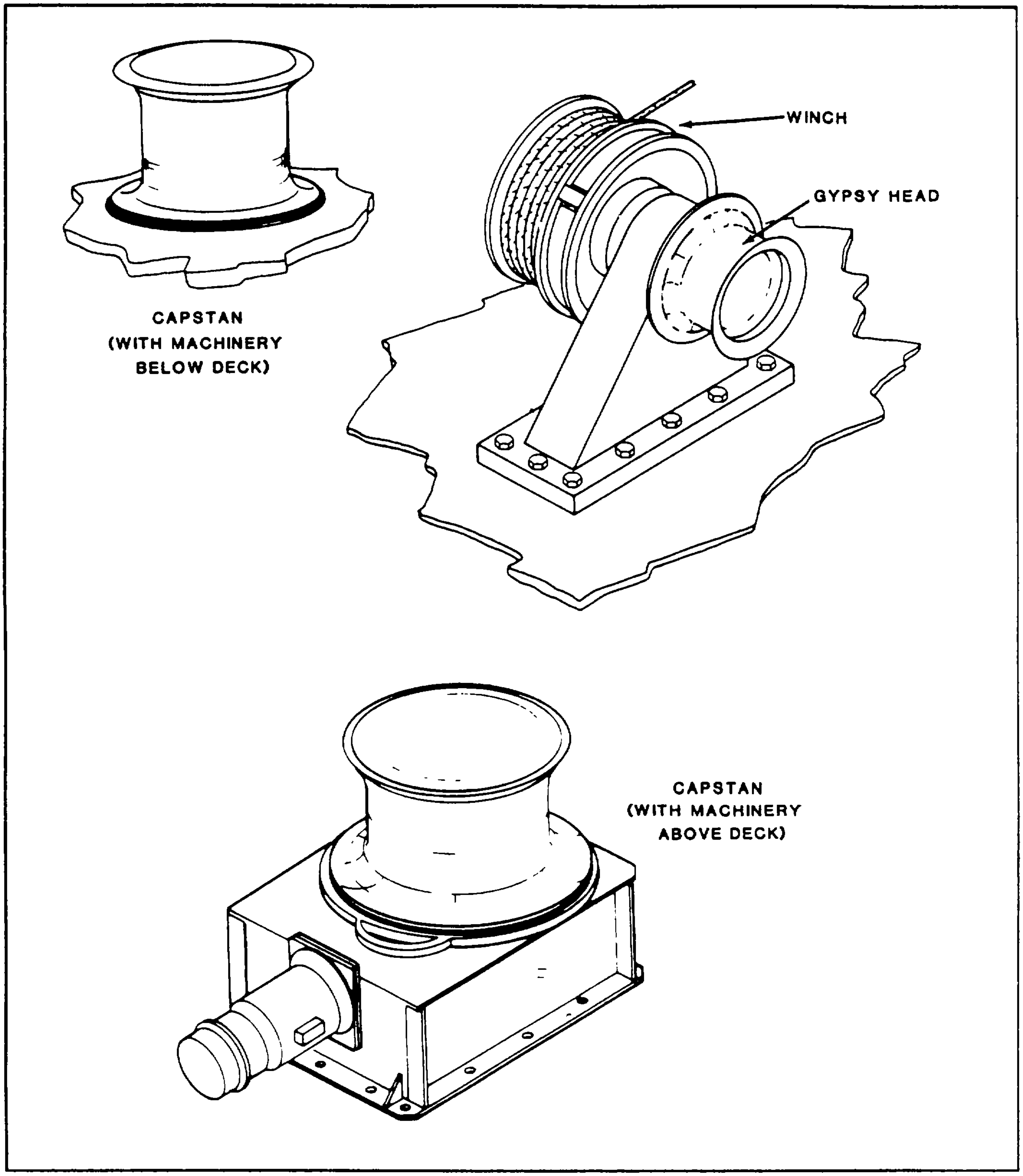


FIGURE 2-28. Capstans and Gypsy Head.

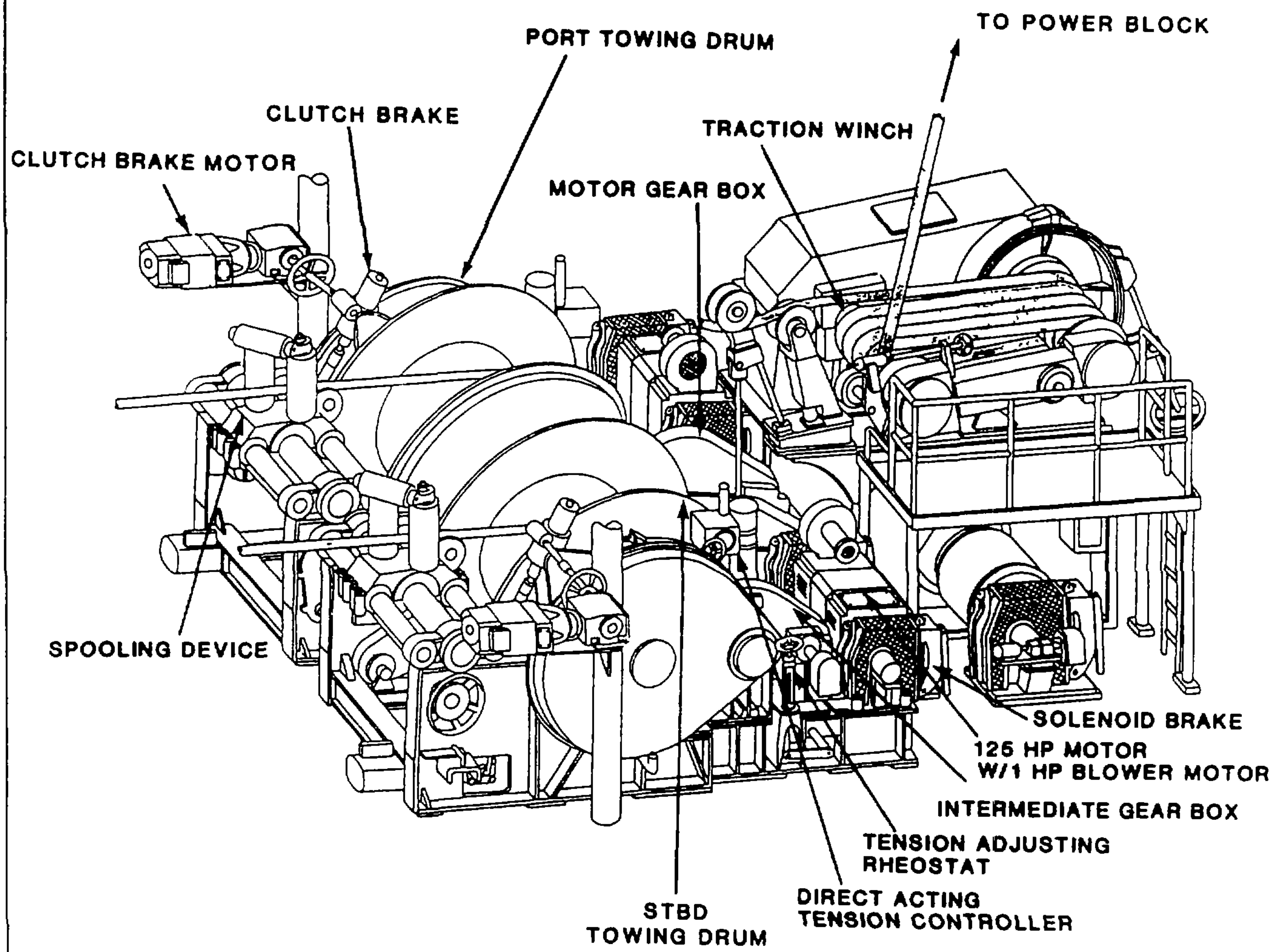


FIGURE 2-29. Almon A. Johnson Series 322 Towing Machine with Series 400 Traction Winch.

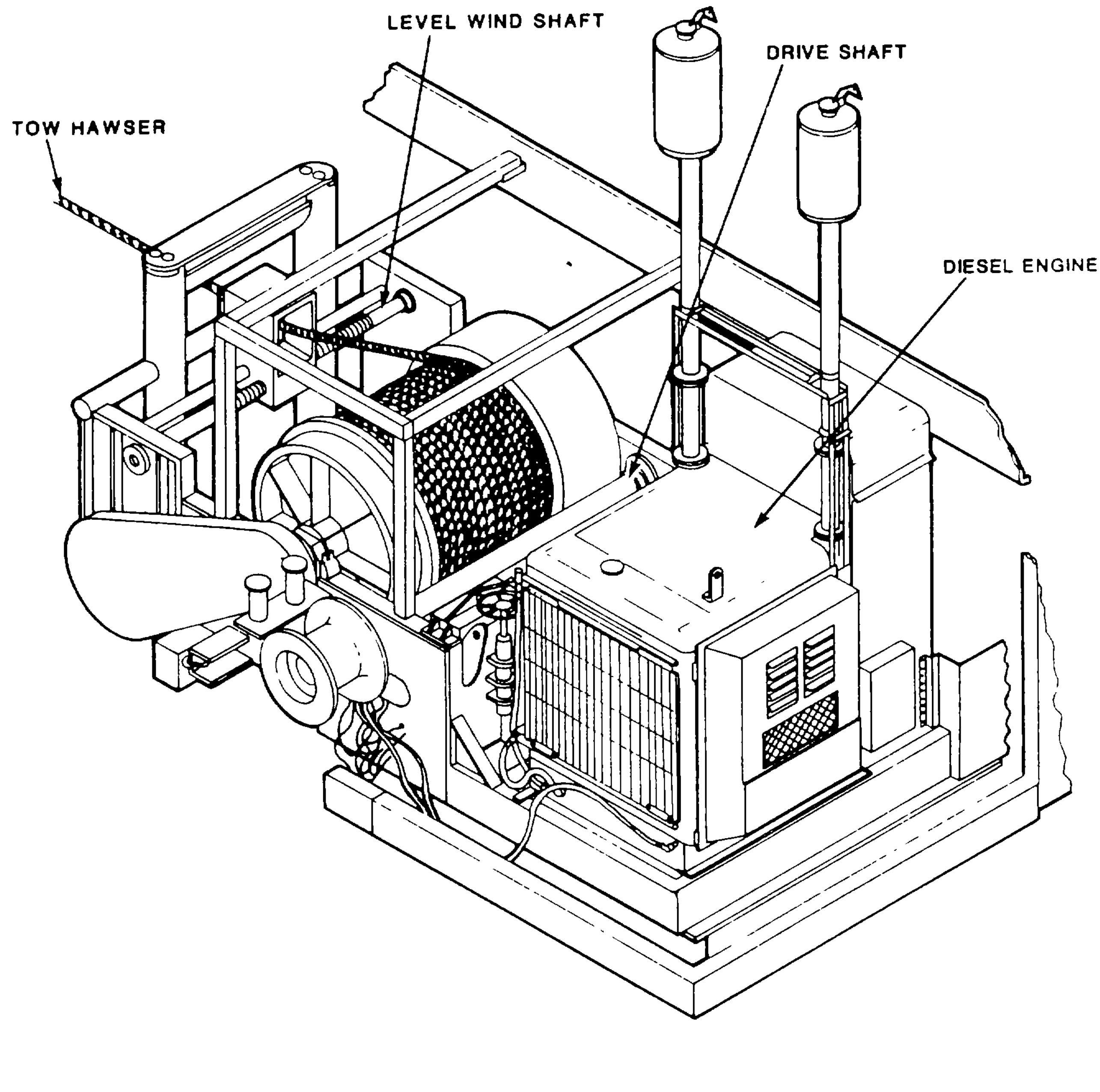


FIGURE 2-30. SMATCO Winch.

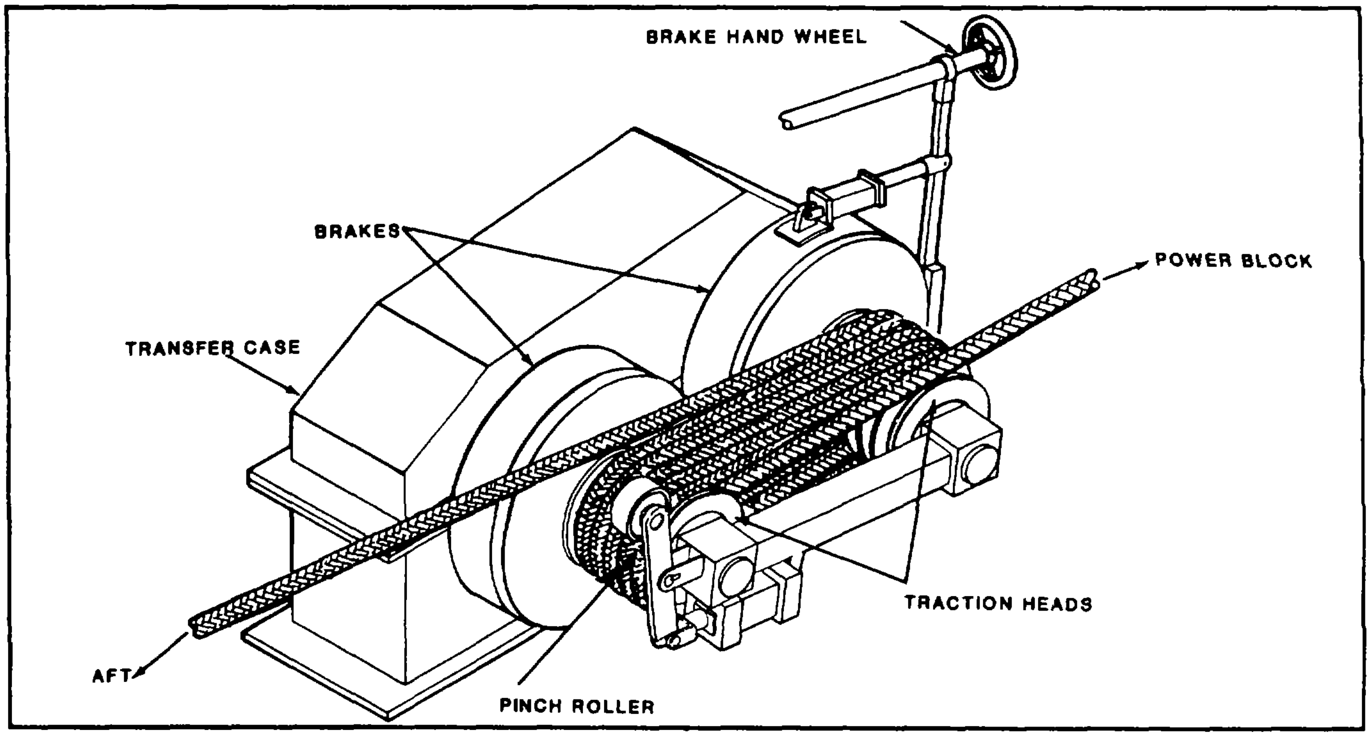


FIGURE 2-31. Multi-Sheave Traction Winch.

(Text continued from page 2-38)

2-5.8.4 Towing Hooks. Towing hooks rarely are seen in the United States, but may be encountered in foreign ports and on foreign, especially European, tugs. They are heavy steel hooks mounted on vertical pins, which allow them to swing. Each hook is shock-mounted by use of a heavy compression spring and fitted with a quick-release device which trips the hook, in much the same way as a chain stopper.

The compression spring provides a small amount of dynamic load relief for the towline system.

2-5.8.5 Bitts. A bitt is a strong post used for belaying, fastening, and working ropes, hawsers, mooring lines, etc. Bitts usually appear in pairs and are named according to their use. See Figure 2-32.. They generally are not suited for towing operations. The term "bollard" occasionally is applied to a bitt, but more commonly is applied to a device on a pier for securing mooring lines. Bitts on U.S. Navy ships are designed to withstand a load equal to at least three times the breaking strength of the line for which they were designed. See Paragraph 5-6.2 for design strengths of U.S. Navy bitts.

2-5.8.6 H-Bitts. Towing or H-bitts are heavy steel castings or weldments secured to the ship's structure and are generally located near the tug's pivot point where they provide the hard point that sustains the athwartship loads imposed by the towline when it sweeps the fantail. In tugs fitted with towing machines, the H-bitts prevent transverse strain on the level wind mechanism and are used to stop off the tow wire when necessary. On the ARS 50, the function of the H-bitts is integrated into the deckhouse structure.

2-5.9 HANDLING SYSTEM. The towing machines, winches and bitts discussed in the preceding paragraphs provide some line han-

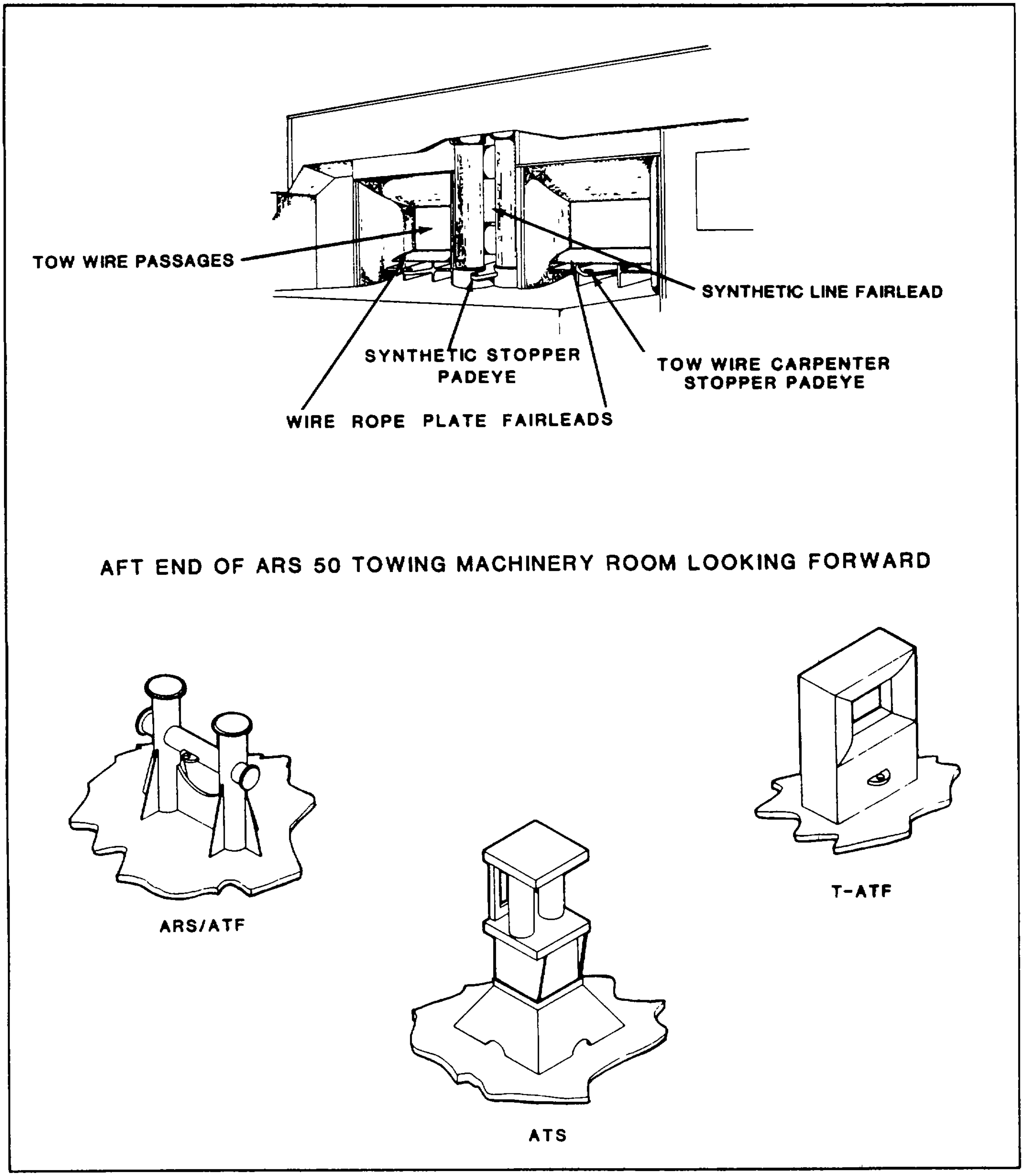


FIGURE 2-32. Towing Bitts and Aft End of ARS 50 Towing Machinery Room.

dling functions and act as attachment points for the towing hawser. Other equipment on the tug generally serves only line-handling functions. These are discussed in the following paragraphs

2-5.9.1 Towing Bows. Towing bows are transversely installed beams or pipe that bridge the caprails on the afterdeck of the tug. Their function is to keep the towline clear of all deck fittings and to provide a protected area below the sweeping tow hawser where personnel can pass safely. See Figure 2-33.

2-5.9.2 Caprails.

CAUTION

Whenever the surface of a caprail becomes rough, steps should be taken to repair or replace it in order to **protect the hawser. Caprails should be kept clear of all appurtenances.**

The caprail is the riding surface on top of the bulwark. The tow hawser bears on the stern caprail as it passes astern of the tug and enters the water. Caprails are installed in several configurations. They are fabricated from pipe or plate. On the newer tugs, they have large-radius surfaces which are contoured to the tug's deck layout. It is important to keep the caprail smooth and free of nicks and burrs which damage both synthetic and wire hawsers. In current design practice, the bearing surface of the caprail is hardened to a minimum Rockwell C hardness of 40 to 50. See Figure 2-34.

2-5.9.3 Stern Rollers (Horizontal). The essential function of the stern rollers is to provide a minimum chafe point for the tow wire during heave-in and payout. It is a large-diameter roller, set in the stern bulwarks on the centerline and faired to the caprail. As it rotates with the movement of the wire, it provides a constantly changing point of tangency, thus spreading the wear from the wire. As it is also hardened, it resists scoring and thus provides a smooth surface on which the wire rides. See Figure 2-35.

2-5.10 SWEEP LIMITING DEVICES. These items restrict the horizontal sweeping of the wire across the fantail

WARNING

The Stern Rollers and Norman Pins onboard the ARS 50 Class ships will drop when a load of 50,000 pounds or more is applied to mid-barrel height. The resulting uncontrolled sweeping of the towline may injure personnel or damage equipment.

2-5.10.1 Stern Rollers (Vertical). Stern rollers are an assembly of rollers used to tend the towline both during heave-m and payout and during long-distance straight towing. Stern rollers prevent a wire from sweeping across the deck and rail. In the newer ships, the stern rollers or pins are normally operated hydrauhcally from a remote location. See Figures 2-35 through 2-38. Onboard the T-ATFs the hook-shaped items on either side, just outboard of each vertical roller, are hydraulically-operated "capture hooks, " often used instead of the vertical rollers to provide lateral restraint for the towline. On the ARS 50 Class, the vertical stern rollers drop (but do not fully retract) when the side force at mid-barrel height exceeds 50,000 pounds.

2-5.10.2 Norman Pins. Ocean tugs generally are provided with sockets along their aft bulwarks into which fixed or movable Norman Pins are fitted. These pins limit the sweep of the towline forward of the pins. Current design practice requires that the wire bearing surface of the Norman Pins be hardened to a minimum Rockwell C hardness of 40 to 50. The limiting of towline sweep may be based on a desire to keep the hawser out of the screws during slack-wire conditions or to prevent the tow wire from sweeping beyond a specified position.

The newer tugs and salvage ships have remote-controlled, hydraulically-operated Norman Pins

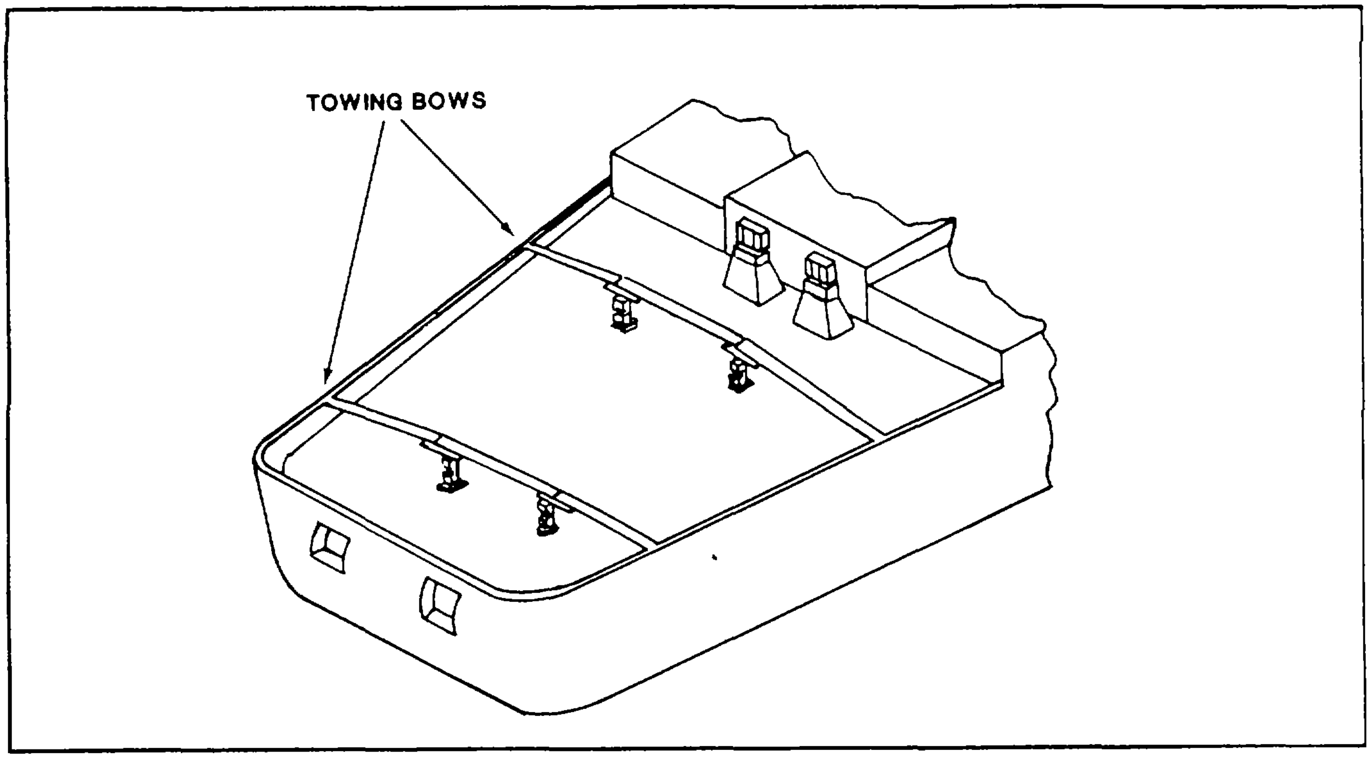


FIGURE 2.33. Towing Bows

in fixed locations, unlike some of the older ships whose round pins physically could be lifted out of any socket and either removed or moved to another location. This necessitated personnel moving about on the fantail and thus being subject to hazards, with remote control, the procedures are now safer. On board the ARS 50 Class, the Norman Pins, like the vertical stern rollers, are set to drop when the lateral force at mid-barrel height exceeds 50,000 pounds. The hazard potential could be formidable, since when the pins start inclining toward the horizontal, the wire with 25 tons force propelling it could jump the pin and sweep forward. See Figure 2-39.

2-5.10 3 Bulwark Forward Limits. On most Navy towing and salvage vessels the bulwark and the caprail are gently curved upward and faired into the deck above the *towing* deck. See *Figure 2-40.* This ship's structure restricts the tow wire from leading forward of the beam at the tug's tow point (H-bitts) just aft of the tow winch.

2-5.10.4 Lateral Control Wire. The lateral control wire is a wire or tackle rigged to control the athwart- ships movement of the towline. A dedicated lateral control winch is available on the ARS 50 Class ships. By changing the scope of the lateral control wire, the bight of the towline can be moved to different locations on the fantail. The lateral control wire also is employed to keep the towline out of the screws during slack wire conditions. The lateral control winches are limited to approximately 2,000 pounds straight line pull.

SECTION VI

2-6 TOWLINE COMPONENT MATERIALS

Some materials used in tensile members of towing systems are characterized by high levels of elasticity

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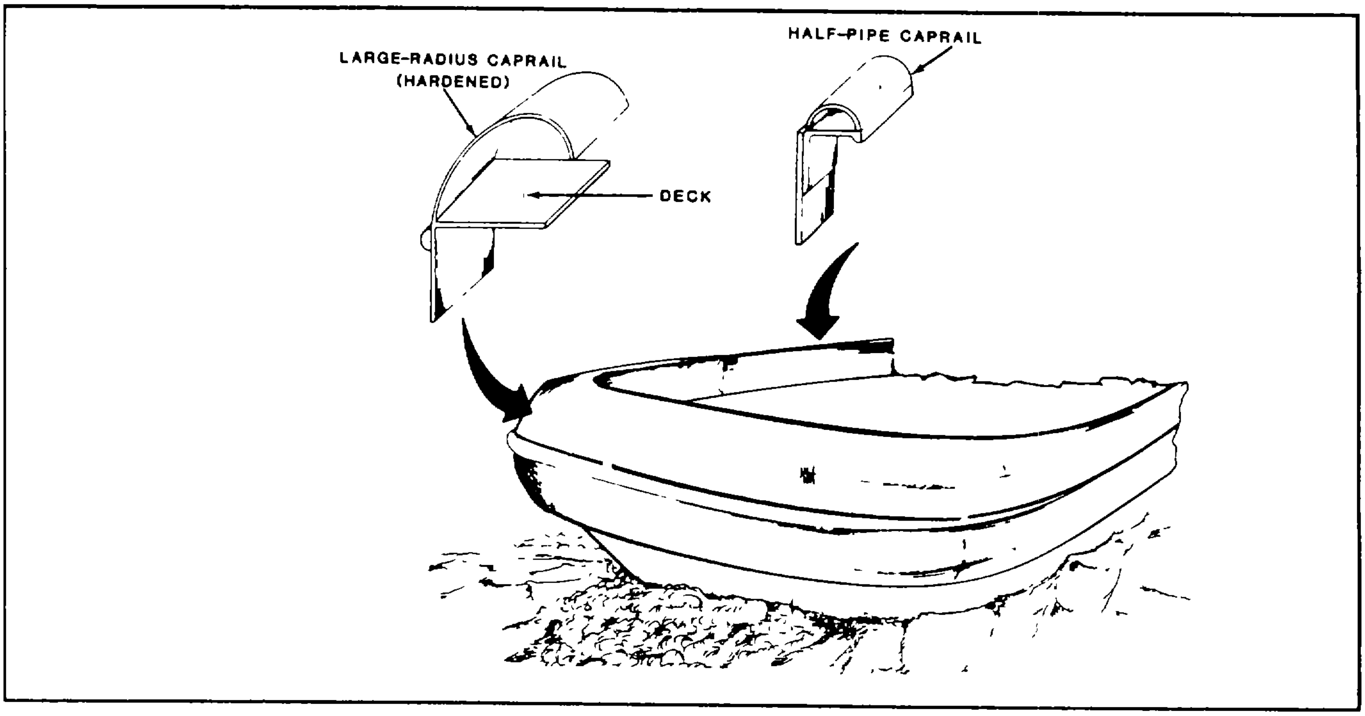


Figure 2-34. Caprails.

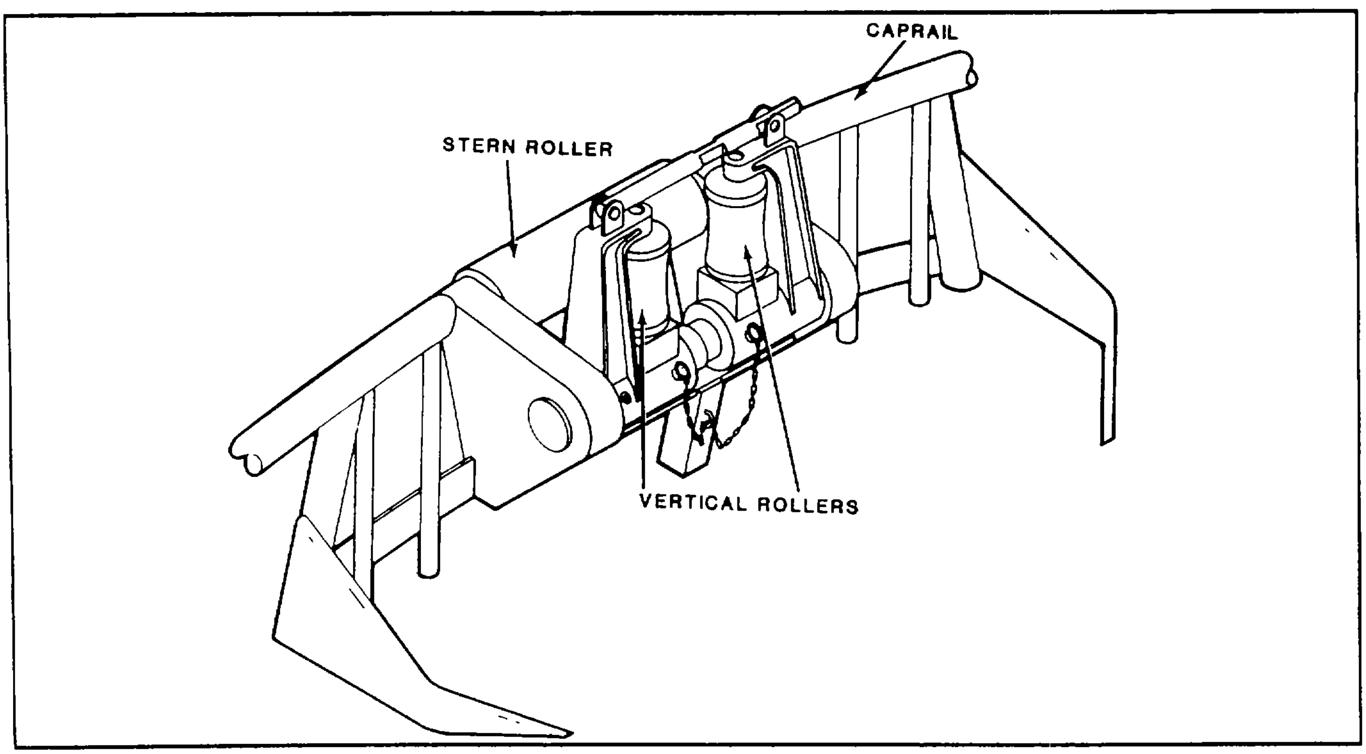


FIGURE 2-35. Stern Rollers (ATF and ARS 38 Class).

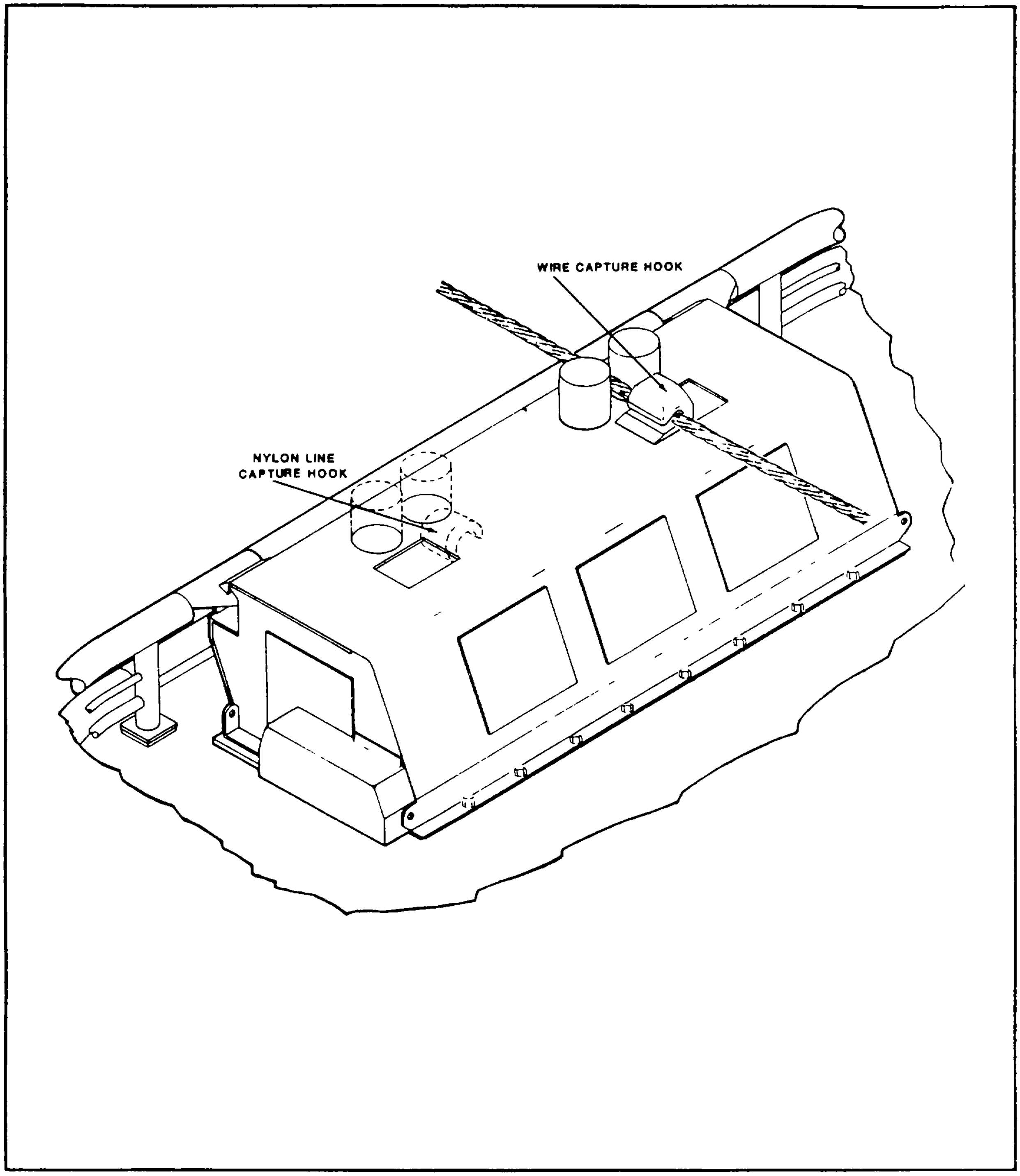


Figure 2-36. Stern Rollers (T-ATF Class

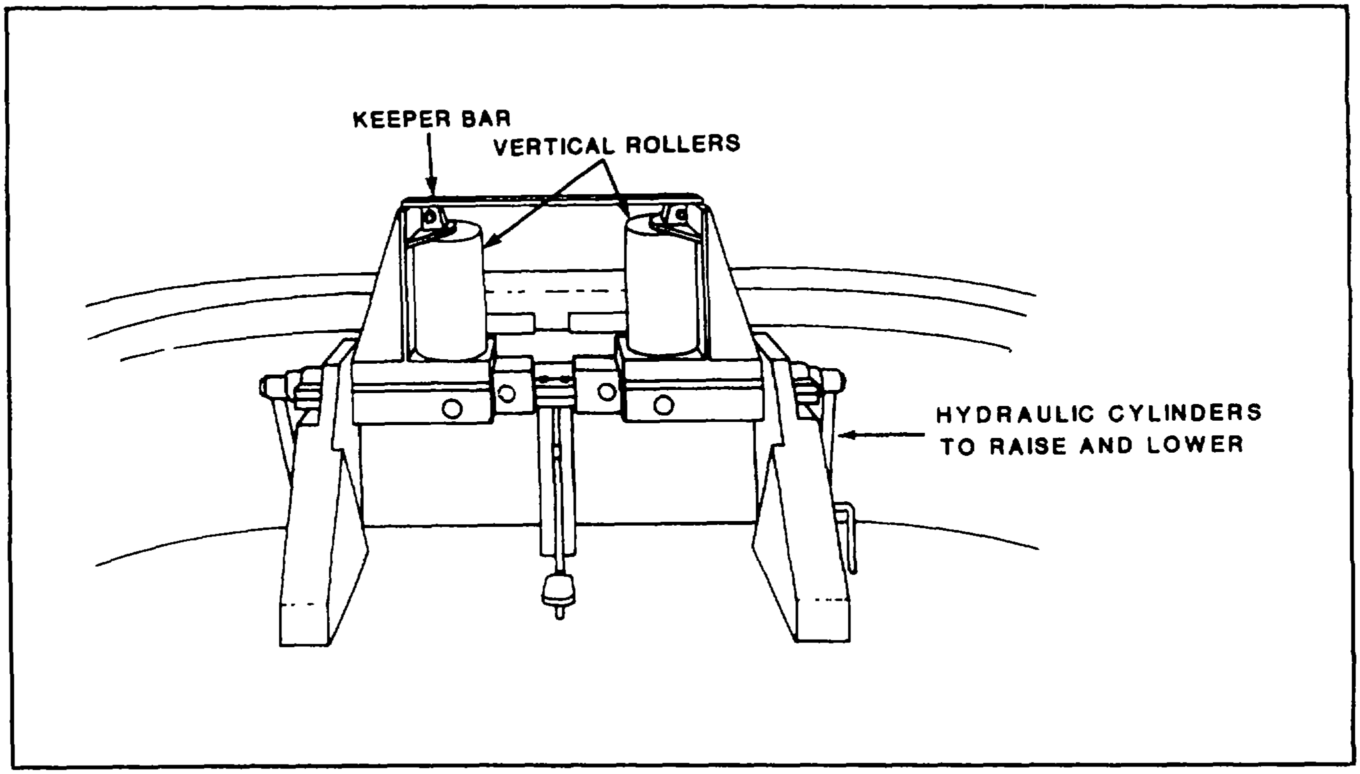


Figure 2-37. Stern Rollers (ATS Class).

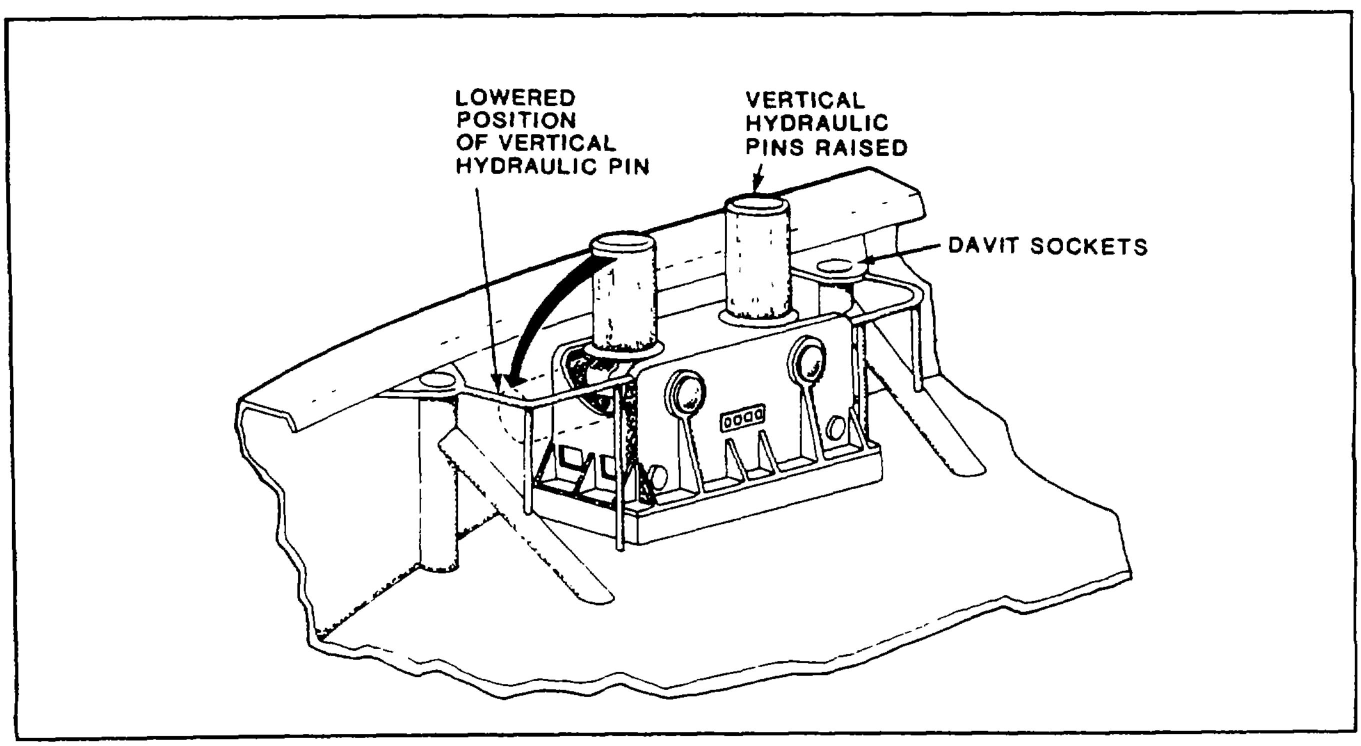


Figure 2-38. Stern Rollers (ARS 50 Class).

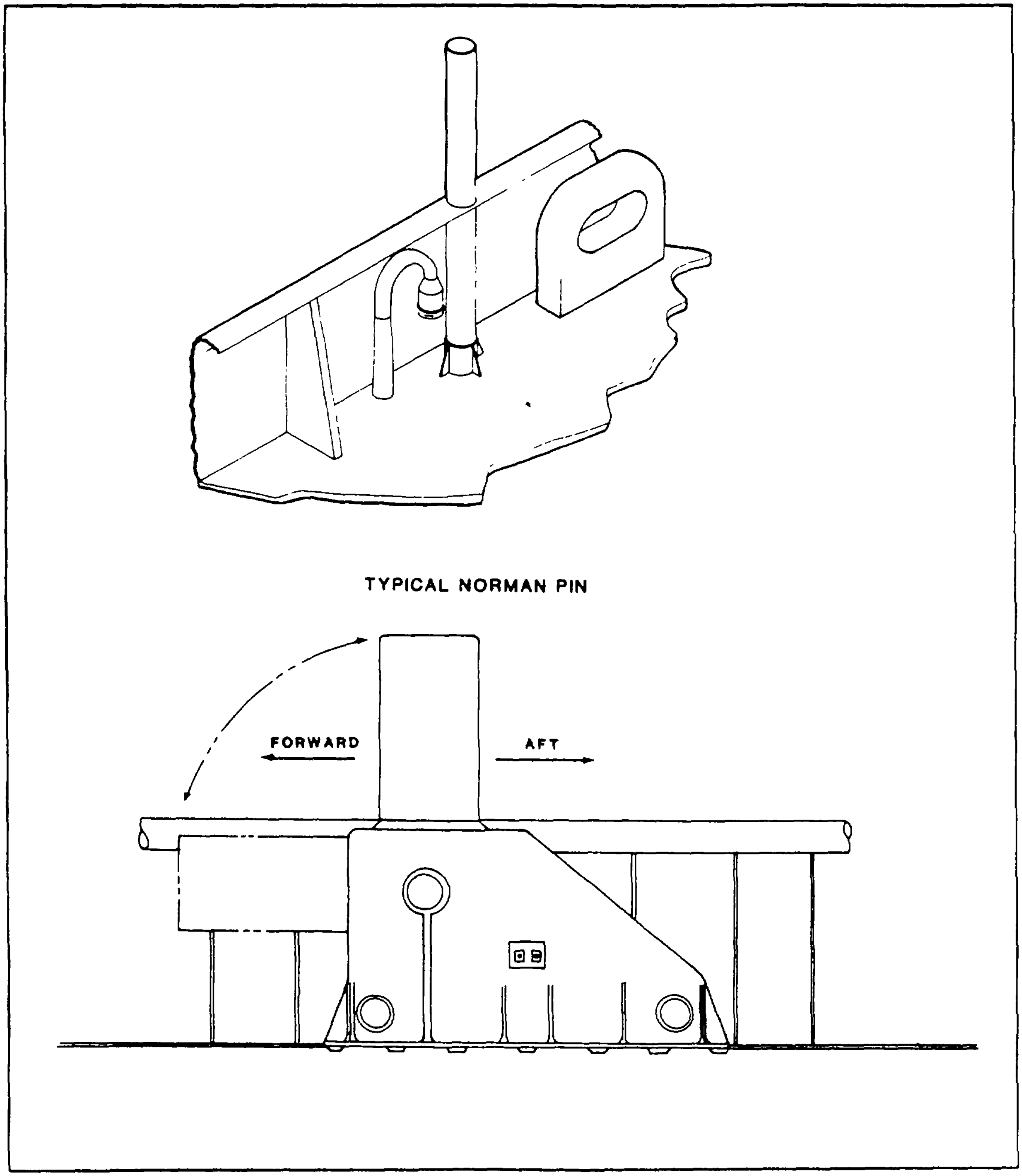


Figure 2-39. Norman Pins.

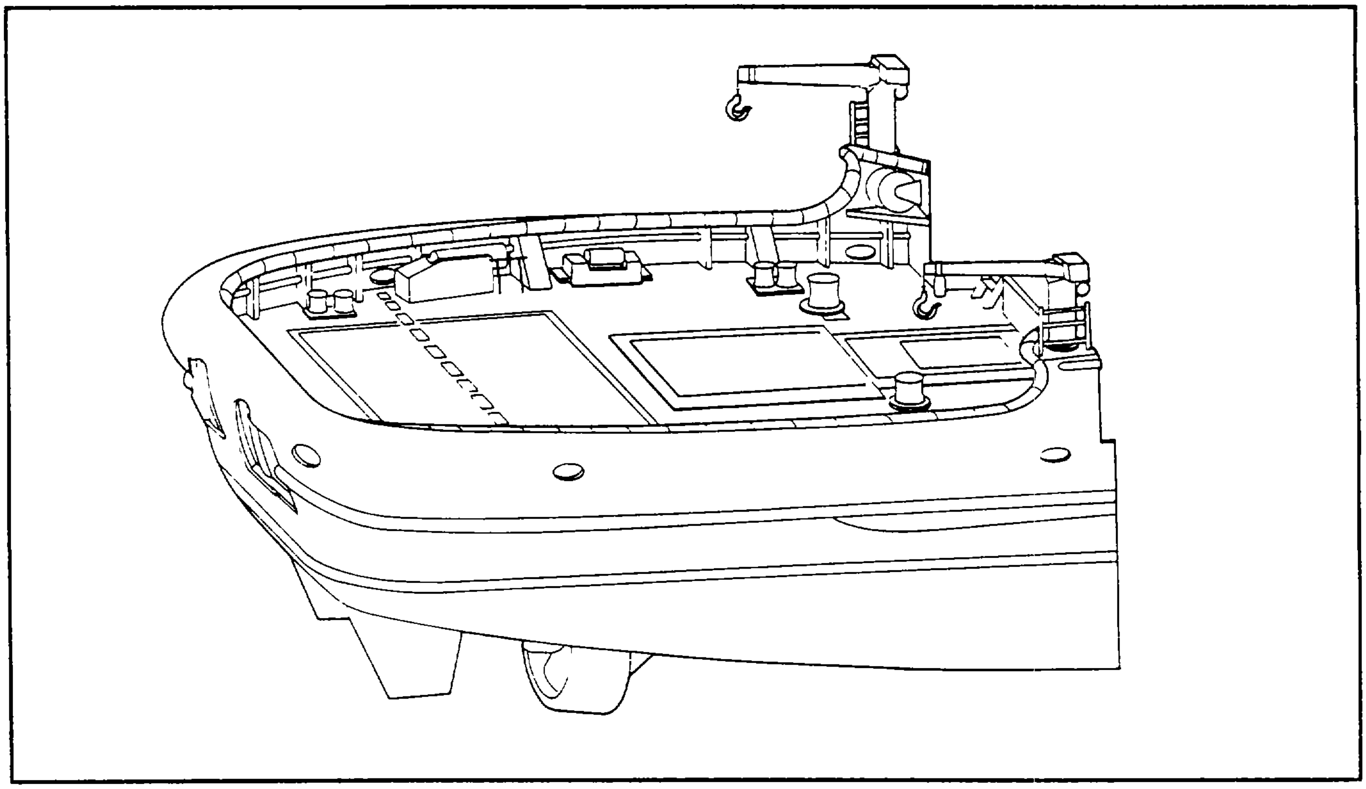


Figure 2-40. Bulwark Forward Limits.

(Text continued from page 2-45)

or "stretchability." In many cases, this high elasticity was why the material was selected. The primary materials used in these tensile members are wire rope, natural fiber line, synthetic fiber lines, chain and connecting fittings.

24-.1 WIRE ROPE. Prior to the development of wire rope, the primary tensile member for mooring and towing was natural fiber line made from such fibers as manila, sisal and hemp. As ships became larger, the loads increased and the diameter of natural fiber lines also increased. This increase occurred to the extent that the lines became too large and heavy to handle easily by manpower and also too large to store easily in the lengths required for towing. During the 19th century, wire rope was developed. Because of its superior abrasion resistance and strength-to-weight and strength-to-size ratios, it rapidly replaced fiber lines for towing hawsers. Acceptance of wire rope for towing occurred despite the fact that its elasticity was far less than that of fiber lines. At first, loss of elasticity was countered by the use of long spans of hawser, where the weight of the wire rope formed a catenary in the wire and provided a measure of effective elasticity. Later, ocean and coastal tows often used manila spring pendants, or "springs," in conjunction with wire rope to provide the needed elasticity. Other efforts to provide wire rope with sufficient stretch included the development of a "spring-lay" rope. The composite rope was a combination of wire and natural fiber. This early composite concept was not unlike present-day efforts to marry other synthetics and Kevlar. Kevlar has a modulus of elasticity of approximately the same value as steel.

2-6.2 SYNTHETIC LINE. When synthetic fiber line was developed for commercial applications, it began to replace manila rope for towing springs and hawsers on small tugs. Synthetics also gained acceptance as open-ocean towing hawsers, often at the expense of wire rope. However, knowledge about the strength, service life, degradation and elasticity of synthetic line now is such that nylon is limited in its use as the main towing hawser. Synthetic line currently is approved for use for open-ocean towing in tow-and-be-towed and emergency towing operations, with craft of less than 600 tons displacement, or other unique/special tows as approved by the originator on a case basis. NAVSEA is continuing to investigate the use of improved and composite designs of synthetic hawsers that may lend themselves to towing applications. See Appendix C for more data on synthetic ropes and their use.

2-6.3 CHAIN. Even though chain may not be viewed as a stretchable component in a towline, it does add "stretchability" to the towline system as a result of its weight, which provides increased catenary in the towline. Chain is discussed in Appendix D of this manual

2-6.4 FACTORS FOR CONSIDERATION. The preceding paragraphs have concentrated on the characteristics of strength and elasticity of wire, rope and chain. Reference has been made to strength-to-weight ratios, abrasion resistance and ease of handling. The following is a list of factors that influence selection of the flexible components of a towing system:

a. Strength (static loads, dynamic loads, fatigue)
b. Elasticity (includes stretch vs. load over a full range of loads and over the lifetime of material, as well as set or permanent stretch)
c. Predictability (strength and compliance factors)
d. External abrasion resistance
e Internal abrasion resistance (related to fatigue life)
f. Weight and specific gravity
g. Survivability against environment (effects of corrosion, ultraviolet light, acids, temperature, moisture, etc)
h Ease of handling (surface character: slippery, sticky, etc.)
i. Stowability (volume shrinkage upon drying, flexibility, etc)
j. Adaptability to fittings and terminations
k Compatibility of fittings and terminations.

In various towing applications, one or more of these factors may have a predominant influence on the choice of material. Chain, for example, often is selected as a chafing pendant or bridle because of its abrasion resistance and survivability. As a lead chain, its specific gravity and flexibility in bending are dominant factors since they provide elasticity through catenary action rather than through material stretching. Likewise, nylon may be suitable for use as a spring, but would not be selected as a chafing pendant. Wire rope is favored for use as a tow hawser on ocean tugs because of its strength and reasonably high abrasion resistance, but its flexibility, stowability and ease of handling also are important reasons for its use

2-6.5 END FITTINGS, CONNECTING LINKS AND ADAPTERS.

CAUTION

Shackles and other fittings frequently come with cotter pins which should be replaced with locking bolts with two jam nuts.

a. Towing adapters. A variety of devices and assemblies for connecting the various towing system components are in use today. They include shackles, plate shackles and detachable links. They all are included in

the categories of towing adapters and jewelry. See Figures 2-41 through 2-43
b Synthetic Couplings and Thimbles. For years the standard end fitting for manila hawsers was a rope thimble through which a shackle was passed. However, with the advent of high-stretch synthetics, the eye of the line could stretch sufficiently to allow the thimble to tumble out of the eye. In addition, the higher strength of the synthetic lines caused thimbles to crush and fail. To resolve these problems, several special thimble connectors were developed. Figure 2-41 shows the approved Navy Standard thimble
c. Shackles.

CAUTION

Special forged shackles, when used with chain stoppers and carpenter stoppers, utilize carefully-machined screw pins and are permissible in towing. Such pins must remain accessible for inspection and service while in use.

A means of connecting the various components of the towing hawser is provided by use of jewelry such as safety shackles, plate shackles and detachable links. Components of different sizes are connected by use of offset plate shackles and pear-shaped detachable links, as shown in Figures 2-41 through 2-43
d Poured Socket.

CAUTION

Whenever a poured socket is installed on a wire rope, the condition of the lubricant in the portion of the rope near the socket should be checked and new lubricant applied to dry areas.

A poured socket is a wire rope fitting used for terminating the end of a rope. These sockets are also called Spelter sockets. Sockets are of two types, open and closed. The open socket is fitted with a locking bolt and nut which, in turn, is secured with a locking bolt with two jam nuts. Frequently used on towing hawsers, the closed socket forms an eye with a solid bail. The broomed end of the wire is inserted into the socket and secured in place with the poured zinc. Figure 2-42 demonstrates use of a safety shackle and three standard pear-shaped detachables for connecting the standard hawser termination to a wide range of chain sizes.
e Swaged Fittings. It is now common to terminate wire rope having wire cores with fittings using the swaging process.

CAUTION

Swaging is acceptable only on IWRC (Independent Wire Rope Core) wire rope. It is not to be used on fiber core rope.

The wire rope swaging process attaches fittings to wire rope by means of cold plastic flow of metal under extremely high pressures. The process uses hydraulic presses in conjunction with suitable dies. The swaged fittings are usually made of special alloy steels This process has the advantage of low cost and high efficiency

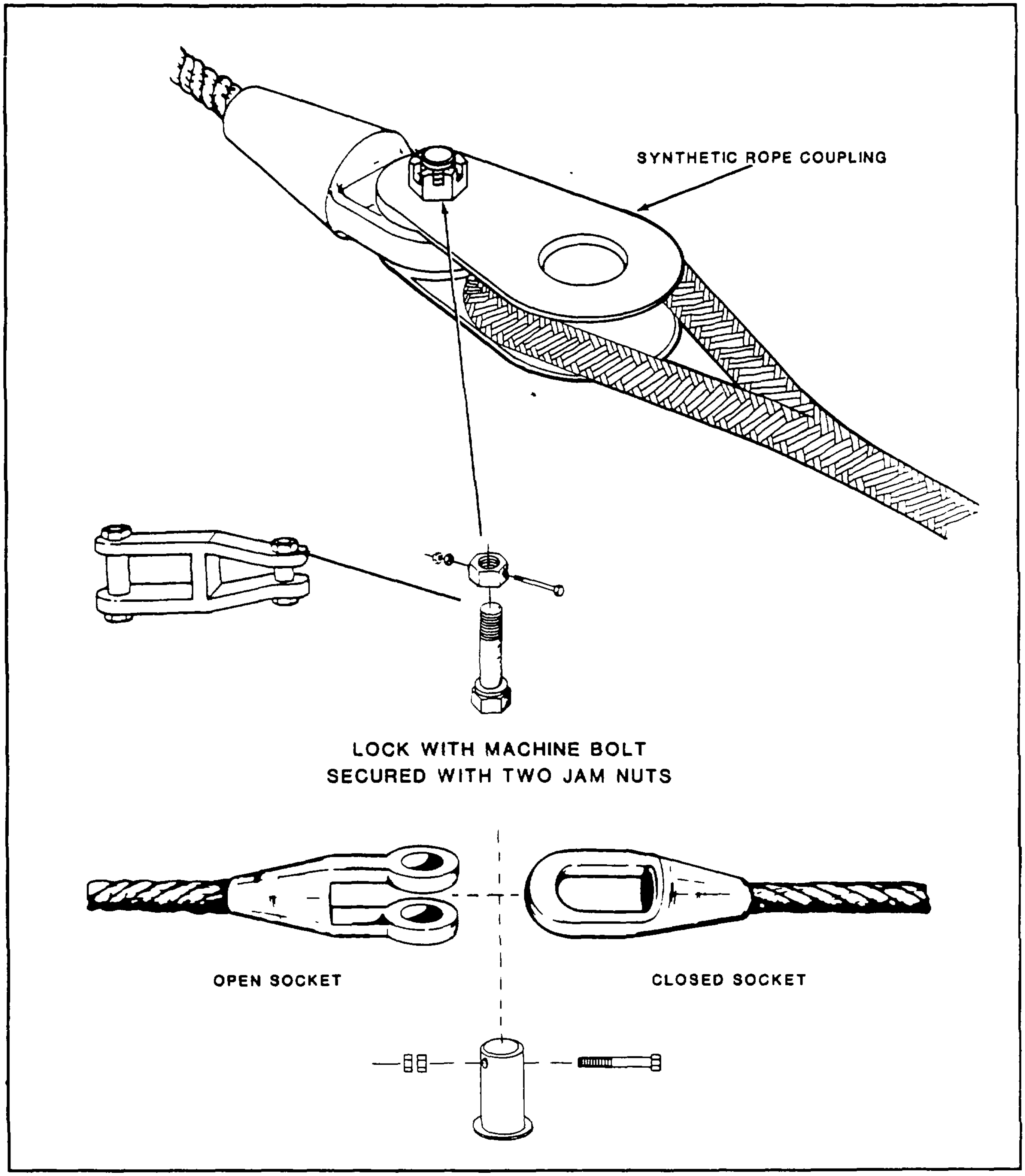


Figure 2-41. Towing Adapters.

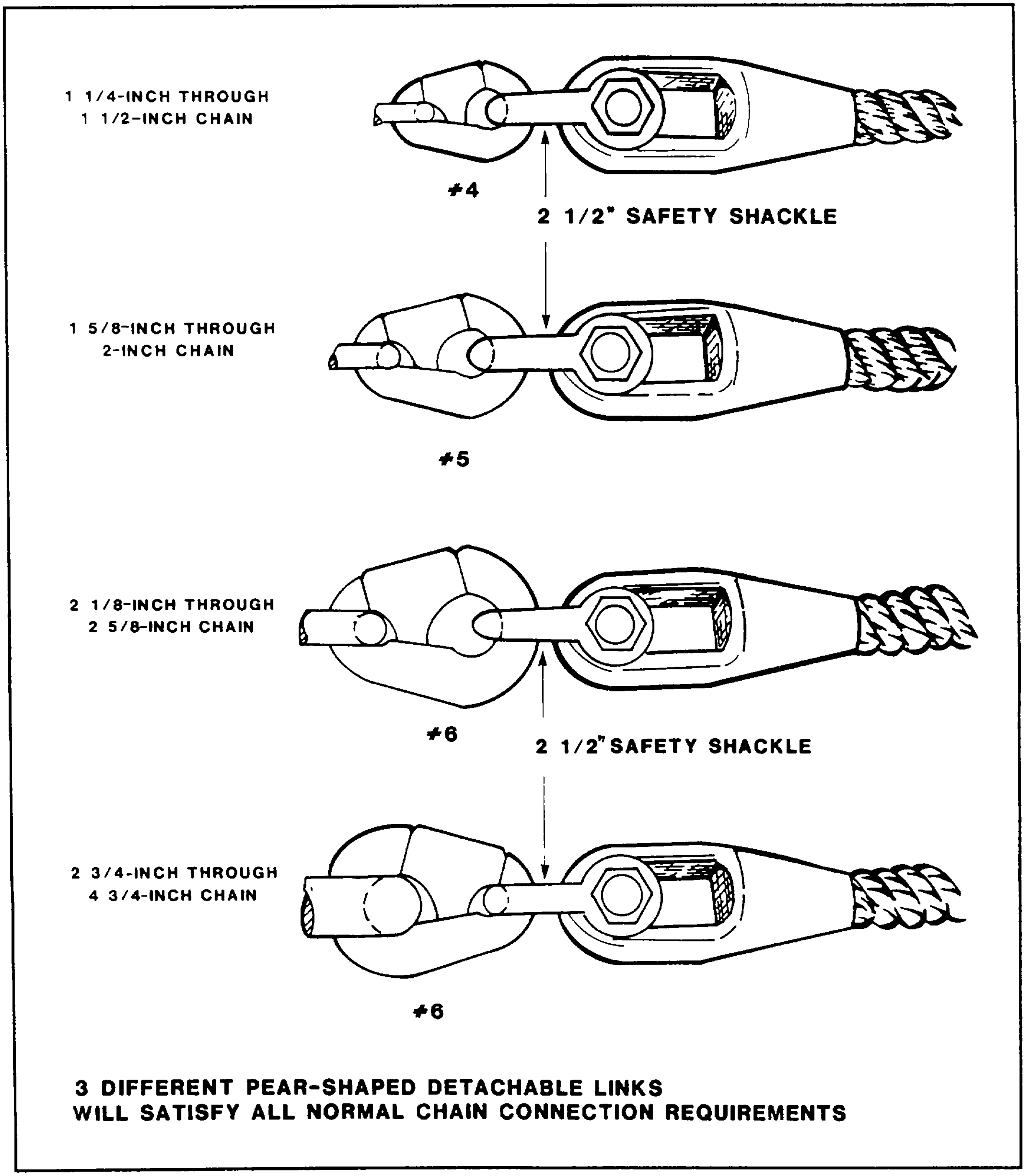


Figure 2-42. Pear-shaped Detachable Links.

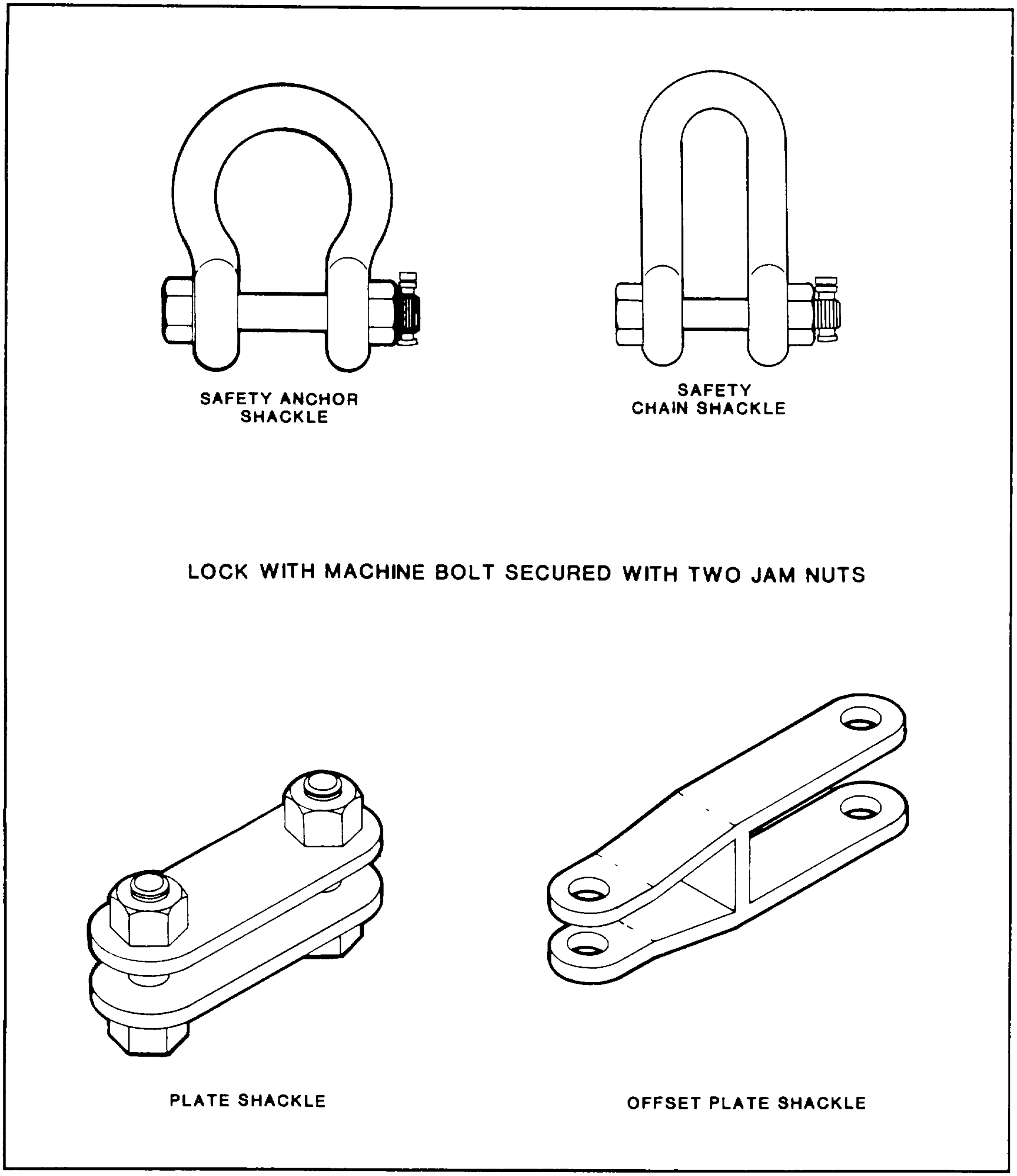


Figure 2-43. Shackles.

CHAPTER 3

TOWING PROCEDURES

SECTION I

3-1 INTRODUCTION

This chapter discusses towing procedures in general terms; however, each tow must be regarded as unique. The planning, preparation and execution have to be carefully worked out for each tow In this regard, the tow preparations must be meticulous, uncompromising and far-sighted. Fleet Admiral Nimitz provided a valuable guide for any ship operation when he said:

"'The time for taking all measures for a ship's safety is while still able to do so. Nothing is more dangerous than for a seaman to be grudging in taking precautions lest they turn out to be unnecessary. Safety at sea for two thousand years has depended on exactly the opposite philosophy"

Tows have been damaged and lost by inattention to these basic principles. In preparing a tow, all of the things that may cause trouble must be considered. This approach involves anticipating and providing for worst-case problems.

Incidents involving loss of tows have demonstrated the absolute necessity for a thoroughly professional approach to towing. Requirements include training personnel, practicing basic procedures and planning for safe evolutions.

This chapter discusses the following-

a Pre-tow preparations
b. Getting underway with a tow
c Taking a tow at sea
d. Ship handling while towing
e. Inspection of tow during transit
f. Delivery of tow
g Special circumstances and emergencies in towing
h. Communications between ships
i. Towing NATO naval ships.

SECTION II

3-2 PRE-TOW PREPARATIONS

The command or activity (hereafter referred to as "sponsor" or "sponsoring command") requiring a tow is responsible for arranging for it. The command or activity with cognizance of the towed vessel at the point of departure is responsible for the towed vessel's proper preparation for sea: providing and assembling towing gear, lights, flooding alarms and riding crew, if any.

3-2.1 CHECK-OFF LIST FOR OCEAN TOWS.

The required check-off list for ocean tows must be completed by a representative of the activity preparing the tow Confirmation of applicability of various sections of this check-off list is required by the towing ship's Commanding Officer prior to the accepting the tow. This can be accomplished at a pre-tow conference with all parties concerned present, or by letter, telephone call or message. Upon accepting the tow, the Commanding Officer of the towing ship should acknowledge acceptance by letter or message. A representative of the receiving activity should acknowledge receipt of the tow by letter. The check-off list and required letters are presented in Appendix H.

3-2-2. SPONSORING COMMAND. The command sponsoring the tow is responsible for the following:

a. Review of the applicable type commander and Fleet CINC numbered instructions and operational orders
b. Preparation of the tow
c. Assembly of the towing rig

d. Certificate of Seaworthiness
e. Recommendation concerning requirement for riding crew
f. Return of all towing equipment, including towing bridle, if required, to preparing activity/tow originator
g. Designation of the receiving activity.

3-2.3 TOWING COMMAND. The towing Commanding Officer is responsible for the following:

a. Determination of date and time of sailing
b Determination of transit route
c. Determination of towing rig and trim conditions
d Inspection of the tow and acceptance, if deemed either satisfactory or a "Calculated Risk"
e Maintenance and security of tow during transit
f. Delivery of the tow and obtaining a receipt from the receiving activity.

3-2.4 TRANSIT COURSE SELECTION.

a. The first consideration in planning a tow is the predicted weather en route. The Optimum Track Ship Routing (OTSR) system must be utilized by the towing command. In addition, frequent contact should be made with the Navy Weather Center. A longer course, on a favorable weather track, should be selected in favor of a shorter one with unfavorable weather. The transit course should be determined using pilot charts as an aid. It is good practice to note locations along or near the track where a lee can be found, where practicable, to effect inspection, repair the tow or take shelter in case of heavy weather.
b The Navigation Officer shall be familiar with the charts of all areas to be transited, including potential safe havens He shall consider geographic features such as lees of headlands, effects of river outflows and tidal currents. On entering a safe haven, the Navigator shall be aware of water depths where the tow wire may snag. The Navigator shall stand ready to recommend shortening the towline as required.
c. It should be clearly understood in advance by all concerned, to within what distance from shore the ocean tug expects to remain connected--and, conversely, how far out from shore the harbor tugs are prepared to retain charge of the tow. Both parties should advise of any weather/sea condition limitations on their abilities.

3-2.5 TOWING LOAD REQUIREMENTS. The tow sponsor should arrange for review of records of previous tows of similar ships or craft and should predict towing resistance, using Chapter 5 and Appendix G if the tow's resistance is not well-known.

WARNING

Do not overextend the tug's capabilities. If necessary, provide for a tug transfer or a means of replenishing either from another ship or from the tow itself. Failure to make such arrangements could seriously jeopardize the mission.

Towing speed should be consistent with safeguarding the tow and tug. It is likewise advisable for the towing ship to independently calculate the towing resistance, to confirm that its towing equipment is adequate and that its power is sufficient for the task at the desired speeds.

3-2.6 TOW RIG CONFIGURATION. Plans for a variety of tow rigs can be found in Appendices I and J Selection of the tow rig is best based on its past performance and the needs of the particular tow Before towing a new or unique configuration, ensure that the design of the rig conforms to appropriate engineering and design criteria; consultation with NAVSEA OOC is recommended.

3-2.7 SHIP TOW PREPARATION.

a. Ensure that all rigging is adequate. If in doubt, use a higher safety factor. Pay particular attention to protection from chafing.
b. Ensure that multiple tows are configured for optimum seakeeping ability. For example, the Honolulu rig permits adjustment during transit.
c Identify the type of towing rig required for the conditions anticipated during the transit and at either end of the tow.
d Provide for a secondary towing rig on the tow in case the primary system is lost. Make provisions for anchoring the tow in case of emergency. Provide for all contingencies, as outlined in the check-off list.
e. Always carefully consider assigning riding crews on tows. The decision generally is based upon safety of the tow rather than upon habitability or administrative factors

(1) Fleet CINCs authorize riding crews in accordance with existing directives. Considerations governing the use of a riding crew include.

(a) duration of the voyage
(b) route
(c) expected and forecast weather
(d) experience and class of towing ship
(e) material condition of the tow
(f) flooding alarms and other monitoring devices installed on board
(g) habitability considerations for riding crew

(2) Riding crews shall be limited to personnel required for maintenance and security during the voyage

(3) When the tow has a Commanding Officer or Officer-in-Charge regularly assigned, the Commanding Officer of the towing ship will obtain a written statement from this officer that the tow is seaworthy and ready for sea. This requirement is in addition to the items on the check-off list referred to in Appendix H

f. The Commanding Officer of the tug has overall responsibility once he accepts the tow.
g. The Commanding Officer or the Officer-in-Charge of the riding crew must ensure that

(1) Adequate training and necessary drills are performed, including firefighting, flooding and other material condition drills; and drills for abandoning ship, boat launching, communications with the tug and securing a secondary towline. Security watches of machinery, watertight integrity, the towline, navigational lights, communications and other watches as necessary shall be stationed.

(2) There is an adequate method of boarding the tow at sea When feasible, fixed ladder rungs are preferred. See Figure 4-1

(3) The preparations include the pre-positioning of radios, pumps, hoses, tools, firefighting equipment and handling gear ready for use by either the riding crew or tug personnel who would board the tow. The towing plan considers these requirements: messing and berthing quarters for the riding crew, plus auxiliary power, fuel, damage-control equipment and life-saving gear.

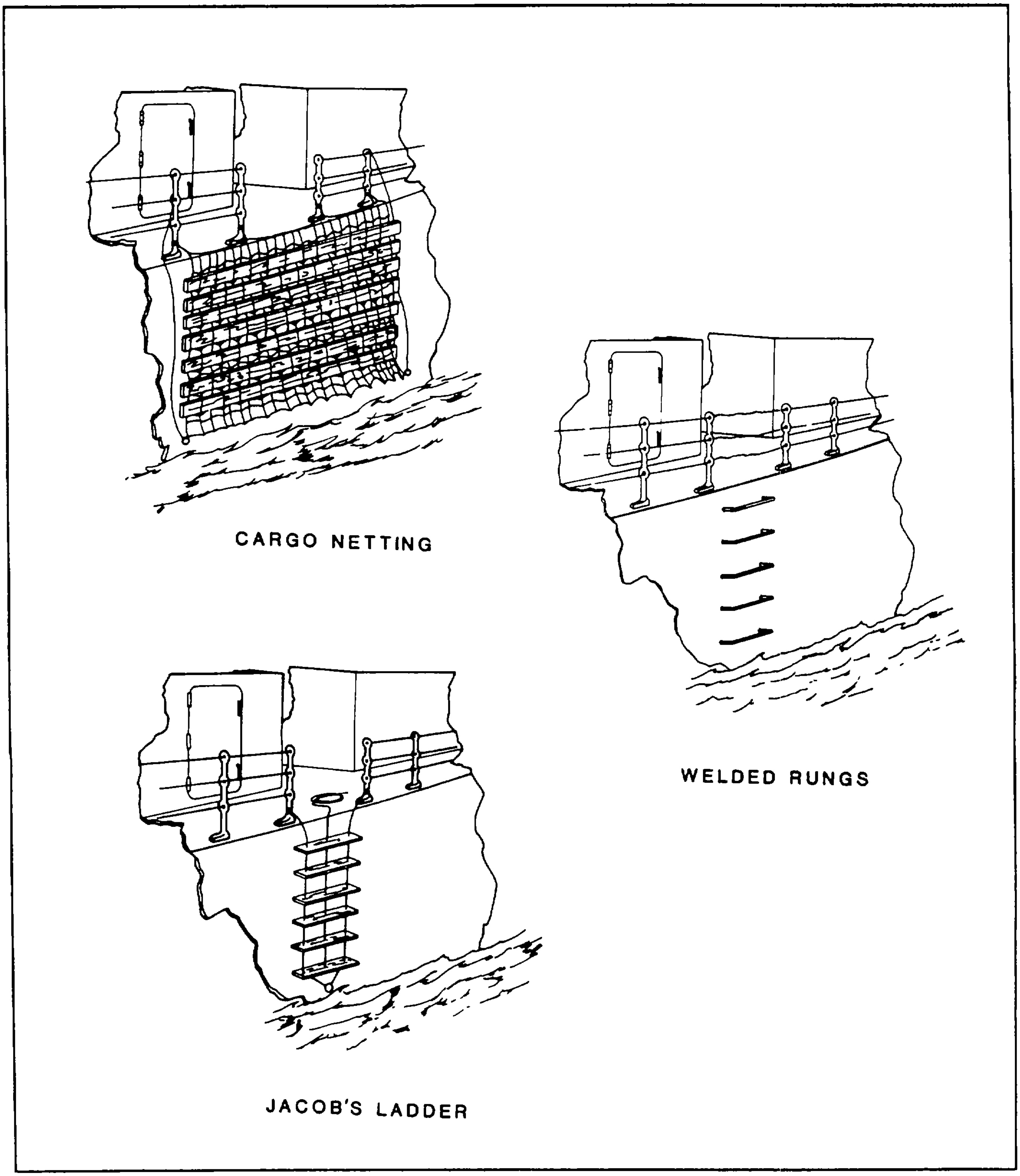


Figure 3-1. Sample Provisions for Emergency Boarding of Tow at Sea.

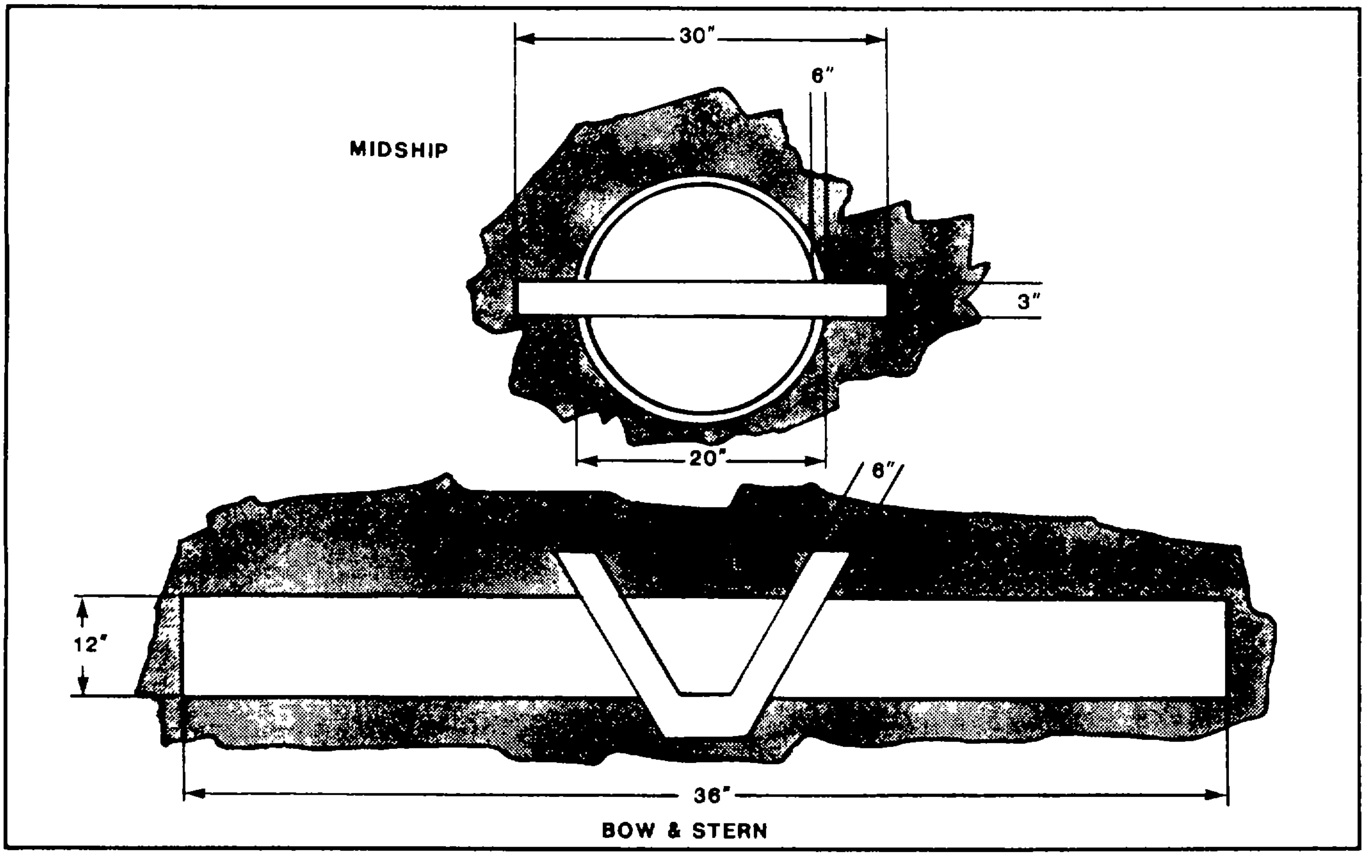


Figure 3-2. Special Draft Markings.

3-2.7.1 Flooding Alarms, Draft Indicators and Other Alarms.

a. There should be flooding alarms in all unmanned tows. Areas that are to have flooding alarms installed must be certified gas-free to prevent explosion and fire from electrical contact sparking.
b. Installation of flooding alarms may require piercing watertight decks and bulkheads. Every attempt should be made to use watertight penetrations, or minimize the size of the penetration. Penetrations should be installed as high as possible.
c. The tow should have sufficiently large special waterline marks painted on bow, stern and midships on both sides, in reflective paint to allow the towing ship to check the trim of the tow visually by day and by searchlights at night. See Figure 4-2.
d. Periodic inspection and test of the flooding alarms is recommended
e. Depending upon the tow, its equipment and cargo, other alarms such as fire, radiological, combustible gas, etc, may also be required.
f. Sufficient electrical power, battery or other, must be provided for all lights and alarms for the duration of the tow.

3-2.7.2 Propellers. The tow's propellers may offer great resistance.

a. Fixed-pitch propellers may be removed for long-distance tows to decrease the towing resistance.

resistance. However, the added drag of locked propellers may be desirable for some hull forms for better directional stability
b. Controllable-pitch propellers may be left installed if set in "maximum forward" pitch, where they offer the least resistance to towing.
c. When propellers must be allowed to free-wheel, propulsion machinery must be disconnected from the shafts or lubrication provided

NOTE

The procedure of free-wheeling propellers is not recommended.

CAUTION

Do not allow main reduction gears to rotate unless they are properly lubricated. This requires full lube oil pressure.

d A means for lubricating the shaft bearings must be provided. The stern gland on the shaft will normally be water-lubricated. Provision for this must be made while at the same time ensuring that the water does not flood the space.
e When propellers remain in place and are not allowed to free-wheel, the shafts must be locked by an installed shaft-locking device or by another suitable method as illustrated in Figure 3-3.

3-2.7.3 Trim. Proper trim of the tow is important because the trim can affect stability, towing characteristics and speed through the water. Ballast, fuel, cargo or equipment on board may be shifted to effect the desired trim. Trimming by the stern has proven an effective measure; a trim of one foot by the stern for each 100 feet of the tow's length has proven a good trimming rule, deep draft tows use somewhat less than one foot per 100 feet. When liquid is used to trim the vessel, care must be taken to ensure that there is no adverse free-surface effect. All tanks should be pressed full or left empty. All sluice valves should be closed In the case of landing craft and other craft with blunt or raked bows, ballasting may prevent heavy pounding, which can be very destructive to the vessel's bottom and other structural members. Prevention or reduction of pounding also reduces shock loads on the towing rig The tow should have a zero list.

3-2.7.4 Stability. Stability of the tow, in the case of an unmodified or undamaged. Navy commissioned ship, can be determined from a review of the data in Chapter II(a) of the ship's Damage Control Book. Similar information for commercial ships should be available in the ship's Trim and Stability Booklet as well as in the Deadweight Survey. For circumstances where formal documentation of the ship's stability is not available, the stability may be approximated by timing the ship's roll period. This method is reasonably accurate and is used by the U.S. Navy, U.S. Coast Guard and regulatory bodies to confirm the accuracy of inclining experiments and other similar stability determinations. For small craft, timing the period of roll is the approved method of stability determination.

This roll period estimate can be performed accurately enough even in fairly calm water by watching the masthead. Time several successive rolls and divide the total time by the number of rolls observed to obtain a good estimate. Then, to determine the adequacy of the roll stability, compare the timed period with the value calculated from the following formula:

$$T = 2\sqrt{\text{Beam (ft)}}$$

For adequate stability, the time in seconds for a ship to roll from port to starboard and back to port must be equal to or less than the time (T) calculated. For example, for a ship with a beam of 100 feet, the time observed for the ship to complete a roll period must be less than the 20 seconds calculated. If the observed time is longer than the calculated value (T), the

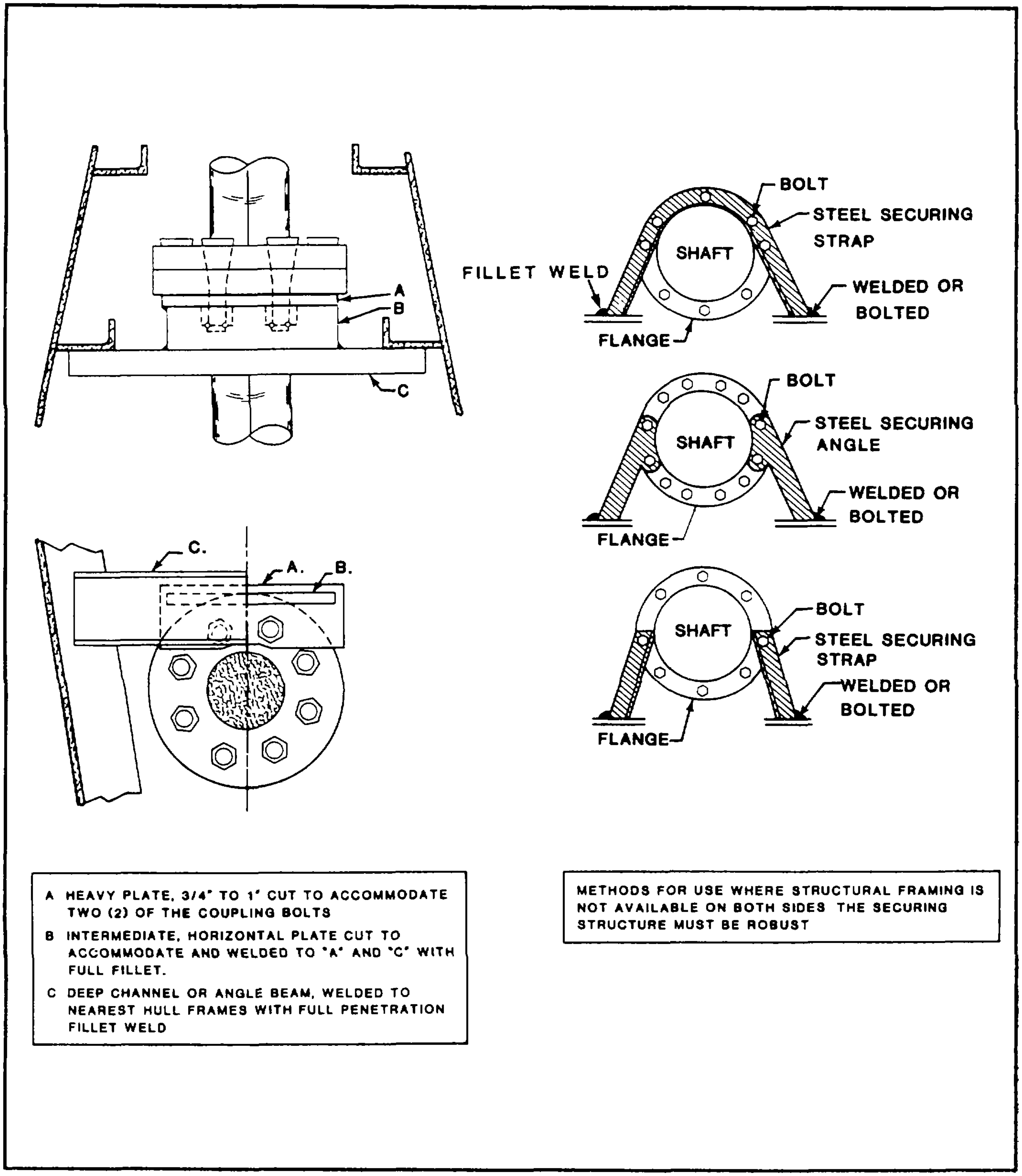


Figure 3-3. Securing the Propeller Shaft.

stability generally is considered inadequate. Equally important is frequent checking for a change in the tow's roll period. Even if overall criteria are satisfactory, investigate promptly any significant increase in period, since this suggests flooding and/or additional free surface.

For small craft and barges which do not have a Damage Control Book, follow a few general guidelines when attempting to improve stability:

a Completely fill any slack tanks
b. Lower and secure or off-load high weights
c Secure any large hanging weights and add ballast.

Completely filling tanks or adding ballast will decrease freeboard as well as improve stability. For commissioned ships in the U.S. Navy, the Damage Control Book contains specific measures appropriate to the ship which can be employed to improve the stability. The book also contains stability characteristics for various loading conditions which meet the Navy's stability criteria

3-2.7.5 Structural Reinforcing.

CAUTION

Many barges and barge-like vessels tend to be more susceptible to damage and deterioration than conventional ship-type vessels. They should therefore be inspected for hull strength prior to towing.

To avoid special dry-docking before towing, barges, cranes and other service craft should be thoroughly examined during routine maintenance. Plate thickness and weld inspections should be made during regularly-scheduled dry-docking, or by ultrasonic inspection in water, and repairs made then In emergencies, such as salvage and rescue towing, structural reinforcement and load distribution may be accomplished with additional structure or shoring. See Figure 3-4 for typical timber framing practice. Protection against slamming damage may be effected by pressing up the bow section of the hull with water. This action may require counter-flooding or shifting of cargo.

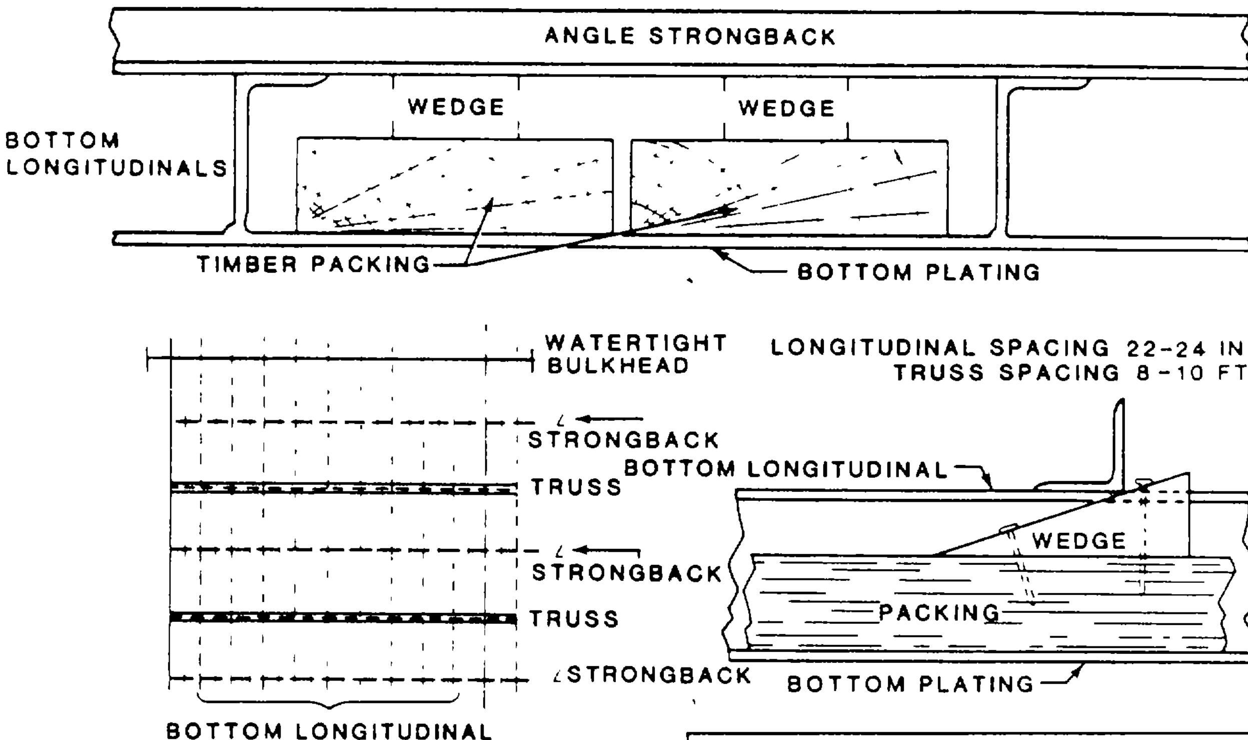
Inspection may reveal damage or deterioration of the frames, bottom or weld seams. Particularly when this occurs in the forward one-fifth of the vessel's length, the vessel should be dry-docked or ultrasonically tested, and necessary repairs made. Bottom plate thickness must meet minimum values for safe towing. See Table 3-1 While in dry-dock, check bottom, side, decks and inner bottom. All defective welds and plating should be repaired or replaced.

3-2.7.6 Rudder.

CAUTION

Do not use temporary lashings or other makeshift measures to lock the rudder of a towed ship. Lock the rudder amidships for towing.

The tow's rudder should be locked, generally amidships. A drifting rudder will cause the tow to behave erratically. During preparation of the tow, an examination of the steering gear on the tow will permit the selection of the best method to secure the rudder. Several general methods are shown in Figure 3-5. Using any method, care and proper engineering should be accomplished to ensure the securing device(s) and supporting structure are strong enough to withstand the forces generated by the rudder. It should be kept in mind that the forces on the rudder, even at low speeds through the water, may be very large due to wave impact and other sea action. These loads will be transmitted through the steering gear and will have to be absorbed by the ship's structure as imparted by the securing device.



NOTES

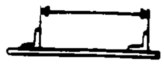
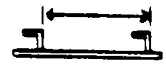
1 WELD STRONGBACK TO LONGITUDINAL FLANGES

2. DO NOT SET WEDGES WITH A HAMMER HEAVIER THAN 2 LBS

3 NAIL WEDGES TO PACKING SO THAT WEDGES WILL NOT WORK LOOSE

4 ALTERNATE DIRECTION OF WEDGES TO SECURE PACKING TIMBERS

Figure 3-4. Reinforcing Bottom Plating in Barges.

Barge Length	 Frame Spacing			 Frame Spacing		
	24 in.	27 in.	30 in	24 in	27 in.	30 in.
100 ft	0 340	0.361	0 382	0.361	0 382	0.403
120 ft	0.359	0 380	0 401	0.380	0 401	0.422
140 ft.	0.378	0.399	0 420	0.400	0.421	0.442
160 ft.	0.398	0.419	0.440	0.419	0.440	0.461
180 ft	0.417	0.438	0.459	0.438	0.459	0.480
200 ft	0.437	0.458	0.479	0.457	0.478	0.499
220 ft.	0.456	0.477	0.498	0.477	0.498	0.519
240 ft.	0 475	0.496	0.517	0 496	0.517	0.538

NOTE

Intermediate values may be obtained by interpolation. Above thickness are for new plates as shown on plans. Shoring is needed when plates are 25% thinner than those listed above.

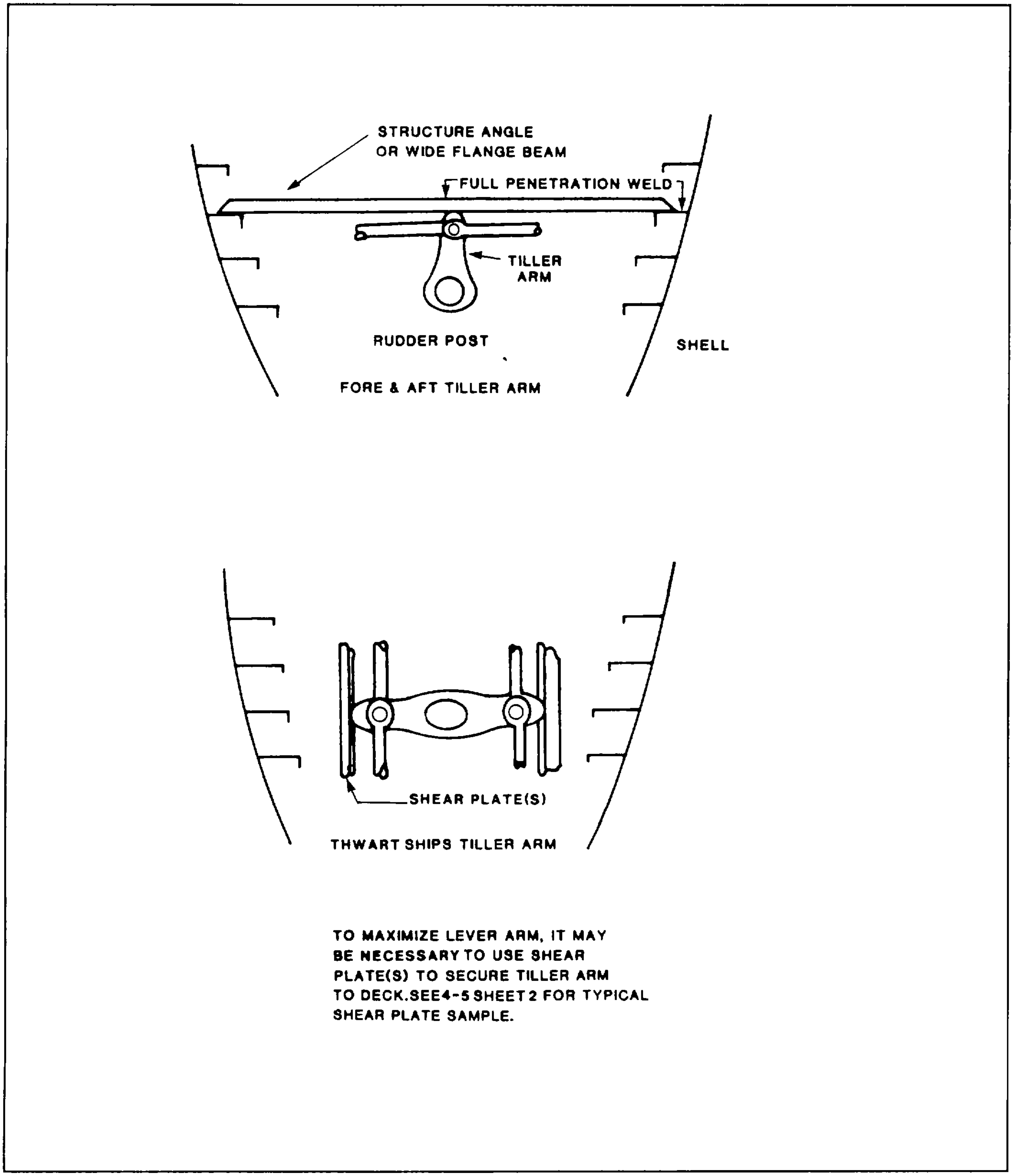


Figure 3-5. Securing the Rudder (sheet 1 of 2).

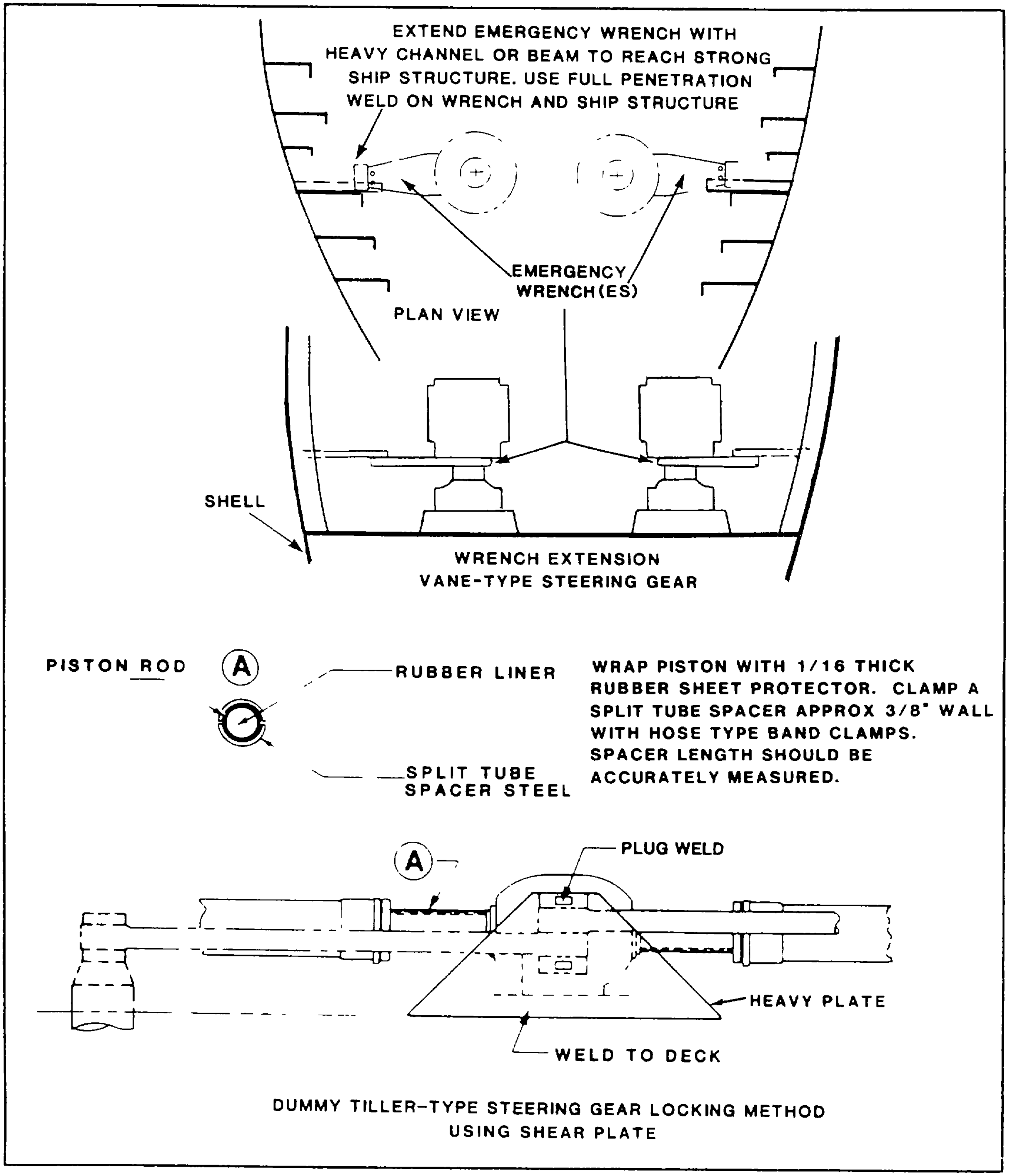


Figure 3-5. Securing the Rudder (sheet 2 of 2)

(Text continued from page 4-8.)

If the steering gear is hydraulic, the rams can be secured by positioning the rudder amidships and securing the hydraulic system in an attempt to maintain a hydraulic lock. Sheet rubber is wrapped around the piston and split pipe is cut to the proper length such that the ends bear against the cylinders and/or yoke. The split pipe should be secured in place with bands. Added security could be provided by welding a plate/structural member to the yoke and to the foundation or ship's structure. Refer to Figure 3-5.

If the steering gear is a yoke or tiller arm-type, then structural steel can be welded across the tiller arm for suitable ship's structure on either side. As above, engineering calculations should be accomplished to ensure that the securing device and ship's structure are adequate. Figure 3-5, Sheet 2 depicts an example or such an arrangement.

It may not always be feasible to utilize any of the illustrated arrangements, as in the cases of rescue and towing at sea and unfavorable weather conditions. A temporary means may then be employed. Chain falls or come-alongs may also be used in conjunction with tiller arms or quadrants. The use of wire rope should be avoided in favor of chain wherever practicable. Ram hydraulic systems may be isolated in some installations to assist rudder locking. These methods are only temporary, a permanent locking arrangement should be installed.

For a manned tow, if the steering machinery is operable and reliable, a decision may be made to steer the tow. In this connection, see Paragraph 3-5.3.6.

3-2.7.7 Navigation Lights. The preparing activity must ensure that the tow is equipped with the proper navigation lights. Specific requirements concerning the correct positioning, number and color of lights are contained in the appropriate COLREGS (Ref. 2).

3-2.7.8 **Electrical Systems.** Electrical power may be required on the tow for the following systems:

a. Fire alarms
b. Lights
c. Flooding alarms (audible and visual)
d. Pumps
e. Communications equipment
f. Crew accommodations
g. Winches/capstans
h. Radiological alarms.

To ensure reliable operation, these systems periodically should be inspected and tested. If electrical power on the tow is supplied by an installed or portable generator, a sufficient amount of fuel for the tow should be provided. A simple rule of thumb is to allow two gallons of fuel per day per generator horse-power on the tow.

For battery-powered systems, the batteries should be checked for capacity and condition. Batteries exposed to the weather must be protected in watertight containers that will not permit the batteries to leak to ground. It is essential that all exposed wires and connections be adequately waterproofed. Wires should be secured to prevent chafing and grounding. Provisions must be made to vent hydrogen gas from the batteries. Two items of equipment are available to aid in conserving battery power-a solar or light-sensitive switch that will turn the lights on at dusk and off at dawn, and a compact solar generating panel that will recharge the batteries during daylight hours.

3-2.7.9 **Crew Accommodations.** Vessels with riding crews should be provided with adequate berthing and messing facilities, including sanitary facilities and ventilation.

3-2.7.10 Emergency Systems. Adequate firefighting equipment and materials, as well as damage control equipment and fuel, should be placed on board prior to the start of the tow

3-2.7.11 Access Within The Tow. A riding crew or boarding party from the tug may find itself in an unfamiliar setting on a large tow. The preparing activity should establish route markings to those areas susceptible to either flooding or fire. Painted route markings from a central location and/or from the boarding point would allow personnel to go by the most direct route to the scene of possible emergency. Establishing route markings to aid a security patrol in making his rounds also would eliminate missed areas, adding to the efficiency of the patrol.

3-2.8 ANCHORING THE TOW. Consideration should be given to the need for anchoring the tow in an emergency, sufficient ground tackle or other anchor-handling equipment should be provided. If water can enter compartments or tanks via the chain pipes, the pipes should be sealed. The simplest method of sealing chain pipes is to pack the pipe with cloth filler and plug with cement.

3-2.9 CERTIFICATE OF SEAWORTHINESS.
The representative of the command having prepared the tow for sea shall complete a Certificate of Sea worthiness for ocean tows. The certificate indicates general characteristics, type of cargo, towing gear, lights, speed limitation, etc. A sample Certificate of Seaworthiness and its endorsements are shown in Appendix H

3-2.10 INSPECTION AND ACCEPTANCE OF TOW. Prior to accepting a tow, the Commanding Officer of the towing ship must make a confirming inspection of the seaworthiness and readiness of the tow . When inspecting the tow, personal observations should include, but not be limited to, the following:

a. Ensure towing vessel's preparation check-off list, shown in Appendix H, is thorough, adequate and properly accomplished
b. Thoroughly instruct the towing inspection team in their duties.
c Inspect the tow rig, appendages and attachment points to ensure that the tow is properly rigged with the appropriate material.

WARNING

Substitution of materials can be dangerous as well as detrimental to the tow. Substitutions shall not be made unless there is a complete knowledge of the material being substituted. Material substitutes frequently introduce a new and unpredictable weak link. Substitution of a stronger material may change the location of the weak link and relocate the potential failure point in the rig to a position that is hazardous to personnel.

CAUTION

A screw-pin shackle shall not be used as a replacement for a safety shackle in towing. A safety shackle will deform under load and still hold, while a screw-pin shackle's pin can work itself out of the shackle.

d. Ensure towline, bridle and associated towing gear are in good condition and that improper substitutions have not been made in fittings and materials. Typical items for which to be alert include:

(1) Substitution of mild steel for the forged steel used for safety shackle pins
(2) Substitution of stainless steel for other high strength alloys because many types of stainless steels are subject to stress-corrosion cracking
(3) Substitution of wrong-size components

e. Ensure that the Certificate of Seaworthiness states how the tow is rigged, including equipment sizes and other pertinent data, means of boarding the tow, and whether:

(1) A retrieving wire is rigged

(2) The tow has power

(3) Mooring lines are available

f Ensure cargo on the tow is properly secured to prevent shifting in heavy weather.

WARNING

Use the applicable safety precautions for entering voids and unventilated spaces. Failure to do so may result in injury or death to personnel.

g. When inspecting a tow, every accessible space shall be checked. All spaces should be completely dry and watertight

h. Check to ensure that vents to tanks and other closed spaces are covered to prevent water entry, but not plugged so as to prevent the escape of air or gas. Plugging a vent allows pressure to build up within the tank with an increase of atmospheric temperature. Barge sides and decks have been known to bulge severely. If necessary, cover compartment vents with canvas socks that prevent water from entering the compartment yet allow air to escape should a pressure increase occur.

i Ensure that running lights and flooding alarms are operating properly, that batteries are fully charged and battery life is computed to be sufficient for the transit.

j Ensure serviceable salvage pumps and associated equipment with fuel are safely stowed on board the tow.

k. Ensure that adequate firefighting equipment with fuel, hoses, chemicals, overhaul gear, etc., is safely stowed on board the tow. Require an operational demonstration that fire pumps can take a suction.

i Ensure that all high-value items on the tow are locked up and inventoried on the tow report form

m. Ensure that provisions have been made for quickly releasing the towline in an emergency.

n. Ensure that provision has been made for streaming a pickup line for the secondary towline.

3-2.10.1 Tug Accepts the Tow. Upon satisfactory completion of the tow preparations and inspection, the Commanding Officer of the tug shall accept the tow, notify his operational commander and proceed with his mission.

3-2.10.2 Action to be Taken for Unsatisfactory Conditions. In the event that unsatisfactory conditions of seaworthiness or readiness of the tow are found, and the differences cannot be resolved at the local level, the Commanding Officer of the towing ship should notify his operational commander stating why the tow is unsatisfactory. The report should include recommendations for the correction of deficiencies. If conditions or circumstances are such that a calculated risk is involved, the Commanding Officer of the towing ship should state that he will accept the tow only on a calculated risk basis

SECTION III

3-3 GETTING UNDERWAY WITH A TOW

A tow can routinely be picked up at a pier, in the stream, at anchorage or at sea. Ocean-going tugs should not be asked to maneuver unassisted in restricted waters If possible, the tow should be delivered to the tug by harbor tugs, or harbor tugs should be available to assist the tug/tow to navigable waters.

CAUTION

When picking up a tow, the Conning Officer on the tug should be cautious when increasing speed and should maintain an even strain on the towing gear. If a readout is not available on the bridge, tow hawser tension information should be provided to the Conning Officer by the Towing Watch.

3-3.1 FROM A PIER. Getting underway from a pier with a tow requires that the Conning Officer be particularly aware of the tides, currents and wind. In addition, he and the harbor tug master and pilot should discuss the intended procedures prior to getting underway.

CAUTION

Care should be exercised when alongside in a seaway. The motions of the tug and tow may be sufficient to part the mooring lines, resulting in damage and causing the tug to lose control of the tow.

If the tow is made up astern and is of relatively large size, a harbor tug may be used to assist in getting it clear of the pier. Once the towing ship and the tow are in the channel, the towline should be set at short stay in keeping with the depth of confined waters to be transited. Keep the catenary shallow to avoid snags.

3-3.2 IN THE STREAM. It may be necessary to get underway and accept a tow in the stream. In this case, the following procedure can be used. See Figures 4-6 and 4-7. The approximate channel course should be taken with bare steerage and assisting tugs should bring the tow to the tug's stern. When the tow is near the tug's stern, a riding slip line should be rigged with its eye on the bitts and then passed to the tow, reeved through a suitable deck chock on the tow and led back to bitts on the tug. The tow then will be steadied on the riding slip line by the harbor tug(s). The tow should then be heaved in, the tow connection made and the riding slip line recovered as the tow is streamed.

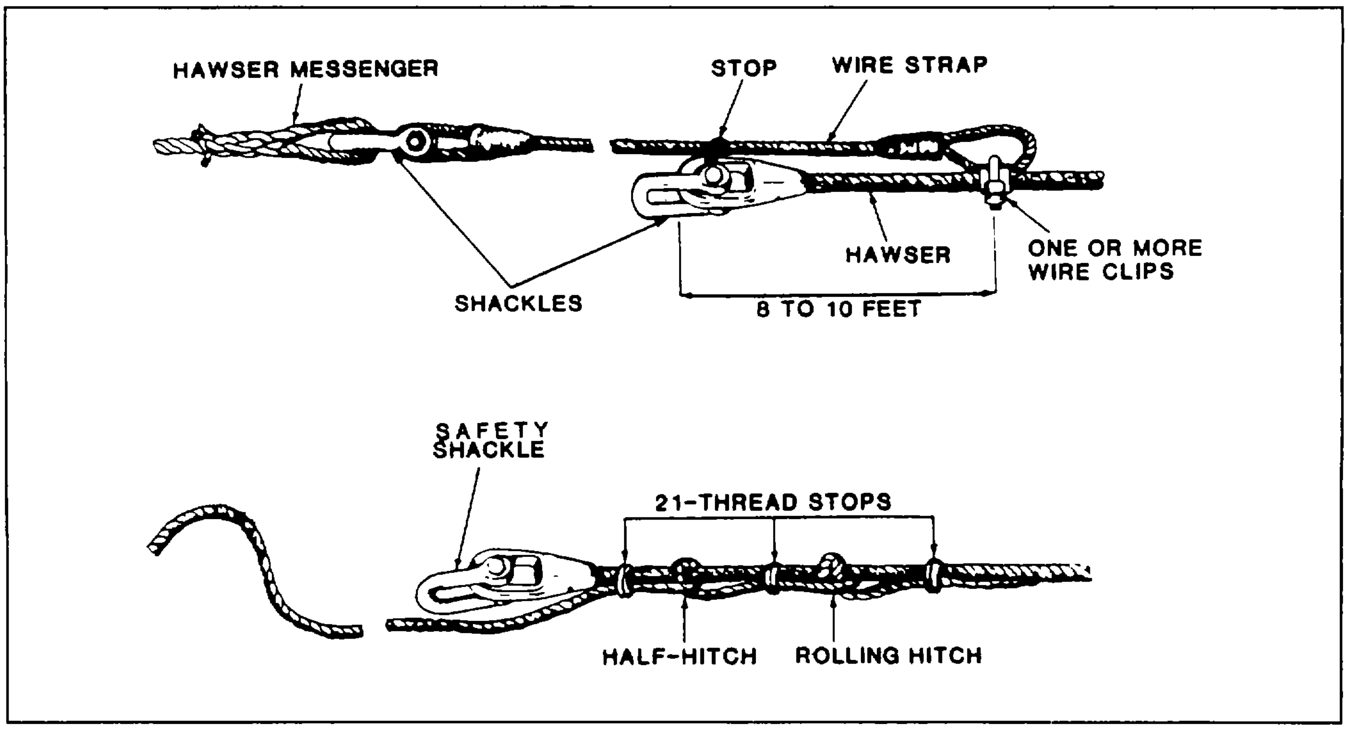


Figure 3-6. Methods for Securing Messenger to Towline.

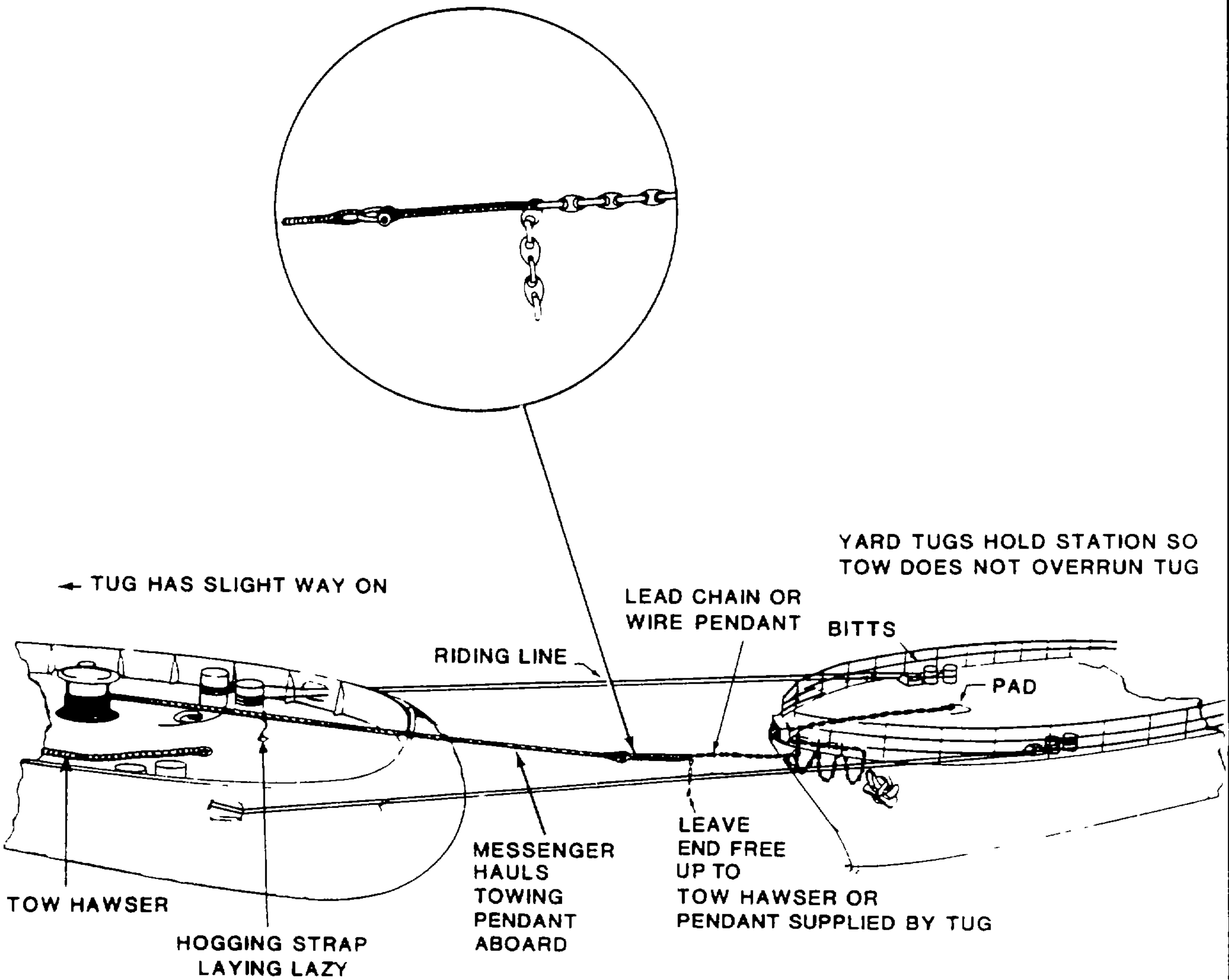


Figure 3-7. Accepting a Tow in the Stream.

3-3.3 AT ANCHOR

a. Tug underway/tow anchored. In moderate seas, the tug should come alongside the anchored tow and tie up with the tug's stern as close as possible to the bow of the tow. The tow then passes a line to the tug, which is used to pull a messenger and then a portion of the tow's chain pendant to the tug As the chain comes down on the tug's fantail, a stopper is passed on it to restrain it while the tug's crew rigs the remaining towline connection. When the connection is made, the chain stopper is released and the tug maneuvers clear. Assistance of a harbor tug usually is required. When headed fair, the tow weighs anchor. With the anchor housed on the ship, the tug can start ahead, slowly accelerating. Significant time is required to attain the desired catenary in the tow hawser and come up to towing speed. If the tow has no power to its anchor windlass, the crew should rig an appropriate retrieval line and buoy so that the anchor can be slipped and recovered later. If unfavorable conditions for going alongside prevail, passing the hawser can be difficult. The tow remains anchored as the tug approaches and maneuvers to receive the messenger. Expert seamanship is required to prevent the tug from drifting out of range on the downwind approach
b. Tug anchored/tow anchored. Rather than passing the towline while underway, often it is advantageous for the tug to anchor upwind/upcurrent from a large ship. While at anchor, the tug can prepare the towline for passing. The tug veers her anchor chain until within a short distance of the tow's bow. When the tug's stern is close aboard the tow's bow, the towline can be passed and the connection made. With the towline connected, the tug can use her engines to come ahead and weigh her anchor, veering towline as necessary. With the tug free to navigate, the tow weighs her anchor and the tow commences. If the tow does not have power, it may be necessary to slip the chain and anchor. A buoy should be used to mark the anchor's position so that the anchor and chain can be recovered later.
c Tug anchored/tow underway with steering tug(s). The tug anchors and settles out into the wind and current. The steering tug(s) brings the tow up to the stern into the current or wind. A pendant or lead chain is passed to the stern of the tug. Using the tug's stern capstan, the messenger is heaved on board until a sufficient amount of chain is brought on board to pass a chain stopper. The connection is made, the chain stopper released and wire paid out as appropriate. The tug weighs anchor and commences accelerating at a very slow rate of speed. This method is safe, simple and expeditious.

3-3.4 ACCELERATION. In all these instances, when getting underway, build up speed slowly. Judicious acceleration and deceleration prevent damage to the towing gear. The preferred means of controlling strain when commencing varies with the class of towing ship.

Frequently the tow will commence in restricted waters or a narrow channel. Beam winds and/or waves may tend to force the tow out of its channel or into the path of other ship traffic. Even with operable steering machinery, the initial towing speed will be insufficient for controlling the tow. For these reasons, it is prudent to retain harbor tugs alongside the tow, or immediately available, until the towing ship's Commanding Officer is satisfied that he can control the tow within all existing navigational constraints.

As speed increases, the resistance of the tow will increase. Yet water depth may not permit sufficient hawser payout to establish a catenary. The towing machine's automatic features are especially useful in this situation.

SECTION IV.

3-4 TOW AT SEA

3-4.1 SETTING COURSE. When adequate sea room is achieved, maneuver to set course and begin streaming the tow. Do not stream to full scope until sufficient water depth is available.

3-4.2 TOWING SPEED. Important factors in determining a safe towing speed are: material condition of the tow, sea states, towing direction relative to the surface waves, wind velocity and direction, hull type of the tow, tug horsepower and available powering assistance from other tugs or the tow's power plant.

The towing speed should be chosen to minimize the probability of damage to the tow. Special care should be exercised when towing damaged vessels and flat bottomed craft to avoid excessive seakeeping motions and pounding When necessary, the towing course and speed should be chosen relative to the sea state and the wind direction to keep the towed vessel motions within safe limits

Barges generally should not be towed faster than about 8 knots under mild sea conditions. Small service craft and some dry-docks should be limited to about 6 knots. Deterioration of weather conditions requires appropriate speed reduction to ensure continued safe towline loading. When towing larger surface ships, the speed limitation usually is a function of the tug's capabilities.

3-4.3 TOWLINE SCOPE. The towline scope employed during a tow depends primarily on four factors'

a. Type of towing rig employed
b Water depth
c Catenary required to absorb changes in towline tension
d Scope required to keep the tug and tow "in step".

To estimate the towline scope required, it is first necessary to estimate the steady towline tension which will be required to maintain the desired towing speed. Having an estimate of the total tow resistance, it is then possible to compute the catenary which will be associated with a chosen towline scope and towline rig. Paragraph 5-4 4 presents a simple formula for estimating the catenary. For hawser scopes greater than or equal to 1,000 feet, Figures 5-4 through 6-12 will provide catenary depth directly, given hawser tension. Catenary and scope also can be used as indicators of tow hawser tension and changes in tension. The AAJ technical manuals have tables that permit easy interpretation of scope, catenary and tension. The scope should then be chosen to provide an adequate catenary for the absorption of changes in towline tension, without exceeding the water depth. Dragging the towline on the sea floor will damage the hawser through abrasion and could lead to fouling the towline on a sea floor obstruction in addition to losing control over the tow.

If the surface wave pattern has a predominant wavelength, an attempt should be made to adjust the towline scope so that the tug and tow ride on crests of the predominant wave components at the same time. Adjusting the towline in this fashion may keep the tug and tow "in step:' thus minimizing changes in towline tension caused by seakeeping motions Refer to Paragraph 3-5.2.

3-4.4 TOWING WATCH. With the tow streamed, the towing watch shall be set to observe the tow, towing machine, towline and the tow's seakeeping performance. The tow watch shall routinely advise the Officer of the Deck of conditions observed. On board newer tugs, much of the information Is displayed in the pilot house and control stations.

SECTION V

3-5 SHIP HANDLING AND MANEUVERABILITY WITH A TOW

With the tow underway, the tug begins to slowly accelerate to towing speed. Rudder orders are to be issued so as to permit slow and orderly course changes. It is important not to subject the tow or towline to excessive dynamic loading. Slow course and speed changes will prevent excessive strain. If an automatic towing machine is installed, a low tension setting can be employed and the tow streamed as speed is increased. Once the desired scope is achieved, the setting on the automatic towing machine may be increased to the desired value.

CAUTION

Small increments of rudder angle are recommended when changing course under tow. This will ensure that the tug maintains control of the tow and prevents the tow from ranging up on the tug. Never permit the tow to pass forward of the tug's beam, as the tug or tow hawser may be severely damaged.

3-5.1 TUG STEERING. The ability of the tug to maneuver itself under all conditions is essential.

NOTE

Maneuvering characteristics of the tug can be dramatically affected when towing another vessel.

The position of the tow point (that point at which towline tension is applied to the tug) and the tension on the towline create a moment which opposes the rudder moment and hence restricts the turning motion of the tug. The tug's ability to steer is increasingly hampered as the tow point is moved further aft. The affect is aggravated at low or zero speed. The term "in irons" is used to describe the condition where the opposing moment of the towline is the same as or greater than the turning moment created by rudder and other hydrodynamic forces. The tug is then rendered incapable of steering. See Figure 3-8. Clearly, being in irons is undesirable, especially when maneuvering in confined waters or in a poor orientation with respect to the sea. A tug also can be rendered in irons when she cannot make headway under her own power because of the towline making contact with the bottom. In this case, the tug effectively is anchored by the stern. Her tow is not anchored and the distance between the two vessels may rapidly close. To avoid being run down, the tug should shorten the wire and regain headway at once.

Ideally, the position of the tow point should be located at the pivot point, to allow the tug maximum freedom of rotation in steering. This is why the towing winch is mounted as far forward from the stern as practicable, and as close to the pivot point as possible. Although it is doubtful that any towing winch is located at the pivot point itself, the pivot point without a tow is usually located on the center line at about one-third of the tug's length from the bow. From a practical standpoint, the towing point is designated as the towing winch or towing bitts, if installed. However, there are times when the towing point is located farther aft-e-g., a Norman pin, hogging strap or stern roller. The operator should be aware of the possible maneuvering restrictions imposed on the tug when towing in these configurations and should take the necessary precautions to avoid being placed in irons.

3-5.2 KEEPING A TUG AND TOW IN STEP.
When a tug is at sea with a tow, the two vessels move distinctly and separately in surge, sway, heave, roll, pitch and yaw in response to the surface waves. The degree and timing of motion which either vessel experiences with respect to the surface waves depends on the individual vessel's characteristics. No two vessels will respond to the surface waves in exactly the same pattern. In cases where the surface wave pattern is characterized by a single predominant wavelength, it may be possible to minimize the difference in the timing of the tug and tow motions. This involves adjusting the towline scope so as to place the tug and the tow on crests of the predominant surface waves at the same time. By placing the vessels on the crest at the same moment, they will move in response to the waves in the same direction at approximately the same time. Adjusting the timing of the vessel motions in this way will reduce the dynamic tension in the

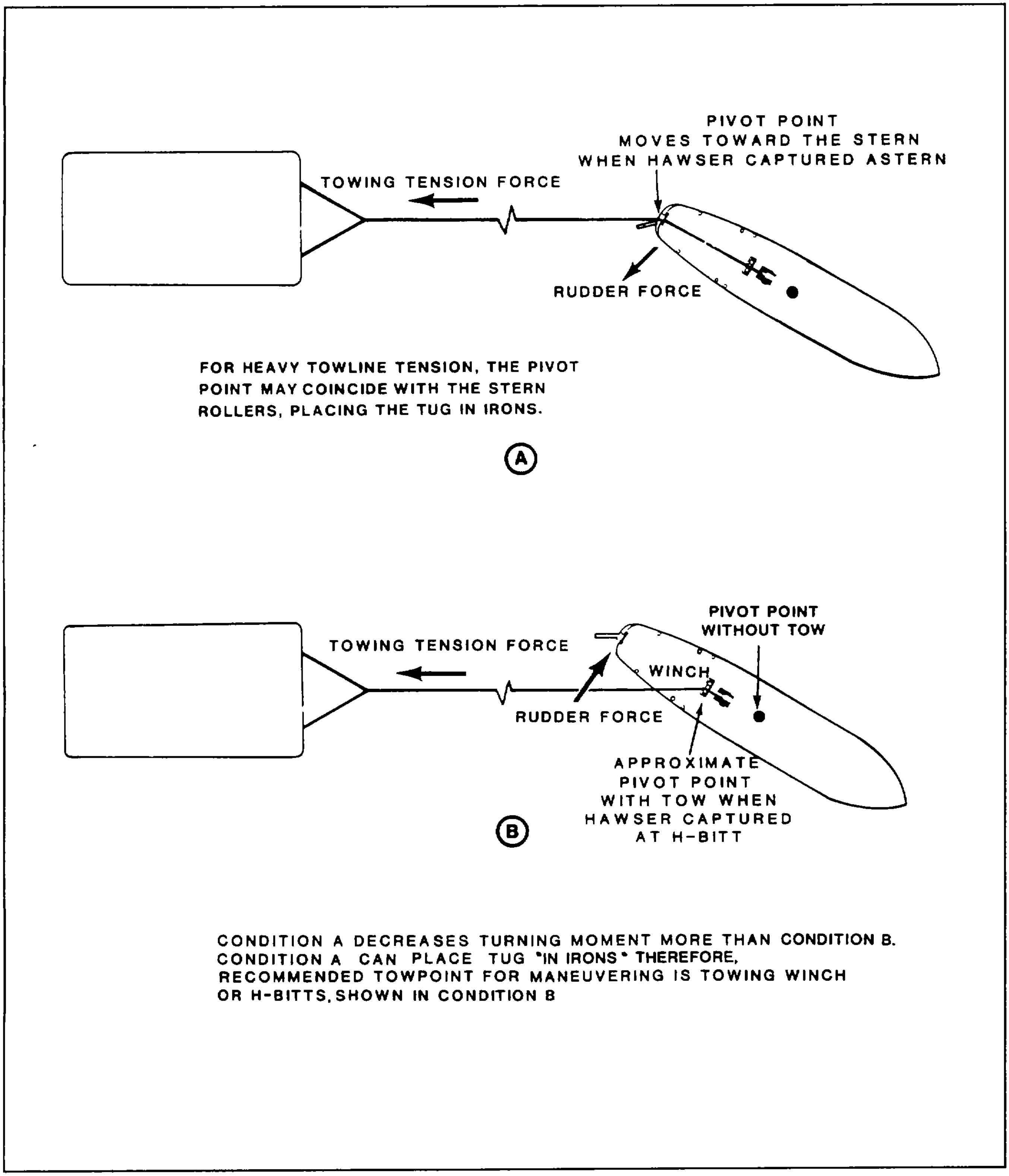


FIGURE 3-8. Effect of Towpoint on Steering.

towline. This practice has been referred to as keeping the tug and tow m step In tandem tows, this is rarely possible

Keeping m step applies equally to all towing situations whether towing on the dog, hook, brake or on an automatic towing machine. The benefit of being in step is lower peak tensions.

3-5.3 EQUIPMENT FOR CONTROLLING THE TOWLINE.
As noted m the preceding paragraph, there can be large relative motions between the tug and tow. There also can be large relative motions, especially m yaw or sway, between the towline and the stern of the tug. The equipment for controlling these motions has evolved over the history of towing.

3-5.3.1 Stern Rollers.

CAUTION

Use of vertical rollers may put tug in irons, which would seriously limit the tug's maneuverability.

NOTE

Stern rollers should be properly maintained and lubricated to ensure rotation and smooth surface conditions. Rollers are often frozen and their surface areas grooved and scored from towline wear. Such conditions directly contribute to the abnormal wear of the towline.

a. Vertical stern rollers act as a fairlead for the towing machine. The long distance between the stern rollers and the towing machine enables the tow hawser to naturally reel itself onto the drum and the level wind performs only light duty. The stern rollers are normally used to capture the hawser and to assist when picking up or disconnecting a tow. The vertical rollers may limit the amount of lateral movement that the tow hawser receives as the tow yaws from port to starboard

b. The horizontal stern roller is an anti-chafing device. On many tugs the cprail is of small radius and often rough from constant use. If the stern roller has a large radius horizontal roller, this will present a more suitable surface on which the tow hawser will ride and also minimize wear. The roller rotates so that the tow hawser is subject to less wear as it heaves in and pays out. (The ATS and ARS 50 Classes are not equipped with horizontal stern rollers. Instead, they have a large-radius transom constructed with hardened steel, which serves to minimize wear)

c. Chafing gear is required on the towline when it is scheduled for long periods in the stern roller. Slacking off a few inches, or "freshening the nip " regularly, is a good practice to reduce wear on the wire.

d. When the towline rides against a vertical stern roller, it is being bent over a small radius. This causes a towline to fatigue more rapidly and to fail at a lower load

e Vertical stern rollers are designed only as a fairlead device and cannot structurally withstand loads of the magnitude of which the H-bitt is capable. Strong side loads commonly seen in towing situations could very easily carry the assembly away. On the ARS 50 Class, the rollers will fold down to their stowed position at a lateral load of 50,000 pounds applied at mid-roller height.

f. The towline is usually restrained in a stern roller assembly only under light sea conditions. The vertical stern rollers should always be dropped when maneuvering in restricted waters or in rough seas.

g The presence of the towline in the stern rollers limits the maneuverability of the tug because it moves the tow point from the H-bitts back to the caprail

3-5 3.2 Norman Pin Use.
The primary tion of Norman pins is to limit the arc of sweep across the stern. The position for Norman pins depends on the situation. Some tugs

have two sets of Norman pins, one set of which is droppable into the stern caprail. Norman pins always are manually removable-or, as in the ARS 50 Class, hydraulically retractable. Retractable or movable Norman pins have various designs, ranging from simple hand-removable round stock or pipe to remotely-controlled, hydrauhcally-operated devices. See Figures 2-38 and 3-9.

3-5.3.3 Hogging Strap.

CAUTION

A hogging strap may be necessary to prevent the towline from jumping the stern rollers when towing a high-bowed ship at short stay. A hogging strap may be subject to excessive vertical loads. Care should be taken not to part the strap. Failure of a hogging strap may result in the loss of tug control or ranging up by the tow.

The hogging strap is used to mitigate the relative movement between the towline and the stern in both vertical and horizontal planes. See Figure 3-10. Movement in the vertical plane is caused by the stern of the tug dropping faster than the towline or by the tow ranging up. When a hogging strap IS used, a shackle or a special saddle-like fitting attaches the hogging strap to the towline. The limitation of the shackle is the high concentration of load it imposes on the hawser to which it is attached. Saddle-like fittings distribute the load over a wider arc and thus over a large radius, and are therefore preferred over shackles. Since the hogging strap transfers the tow point aft from the H-bitt, it can cause the tug to lose maneuverability

3-5.3.4 Lateral Control Wire.
A lateral control wire can be utilized to obtain lateral control of the tug's stern relative to the towline. This rig is similar in configuration to the hogging strap, but it has the added feature of variable scope. Instead of a fixed length strap holding the towline to the deck, a snatch block is secured to the deck and the lateral control wire is led through it to a deck winch, lateral control winch or capstan. In this way, the line can be fully slacked to let the towline sweep free or can be taken in to give either partial or full snugging like a hogging strap. The lateral control wire is helpful in keeping the towline out of the propellers. Like the hogging strap, the lateral control wire moves the tow point aft and can limit maneuverability.

3-5.3.5 Two-Leg Slip Method.
The two-leg slip method is an alternative for lateral control when towing a small vessel at very short scope in shallow restricted waters and prior to final streaming of the tow. See Figure 3-7

3-5.3.6 Active Control of Tow's Rudder.
The tow's rudder can be used to stabilize an unwieldy tow or to maneuver in close quarters. Caution must be exercised, as improper or excessive use could cause the tow to become directionally unstable. The decision to use active steering on the tow will depend on the reliability of the tow's steering machinery and the qualifications of the riding crew. The decision whether to use active steering rests with the tug.

3-5.4 YAWING AND SHEERING OF THE TOW.
Most tows will yaw somewhat—i.e., oscillate in heading about the base towing course, usually in response to wave action on the tow's bow or stern. This is not a serious problem in itself. However, many tows also will sheer off to the side, where the tow's track is offset from the tug's track. This may be especially prevalent in beam winds for ships with large deck houses aft. See also Appendix J.

The vessel may remain at a nearly constant sheer angle, or sheer from side to side, with a long period of as much as 10 minutes or more. Excessive sheering will cause poor control of the tow, reduction in tow speed, additional strain on the towline, possible tow collision or stranding in restricted waters and excessive chafing of the towing rig. In extreme cases, the tow can range up to a position abeam of, or even ahead of, the tug

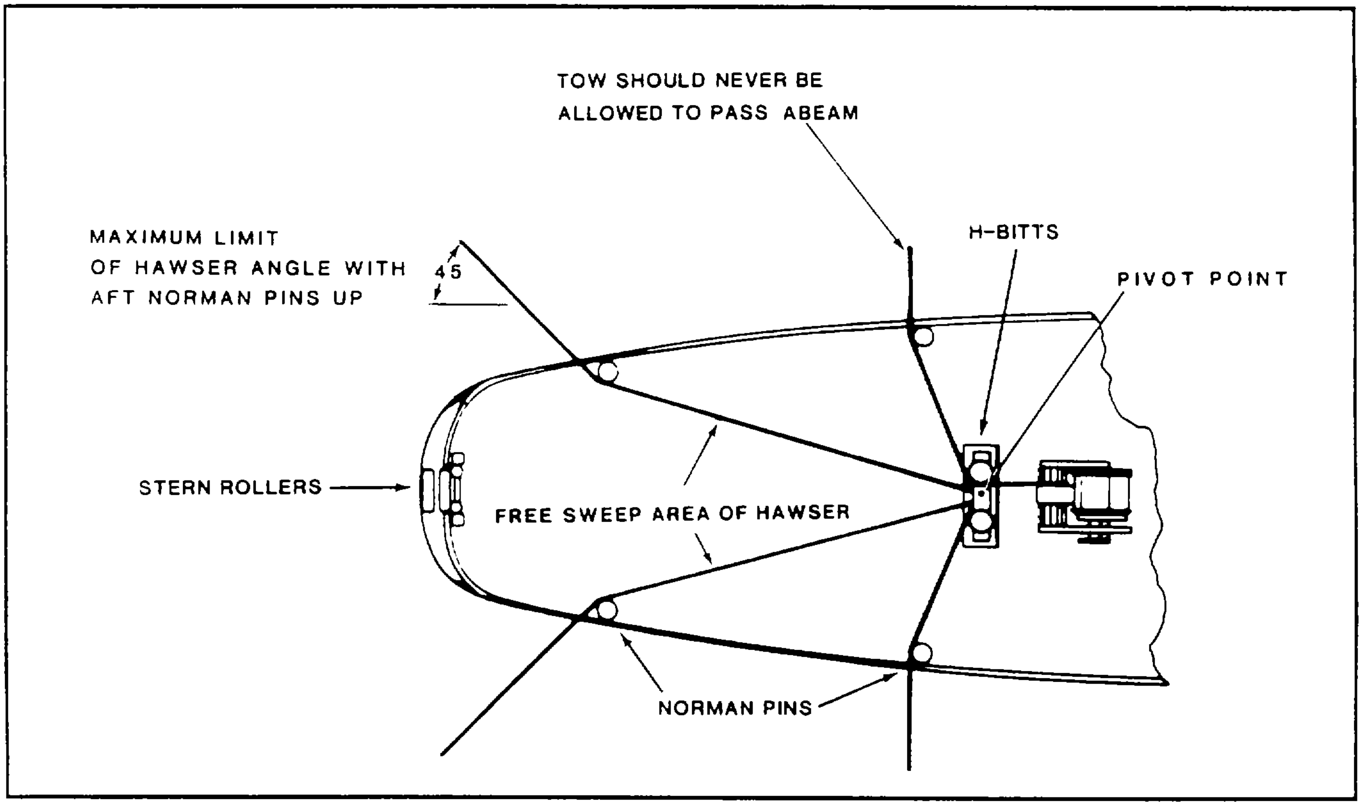


FIGURE 3-9. Norman Pin Use.

Sheering may be initiated by an external force or disturbance, such as wind or wave action. Tows with bulbous bows tend to sheer more than those with "fine" bows. Improperly-rigged bridles can also cause sheering. Yaw, of course, can lead to sheering. Depending on the tow's inherent maneuvering characteristics, the amount of yaw and sheer may range from small to substantial. In general, the tow is considered directionally unstable if the sheer angle continues to increase from swing to swing, despite an absence of the force that initially caused the motion. The following paragraphs discuss operational factors that, properly used, influence the yawing and sheering of a tow.

3-5.4.1 Trim. Before undertaking the tow, the towed vessel should be trimmed by the stern slightly as described in Paragraph 3-2.7 3. Trimming by the stern makes the towed vessel less susceptible to yawing.

3-5.4.2 Speed. Yaw of the tow may be increased or decreased with a change in speed; a range of tow speeds may be attempted in an effort to obtain a desired reduction in yaw.

3-5.4.3 Use of Rudder or Skegs. If the tow is tracking poorly but is steerable, use of rudders can reduce or eliminate yawing and sheering. However, active use of the rudder increases drag and adds the risk of steering machinery failure at a permanent rudder angle. Hull damage may cause the tow to take up a permanent sheer angle. In this case, permanent adjustment of the rudder can significantly improve the tow's behavior.

If excessive yawing on a movable twin-skegged tow occurs, each skeg can be splayed at an outboard angle. Although the drag will increase, the directional stability should improve Out-

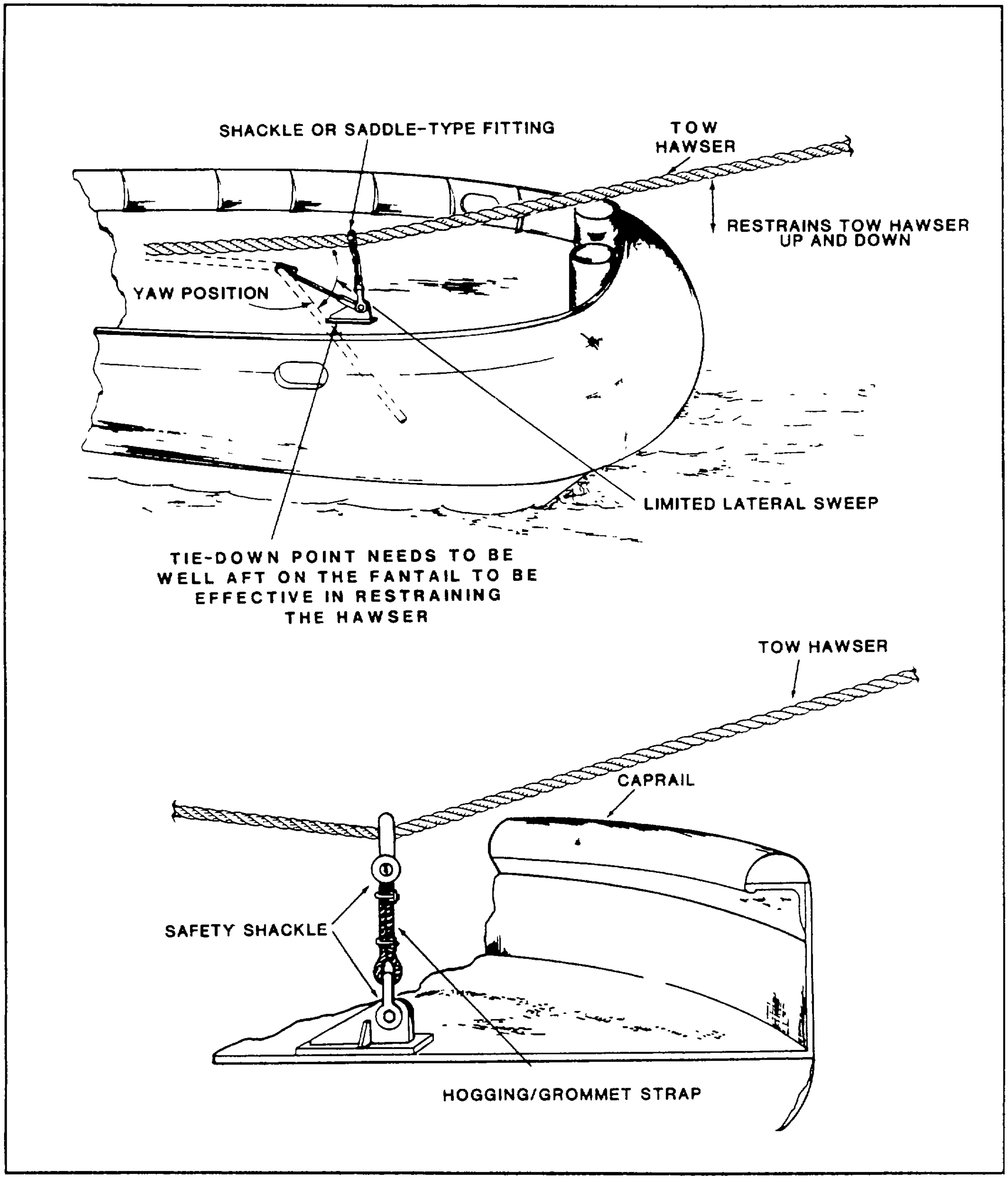


FIGURE 3-10. Rigging of Hogging Strap on Ships without Horizontal Stern Rollers.

board splaying is commonly done on barges and the technique has been successfully applied to twin-ruddered ships and floating dry-docks. All such rudder or skeg movements should be made in moderation to obtain optimum towing performance with aluminum increase in drag.

3-5.4.4 Location of Attachment Point.
A point of bridle entry into the tow may be selected to offer an optimum angle, and thus eliminate or reduce excessive yaw or sheer. Care must be taken to prevent towline chafing, and to ensure that a fairlead is sufficiently robust. As an example, the LST 1179 Class requires either a bridle or an off-centerline pendant because of the bow doors Towing is per-formed through a mooring chock on the side. These ships tow quite steadily with a very slight sheer. Care must also be exercised to ensure equal leg lengths on the bridle rigs, to avoid generating a sheer problem with the tow.

3-5.4.5 Propellers. A locked propeller will create a larger drag than a free-wheeling propeller, thereby resulting m reduced towing speed. However, the additional drag in the stern due to a locked propeller may decrease the tendency of the vessel to sheer off from the intended track. Refer to Paragraph 3-27.2 for information on preparing the propellers for tow

3-5 4.6 Steering Tug. The addition of an operational ship astern of the tow can offer effective steering control of the tow The trailing ship can use its engines and rudder to maintain a light tension on the line to the tow. Following steering orders from the tow ship, it can assist in keeping the tow from sheering off.

3-5.4.7 Sea Anchor or Drogue. An object towed from the stern of a tow will create a drag that acts to resist yawing motions. Nets, anchor chain, line, wire, kite anchors, mine-sweeping gear and a wide variety of other drogues have been used as stabilizing devices on small tonnage or shallow draft ships, especially those with fine hull forms. Care should be taken to prevent snagging of the drogue in shallow water.

3-5.4.8 Bridle vs. Single Lead Pendant. Certain hull forms are more conducive to being towed by a single lead pendant Submarines and ships with bulbous bows or forward sonar domes tow better on a single pendant than on a bridle.

3-5.5 HEAVY WEATHER. Long ocean passages rarely offer opportunity to plan a tow schedule that can guarantee favorable weather. Seasonal storms and sudden, unexpected weather can cause difficulty for both the tug and tow. Hurricanes, or typhoons, are the most dangerous and destructive of all storms. Advice on actions to take in the event of such storms is contained in Chapter 18 of*Knight's Modern Seamanship* (Ref. 13)

Steps to take upon receiving warning that a tow may encounter a hurricane include the following:

a. Determine the relative locations and tracks of the tow and the hurricane in order to best plan a course to avoid at least the dangerous semicircle.

CAUTION

Running before the sea and wind can cause difficulty in steering and in keeping the tow astern or in the desired position. The tug may be pooped or the tow may tend to overtake the tug. The overtaking will reduce the tension in the towline and cause an increase in the catenary which may also cause the towline to snag on the bottom or bring the tug and tow to collision. The recommended course of action is to head into the weather and maintain steerageway, increase hawser scope and, as long as there is enough searoom, tolerate a negative speed over the ground. There is no reason to slip the tow unless the towing ship is in danger of grounding.

b. Change course if necessary to avoid or ride out the storm. It is far better to depart from the projected track, ride out the storm and then set a course for the original destination than to endanger the ship and tow by remaining on a dangerous course and speed.

CAUTION

Under more strenuous sea conditions, dynamic hawser tensions, when towing down wind, can be significantly higher than when heading into wind and seas at the same speed and power. Turning into the wind and seas, and slowing to maintain steerageway, are appropriate under such conditions.

c. Estimate the size and direction of the waves. Review the applicable data in Appendix N to establish average hawser tension limits for the different wave heights and directions. Determine whether extreme tension predictions can be eased by slight changes in course away from towing directly into the wind.

d. Recognize that the tug and tow likely will make negative speed over the ground Sail for a position that will minimize navigational hazards of a down-wind track.

e Rig the fantail for heavy weather. Stern rollers and Norman pins should be down and other obstructions to the towline cleared.

f. Increase hawser scope, if possible.

g. Set the towing machine on automatic if it has an automatic feature. Otherwise, tow on the brake, rather than on the dog, in order to ensure a capability of rapid reaction to changing circumstances.

h Arrange for quick-disconnect of the towline by free-spooling the towing machine drum or other appropriate means.

NOTE

Water depth permitting, an increased towline scope and the automatic feature of the towing machine should be used in heavy weather. This enhances shock load reduction for the towline system. Every vessel rides differently in severe storms and the tug Captain should use good seamanship to determine how his tug and tow ride best. He should use the best combination of towline scope, speed and heading. Generally, better control of the tow results from heading into the weather.

3-5.6 PASSING THE TOW AT SEA (TUG-TO-TUG). Casualty, operational orders, weather or other requirements may necessitate transfer of the tow to another tug. Preparation for transfer and an understanding of the evolution between the tugs are necessary to ensure success and to minimize difficulty.

The following sequence may be used for disconnecting the towline and passing the tow. Refer to Figure 3-11.

a. Set a course into the seas and reduce speed.
b. Heave in until the pendant and connecting jewelry to the towing hawser are on deck.
c. Signal the receiving tug to come close aboard on the designated side on a parallel course.
d Secure the tow bridle or pendant on deck with a chain stopper; allow sufficient length to lay on deck to facilitate disconnecting from the hawser.
e. Break the tow hawser from the pendant.
f The receiving tug passes a messenger connected to the bitter end of its hawser, or to a messenger strong enough to control the tow.
g Bring the receiving tug's hawser or heavy messenger on deck and bend it onto the tow pendant.

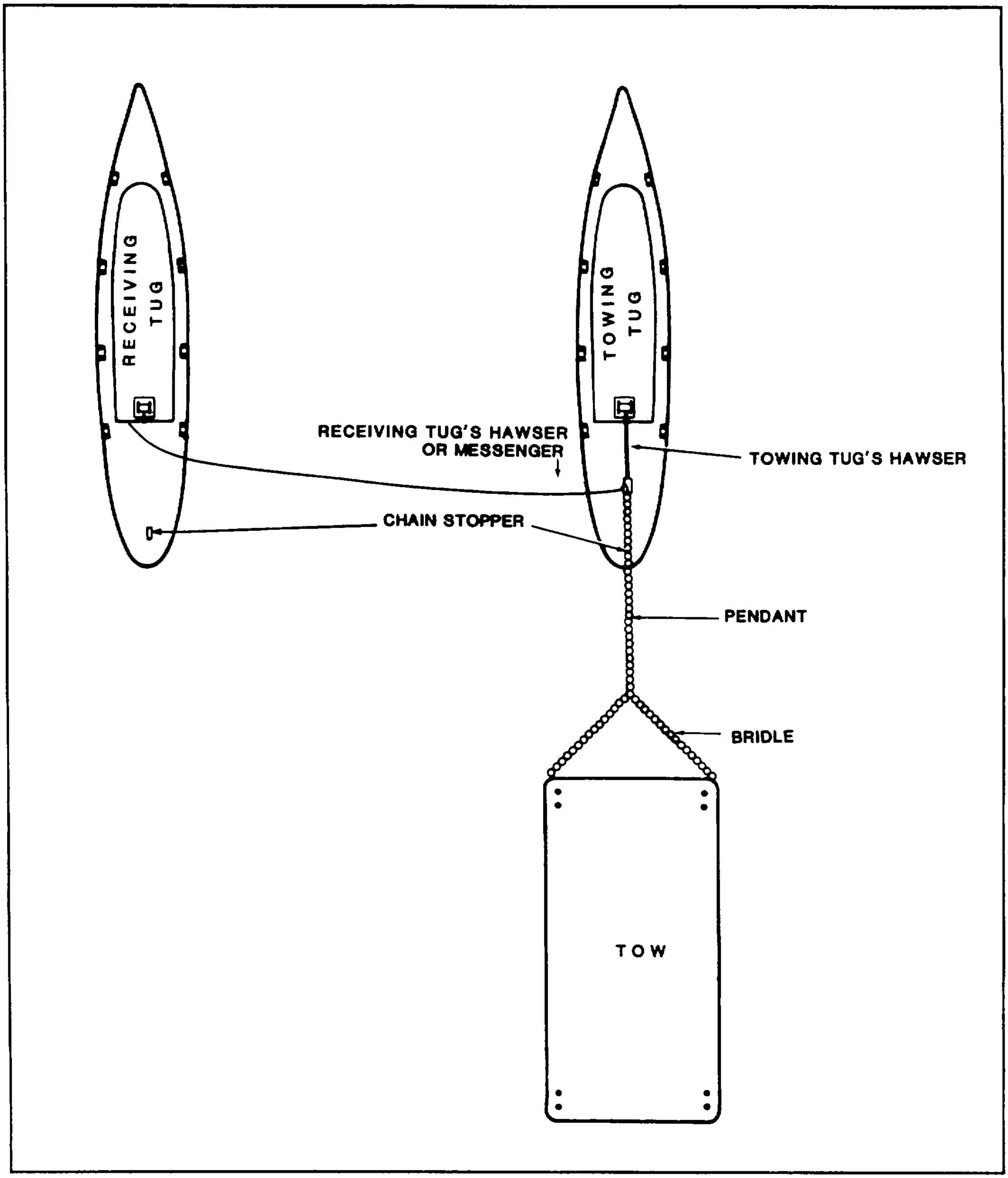


FIGURE 3-11. Passing a Tow at Sea.

h. With all lines and personnel clear, trip the stopper and transfer the tow to the receiving tug.

i If a messenger was used in Step "f," the receiving tug will make the final connection to the tow pendant on its own stern.

SECTION VI

3-6 INSPECTION OF TOW

Elements of the tow's material condition should be visually inspected and continuously monitored. They include.

a. Flooding alarms, draft marks, heel and trim

b. Timing of roll period for stability.

The towline should be inspected frequently for chafing and damage during the tow.

When the tow carries a riding crew, the majority of inspection functions are performed by the crew. Long-distance and valuable tows without a riding crew embarked should be periodically boarded and inspected, preferably by the same personnel on each inspection. Since this operation is often difficult and hampered by weather and sea conditions, the inspection preparations should be well-planned and promptly and efficiently executed. The following suggestions may aid this process:

a. When possible, consider seeking the lee of a land mass to make the operation safer, easier and more controlled.

b. Shorten up the tow. This provides an opportunity to inspect the towline and any part of the tow rig that can be brought aboard safely.

c. Preferably, use an inflatable boat to transport the inspection party to and from the stow. This boat can be streamed aft on a light line and brought alongside the tow. Tug and tow should be making minimum speed during this operation to minimize the bow wave of the tow, which could be dangerous to the inflatable boat.

d. The inflatable boat should be equipped with an outboard engine, whether or not it is streamed on a line. This greatly enhances its maneuverability and permits its recovery if the line parts.

e. The tow inspection party should perform the following:

WARNING

Carefully adhere to safety requirements when entering closed spaces. See NSTM 631 (Ref.4).

(1) Check tow connection and bridle for integrity and unusual wear.
(2) Check propeller shaft locking system.
(3) Check rudder locking system.
(4) Check navigational lights and batteries.
(5) Check flooding and fire alarm system.
(6) Visually check open habitable compartments and topside areas.
(7) Sound any suspicious or questionable voids, double bottoms and liquid tanks.
(8) If indicated, visually check structural framing and hull plating in the bow area.
(9) Operationally check firefighting and de-watering equipment weekly, or more often if conditions warrant.
(10) Upon completion of the inspection, close and make watertight all hull access openings.

Any additional checks appropriate to the peculiarities of the tow should be incorporated as needed into the inspection check list.

SECTION VII

3-7 TERMINATING THE TOW

Terminating the tow at its destination calls for the same preparation required by all other evolutions in towing. Unless operational schedules require, or the condition of the tow demands otherwise, it is best to adjust speed to arrive at destination during daylight hours. Darkness can easily magnify the routine into a more difficult and dangerous situation. Based on the nature of the tow, consideration should be given for requesting pilot assistance and/or harbor tug assistance.

3-7.1 REQUEST FOR ASSISTANCE. The use or non-use of a pilot is strictly a decision of the Commanding Officer, unless an order from senior authority supersedes. However, some pilots may be unfamiliar with towing and with the characteristics of the tug so that the Commanding Officer should be alert to difficulty and should relieve the pilot, should he deem it necessary Harbor tug assistance may be necessary. Sea conditions may not permit harbor tugs to make up alongside. If assistance is required at this time and under these conditions, then the only significant assistance that can be rendered is for the harbor tug to put a head line to the tow's stern to assist in steering the tow. Once within sheltered waters, harbor tug assistance can be utilized as required. If an additional tug is available, it and the original tug can be made up, each on a quarter, to provide more effective control in keeping the tow heading fair to the channel. If the tow is large and unwieldy, additional tugs may be used to provide both steering assistance and propulsion power. In the use of multiple tugs in this fashion, it is advisable to have a pilot on board both the tug and the tow to coordinate control of the assisting tugs.

3-7.2 SHORTENING THE TOWLINE. Upon approaching restricted waters a shorter scope, in conjunction with slower speed, will assist m the handling of the tow. It may be necessary to keep the tow at short stay to prevent the towline from fouling on the bottom. Great care must be taken to maintain positive control of the heading and of the tug's steering capability in order to avoid being overtaken by the tow or fouling the towline. A delicate balance must be maintained between scope and speed. In this situation, an automatic towing machine is invaluable. Since there will be little or no catenary, automatic control of the towline is the only means of surge control available. The automatic towing machine also is used to shorten the scope both in automatic and manual mode. Often, where there is a long distance from the sea buoy to the berth, the ocean tug may continue to tow, at short stay, to a convenient and safe location well inside the harbor.

3-7.3 DISCONNECTING THE TOW. Prior to the actual evolution of disconnecting the tow, necessary equipment should be laid out, potentially involved machinery energized and all personnel briefed on procedures. A well-drilled, disciplined team will perform the routine smartly and yet will be responsive to any unexpected occurrences.

Disconnecting procedures are similar to those outlined in Paragraph 3-5.6. With bare steerageway on the tug, the tow is brought up short by the towing winch and assisted by whatever harbor tugs are in attendance. When the connection fittings are on deck, a stopper is passed onto the pendant, the connection broken, and then with all personnel clear, the stopper is released

CAUTION

Do not permit the disconnected pendant or bridle to drag on the bottom, as considerable additional resistance will result and maneuvering will be seriously disrupted.

When a tow bridle is long enough, the pendant may be brought fully aboard the tug, and the disconnection made at the bridle apex. This may keep the pendant from dragging the bottom. The bridle and the pendant may also be retrieved on the tow by means of a previously rigged retrieving line at the apex of the bridle.

3-7.4 TOWING DELIVERY RECEIPT AND REPORTS. If a harbor tug master is authorized to receipt for the tow, he should do so. This allows for the physical and legal transfer in the stream without the necessity of docking or anchoring When this responsibility Is not assigned to the harbor tug master, it may be necessary to send personnel ashore to obtain the necessary signatures on the letter of acceptance

SECTION VIII

3-8 SPECIAL CIRCUMSTANCES IN TOWING

Tug and tow transits, transocean or coastal, are routine operations and generally accomplished uneventfully. Operational emergencies and other special circumstances are discussed m this paragraph, and general operational guidelines are presented for reacting to them at sea.

3-8.1 RESCUE TOWING AND RECOVERY OF LOST TOW. There are occasions when it may be necessary to pick up a tow at sea. The first instance is the recovery of a lost tow for which contingency planning may have been made. Other circumstances may involve taking a disabled vessel or a derelict in tow. These evolutions will be affected by the presence of personnel on the tow and by sea and weather conditions.

3-8.1.1 Recovery of a Lost Tow. Chafing of the towline, a mechanical break or other circumstances may cause the tow to separate from the tug. It is then necessary to recover the tow.

a. If the tow is unmanned and the weather and seas favorable, a boarding party may be put on board the tow, a messenger passed and the tow reconnected by routine procedures The risks involved in sending a boarding party and the difficulty of passing a new towline justify rigging a secondary, emergency towline as previously discussed. If the emergency towline has been used, consider rigging another emergency towline.

b If the tow is manned, it may still be necessary to send a boarding party onboard. If the riding crew is not sufficiently large or able to safely and adequately handle the re-rigging of the tow, knowledgeable assistance should be made available from the tug.

3-8.1.2 Emergency Connection of a Disabled Vessel or Derelict. In the emergency connection to a disabled ship, the presence of a functioning crew aboard is of considerable help If the ship has auxiliary power and is able to operate its anchor windlass or other winches, the passing of the towline assembly is a relatively simple task, complicated only by adverse sea and weather conditions The tow pendant may be secured on the forecastle in a variety of methods, but often the simplest, strongest and most efficient method is to shackle it into the tow's anchor chain with the correct connecting link.

The connection to a derelict poses the immediate problem of placing a boarding party on board. If there are no means of boarding, grapnels may be heaved on deck or fabricated pipe boarding ladders may be used to get a man aboard. He can then lower more conventional means such as a Jacob's ladder. The boarding party may have to carry an assortment of tools and rigging devices to facilitate hauling the messenger on board and hooking up the tow. After a sufficient length of the initial messenger is onboard, it may be run through a block and the bitter end passed back to the tug where the tug's machinery could be utilized in hauling the heavy messenger and towing assembly on deck. The stow pendant is then made up to an available strong point on the derelict.

3-8.2 APPROACHING THE DRIFTING TOW.
There are as many variations of approaching a drifting tow as there are variables in wind and sea Several conventional methods are discussed and illustrated in the following discussion. It takes good shiphandling to approach and safely take in tow a vessel of any size. Absolute coordination between the Conning Officer and the fantail crew is essential.

and direct communication with personnel on the tow and all parties involved in the towing vessel is crucial.

3-8.2.1. Establishing the Relative Drift. For collision avoidance and positioning, the first step in approaching a tow to be picked up at sea is to establish the drift differential between the vessels involved. Despite obvious differences m size and configuration, vessels' rates of drift are also affected by a host of other variables. Drift characteristics are affected by displacement draft, stability, trim, damage, seas, wind, sail area and location of the superstructure and currents, as well as a variety of other factors The above-water hull configuration will determine the tow's relative heading into the wind. Depending on trim, ships having a greater portion of their superstructure aft will have a tendency to head into the wind; ships having a greater portion of superstructure forward will have a tendency to he with the wind from aft of the beam to astern. A midship superstructure will normally cause the ship to lie with the wind abeam. With the relative drift between tug and tow determined, and the state of the seas and wind taken into consideration, the tug can make its approach.

3-8.2.2 Similar Drift Rate. Figure 3-12 describes a tug's approach across the wind and seas where similar drift rates exist. The tug begins an approach leading to pass close aboard on the weather bow; the messenger and towline can then be passed. The tug keeps station while passing messengers and making the connection.

3-8.2.3 Downwind Approach. Where dissimilar drift rates exist, a downwind approach may be executed as seen in Figure 3-13. In such an approach to a ship lying broadside to the wind, the speed of the tug should be slow, but still fast enough to offer good steerageway. Passing of the messenger must be timely, as the on-station time is short. Passing the towline can be accomplished in the lee of the ship's bow. Great care is required to keep all lines clear of the propellers. Once the tow is connected, acceleration should be slow and maneuvering sequences gradual.

CAUTION

Approaching at too small an angle in the lee of the larger vessel is not recommended.

When working in the lee of a larger ship, establish an attitude that permits the tug to maintain a safe distance from the more rapidly-drifting tow

3-8.3 PASSING THE TOWLINE. The towline is passed by messenger to the tow. It is generally desirable to have the tug pass the messenger and towline. The messenger may be passed by a hand-thrown heaving line, rocket, or line-throwing gun, boat, buoyant float, helicopter or any other expedient way. The hand-thrown heaving line, backed up with a line-throwing gun, is a common and practical way of passing a messenger. An experienced seaman, under favorable circumstances, can throw a heaving line over 100 feet with accuracy. However, time considerations and attendant dangers make it prudent to give as much time as possible to pass the messenger. Thus, the use of the line-throwing gun is the preferable procedure.

a. It may be imprudent to navigate the tug close aboard the distressed ship. In the event that such navigation is ill-advised, a boat can be used to pass the messenger. Line, free for running, should be faked down in the boat and on board the tug, with the maximum amount possible in the boat

b. A buoy, lifejackets, salvage floats, foam fenders or drums can be attached to the messenger's bitter end and floated to the distressed ship. This can be expedited by the tug crossing the disabled ship's bow with the messenger streamed.

c. Line-throwing guns can carry the bitter end of the messenger and an experienced seaman can fire the gun with accuracy and safety a distance of over 300 feet. A

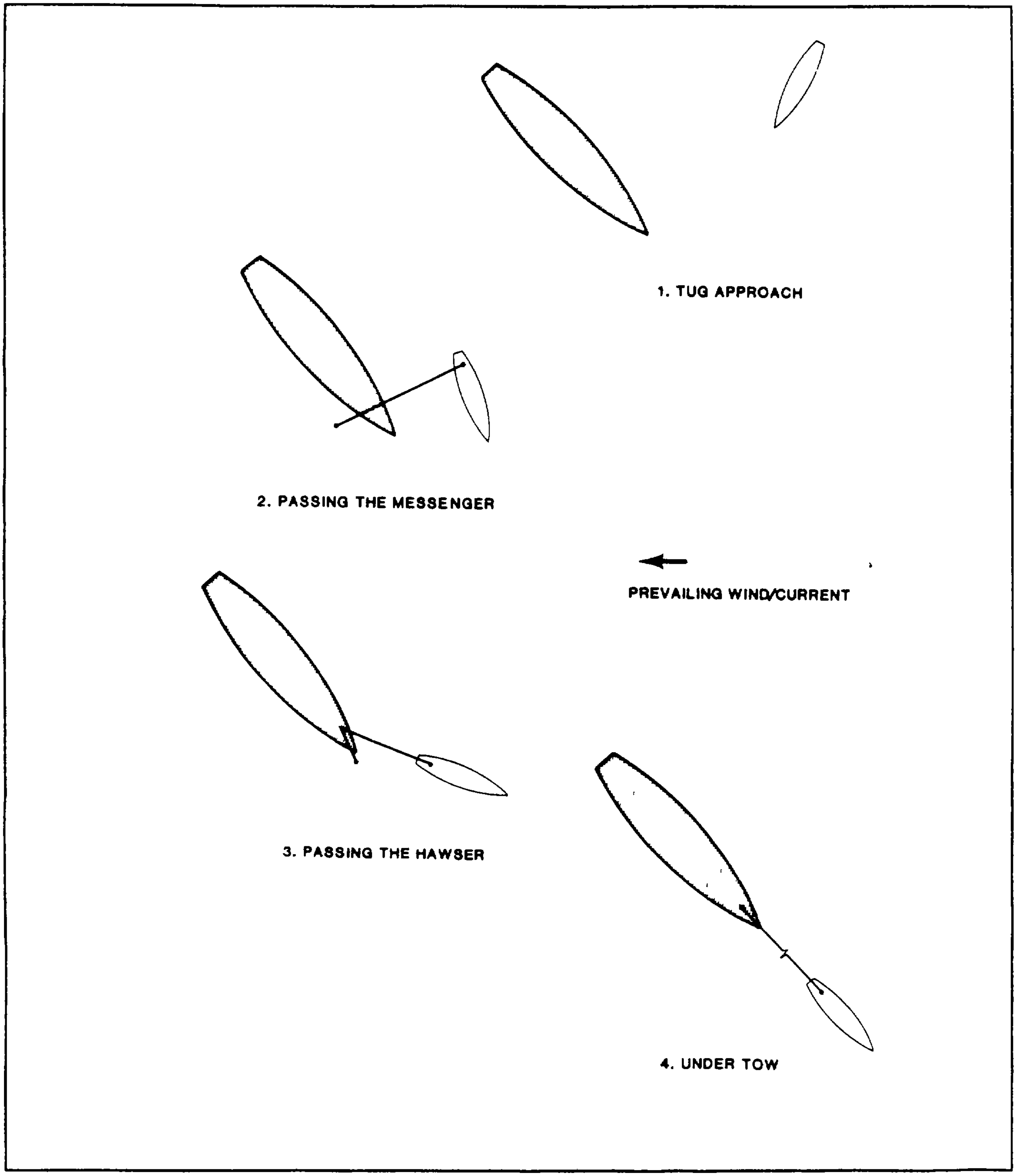


FIGURE 3-12. Across Sea/Wind Approach-Similar Drift Rate

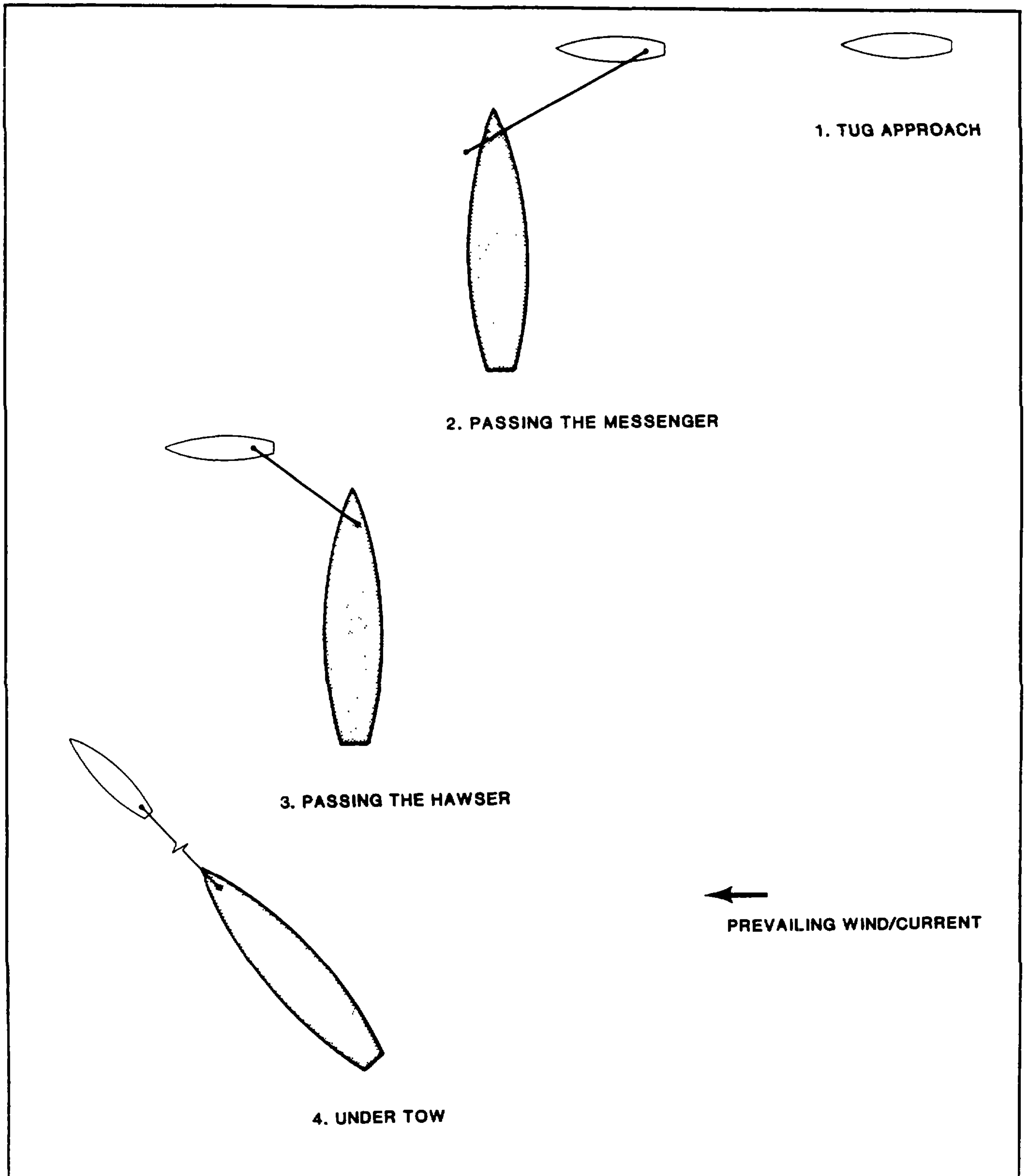


FIGURE 3-13. Downwind Approach Crossing the “T” to Ship Lying Broadside to Wind /Sea.

heaving line can also be used effectively for shorter passing distances

WARNING

Rockets should be used only where no explosive fuels, deck cargo or other flammable objects are exposed. All uses of line throwing guns, rockets or heaving lines should be accompanied by verbal warnings and sound warnings to take over. Failure to do so may result in injury or death to personnel.

d. Rockets can be used for line throwing. Rocket range exceeds that of the line gun by several hundred yards. In light air, a rocket can be aimed and fired with reasonable accuracy and line carrying ability. Cross winds will cause the rocket to head up into the wind, tail winds will cause the rocket to fly high and head winds will cause it to fly low. Experience with firing and accurate judgment of the wind will improve accuracy

3-8.4 FIRE.

CAUTION

Riding crews normally consist of a minimum crew and can be expected to perform only minimal emergency functions on board.

Fire on board is a known hazard. Fire prevention and methods of fighting fires should be drilled with the riding crew. On board an unmanned tow there should be little danger of fire. One exception is in the event of a failure of the shaft locking device, which can result in an engineroom fire. When a riding crew is on board, the fire potential should be evaluated. If equipment is operated for propulsion, auxiliary power, pumps or allied systems, the danger of fire on the tow can be greater than on the tug. Prudent and adequate placement of pumps, hoses, fire extinguishers, axes, foam and firefighting equipment on board the manned tow is necessary to support the riding crew in firefighting. If necessary, personnel may be transferred from the tug to the tow to perform firefighting and damage control. The tug, if it can be brought alongside, can deliver large quantities of water for use on board the tow; associated power, foam, hoses and personnel from the tug can be of valuable assistance. A charged 21/2-inch fire hose can be streamed aft on salvage balloons if alongside firefighting is not practical

3-8.5 TUG AND TOW COLLISION.

CAUTION

When towing under unfavorable conditions or inclement weather and at short stay, danger exists of being overridden. In such a situation, particular care is advised in setting an underway material condition so that watertight doors, hatches and other openings are secured.

a. Maneuvering in restricted waters with the tow at short stay, or under other operationally complex circumstances, may cause the tug and tow to collide. Tug and tow can collide if there is a loss of propulsion power or sudden reduction of the tug's speed. With sufficient way on, the tow may override the tug, and in extreme circumstances sink it. The override condition is aggravated if the tow is at short stay. When propulsion power is lost on the tug, the rudder should be put hard over to the weather and the towline slacked. With sufficient way on, the tug may fall clear of the advance of the tow If power loss is imminent, and the ability to make turns remains for a time, consideration should be given to going alongside the tow or otherwise clearing the tow In favorable weather the tug can tie up alongside the tow, effect repairs, stream the towline and continue the tow.

b. Differences in sail area, underwater hull form and displacement can cause tug and tow to experience different set and drift from seas, currents, winds or towline drag. An unfavorable combination of events such as these may cause tug and tow to collide. A general measure taken to avoid this situation is the reduction of speed and an increase in towline scope. When tug and tow are dead in the water, the towline catenary will have a tendency to draw the tug and tow together. The same situation can occur between two tandem tows. In an emergency, in shallow waters, it may be possible to anchor the tug and tow by letting the towline come into contact with the bottom.

3-8.6 SINKING TOW.

a. Flooding, structural damage, shifting of ballast or cargo and other events may degrade the tow's stability, and in an aggravated condition of stability, the tow may be in danger of sinking. Prompt action is necessary to save the tow and to ensure the safety of the tug

b. It is vital to monitor the condition of the tow during transit, trim, list, roll period, seakeeping and draft are monitored from the tug or by the riding crew if on board. Upon noting an irregularity, a boarding party should be dispatched, if possible, to investigate and correct the deficiency on board the tow. If the material condition of the tow is so deteriorated that sinking is likely, the tug should consider beaching the tow or paying out the towline to the last few wraps to prepare to slip it.

c It may be impossible to disconnect on board the tow. This will necessitate cutting or slacking the towline. Excessive strain placed on the tug as the tow sinks can cause great damage and seriously endanger the tug before the tugline parts. Rather than endangering the tug, it is considered good seamanship to slip the towline from the drum and to provide some method of cutting the hawser if it fouls on the tug. Cutting torches or wire cutters (mechanical or explosive) should be on standby. If time permits, carpenter stoppers or other devices should be rigged.

d. Use of educators operating from a floated 2 1/2-inch fire hose may be feasible in dewatering.

3-8.7 BEACHING A SINKING TOW.

a. When towing a casualty or a tow where the material condition has deteriorated so as to make sinking probable, beaching the tow may be the best possible action to save it. Permission to beach should be obtained from the cognizant authority when feasible. The decision to beach the tow should be made by immediate message or voice communications when feasible. Significant time may be required to steam the distance to a suitable site. If pumps are on board the tow and damage control procedures are employed, the tow may be kept afloat for days before beaching. The decision to beach the tow is operational and should be based on an assessment of conditions. Many times the beaching of tows has saved them. Indecision has caused tows to sink.

b. If available, a beach with a smooth, gradually sloping bottom should be selected as the beaching site The tow should be grounded with the bow toward the beach. It is important to prevent the tow from broaching and sustaining additional structural damage through excessive hull loading. Flooding the tow can prevent it from broaching or going further aground. The ship should be set down hard enough so that it will not be too light and, consequently, broach at high tide It should be assumed that in time the tow will be pulled off; however, this does not eliminate the need for securing it properly and thus preserving it until it is extracted from the beach. It may be impossible to locate a smooth beach in time. Rocky shores, with breaking surf, should be avoided. Potential loss of the tow plus imminent danger to the tug exist in shallow, rocky waters. In order to put the tow on the beach bow first, the tug's assistance may be required. If the water is sufficiently deep, the tug can tie up alongside in the lee of the tow and take the tow in. The alternative of allowing the tow to drift onto the beach should be avoided. Danger to the tug is always an important consideration. Assistance from a small, shallow-draft harbor tug may be available for beaching and would be of great help. The pendant and bridle should be disconnected. If possible before beaching, to prevent the tow from stopping short of the beach.

c. Ballast the tow down as soon as possible after grounding, to hold it securely in position. This requirement may not be apparent in completely sheltered waters, but even so, the range of tides and consequent current should be considered as forces powerful enough to alter the position of the beached ship.

3-8.8 ANCHORING WITH A TOW. In evaluating the reason for anchoring, always consider it to be a less desirable alternative to remaining underway. Steaming with the tow may prevent many difficulties encountered at anchor. Provided that there are no limiting operational factors and there is sufficient sea room, steaming is usually the better choice. When anchoring with a tow is necessary, the following alternative procedures should be considered.

CAUTION

The mooring loads of the tug and tow may be greater than the holding power or strength of the tug's ground tackle. A dragging anchor or failure of the ground tackle is possible, resulting in loss of control of the tug and tow.

a. Reduce speed to bare steerageway, head into the predominant set, allow the tow to remain well astern; then reduce speed and allow the tug and tow to come dead-in-the-water at the anchor drop point. Let go the tug's anchor and pay out the necessary scope of chain. The tow will follow as affected by set.

b. Reduce speed and approach several hundred yards to port or starboard of the desired anchorage. With the anchorage position broad on the bow and approaching abeam, put the tug's rudder hard over and reduce speed, maneuver to hold at the anchoring point, letting the tow pass by.

When the tow clears the tug, drop anchor.

c. The tow can be taken alongside in favorable sea and wind conditions. With the tow alongside, the tug can maneuver in restricted waters, back down as necessary and drop her anchor.

In some circumstances, in shallow water, the towline itself may be used for light holding of the tow and tug when the towline comes in contact with the bottom Routine use of this practice is discouraged because of possible damage to the towline.

If there is little wind or current, the tug must be alert to the probability of the hawser's weight pulling the tow toward the tug, until the hawser rests on the bottom.

3-8.9 SLIPPING THE TOW HAWSER.

CAUTION

Releasing the hawser under tension, or even its own weight, can be hazardous.

In emergencies, wartime conditions or heavy weather, it may be necessary to slip the tow hawser. It may be slipped in a variety of ways: if circumstances permit, the hawser can be paid out, allowed to run off the towing machine, or cut with a torch or explosive cable cutter. An ax can be used to cut a synthetic hawser provided that the hawser is under no tension. If a ship with power is being towed, it sometimes can cast off the towing pendant on the tow's bow. In all of these cases, releasing the hawser under tension can be hazardous.

If the towline is slipped by the tug without being buoyed off, it may become difficult, if not impossible, to recover it on board the tow. Certainly a boarding party, or rider crew, will be required to assist. If time allows, the bitter end of the towline should be buoyed off using a messenger at least 200 feet longer than the water depth, and strong enough to lift the hawser. One end of the messenger is connected to the hawser and the other to a recovery buoy line. The buoy line must be long enough to reach the bottom and strong enough to lift the messenger, but it need not be strong enough to lift the hawser itself. For ease of location, the buoy should be adequately marked with a bright color, radar reflector, staff or flag

3-8.10 REPLENISHMENT AT SEA WITH A TOW. Long ocean tows or emergency circumstances may require the tug to replenish at sea. Replenishment at sea is a well-established evolution, with procedures documented in NWP 14 *Replenishment at Sea* (Ref. 5). The methods outlined therein are suitable for passing fuel, water and other logistic necessities to a tug with tow. The choice of which method to use will be influenced mostly by sea and weather conditions, bearing in mind all the other factors which affect safe and efficient shiphandling. However, due to the reduced maneuverability of the tug with tow, consideration should be given to having the supply ship maintain station on the tug rather than the usual procedure of the receiving ship doing the station keeping. It may be advantageous due to speed and maneuvering limitations to replenish from the stern of the replenishment ship. It is also possible to replenish from the tow.

3-8.10.1 Emergency Replenishment. Emergency conditions, wartime operations or heavy weather may require great ingenuity to effect logistic replenishment of the tug or tow. Water and fuel can be received from the tow, if available, by shortening the towline and streaming hoses from the tug. In calm seas, the tug may go alongside the tow to effect the necessary replenishment. This requires disconnecting the tow, but in calm seas the matter of reconnecting should pose no problem.

3-8.10.2 Rigging and Use of Fueling Rigs. Surging, often experienced in towing, may require that the replenishment ship keep station on the tug. The greater maneuverability of the oiler and the lack of complete control by the tug recommend this procedure. The tug designates the fueling station, receives the hose and proceeds to take on fuel while employing standard precautions of proper stability, safety on deck, adequate communication and proper navigation. Astern refueling is also recommended.

3-8.10.3 Astern Refueling from Another Tug. Being refueled astern from another tug while towing has become a necessary and common evolution due to the limited number of replenishment ship assets. The evolution is somewhat different from that described in NWP 14 and can be accomplished either with or without the sending ship taking the receiving tug in tow. Due to the slow pumping rates available, taking the receiving tug in tow does, however, simplify station-keeping in what is sometimes a 24- to 36-hour operation.

3-8.10.4 Replenishment Near a Port. The towing ship can arrange to temporarily transfer the tow to a local tug(s). The ocean tug enters port to replenish, while the tow is maintained offshore by a temporary replacement tug(s). Upon completion of replenishment, the towing ship returns, the tow is re-transferred and the journey resumes.

3-8.11 MAN OVERBOARD. If the recovery is to be accomplished by maneuvering the ship back to the man, seamen should be stationed with heaving lines and swimmers outfitted with immersion or wet suits and safety lines ready to swim out to the man.

In most towing situations the standard man overboard maneuvers may not provide a satisfactory solution, primarily because of the time involved and the tug's limited maneuverability. In this situation, the tug should be stopped, or its speed reduced to bare steerageway, and the recovery accomplished by use of a ship's boat. If the tug is stopped, great care must be exercised to prevent the tow from overriding the tug and also to keep the towline clear of the propellers

Communications should be available between the boat and the tug to allow the tug to direct the boat to the man.

3-8.12 USE OF LIVERPOOL BRIDLE.

CAUTION

In operating the Liverpool Bridle, limit the tension to the safe working load of the bridle's 1 5/8-inch wire rope pendant.

The Liverpool Bridle, as shown m Figure 3-14, is a towline harness designed to permit a towing vessel to maintain fine control over heading and position. It is particularly useful when it is necessary to have the heading of the tug different from the direction of application of towing force. The lazy jacks are retrieving lines only and take no strain. The section of the hawser between the carpenter stopper and the winch takes only light strain. Thus configured, the point of tow is forward of the vessels' normal pivot point, and the tug is able to maneuver to keep her head in the desired direction. By rigging a bridle on either side of the tug, the towing point can be shifted from side to side to facilitate ship control.

The Liverpool Bridle is needed m circumstances (typically strandings) where currents and weather make it impossible for a conventionally rigged tug to maintain its station in relation to the tow. The Liver- pool Bridle requires the use of a towing winch. Its components are two pendants of 15/8-inch wire rope with a soft eye spliced in one end and an eye with a thimble spliced in the other end. One pendant is used on the starboard side, the other on the port side. The pendants should be sufficiently long so that they will run slack from the forward rail or shoulder bitts, which are closest to the pivot point of the ship, outboard and in over the quarter to a point on the centerline about 20 feet abaft the towing H-bitts. The Liverpool Brldle requires:

a. One carpenter stopper secured to the towline.
b. A 15/8-inch wire rope pendant with soft eye and thimble, length to suit ship.
c.Two 3-inch synthetic fiber lazy jacks made in the following lengths: one 50 feet long and the other 100 feet long, both with eye and thimble spliced in one end. A typical application of a Liverpool Bridle is shown in Figure 3-15.

3-8.13 TRANSFER OF PERSONNEL AND FREIGHT. Simple light line procedures are used for small freight. During these transfers it may be advantageous, as in fueling, for the transferring ship to keep station on the tug.

Transfer of personnel and mail should be by means of boat or helicopter. In unusual circumstances, transfer of personnel is accomplished by rigging a highline, or, if necessary, a Stokes stretcher. Conditions permitting, a rubber raft or boat should be used to effect transfer to avoid the maneuvering restrictions of underway replenishment.

3-8.14 BACKING DOWN WITH A TOW.

CAUTION

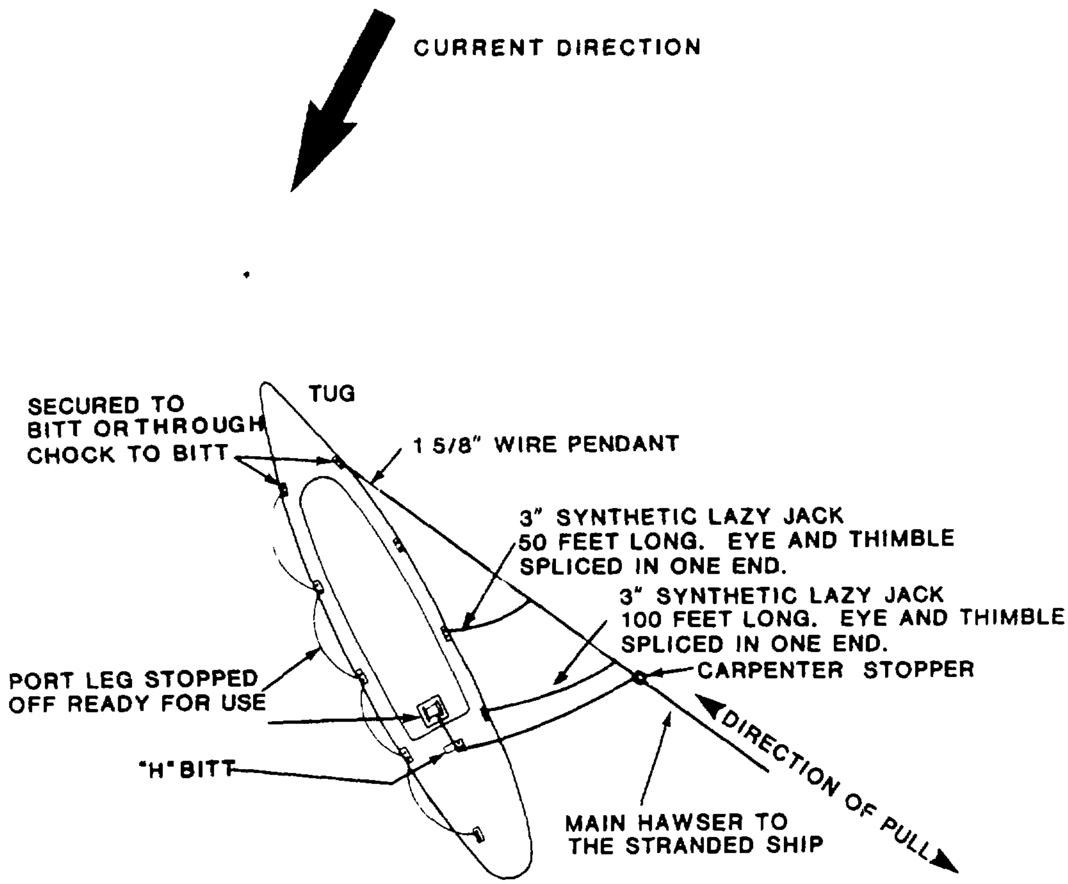
Except in an emergency, backing down with a tow is not recommended. If a collision with another ship is imminent and backing down appears necessary, it may be attempted.

If backing down is necessary, great care must be taken not to foul the towline in the propeller. Tow position and speed of advance must be considered to avoid collision.

SECTION IX

3-9 COMMUNICATIONS BETWEEN SHIPS

Most communication between ships, tug-and-tow and tug-and-tug is by radio. A tug may en-counter circumstances such as loss of radio, radio silence, weatheror foreign language barriers that require an alternate means of communicating. The most commonly-accepted methods for communicating between ships at sea are identified in the*International Code Of Signals,* (Ref 6). Since these signals are standardized and well-known, they should eliminate



FIRGURE 3-14. Liverpool Bridle.

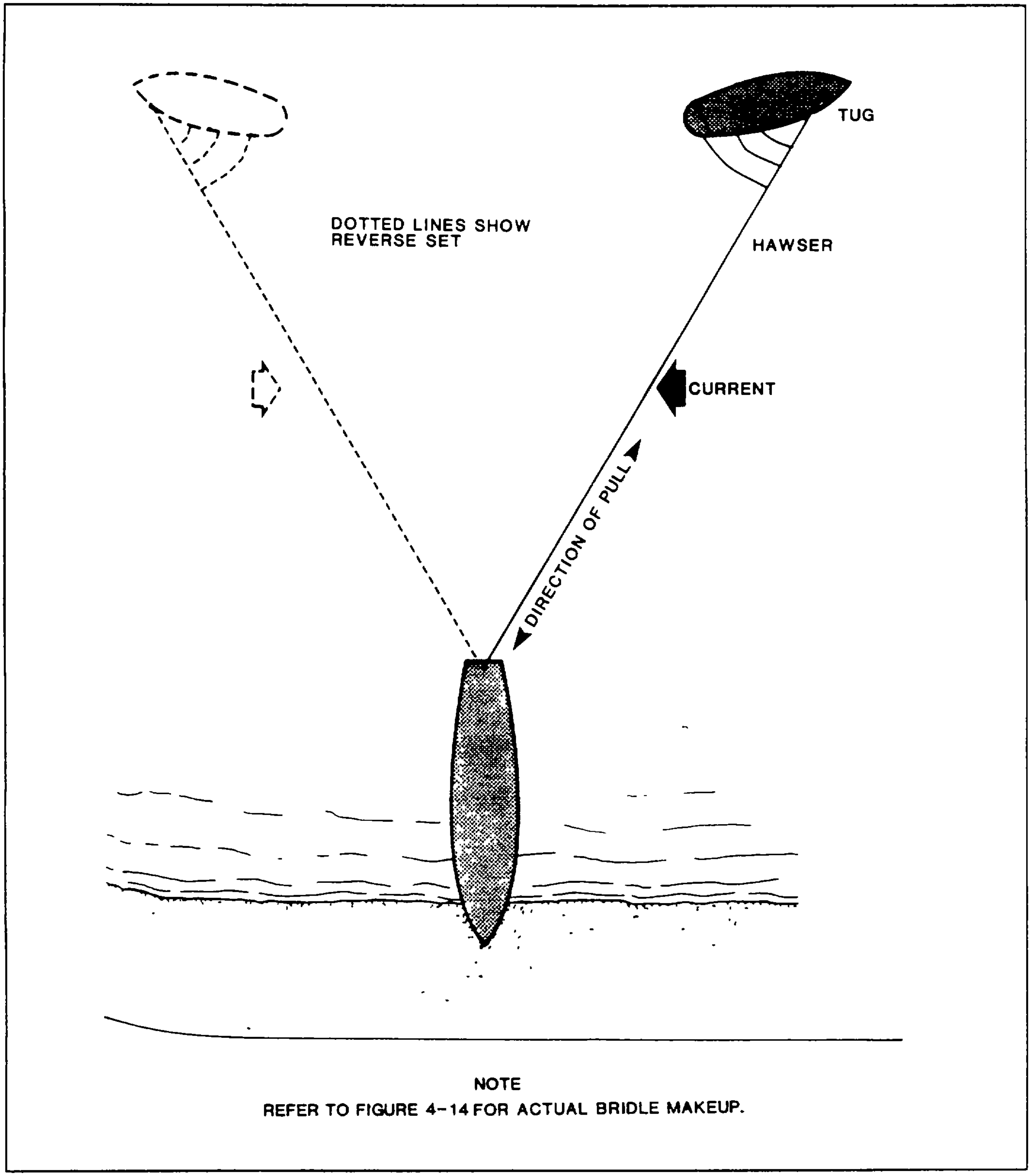


FIGURE 3-15. Use of Liverpool Bridle on Stranding Salvage.

confusion and misunderstanding when communicating ship-to-ship. They are by no means the only means of communicating. Pre-arranged signals and codes, as well as Navy standard procedures such as found in NWP 14, are valuable and highly useful tools available for communicating during towing operations.

3-10 TOW AND BE TOWED.

All U.S. Navy ships except submarines and aircraft carriers are capable of towing using its own emergency towing hawser, usually a synthetic rope. When two Navy ships are involved in a "tow and be towed" operation, each provides its own emergency towing hawser to form half of the total towing system connecting the two ships. See Figure 3-16.

Some Navy ships may be equipped with little used hawsers that are quite old, not realizing the recently understood problems with deterioration of nylon rope over time. All should be alert to current directives concerning replacement of emergency towing hawsers. Double-braided polyester hawsers, MIL-R-24677, are preferred.

3-11 TOWING NATO NAVAL SHIPS.

The NATO navies are concerned with emergency towing as part of their military mission as well as normal maritime concerns for safety of life at sea and pollution prevention for all ships.

3-11.1 EMERGENCY TOWING PROCEDURES. NATO emergency towing procedures have been standardized in the unclassified Allied Tactical Publication ATP-43 (NAVY) *Ship-to-Ship Towing* (Ref. 7). It was written with towing by another combatant in mind. Generally this operation is accomplished with each ship providing its own towing hawser as half of an entire rig of reasonable length. This activity is sometimes referred to as "tow and be towed." ATP-43 chapters include sections on:

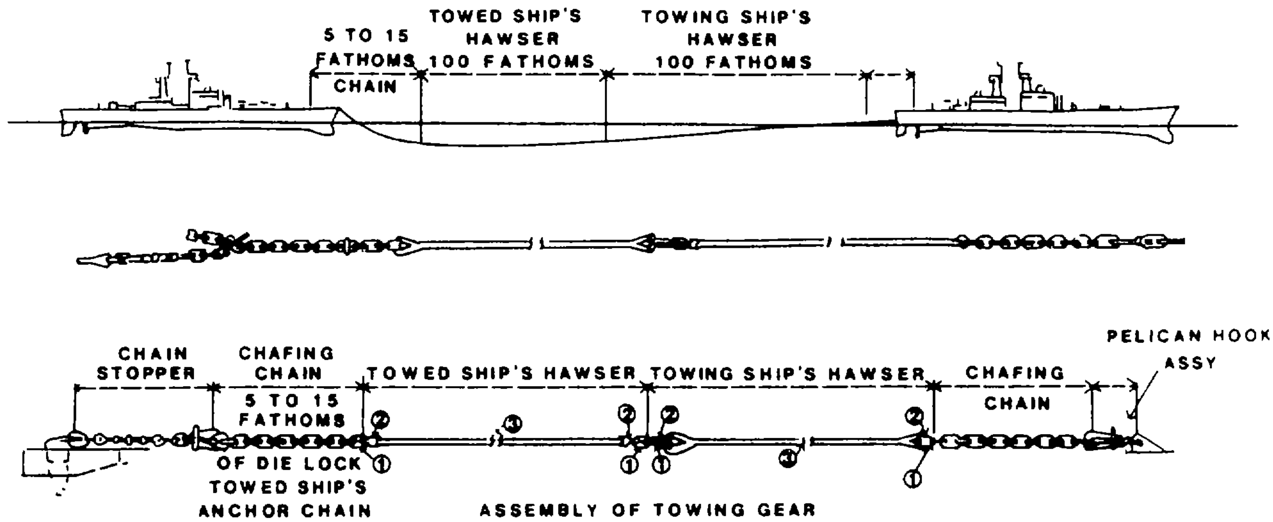
a. Principles of Operations
b. Organization and Command (including communications)
c. General Consideration of Towing Operations
d. Preparation, Approaching the Casualty, Passing and Connecting the Towing Rig
e. Conduct of the Tow
f. Emergency Release or Parting of the Rig
g. Transferring the Tow

The Annex to ATP-43 contains a description of the emergency towing hawser and its end fitting for most NATO warships and auxiliaries. Change 1 to the publication (May 1987) also describes a NATO Standard Towing Link, which in the near future should be found on NATO ships of over 1,000 tons displacement.

ATP-43 should be available on board every NATO warship and auxiliary vessel. The assigned tow ship might remind the disabled ship's Commanding Officer of its existence, so that the disabled ship can better prepare for the arrival of the tow ship

3-11.2 TOWING DISABLED NATO COMBATANT AND AUXILIARY VESSELS. As noted in Paragraph 3-11.1, the operational data contained in ATP-43, while accurate, are quite elementary compared to the background of the experienced tug crew. Nonetheless, knowledge of the contents of ATP-43 will be useful to the naval tug or salvage ship since it describes what the crew of the casualty should know concerning being towed. Additionally, Annex A to ATP-43 contains data on the towing hawser carried by each class of ship, as well as the end fittings on the hawser. Hawser strength and dimensions, and static test of the end fittings are also provided.

While the fully-equipped tug or salvage ship normally can be expected to make the towing connection using its own hawser and connecting hardware, there may be cases when it would be prudent to use the casualty's own hawser



1 DETACHABLE LINK OR SAFETY SHACKLE SEE WARNING

2 SYNTHETIC ROPE COUPLING. NAVSEA DWG 804-5000916
ALTERNATES ARE.
THIMBLE AND LINK NAVSEA SKETCH 56W41-14A DTD 1/12/84
NYLITE CONNECTORS, SAMSON OCEAN SYSTEMS, WITH GALVANIZED PIN AND SHACKLE WITH PIN ENDS PEENED OVER

FOLLOWING CONNECTORS ARE NO LONGER APPROVED FOR USE

BOSTON THIMBLE NAVSEA DWG 805-2130889
NEWCO THIMBLES

3. WHEN NYLON HAWSERS ARE UNSERVICEABLE, REPLACE WITH DOUBLE-BRAIDED POLYESTERS, MIL-R-24677, SIZE FOR SIZE

WARNING
DO NOT USE SCREW PIN SHACKLES IN OCEAN TOWING

THIS FIGURE IS ADAPTED FROM NAVSEA DWG 804-4759441 WHICH IS CURRENTLY UNDER REVISION (1988) AND SHOULD BE REISSUED IN 1989

FIGURE 3-16. Tow-And-Be-Towed.
Adapted from NAVSEA DWG 804-4759441

and end fitting to expedite removal of the casualty from immediate danger. In such a case, the casualty might have already rigged its own hawser ready to pass to the tug. The tug need only heave the casualty's hawser on board the tug to make the final connection to its own hawser, thus being ready to commence towing within a short time after arrival at the scene. The towing system can be re-rigged with the tug's more robust gear after the casualty is removed from immediate danger.

Provided that the water depth is sufficient, when connecting to the casualty's own emergency towing hawser, the towing ship should consider inserting a shot of chain between the two hawsers to assist in maintaining a healthy catenary.

In addition to the hawser end fittings described in ATP-43, Change 1 includes a NATO Standard Towing Link. See Figure 3-17.

The ATP-43 comments relevant to the NATO Standard Towing Link are:

1. The NATO Standard Towing Link is to be used during ship-to-ship towing operations as an interface between the towing equipment of the towing ship and that of the ship towed, whichever of the two ships provides the equipment, in order to improve interoperability
2. Ships of less than 1,000 metric tons displacement, other than tugs, are not obliged to have the Standard Towing Link
3 The interface will be at the presented end of one or both ships' towing hawsers. (One of the ships will have to provide a joining shackle.)
4. The NATO Standard Towing Link shall conform to the dimensions shown.
5. The strength of the link is the responsibility of the Providing Nation.

The link is quite large-the largest conceivable tow shackle (4 inches) can be dipped through the link. Note that the strength of the link is left to the Providing Nation. In the absence of information to the contrary, it may be assumed that the link strength exceeds the breaking strength of the casualty's emergency tow hawser. Additionally, it may be assumed that the casualty's attachment points also exceed the strength of its hawser.

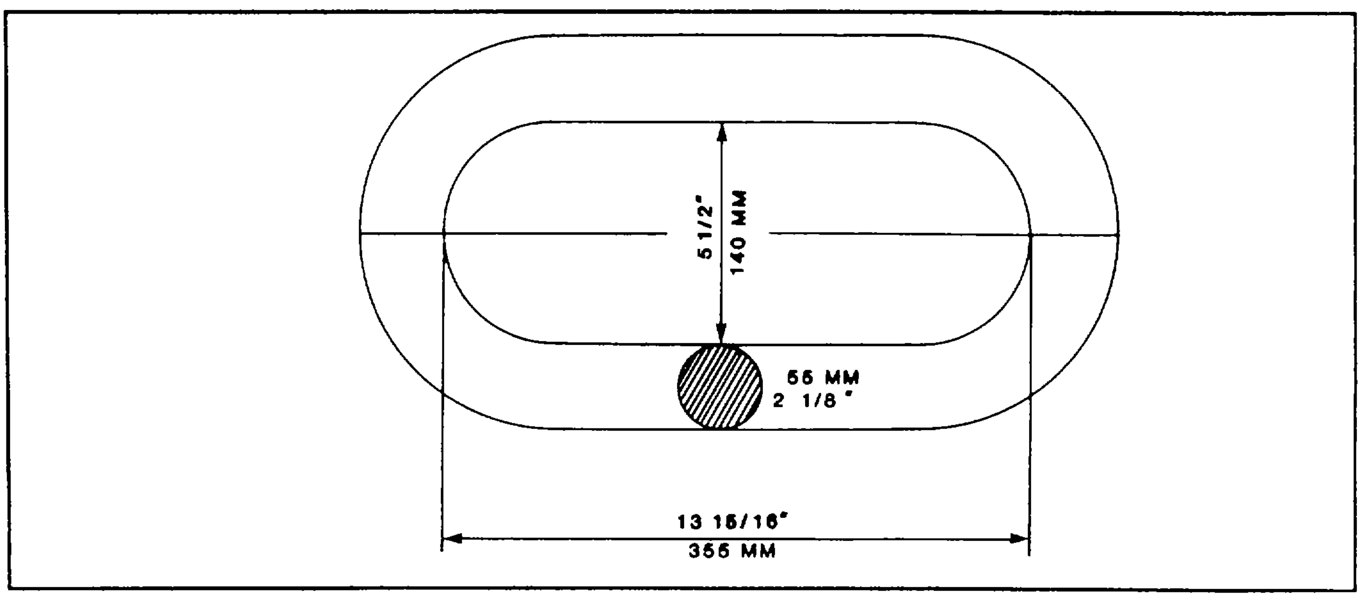


FIGURE 4-17. NATO Standard Towing Link
(English dimensions are approximate).

The foregoing discussion of ATP-43 is not intended to suggest that the damaged ship's towing gear is preferred over a tug or salvage ship's gear. On the contrary, the tug's gear will be more robust than that of all but the largest warships, and always will be longer than the casualty's hawser. Furthermore, unless the emergency hawser is connected to the ship's anchor chain, there will be insufficient long-term chafing protection for the casualty's own hawser, and possibly insufficient catenary as well. Use of the tug or salvage ship's towing gear always will be the first consideration for towing a warship or naval auxiliary. Connecting to the casualty's hawser as an expedient means should be based on a careful balancing of the tactical circumstances, rapidity of commencing the tow, distance to be towed and existing and forecast wind and sea conditions. If the tactical situation requires initial use of the casualty's hawser, re-rigging to the more conventional connection is recommended at the earliest possible opportunity.

CHAPTER 4

SPECIAL TOWS

SECTION I

4-1 INTRODUCTION.

Routine tows provide logistic support and directly aid fleet support operations and the operational readiness of the Fleet. Routine tows are addressed in Chapters 2 and 3. This chapter introduces and discusses tows of unusual configuration

Tows of unusual configuration occur infrequently or are of a highly specialized nature. As their recurrence is unpredictable, they are not treated in depth in this manual. However, they are noted so that planners and operators are made aware that such operations have been successfully completed in the past. When faced with a recurrence, reference should be made to the reports of such operations.

This section discusses the special situation of towing in ice, as well as towing targets, submarines and ships in peril Emphasis has been placed on rigging and procedural differences between these types of tows and towing operations previously discussed.

SECTION II

4-2 TARGET SERVICES.

4-2.1 TYPES OF TOWING SHIPS. The primary functions of noncombatant ships such as the T-ATF, ATS, ATF and ARS Classes are salvage and ocean towing. These ships routinely conduct ocean tows and, when required, tow disabled ships; their target towing capability is a secondary function. Despite the secondary nature of the task, these ships perform most of the target towing, largely by default.

Most combatants have the ability to tow target sleds with their standard shipboard equipment and should be used, when possible, to provide target services.

4-2.2 TYPES OF TARGETS. Currently, the catamaran-hulled Williams Target Sled is the prevalent target used by the U.S. Navy for gunnery exercises. See Figure 4-1. Other targets such as sonar buoys, arrays, drones and remotely operated boats are also utilized. They are carried to the operations area as deck cargo, towed or escorted.

SEPTARS (SEaborne-Propelled TARgets) are remotely-controlled, high speed surface targets that are transported to the operating area by the tug, then operated from the tug. Similarly, tugs also carry drone type targets for providing services in anti-aircraft and anti-missile training exercises. They can carry, tow and service transducers and arrays for support of submarine and anti-submarine training exercises. Each of these services is unique and presents special problems not encountered with standard target sled towing. Some of the information necessary to support target services is classified.

4-2.3 WILLIAMS TARGET SLED.

4-2.3.1 Towing Equipment. The Williams Target Sled is towed from a synthetic line bridle shackled to the inboard sides of the catamaran hulls. The two bridle legs are joined by a triangular flounder plate; a 30-foot pendant of synthetic line is also shackled to the flounder plate. The pendant is shackled to the main synthetic towline.

The towline is a 3-inch circumference, double-braided synthetic line, 4,500 feet long. On occasion, when a longer line is required, two lines are bent together. It is important that a non-rotating line be used in this application. If a three-strand line were to be used, the torque generated would list the target and might cause a damaged sled to capsize.

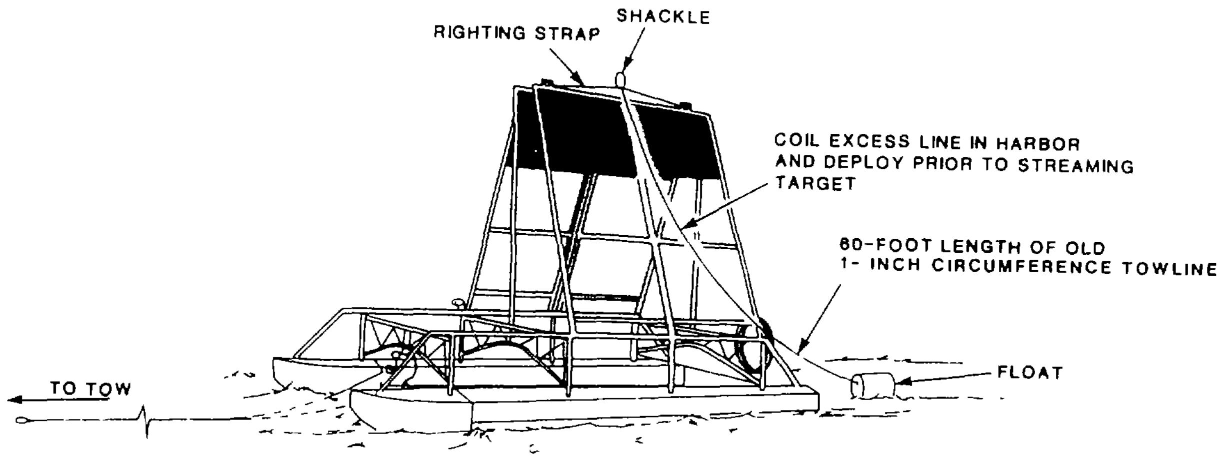


FIGURE 4-1. Williams Target Sled Rigged for Tow with Righting Line Streamed.

4-2.3.2 Clearing the Harbor.

CAUTION

If the target is made up bow-to-stern, it will reverse direction and swing into position when slipped, unless there is too much way on the ship. Too much way on will cause the target to be towed stern first. Ensure that the target does, in fact, tow bow first as the target has a tendency to stream aft without reversing itself and will end up by straddling the towline in a stern-first position.

If the tow is to commence at the target's berth, some crews make up the target to the towing ship bow-to-stern alongside and shackle the towline to the target's bridle pendant. Others make up the tow bow-to-bow alongside, bow-to-stern aft of the towing ship, or on the fantail of the towing ship. If the tow is made up in the water, the target mooring lines are slipped when clear of the pier. Tow the target at short stay until congested waters are cleared. Streaming at short stay does not affect maneuverability or speed.

If a delivery ship, usually a work boat, is to bring the target out of the harbor to the towing ship, the towing ship should slow and maintain steerageway so that the delivery ship can easily approach her stern. If the target has been made up on the fantail, it can be set overboard by the ship's crane or boom upon arrival at the operations area It may be similarly made up on the fantail during protracted delays between exercises or in the event of impending heavy weather.

4-2.3.3 En Route to the Firing Range. When clear of the harbor and congested waters, which require towing at short stay, about 600 feet of towline is usually streamed. If the towline Is not on the drum of a winch, it may be paid out using a gypsy head or capstan to maintain control. Ships with towing bitts can control the payout of towline by making turns around the bitts. When enough line has been pulled out, the towline is stopped off to the towing bitts with the towline passing over the stern roller. Speed is then built up slowly until the target is towing steadily.

4-2.3.4 At the Firing Range. The towing ship times its arrival at the firing range long enough before the exercise begins to allow time to stream the target. Slowing to about 4 knots and payout line at 150 feet per minute is the safest way to stream. The tow hawser can be recovered at the maximum speed of the capstan or traction winch used. Hawser payout typically proceeds at 40 to 60 feet per minute.

4-2.3.5. Turns. With the Williams Target Sled, turns can be made in one increment, depending on the weather, by using a small amount of rudder so as to have about a 1,000-yard diameter turning circle. When making turns, the target must be kept aft of the towing ship's beam, preferably broad on the quarter. When proceeding on a circular course, the target's tendency to capsize depends on the speed of the tow, length and depth of towline and the sea state and heading relative to the wind.

The characteristics of turns to windward differ from those of turns to leeward. In turning into the wind, the target screen area acts as a mainsail and holds the target away from the turn, requiring an increased rudder angle and giving a smaller transfer with a slightly greater advance. In turning to leeward, the sail effect propels the target toward the inner part of the turn, requiring less rudder and performing a greater transfer with less advance. In all turns the target acts as a sea anchor, making a small tactical diameter while the ship turns around the target with a larger tactical diameter.

Turns with the current increase transfer, and turns against the current reduce transfer. The advance in all turns is small. To keep the towline tension low and to avoid capsizing the tow, keep the rudder angle as low as is practical. A mean rudder angle of 12 or 13 degrees is satisfactory. A good practice is to make the turn in small increments, steadying up until the target is directly astern before going to each new increment.

4-2.3.6 Concluding the Exercise. When the exercise is over, the towline is heaved in to shorter stay for the tow home or brought up short to permit the target to be lifted aboard. The methods of heaving the line vary with the towing ship's equipment. For example, combatants use their capstans to heave the towline, MSOs can use one drum of the sweep-wire winch, and salvage ships use their capstans or traction winch. Immediately on bringing the towline aboard, it should be faked on deck or spooled on a reel. Significant time must be allowed to bring the hawser in at even maximum capstan speed. Entering port, the tow can either be brought alongside, brought to short stay or lifted aboard. The use of riding lines which have been stopped off on the tow hawser during streaming contribute to the ease of bringing the sled alongside. For leaving and entering port, some ships have preferred two-blocking the bow of the sled against their stern. When firmly snugged into position and adding riding lines, this method allows good maneuvering.

4-2.4 SPECIAL PROCEDURES.

4-2.4.1 Passing the Target to a Combatant Ship. It is sometimes necessary to exchange towing ships during an exercise. The methods described in Paragraph 4-2 3.2 for delivering a target to a towing ship do not apply on the open sea.

WARNING

Most casualties in passing a tow occur because the ships do not maintain a steady course or speed, or because the towing ship releases the tow before the other ship is ready to accept the strain.

Stop off the hawser along one side of the towing ship. The towing ship selects the side and speed for passing and signals them to the receiving ship well in advance of passing the tow. The receiving ship steams into the wind alongside the towing ship.

The receiving ship signals and sends a messenger when she is ready to receive the tow. The towing ship receives the messenger and secures it to the hawser. The receiving ship hauls the messenger and hawser through its towing chock. The towing ship frees the hawser, and the receiving ship hauls it away. See Figure 3-6.

4-2.4.2 Capsized Target.

WARNING

Always remain with a target sled until it is recovered or righted and towed to port; it becomes a hazard to navigation if it is left to drift.

A capsized target must be righted immediately because it cannot be towed capsized at any speed. Safety precautions must be strictly observed because of the hazards of recovery work. In case the target does capsize, the towing ship should heave in slowly. The ship may be required to back slowly while heaving in, being careful not to foul the towline in the propellers or rudder. Another method is to reverse course and place the ship alongside the target. Either method is dependent upon weather conditions. Prior to getting underway, the target should have been prepared for righting by attaching a wire strap to the pipe framework at the apex of the target. Once the capsized sled is alongside, this strap is then led between the ship and the target and attached to the towing ship's boom, or to a fairlead through the quarter rollers or chock, so as to enable approximately 20 feet to be heaved in (approximate depth of the target below the water). When heaving in, this attachment will allow the target to rotate away from the ship and will minimize damage to the target. Upon righting the target, it must be inspected to ensure that no damage has resulted, and that it is fit for tow. If unfit, the target should be brought aboard. A second method for righting a capsized Williams Target Sled is to pre-rig it for a recovery operation prior to towing. A recovery pendant can be made from 60 feet of line. One end of the towline is attached to the middle of the pipe framework at the apex of the target. The remainder of the line is coiled and secured with small stuff to one of the pipe frames near the trailing edge of one of the catamaran floats. The bitter end of the line is tied with a bowline onto the float. Prior to streaming the target, the line and float are released to stream aft of the tow. If the sled capsizes, the ship is maneuvered alongside the sled, and the float and recovery line are brought aboard the ship. By leading the recovery line over the caprail to a capstan and heaving in, the sled can be made to rotate to an upright position in a motion that carries the target away from the hull of the ship. See Figure 4-1.

4-2.5 TARGET TOWING PRECAUTIONS. Take the following precautions when towing a target:

a. Avoid surges.
b. Maintain a steady course, avoiding tight turns.
c. Ensure that the target's stern and side lights are lit at night.
d. Do not tow the Williams Target Sled at speeds in excess of those authorized by Fleet directives.
e. Do not tow a capsized Williams Target Sled.
f. Alter course gradually with a target under tow in order not to capsize the sled.
g. Approach the target with caution. The shallow draft of the target sled causes considerable pitching and rolling at slow speeds or when drifting

SECTION III

4-3 INLAND BARGE TOWING.

Barge towing supports Navy logistic requirements. The basic techniques for inland barge towing are almost identical for harbor tugs as well as towing ships. The principles of alongside towing and handling become part of the open-ocean tow in making up, streaming and entering the harbor. The Boatswain's Mate First Class and Chief Rate Training Manual (Ref. 8) provides a thorough discussion of inland barge towing in its most usual fashion, alongside. Understanding the basic principles set forth therein will enable personnel on board the oceangoing tug or salvage ship to approach inland towing in a professional manner.

SECTION IV

4-4 TOWING IN ICE.

Arctic operations make it necessary to tow in ice, and it may also be necessary to recover a ship whose steering and propulsion equipment are not functional. An icebreaker may be required for breaking through heavy ice, but Navy ocean tugs can tow in broken ice. U.S Coast Guard icebreakers equipped with towing machines now are being decommissioned.

Although Navy ARS 50 and T-ATF Classes were built to modified ice strengthening rules, their Kort nozzles may make them less suitable for heavy ice operations than the ATS 1 and ARS 38 Classes. The ATF 76 Class is not suitable due to its light hull construction.

If possible, during tows of long duration in ice conditions, the catenary should be adjusted so that the chain bridle, or chain pendant, enters the water at the towed vessel and prevents the hawser coming into contact with the ice. After a period of exposure to ice, the hawser will wear and chafe. This item is addressedinATP-15 Arctic Operations (Ref. 9).

4-4.1 TOWING METHODS. The tow should be close to the tug's stern to keep the ice passage open ahead of the tow.

4-4.1.1 Short-Scope Method. Paragraph 4-4 1.2 discusses the saddle method of towing in ice. Navy ocean tugs should utilize the short-scope method since they have no saddles. Even for towing ships that do have saddles, the saddle method may not be practical for towing a high-bowed or bulbous-bowed ship Such ships can be towed at short scope by the conventional method, using both anchor chains and a towing bridle to provide extra weight in the short scope. A scope of 150 to 300 feet can be maintained. The tow's rudder should be used, if possible, to keep the tow in the tug's wake. Occasional kicks from the tow's propeller may be necessary to augment the rudder's force. The tug's propeller wash should keep the tow from riding up on the stern; if it does not, the propeller of the tow should be backed, if possible.

4-4.1.2 Saddle Method. If the short-scope method of towing in ice is not feasible, a variation of the saddle method formerly used by icebreakers may be possible for tow ships having strong, broad sterns. The tow is brought up snug against the tug's stern, using extensive chafing gear, heavy fenders and puddings. The towline is attached in the normal fashion The towing machine should be in the automatic mode to prevent the towline from parting if the ships pitch or surge Two mooring lines can also be passed from the tug's quarter-bitts to the tow's forecastle bitts to help keep the tow following fair. The tow's engines can be used; however, if the tow begins to sheer or yaw badly, it should slow at once until it is again under control.

A fire hose should be kept ready at the saddle when using the tow's engines; friction may cause fires in the chafing material. Of course, the saddle method cannot be used on tows with sharp prows, bulbous bows or any other protuberances which can interfere with the tug's propellers and rudders.

4-4.2 RIGGING FOR TOW.

CAUTION

The strain on the towline will be severe if the towed ship contacts heavy ice. Take special precautions to prevent the chain bridle, chain pendants and hawser from chafing. An automatic towing machine makes this easier. Avoid towing on the bitts; they may be torn out by the sudden increases in tension if ice is encountered when towing at short scope.

In a convoy with no icebreaker, all ships may be expected to tow. All ships should be prepared for both towing and being towed The time saved in rigging the tow lessens the chance of being caught in the ice. Gear should be prepared in advance; the crew should know how to complete the rigging quickly and safely.

The recommended gear for towing in ice consists of the following: wire rope towing hawser, a 21/4-inch chain pendant and connection jewelry, or a 2/4-inch chain bridle with flounder plate and connection jewelry.

Before entering the ice, the bridle or anchor chains should be rigged to receive the towline. Even when using a bridle, it is necessary to secure the bow anchors to keep them from striking hummocks in the ice This is especially important on low-bowed ships.

SECTION V

4-5 TOWING DISTRESSED MERCHANT SHIPS.

Occasionally, during routine operations and national emergencies, the Navy is called upon to engage in towing merchant-type ships in distress. These may be MSC ships, chartered ships, ships engaged in support of operations and any other merchant ships requiring assistance. In emergencies and in remote areas, these services also may be required to save lives and valuable ships and cargo.

4-5.1 INFORMATION SOURCES. In recent years, various companies and trade groups have assembled information intended primarily to provide guidance to merchant tanker operators in contingency planning. This same information can be equally valuable to Army personnel who may become involved in rescue responses to merchant ships in distress. Some particular publications are cited in *Recommendations on Emergency Towing Requirements for Tankers, published by the IMO and Peril at Sea and Salvage. A Guide for Masters (Refs. 11 and 12).*

4-5.2 ATTACHMENT POINTS. In an ideal scenario a distressed ship would present to the rescuer an easily-reached connection. This would be either a complete system including the hawser, or at least everything necessary to connect the hawser to the ship The OCIMF recommendations have been superseded by similar IMO standards, which themselves have not been formally adopted. Nonetheless, many of the larger tanker operators have complied with the IMO requirements. See Appendix K for a more thorough discussion of towing large merchant ships. Lacking more definitive information, the following apply to the linkage system which may be found on board some merchant ships, and to alternative methods which may be used.

a. Pre-arranged tow points-Currently, the most popular pre-arranged attachment point on the tow is the Smit Towing Bracket as shown in Figure 2-24.
b. Alternative points-The alternative points considered for attachment to a distressed ship are discussed in Paragraph 2-5.6.

SECTION VI

4-6 UNUSUAL TOWS. Conditions may require towing floating structures in unusual positions. In recent years several unusual tows have been successfully completed.

4-6.1 DRYDOCK (CAREENED). One example is the towing of an AFDM through the Panama Canal. These docks are approximately 124 feet wide and, because of the limiting 109-foot width of the Canal, must be careened for transit. This has become an established practice. When the transit operation has been completed, the careening procedure is reversed to restore the dock to its even keel condition for towing to its destination.

4-6.2 DAMAGED SHIP (STERN FIRST). If a ship cannot be prepared properly for tow due to bow damage, the feasibility of towing from the stern may be considered. Some ships will tow fairly easily from the stern, but most can be expected to track very poorly.

4-6.3 OTHER TOWS. Unusual and unique tows include:

a. NR-1, submerged tow

b. Towing of gravity structures

c. Non-self-propelled floating structures

d. Minesweeping devices

e. Submerged and surface towing of submersibles

f. SINKEX

g. Test bodies

h. Platforms

i. Pipe structures

j. Cable-layers

k. Acoustic arrays

l. Semi-submersibles

m. Ships of unusual hull forms (SWATHs, PHMs, etc.)

CHAPTER 5

TOWING SYSTEM DESIGN

SECTION I

5-1 INTRODUCTION

This chapter addresses technical aspects of towing, including resistance of the towed vessel, effects of statics and dynamics of the tow on the tow hawser and selection of components to be used in the tow connection. Data presented will be useful to both the crew of the towing ship, in sizing the towing components and fittings, and to the Commanding Officer in better understanding options he has available to minimize risk during strenuous tows and heavy weather. The shore-based planner will find useful data for predicting operational aspects of alternative towing ships, where there is a choice, for a given tow. This applies whether the operation is pre-planned or conducted under emergency conditions. Finally, the chapter discusses navigational lights and flooding alarms.

SECTION II

5-2 TECHNICAL DATA

When planning a tow and designing the tow system components, important considerations are:

a. Expected or required towing speed.
b. Selection of the towing ship.
c. Towline tension as determined by the total resistance of the tow and respective seakeeping motions of the tug and tow.
d. Towing hawser system specifications (eg., type, diameter, expected maximum tension and scope) and configuration.
e. Maximum practical towline length, as determined by navigational and hydrographic restrictions on towline catenary depth.
f. Tug's endurance required to complete the mission.
g. Unique characteristics of the anticipated tow.

These factors are interdependent. For example, in theory the desired towing speed would largely determine the required tow hawser size. But in practice, there is little choice of tow hawser for a given tug class. Hawser choice, therefore, is governed by the ships available for the towing assignment. For larger tows, those fully utilizing the propulsion power of the tug, the tug determines the potential speed of the tow. If this is insufficient, alternative tug arrangements will be required. Given the tug and the resulting speed of the tow, the tow hawser size can be checked and an initial towing rig design can be accomplished.

There are three steps in the design of a towing system.

a. Select the desired towing speed. Then calculate the towline tension for several speeds above and below recommended (or desired) speed and at different wind/sea combinations. This will assist in determination of towing speed. Section 6-3 and Appendix G provide the methods for predicting the resistance of the tow.

b. Review and evaluate available tug/hawser combinations by comparing them to requirements established by the towing resistance and desired towing speed. Account for effects of weather, type of towline, dynamic load mitigation, etc. Safety factors used in the calculations must be appropriate for materials and equipment involved, anticipated weather and other conditions of the particular towing mission.

c. Recheck the refined calculations against the towing ship's capabilities. If calculated requirements for power or towline.

strength exceed capacities of available equipment, further evaluation is required. Options may include:

(1) Selecting a slower towing speed.
(2) Using additional or more powerful tugs.
(3) Decreasing resistance by changing the tow's characteristics, routing and/or schedule.

SECTION III

5-3 TOWLINE TENSION.

There are three components of towline tension

a. Tensions generated by the tow
   (1) Steady tow resistance
   (2) Slow dynamic cyclic loads caused by the tow's yawing, sheering and surging
   (3) More rapid dynamic cyclic loads caused by relative seakeeping motions of tug and tow
b. Towline resistance or hydrodynamic drag (adds to the tug's propulsion requirements)
c. Vertical components of wire catenary (contributes to the total tension of the towline itself but not to tug propulsion requirements)

5-3.1 ESTIMATING STEADY TOW RESISTANCE. The steady tow resistance (RT) may be estimated using the following approximation:

$$R_T = R_H + R_p + R_w + R_S$$

where.

R_H = Hydrodynamic hull resistance of the tow

R_p = Hydrodynamic resistance of the tow's locked propellers

R_w = Wind resistance of the tow

R_S = Additional tow resistance due to sea state

Appendix G provides a met hod for predicting each of the steady tow resistance components. Effort can be saved by computing the resistance for two or three different speeds for later comparison to tug capabilities. Remember to consider towing speed limitations cited in Paragraph 3-4.2. Likewise, wind and sea state resistances should be computed for best and worst expectations as well as for the most probable conditions of each assumed tow speed.

5-3.2 RESISTANCE OF THE TOWLINE. The hydrodynamic resistance of the towline, R_{wire}, can be significant for a typical wire hawser tow rig. This resistance is dependent upon the size, length and catenary of the towline, which in turn are dependent upon characteristics of the selected tug and towing speed.

If the tug has not been selected, add 10 percent of the tow resistance of the towline. Accordingly, to approximate the total towline pull required of the tug, multiply by 1.1 the values of R_T obtained using the methods described in Paragraph 5-3.1.

If the tug already has been selected, or if tugs are being evaluated, Table 6-1 provides a more refined estimate for the hydrodynamic resistance of the towline R_{wire}. In this case:

$$R = RT + R_{wlre}$$

The added resistance of the towline when using a synthetic hawser can be ignored since it will be small compared to the resistance of the tow.

5-3.3 CYCLIC AND OTHER LOADS IMPOSED ON THE TOWLINE.
Towline loads imposed by the seakeeping motions and the vertical component of the towline catenary

TABLE 5-1. Hydrodynamic Resistance of the Towline.

Wire Size (in)	Wire Scope (ft)	Chain Size (in)	Chain Scope (ft)	Added Resistance (lbs) 10,000 lb. Tension			Added Resistance (lbs) 20,000 lb. Tension		
				4 kts	8 kts	12 kts	4 kts	8 kts	12 kts
1⅝	3000	—	—	1000	4000	7200	1000	3000	5800
1⅝	2000	—	—	900	3500	4100	700	2500	3300
2	2000	—	—	2000	2200	6000	1500	2200	4000
2	2000	2¼	90	2500	5100	12000	1900	3900	7900
2	2000	2¼	270	3100	10000	19300	2000	7200	15000
2	2000	4¾	270	3700	12000	24500	2700	8900	17600
2¼	2000	2¼	90	1500	5200	11500	1300	3800	8000
2¼	2000	2¼	270	3000	8000	18500	1600	6500	14500
2¼	2000	4¾	270	5000	14100	25500	4500	12900	23000
2¼	3000	2¼	90	1900	8300	17500	1600	5700	13100
2¼	3000	2¼	270	3100	12000	24800	2500	8700	20100
2¼	3000	4¾	270	5500	14400	27800	5000	13300	26000

Wire Size (in)	Wire Scope (ft)	Chain Size (in)	Chain Scope (ft)	Added Resistance (lbs) 40,000 lb. Tension			Added Resistance (lbs) 60,000 lb. Tension		
				4 kts	8 kts	12 kts	4 kts	8 kts	12 kts
1⅝	3000	—	—	600	2200	5000	500	1900	4200
1⅝	2000	—	—	500	2000	3300	250	1000	2500
2	2000	—	—	1000	1700	3500	300	1200	3000
2	2000	2¼	90	1200	3200	6500	1000	2500	5100
2	2000	2¼	270	1500	5100	10900	1300	4200	8800
2	2000	4¾	270	2500	6900	14600	2000	6800	13200
2¼	2000	2¼	90	1200	3500	6500	1100	3100	5000
2¼	2000	2¼	270	1400	5100	11500	1200	3700	8500
2¼	2000	4¾	270	3900	9300	18100	2900	5700	13200
2¼	3000	2¼	90	1400	4100	9500	1200	2500	5900
2¼	3000	2¼	270	1900	6500	15500	1300	4200	10900
2¼	3000	4¾	270	3500	10500	21500	2000	7700	17000

USE OF TABLE: Towline resistance can be selected for the case closest to the actual towline configuration. The figures can be interpolated as required if additional accuracy is desired.

- For towline scopes less than shown, make a proportional reduction from the scopes listed.
- For tension greater than 60,000 pounds, extrapolate assuming a resistance curve between 40,000 and 60,000 pounds in a straight line

Ignore the slightly greater resistance in figures that would result for 2¼-inch IRWC wire because of the greater weight resulting in a deeper catenary are significant and are considered in Section 6-4. However, they do not impact on required towing power or selection of the tug.

5-3.4 TUG SELECTION. The tug's available propulsion power determines the speed of the tow, and therefore, steady forces on the towline.

The available pulling power of a tug is the difference between the total thrust from the engine-propeller combination at a given speed and the thrust expended in propelling the tug alone at that speed. The available pull is maximum at zero tug speed (the "Bollard Pull" condition) and zero at the tug's maximum free-running speed.

Each class of ship should have its own unique set of available tow tension curves that depend upon engine power setting, ship speed, propeller RPM and propeller pitch for those ships with CPP. The problem is simplified for tow planning because the maximum available tow speed is the figure of interest. Figure 6-1 provides the approximate pull available to the tow hawser, versus speed of Navy tugs at each ship's maximum continuous power rating. These curves, when compared to the several $R_T + R_{wire}$ values developed in Paragraphs 5-3.1 and 6-3.2, provide approximate maximum tow speed for the assumed conditions. If the maximum speed available does not coincide with one of the assumed tow speed conditions, additional tow resistance computations should be performed to achieve a balance between tension required and tension available. A more direct method is to plot a curve of tow resistance (plus 10 percent for a wire hawser) directly onto a copy of Figure 5-1 The tug and tow curves will intersect at the maximum speed attainable with each tug for assumed tow conditions.

If the available tow speed exceeds the amount needed (usually for small or non-ship-type tows), the tow ship will require less than maximum continuous engine power. In this situation, a less powerful tow ship can be considered. Conversely, if available tow speed is less than required, a more powerful towing ship or multiple tugs must be selected. In the latter case, there will be two or more towlines, so R_{wire}, must be increased appropriately. Otherwise, the available towline tension of the tugs is additive.

When the available tug is underpowered for the desired tow speed, the most important consideration is whether it has sufficient power to keep the tow out of danger under the most strenuous wind and sea conditions that can be reasonably expected For instance, it may be acceptable that a given tug is unable to make headway over the ground, while towing a large ship in a sudden gale in the open sea However, the same tug may be considered inadequate for towing the same ship under the same conditions near a lee shore. In the case of a planned tow of a large ship, adjustment to tow dates and careful weather routing always are appropriate. For more strenuous cases, adjustment of the assignments and schedules of other tow ships also may be required to provide the required towing capability.

For emergency or unplanned towing requirements, the tow will be initiated by the first available tow ship Procedures outlined herein are useful in determining whether additional towing assets should be diverted to escort or take over the tow.

Appendix L provides data useful in predicting the towline pull versus speed for non-U.S. Navy tugs.

SECTION IV

5-4 TOWLINE TENSIONS AND CATENARY

Paragraph 5-3 addressed the prediction of tow speed and tug selection based on tow resistance. This section discusses the steady state and dynamic effects on the towing system, limitations imposed by the tow ship's hawser, selection of towing rig components and the geometry of the towline catenary.

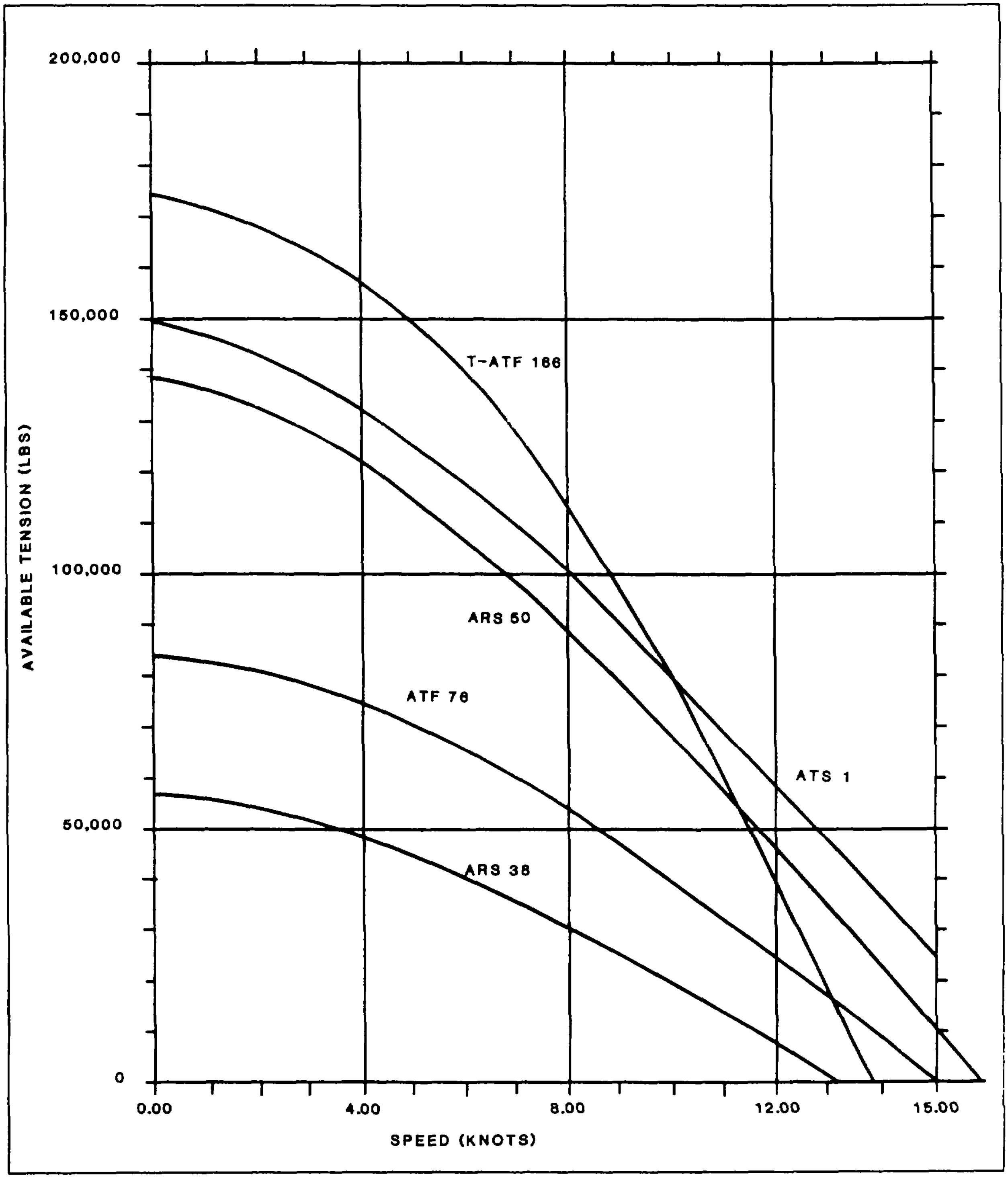


Figure 5-1. Available Tow Tension vs. Ship's Speed for U.S. Navy Towing Ships.

5-4.1 STEADY STATE TOWLINE TENSION. Normal wire rope towline arrangements will assume a sag or catenary as depicted in Figure 5-2. The total towline stress at a given point is the vector sum of the horizontal and vertical components of the stress at that point These stresses will be maximum at the stern of the tug, where the hydrodynamic resistance of the entire towline is added to the resistance of the tow. Figure 5-2 includes a vector diagram of the towline forces acting immediately astern of the tug. The total tension in the towline at the stern of the tug is expressed by the formula:

$$T = \sqrt{(/RT + R_{wlre})2 + _{Tv2}}$$

where:

T = Total tension

RT = Steady state tow resistance (Paragraph 6-3.1 and Appendix G)

R_{wire} = Hydrodynamic resistance of the towline (Paragraph 6-3.2 and Table 6-1)

T_v = Vertical component of the towline tension

R_T and R_{wire} are computed as noted T_v is the weight of the towline forward of the catenary low point, less the slight upward component of hydrodynamic drag on the forward half of the catenary. Location of the catenary low point and the vertical component of the hydrodynamic drag are beyond the scope of this manual. However, errors will tend to cancel out if T_v is assumed to be the weight (in water) of one-half the scope of the wire towline. Do not include the weight of any chain pendant at the tow in this computation.

For example, assume that ARS 50 is towing a ship at 8 knots with a scope of 2,000 feet of 2 1/4-inch IWRC tow hawser and 270 feet of 2 1/4-inch chain pendant at the tow. The tow provides a steady tow resistance of 60,000 pounds at 8 knots.

R_T = 60,000 lbs.

R_w = 3,700 lbs (Table 6-1)

T_v = 8,143 lbs (1,000 ft. x 9.36 x .87*)

*9 36 is the dry weight of the wire from Appendix B and the .87 factor corrects dry weight for wet weight

Solving the vector diagram provides a maximum steady state tension:

$$T = \sqrt{(60{,}000 + 3{,}700)2 + 8{,}1432} = 64{,}2181bs.$$

This example supports the rule of thumb that using a 10 percent factor on top of the predicted steady state tow resistance is reasonable and accounts for the hydrodynamic resistance of the wire plus the vertical components of the catenary. Computing the total towline tension at the tow, even with as much as 270 feet of chain pendant, shows that the total tension is less than at the tug. Further, combinations of different $_{RT}$ and different towline designs show that when Rwire is significantly above 10 percent of RT, the catenary is very deep and tension is therefore out of the range of concern for towline strength.

In Figure 5-2, the towing ship must supply excess thrust only equal to the horizontal component of the tension, i e., RT + R_{wire}. The vertical component of towline tension T_v is absorbed by the buoyancy of the tug The additional apparent displacement caused by T_v will require additional propulsion power, but the amount generated is so small that it can be ignored.

5-4.2 DYNAMIC LOADS ON THE TOWLINE.

While towing at constant tug speed in a seaway the towline tension is not steady, but varies with timeas illustrated in Figure 5-3 The total towline tension or extreme tension, T_e, can be expressed as.

$$T_e = T_1 + T_2 + T_3$$

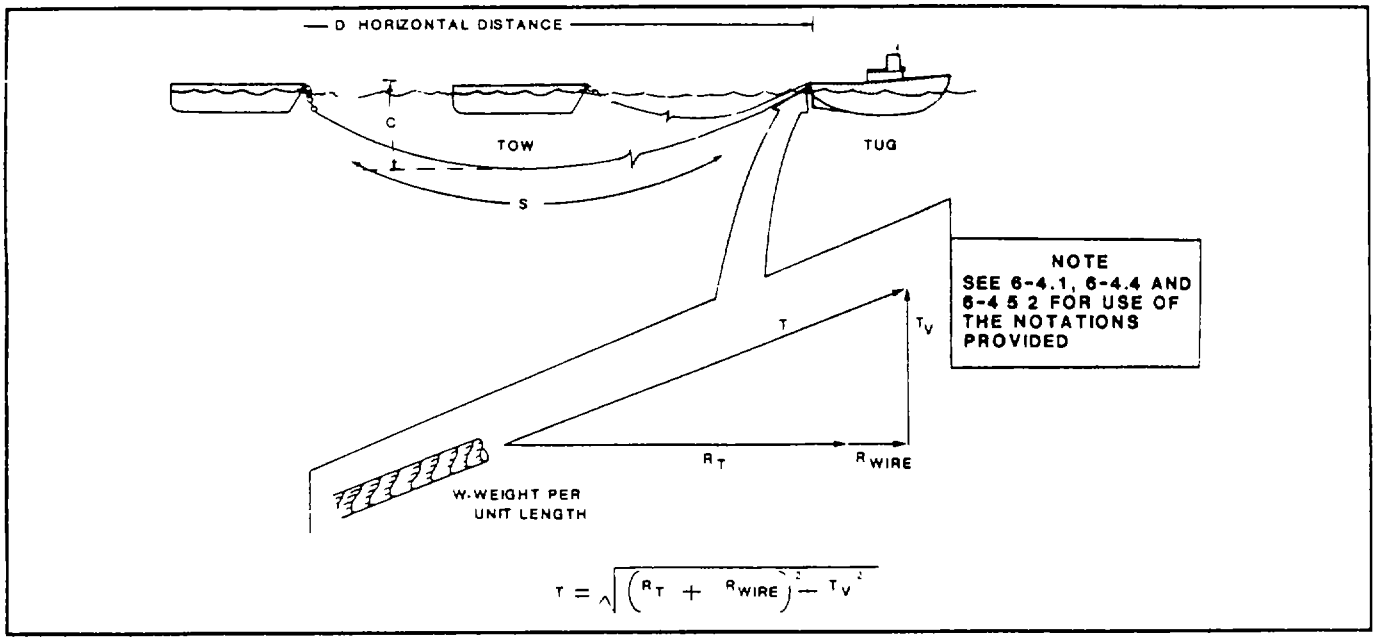


Figure 5-2. Towline Forces at Stern of Tow.

T_1 is the steady or static component of the towline tension, (R_T + R_{wire}) as discussed in Paragraph 6-3.2 In Figure 5-3, T_1 20,000 pounds. T_2 and T_3 fluctuate such that each has an average value of zero and their long-range effect on towing speed will be nil. Maximum towline tension occurs when T_2 and T_3 are additive.

T_2 is a slowly varying component of the tension due to yaw or sheering of the tow-slow swinging of the towed vessel from one side of the course line to the other-and surge, or slow change of span between the tug and towed vessel Since each swing takes several minutes, T_2 also takes several minutes to vary from its maximum to its minimum and is sometimes called a "quasi-steady" tension. In the example shown in Figure 5-3, T_2 varies between -3,000 and +3,000 pounds.

The example shown in Figure 5-3 assumes constant speed and could apply to a small tow compared to the size and power of the tug. For large tows, where slow swings can take 10 minutes or more, and for the typical situation where the tow ship's power setting is constant, the tug and tow both slow down to accommodate the increased tow resistance This is especially true when the tow sheers off to one side A poorly-behaved tow, therefore, cannot be expected to attain the speed predicted by Appendix G without a significant increase in tug power and hawser tension, neither of which may be possible or wise.

Another aspect of the badly sheering tow is that it can apply a significant additional tension peak when it "fetches up" at the end of each excursion to the side This may dictate a further, deliberate slowing to protect the towing gear, especially if the towing machine is not in its automatic mode.

T_3 is due to the wave-induced seakeeping motions of the tug and tow. It is a random process with typical half-periods, the time taken to vary from maximum to minimum, of 1 to 8 seconds. T_3 depends on the detailed dynamics of the responses of tug, tow and towline to time-varying forces. Thus, T_3 is called a "dynamic-tension" component of the towline tension and must be considered.

Determination of maximum values for the three components of towline tension is

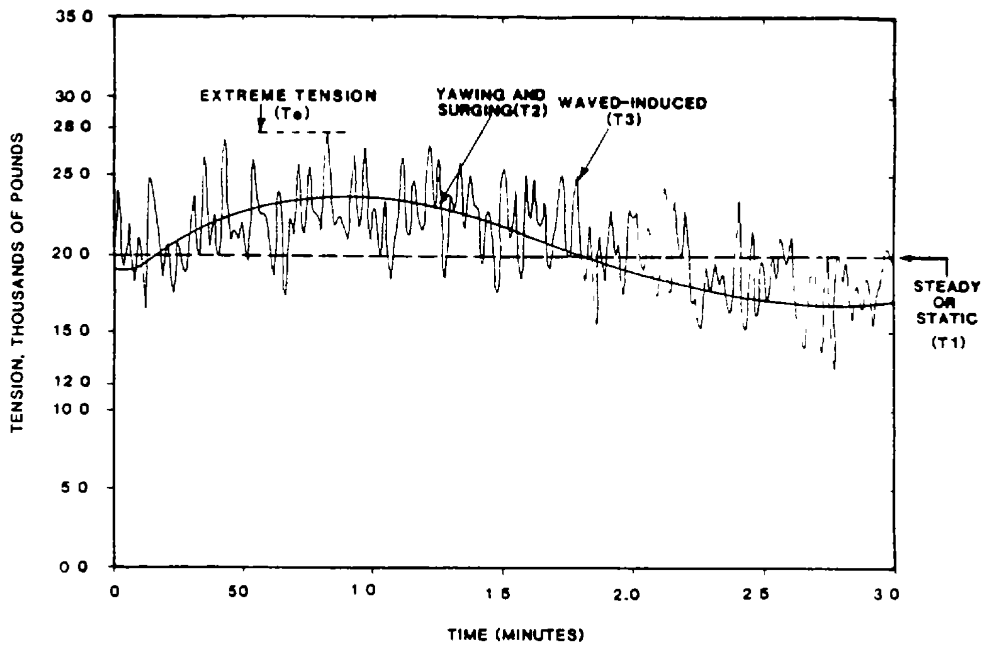


Figure 5-3. Towline Tension vs. Time.

desirable in the planning or design of a tow, as well as in the actual towing operation. During a tow operation, precise determination of towline tension requires precision instrumentation. Normally tugs are not equipped with instrumentation sufficiently accurate to measure $_{T3.}$ Most tugs, however, are equipped with towing machine tension meters sufficiently accurate for determining steady and quasi-steady tension T3 must be treated as discussed in the following section.

54.3 DYNAMIC TENSIONS. Since the dynamic tension is a random function, it must be described in terms of the statistics of the ship's motion under stated sea conditions. The statistical approach is just beginning to be used in towing technology. In the past, tow planning and operations dealt with the dynamic tensions by applying large safety factors to steady tensions when sizing components. These safety factors are based on experience They account for many effects in addition to dynamic tension, such as towline fatigue, corrosion and wear.

The "safety factor" approach is suitable when the operators have a great deal of experience with the towing system under consideration. Difficulties with this approach occur when using a new towing system or towing a ship or structure with which there is no previous experience. Sometimes this happens when operating with synthetic towlines or towing systems for which the standard design or material has been changed. The more effects that are combined in one factor of safety, the greater the uncertainty. Nonetheless, recommended safety factors have been established for some known towing systems. See Table 5-4.

Appendix N presents new work that predicts the statistics of dynamic loading of the towline. As confidence in this approach is developed, inclusion of dynamic effects in the factors of safety, as listed in Table 5-4, may no longer be required Removal of the dynamic uncertainty eventually may permit reduction in traditional towing system safety factors.

5-4.4 CATENARY DEPTH. To avoid dragging or fouling the towline on the bottom, while maintaining a sufficient catenary depth to absorb changes in tug-tow separation, it is necessary to estimate the catenary depth, or sag, of the towline. A number of methods have been utilized for estimating towline catenary.

WARNING

Do not allow the tow hawser to drag on the bottom.

In order to estimate catenary depth it is necessary to have the following data available:

a. Steady tension in the towline

b. Lengths of the towline components and their weight per unit length in water

c. Total scope of the towline.

The steady tension in the towline may be estimated by using the tension meter on the towing machine, by the estimating procedure in Appendix G, or by using the chart in Figure 6-1 which presents the calculated tug pull available versus speed through the water. The composition and total length of the towline should be known Appendices B and D provide the weight per unit length for various towline components. When weight in water of steel components is not given, multiply weight in air by 0.87 to obtain weight in salt water.

An initial estimate of the catenary depth of the towline may be determined using the following formula'

$$C = T/W - T/W \sqrt{1-(WS/2T)^2}$$

where:

C = Catenary or sag (ft)

T = Steady tension (lbs force)

W = Weight in water per unit length (lbs/ft)

S = Total scope (ft)

Total weight in water per unit length is computed as the sum of the weights of the individual towline components divided by the total towline scope This formula applies to single component wires hanging under their own weight similar to power lines However, for towline configurations where the ratio of towline scope (S) to catenary (C) is greater than 8:1, this formula provides an acceptable estimate of tow-line catenary.

Figures 5-4 through 5-12 show the calculated catenary for various compositions and lengths of towline. These curves may be used for towing speeds up to 12 knots. In order to decrease catenary, towline scope may be shortened or the towing speed increased.

To quantify effects of changes in tension, the user can draw in his own curve representing the scope actually used, and proceed along that curve to different tensions to find the new catenary. For example, with a scope of 1,500 feet of 2-inch hawser and no chain, Figure 5-7 shows that increasing tension from 20,000 pounds to 30,000 pounds will decrease the catenary depth from about 100 feet to about 65 feet. Slowing down to a tension of 10,000 pounds will almost double the catenary to about 190 feet.

Likewise, the user could plot curves of catenary versus tension for several tension figures to provide a graphical representation of the effect of change in hawser scope. For a fixed limit on depth, the user could plot scope versus tension for several catenary figures to assist in determining scope/tension combinations required by the water depth.

Some towing machine technical manuals include tables or curves to assist in solving scope/catenary/ tension questions.

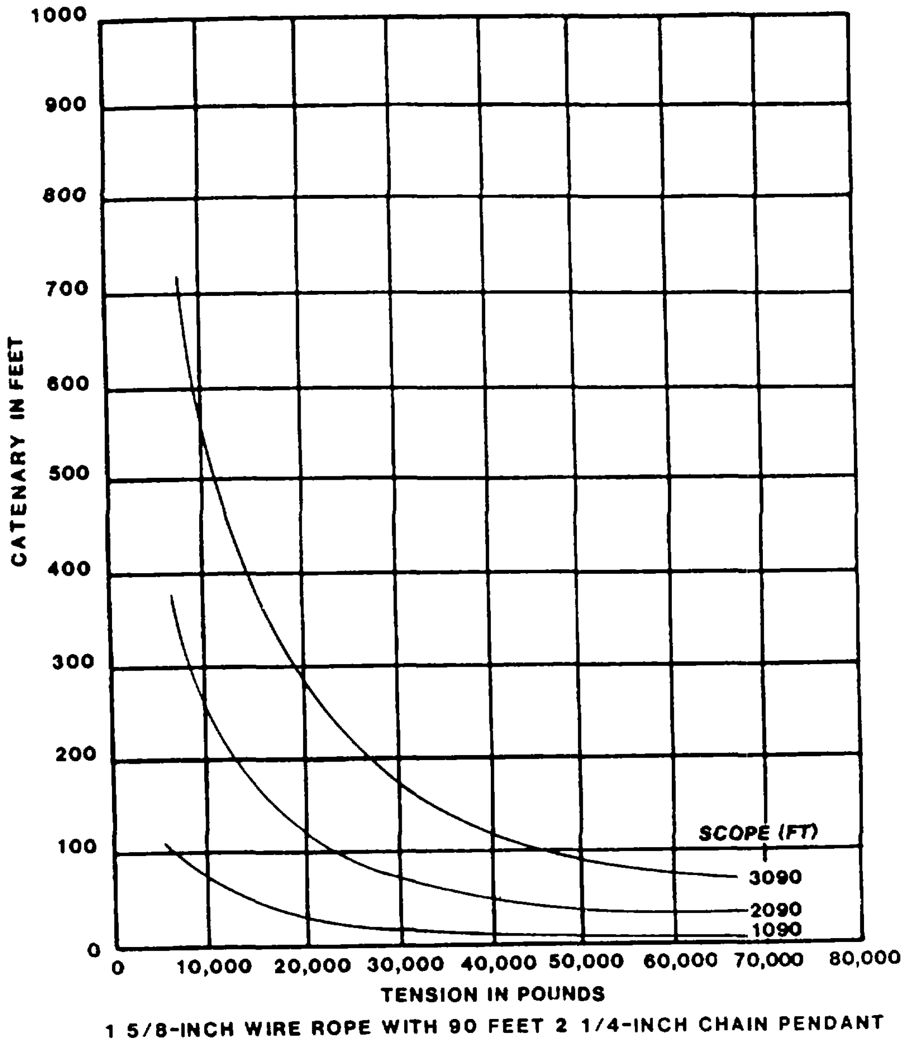


Figure 5-4. Catenary Tension for 1 5/8-inch Wire Rope.

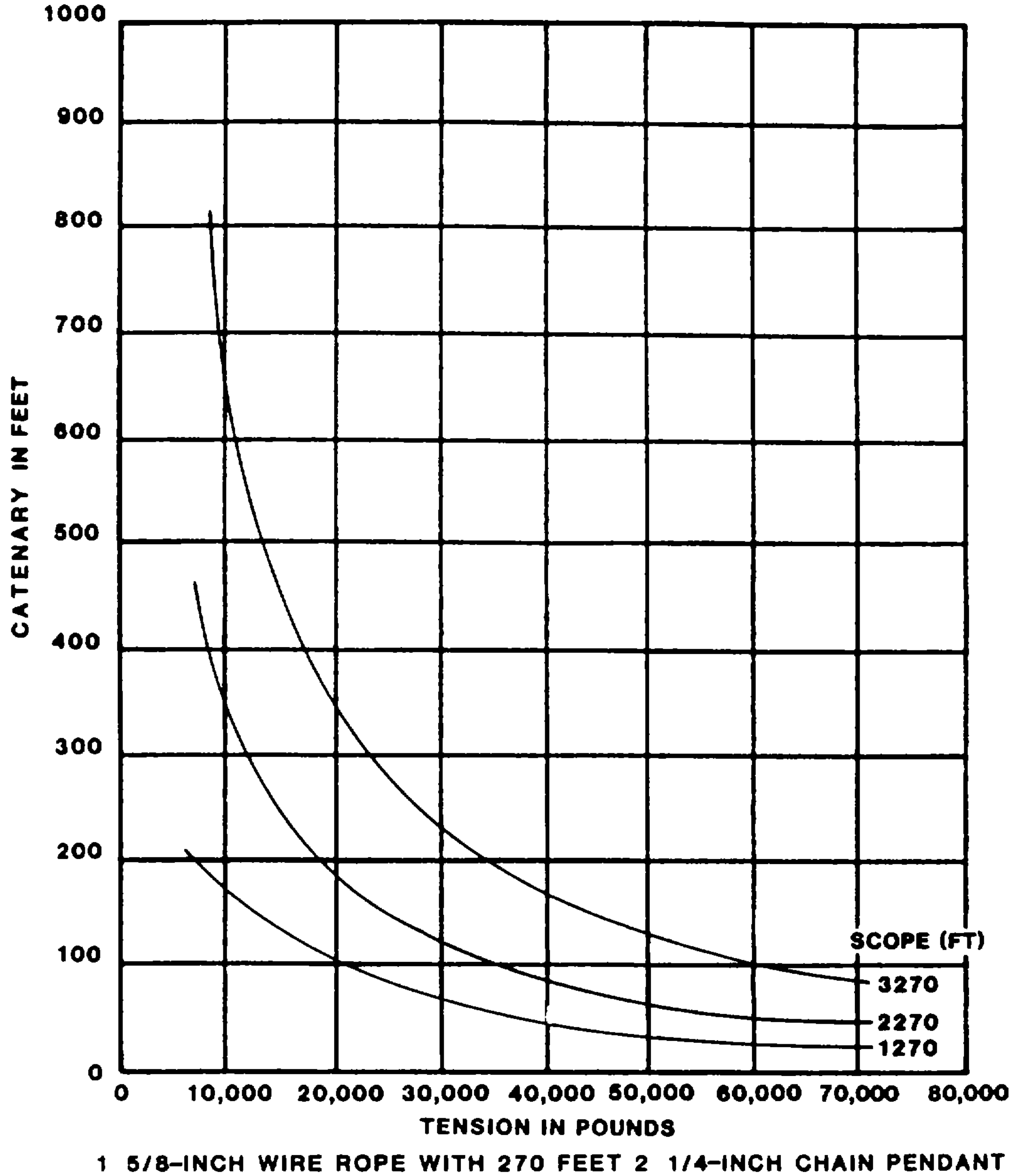


Figure 5-5. Catenary Tension for 1 5/8-inch Wire Rope.

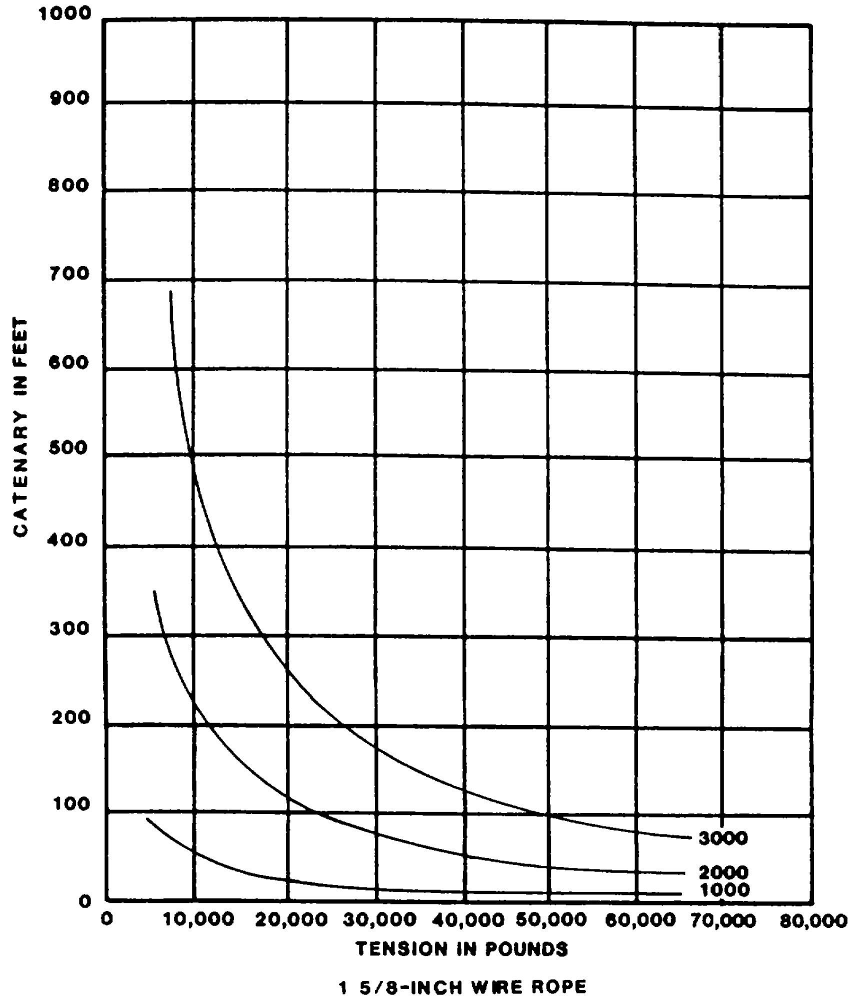


Figure 5-6. Catenary Tension for 1 5/8-inch Wire Rope.

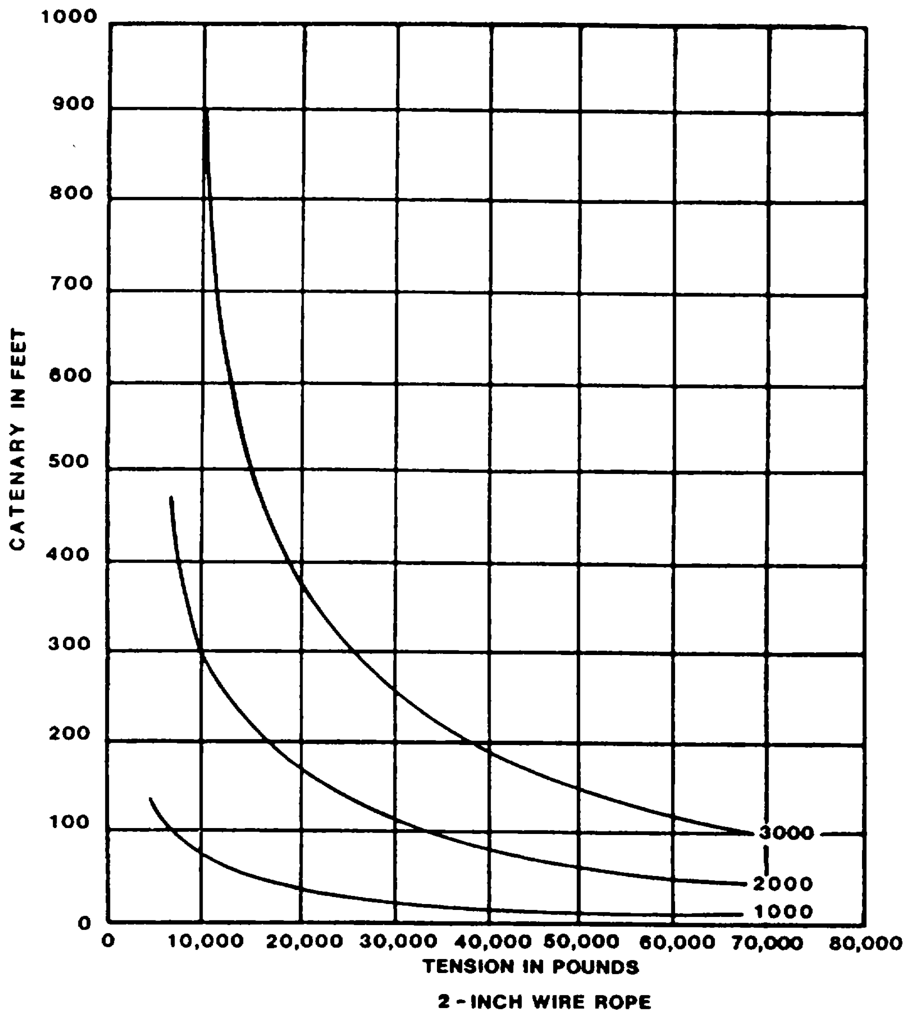


Figure 5-7. Catenary Tension for 2-inch Wire Rope.

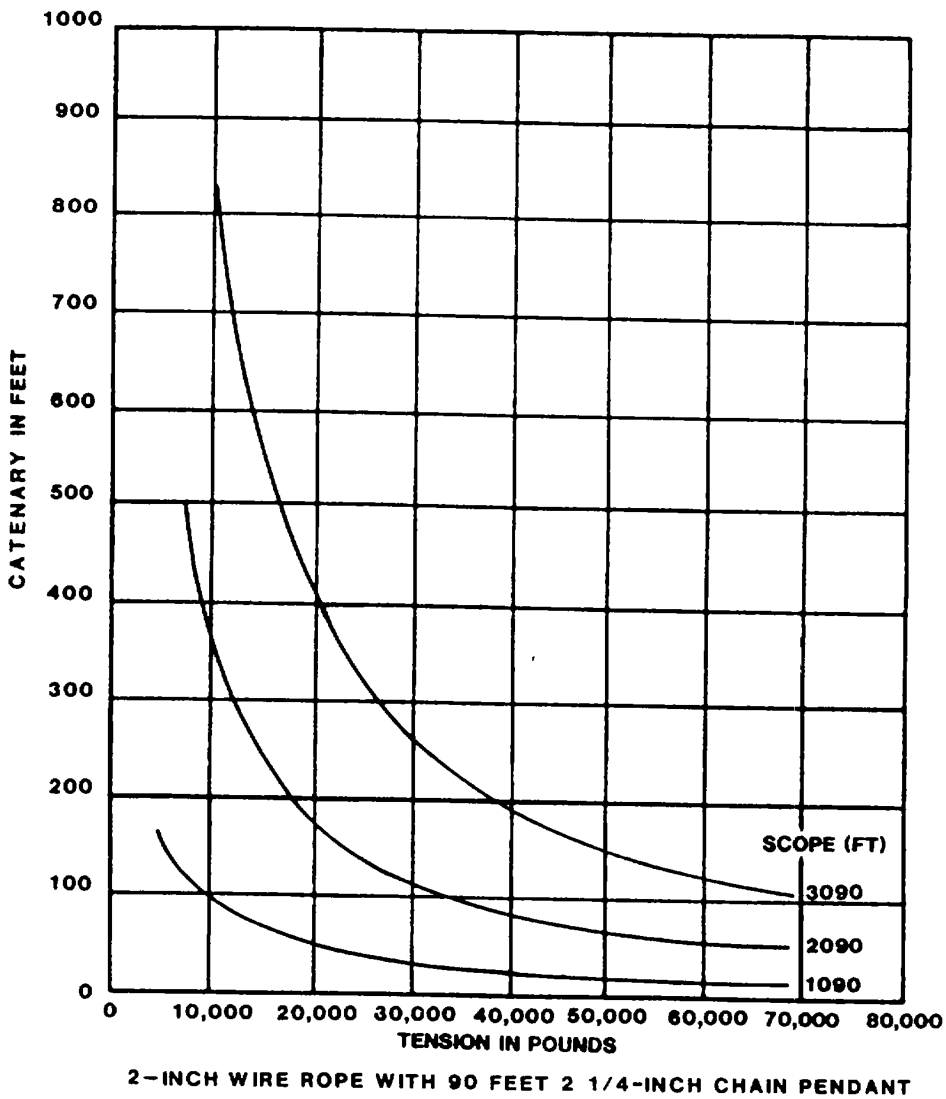


Figure 5-8. Catenary Tension for 2-inch Wire Rope.

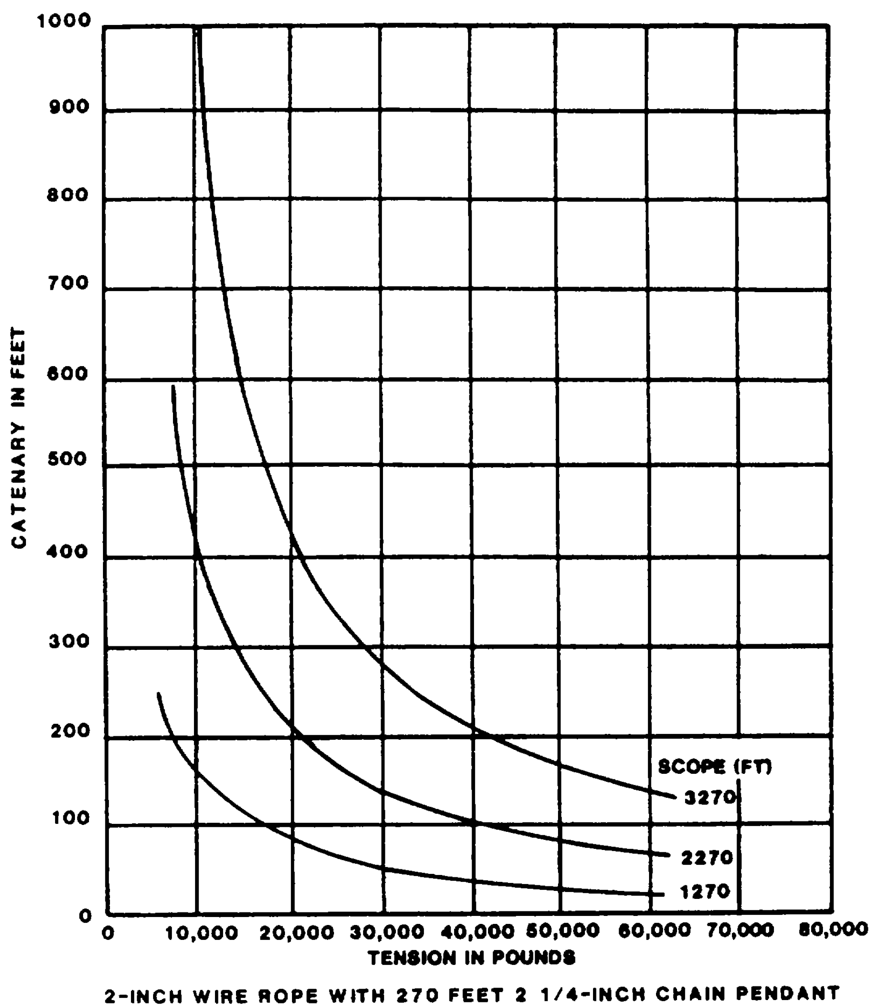


Figure 5-9. Catenary Tension for 2-inch Wire Rope.

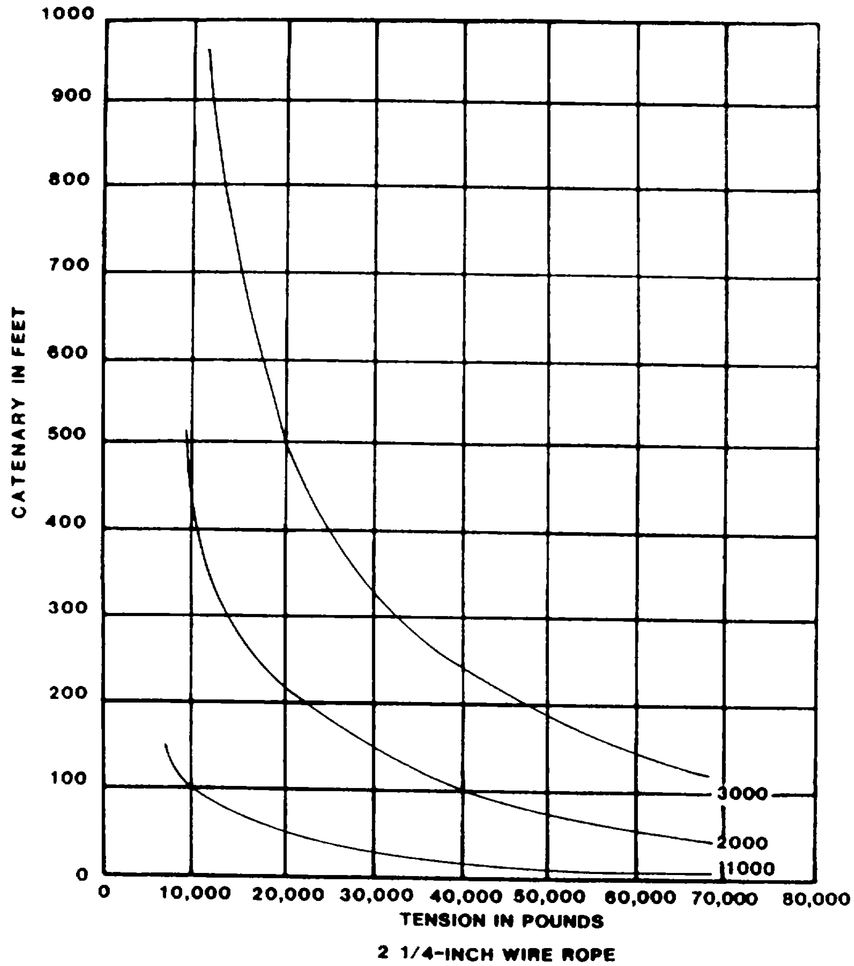


Figure 5-10. Catenary Tension for 2 1/4-inch Wire Rope.

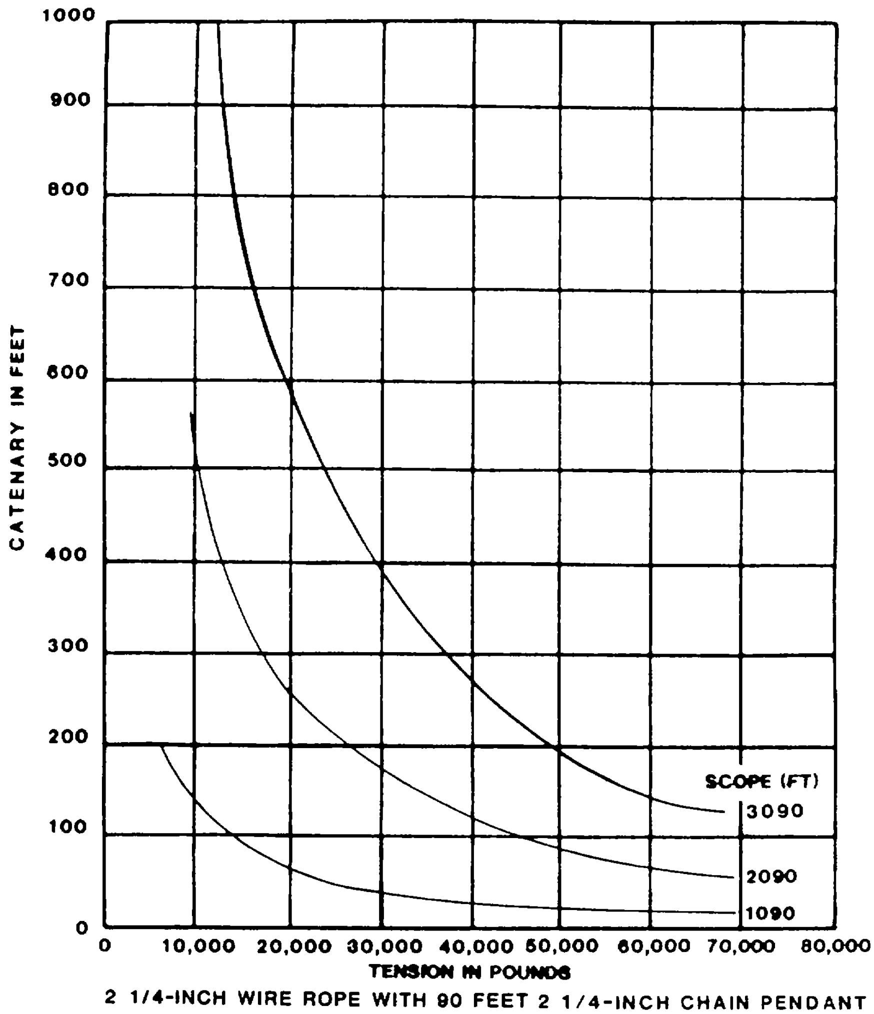


Figure 5-11. Catenary Tension for 2 1/4-inch Wire Rope.

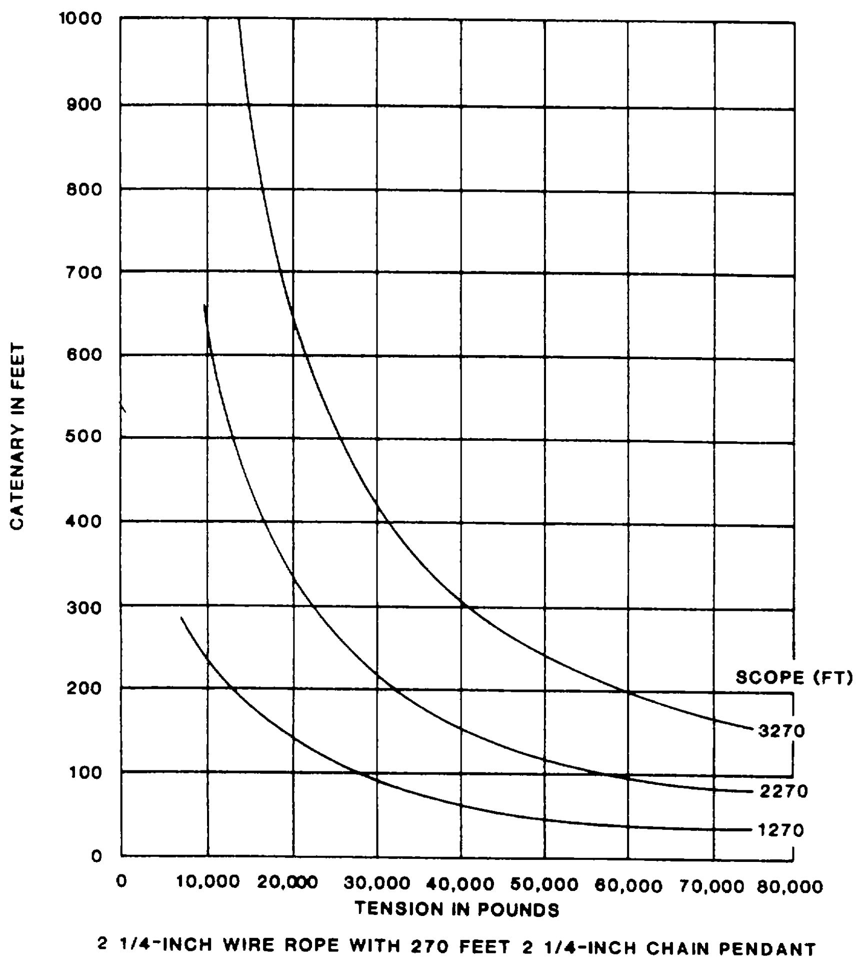


Figure 5-12. Catenary Tension for 2 1/4-inch Wire Rope.

(Text continued from page 6-9.)

5-4.5 TOWLINE PEAK LOAD REDUCTION. Paragraph 5-4.2 qualitatively discussed the peak load that would be seen by a non-elastic towing system Appendix N, supported by experience, quantitatively demonstrates that short-term peaks can be much greater than steady-state loads in heavy seas. There are several factors or actions that can reduce the magnitude of these peak loads. These are listed in the following paragraphs.

5-4.5.1 Towing Ship Actions. The tow should have been planned in full consideration of resistance of the tow, tow hawser and tug selection, towing connection and selected towing speeds appropriate to the expected weather. In some cases, the forecast will be inaccurate or unavailable, or the tow may be carried out on an emergency basis by the first available tug. In addition to the use of the automatic feature of its towing machine, there are four actions the towing ship can take to reduce peak towline forces:

a. Increase towline scope

b. Reduce power and speed

c. Change course

d. Bring tug and tow in step.

Increasing the towline scope is usually the first action taken by the tow ship under deteriorating sea conditions However, water depth may limit allowable catenary. Furthermore, present knowledge suggests that the catenary is not as effective a "spring" as was formerly thought. Nonetheless, increasing towline scope, if possible, is appropriate under worsening sea conditions.

A reduction in tow speed reduces peak towline tensions in two ways. First, steady tow resistance decreases, allowing the catenary to increase, providing an increased ability to absorb the relative motions of the tug and tow. Second, the reduction in steady tension reduces the base to which the dynamic tensions are added, thereby reducing peak tensions.

The towing course has a significant effect on dynamic motions of the tow ship and the tow. In general, the dynamic effects on the towline are minimized when the seas are on or near the beam However, in heavy weather, resulting rolling motions probably are more dangerous from a stability stand-point than the advantage of reduced peak towline tensions. Dynamic seakeeping effects on the towline generally are most severe with following seas. Heavy sea conditions, therefore, usually dictate steaming into the seas at reduced speed. In the heaviest storms, it may be appropriate to let the tow pull the tug downwind, with the tug maintaining only enough power to assure steerageway.

Results of seakeeping studies described in Appendix O suggest that, in some cases, dynamic towline loads may be significantly reduced by steering a course 30 to 60 degrees relative to the sea direction. This assumes an acceptable degree of tug and tow rolling, as well as the ability to maintain course control.

Sometimes adjusting the towline length will bring the tug and tow in step This applies to tugs and tows that are small relative to the length of the waves, and assumes a regular, unconfused wave system such as is sometimes found off the U.S. West Coast. In most cases, however, the ocean surface is composed of many different wave components coming from random directions Therefore, a particular towline scope seldom will keep a tug and tow in step for very long.

5-4.5.2 Changing Towline Composition. Several aspects of the towline design can significantly affect the peak towline tensions Some are adjustable during the tow; some are not, but nonetheless should be considered during the tow planning phase. These measures include;

a. Increasing towline scope

b. Increasing length of chain pendant/bridle
c. Inserting a synthetic spring into the towline system.

The following explores the ability of a wire catenary to absorb ship movements by including "stretch" of the wire. From paragraph 5-4.4 the depth of a tow hawser catenary can be estimated by the formula:

$$C = T/W - T/W \sqrt{1-(WS/2T)^2}$$

If the effects of hydrodynamic drag are ignored, catenary theory further estimates the separation between tug and tow as:

$$D = S(1-WC/3T)$$

Where
C = Catenary depth or sag (ft)
T = Steady tension in the towline (lbs force)
W = Weight in water per unit length of the hawser (lbs/ft)
S = Total scope of the hawser (ft)
D = Horizontal distance between the tug stern and the bow of the tow (ft)

See Figure 5-2 for a graphical representation of the notation used.

In order to quantify the effect on the hawser tension for a given change in distance between tug in tow, it is necessary to develop a table or curve of distance (D) vs. tension (T) for various hawser scopes. The computation is fairly direct if tension (T) is assumed for a given scope (S) of hawser, catenary depth (C) is computed, then horizontal distance (D) of the catenary

Two components of wire "stretch" must also be included: constructional stretch and elastic stretch The Wire Rope Users Manual (Ref. 13) estimates constructional stretch as 1/2-3/4percent for 6-strand fiber-core wire and '1/4-1/2, percent for 6-strand IWRC wire. It can be assumed that constructional stretch is linear up to a load of about 20 percent of breaking strength, beyond which there is no additional constructional stretch.

The elastic stretch of hawsers likewise varies with load. For convenience, elasticity is assumed to be constant through 20 percent loading, with a different figure applying beyond 20 percent loading For common Navy hawsers, the following figures can be used, expressed as section modulus in feet stretch, per pound load, per foot of length'

	wire dia.	1 5/8-in.	2-in.	21/-in.
6x37FC				
	0-20%	10.9	16.6	21 0
	>20%	12.1	18 4	23.0
6x37IWRC				
	0-20%		24 6	30 9
	>20%		27.2	34.4

(multiply all values times 106)

Example: A 1,000-foot, 2-inch FC hawser with a 20,000-pound load will elastically stretch

20,000 x 1,000/16.6 x 106 = 1.2 ft.

Table 6-2 is developed for a 1,000-foot, 2-inch, FC hawser, with the results plotted in Figure 6-13 An 1,800-foot hawser of the same material is also plotted for comparison. Ships with different hawsers can prepare a family of curves showing the change in tension as the separation between the ships changes For instance, from an initial tension of 20,000 pounds, the 1,000-foot hawser can absorb about 19 feet of additional separation between the tug and tow before it reaches 200,000 pounds tension; the

Table 5.2. Elongation of 1,000 feet of 6x37, 2-inch FC Wire Rope

	Tension	Sect Mod [1]	Se[2]	Sc[3]	Scope[4]	Catenary[5] (ft)	Distance[6] (ft)
	0	0	0	0	1000	—	—
	5,000	16 6 x 10^6	3013	625	1001	161.7	938
	10,000	16.6 x 10^6	.602	1.25	1002	75	987
	25,000	16.6 x 10^6	1 5	3.12	1004.5	29 6	1002
(20%)	57,000	16.6 x 10^6	3.4	7.125	1010.5	13	1010
	60,000	18.4 x 10^6	3 56	7.5	1011	12.4	1010.6
	80,000	18.4 x 10^6	4.65	7.5	1012.2	9 4	1011.9
	100,000	18.4 x 10^6	5 7	7 5	1013.2	7.5	1013
	125,000	18.4 x 10^6	7.1	7.5	1014.6	6	1014 5
	150,000	18.4 x 10^6	8.46	7 5	1016	5.03	1016
(65%)	185,000	18 4 x 10^6	10 3	7 5	1017.8	4.09	1017.7
	200,000	18 4 x 10^6	11.2	7 5	1018 7	3.8	1018.6
	250,000	18.4 x 10^6	14	7 5	1021.5	3.05	1021.4
	288,000	18.4 x 10^6	16	7.5	1023.5	2.65	1023.4

Notes.

1 Section Modulus (A x E) for 2″ FC hawser is 16.6 x 10^6 through 20% strength of the wire; 18 4 x 10^6 over 20% load See accompanying table for other hawsers.

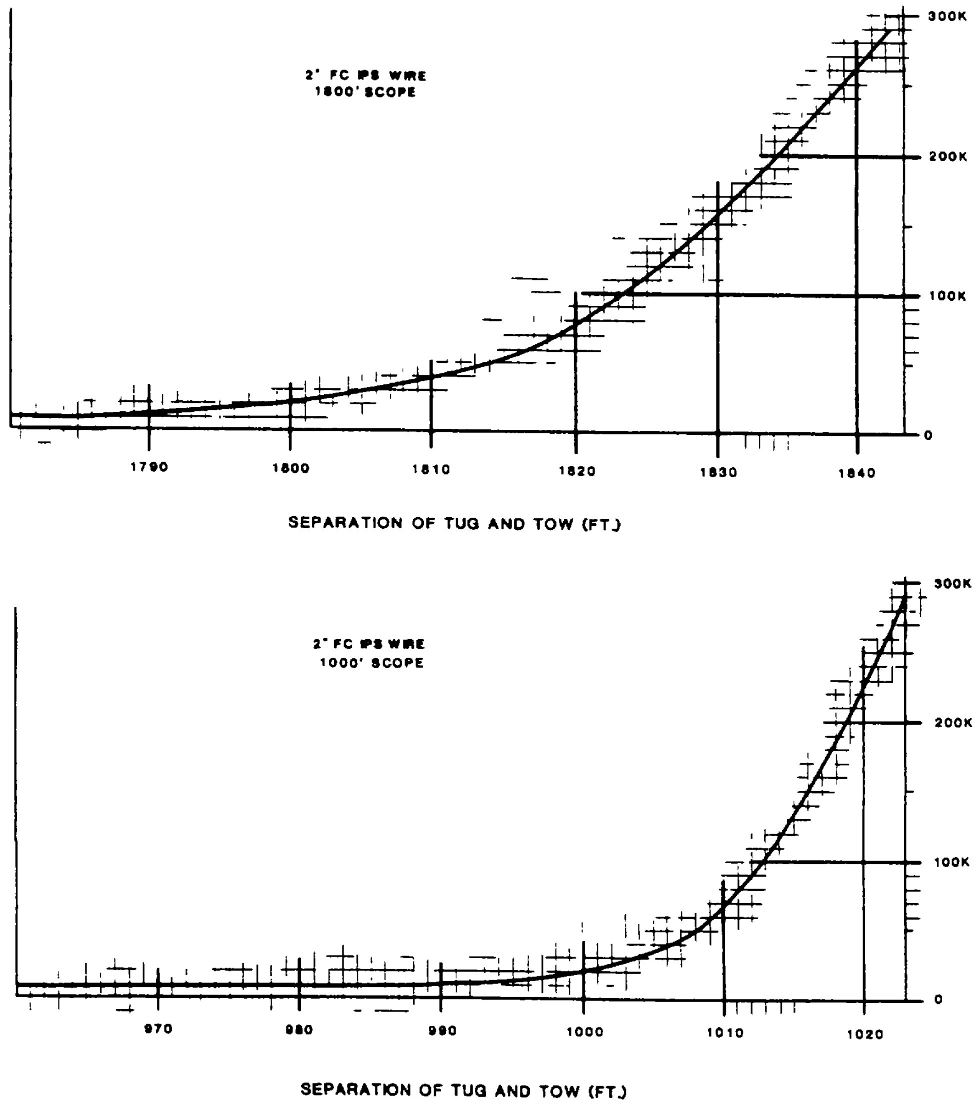
2 Change in scope due to wire elasticity. (ft)

3 Change in scope due to constructional stretch of wire. (ft)

4 Total scope of hawser after stretch. (ft)

5 Catenary depth per formula $C = T/W - T/W \sqrt{1 - (WS/2T)^2}$

6 Distance between tug and tow per formula $D = S(1 - WC/3T)$.



NOTE

THESE CURVES PLOT THE HAWSER TENSION VS TUG/TOW SEPARATION. THEY DEMONSTRATE THE MUCH "SOFTER" NATURE OF THE LONGER SCOPE FOR THE SAME CHANGE IN SEPARATION.

Figure 5-13. Distance Between Vessels vs. Hawser Tension for 1,000 and 1,800 feet of 6x37 FC Wire

1,800 foot hawser will not reach that tension until separation is increased by almost 34 feet On the other hand, a 20-foot "stretch" of the 1,800-foot hawser will increase its tension to only about 75,000 pounds. The longer hawser significantly reduces the peak tensions caused by the same ship movements.

The classic catenary is limited in its ability to absorb tug and tow motions, even where there is a relatively modest average hawser tension.

The quantitative data shown in Figure 5-13 are based on slowly-applied changes. The data are now somewhat suspect because of newly-understood limitations on the effectiveness of the classic catenary in reducing dynamic loads. This is because the hydro-dynamic resistance normal to the tow wire significantly impedes the rise and fall of the wire at typical frequencies of dynamic seakeeping loads This causes the classic hawser catenary shape to flatten out somewhat. Nonetheless, Figure 5-13 provides qualitative comparisons of different towline configurations acting under dynamic loading.

The reader could prepare a similar analysis of the advantages of adding chain to the towline Using the methodology shown in Table 6-2, prepare curves showing the effect of adding one or two shots of chain pendant to a given hawser length. The calculation process is identical, except that the comparison will be between hawsers of the same length but with different total length and unit weights, since the weight of the chain is distributed throughout the hawser length. The analysis will demonstrate that adding only one shot of 2/4-inch chain pendant provides a considerably softer system that develops lower peak tensions for the same change in the separation between tug and tow.

5-4.5.3 Use of Automatic Towing Machines. Use of the automatic payout and reclaim feature of the towing machines installed in most towing ships is a very effective means of reducing peak towline tensions. Table 6-3 provides the range of automatic settings available on various tow ships. Generally used when water depth precluded an adequate catenary, the towing machine was often taken off "automatic" after sufficient towline catenary had been established in deeper water. Now, however, with questions concerning real effectiveness of a wire catenary in reducing peak tensions, it appears that the automatic feature is equally as important in deep water. **The automatic mode should be used at all times.**

Appendix N provides additional data on towing machines and winches.

5-4.5.4 Use **of Synthetic** Towlines. The elasticity of synthetic hawsers, particularly nylon, will reduce the dynamic loading of the towing system. Significant questions raised elsewhere in this manual dictate against use of nylon for routine towing However, the use of polyester (Dacron) hawsers is under investigation, the results of which may justify the use of synthetic hawsers in towing. Synthetic springs are discussed in Paragraph 5-5.2.4.

SECTION V

5-5 SAFETY FACTORS, SELECTION AND SIZING OF TOWLINE LINKAGE COMPONENTS

Towline linkage components are shown schematically in Figure 2-9. Of these components, the hawser, pendants, bridles and connecting jewelry are the items to be sized based upon towing loads and factors of safety Connecting components, or towing jewelry, must be given careful attention. Hawser size generally is fixed for a given tow ship. If a specific size hawser is required, this, rather than the availability of towing ships, will determine tow ship selection.

5-5.1 SAFETY FACTORS. Table 5-4 provides guidance on safety factors applicable to towing. The following paragraphs will assist in the application of Table 5-4.

5-5.2 HAWSER. The hawser is primary tensile-load carrying component of the towing system In the past, ocean tugs have used

TABLE 5-3. Operating Range for Automatic Towing Machines on Various Types of Ships.

Types of Ships	Operating Range (lbs.)
Icebreaker (AGB)	35,000 - 80,000
Salvage Ship (ARS 6/38)	35,000 - 80,000
Submarine Rescue Ship (ASR)	24,000 - 60,000
Fleet Ocean Tug (ATF)	24,000 - 60,000
Towing and Salvage Ship (ATS)	15,000 - 96,000
Fleet Ocean Tug (T-ATF)	N/A
Salvage Ship (ARS 50)	25,000 - 115,000

NOTE

The tension (in lbs.) for the automatic operating mode can be set at any point within the operating range shown.

manila and sisal (natural fiber) lines and wire ropes for hawsers. Since the early 1970s, nylon and other synthetic-fiber lines also have been used for towing, both as hawsers and as pendants, with varying results. The following section details the current engineering technology for design and selection of tow hawsers.

5-5.2.1 Required Strength. For a given tow assignment, towline tension forces and the appropriate factor of safety are controlling elements in the initial selection of hawser size and tug Steady towline tension values may be calculated according to the methods outlined in Paragraph 5-3. Calculate or approximate steady towline tensions for several wind and wave conditions. The three main conditions are:

a. Most favorable wind and sea conditions.

b. Most probable winds and waves as forecast.

c. Worst-case maximum winds and waves.

Obtain the appropriate safety factors from Table 5-4 and apply them for the tow system configuration to be used. Unless it is known that dynamic loads will increase the steady state tensions by more than 100 percent, apply the safety factors obtained from Table 5-4 to the steady state tension to determine the required hawser strength. The safety factor shown in Table 5-4 should be increased appropriately if the tow is unfamiliar or there is significant uncertainty concerning the degree of dynamic loads of the hawser.

Appendix N provides a means of estimating the extreme tension on a statistical basis. When these techniques are used, use a safety factor of 1.5 against the "extreme tension". This does not supersede the Table 5-4 factors of safety. Both must be checked since either may control for a specific set or circumstances.

TABLE 5-4. Safety Factors for Good Towing Practice.

Minimum Factors of Safety*							
Towing Mode for Tug	**Wire-Rope Hawser**	**Wire-Rope Pendant**	**Chain Pendant or Bridle**	**Synthetic Line**	**Detachable Links**	**Shackles**	**Bitts Padeyes, etc.**
Note	1	1	2	4	2	2	3
Long-Scope Wire Rope Hawser							
• On Automatic Tension Control	3	4	4	-	3	3	3
• On the Brake	5	6	6	-	5	5	5
· On the Pawl (Dog)	7	8	8	-	7	7	7
• On the Hook (Bitt, Pad, etc.)	7	8	8	-	7	7	7
• On the Hook with Chain Pendant	4	5	6	-	4	4	4
• On the Hook with Synthetic Spring	4	5	5	14**	4	4	4
Long-Scope Synthetic Hawser with Wire Rope Pendant			Chain Bridle				
• On Automatic Tension Control	-	4	4	10	3	3	3
• On the Brake	-	6	6	12	4	4	4
• On the Pawl (Dog)	-	8	8	12	4	4	4
•· On the Hook (Bitt, Pad, etc.)	-	8	8	12	4	4	4

NOTES

1. Based on Minimum Breaking Strength
2. Based on Proof Load ***
3. Based on Material Yield Strength
4 Based on Minimum New Dry Breaking Strength (for nylon only, reduced by 15% for wet strength).

*"Minimum" applies only to new components, good weather, short duration, or emergency conditions Old components, possible heavy weather, long-duration use, etc., may impose uncertainties which require use of safety factors greater than the listed minimum safety factors.

**For synthetic line used in a grommet.

***Navy safety shackles (see appendix D) have a Safe Working Load (SWL) that is 50% of proof load for Grade A shackles and 40% of proof for Grade B (high strength) shackles. Do not confuse SWL with factors of safety See Section D-14.

****When pendant is used as a deliberate "fuse" (i.e., weak link), use the same factor of safety as for the hawser but applied to the breaking strength of the pendant.

5-5.2.2 Wire Rope. For wire rope in new or very good condition and used in conjunction with an automatic towing machine, a minimum safety factor of 3 is appropriate for routine ocean tows in good weather See Table 6-4 To be on the conservative side and allow for unforeseen occurrences, a value of 4 is a preferable factor of safety to use for routine tows. Other conditions require higher factors as noted in the table. The calculated steady towline tension values are multiplied by the safety factor to obtain the required minimum breaking strength of the wire rope hawser. With these breaking strength values in hand, Appendix B may be used to evaluate the wire hawsers carried by candidate tow ships If there is no good match, the assumed tow speed can be adjusted until a match between required hawser strength and available tow ships is achieved For an individual towing ship, with a specific hawser, the problem may be reversed to find the maximum allowable steady tension.

5-5.2.3 Synthetic Line. Subject to any other restrictions on their use, for synthetic lines in new condition and over 8 inches in circumference, a value of 12 is a reasonable safety factor when towing with synthetics is unavoidable. The steady towline tension value calculated in Section 6-3 then is multiplied by a safety factor of 12 to obtain the required minimum wet strength Appendix C provides data for use in evaluating one or more candidate synthetic lines.

NOTE

Appendix C provides the breaking strength values for synthetic line. Manufacturer's tables usually quote values for dry nylon. Breaking strength for wet nylon rope is about 15 percent less than for dry rope and thus, the manufacturer's values generally must be decreased by 15 percent for towing or other "wet" uses. Wet strength reductions do not apply to synthetics other than nylon.

When towing with an automatic rendering feature activated, the factor of safety for synthetics over 8 inches in circumference may be reduced to 10.

Smaller lines, with a greater portion of their fibers exposed to abrasion and the effects of ultraviolet light and other chemical attack, require higher factors of safety. Increase the factors listed in Table 5 4 by 2.

5-5.2.4 Fiber Rope Springs. As a peak tension-reducing element, a spring or fiber-rope pendant or grommet sometimes is inserted in the towline between the hawser and the wire rope pendant. Double-braided nylon line has been the most widely-used material. A grommet is fabricated by splicing a line to form one continuous loop. The two sides of the loop are pulled together around two thimbles, and seized with small stuff to form the grommet or strap shown in Figure 5-14 The size of the line used to make the grommet must be such that the assembled grommet will have a total safe working load that is equal to or greater than the main hawser's safe working load.

Although the line is doubled in the grommet, its strength is not the same as two lines of the same size or one line of the same total cross-sectional area would have. There are losses in strength in the splices, and especially in the two eyes, so that the assembled grommet is only 0.9 times as strong as a single line of the same cross-sectional area. For this reason, the line used for the grommet must have a basic breaking strength equal to at least %5 of a single line spring in order to have the same total strength when fabricated into a grommet. A factor of safety of 14 is required for the wet breaking strength of a synthetic spring.

At present, there is no agreement on the method to calculate the proper length of a nylon towing spring. When used, commercial operators generally use a spring of 200 to 400 feet in length. Furthermore, as knowledge about towing with nylon has increased, requiring a larger size spring, the use of fiber rope springs has declined. As an example, with a 2-

Figure 5-14. Nylon Rope Grommet.

inch IPS fiber core hawser towing on the brake, the following paragraph shows that the comparable nylon grommet would be made from 15-inch circumference double-braid nylon.

With a spring, the required wire FS is 4, maximum steady working load is 288,000/4 = 72,000 pounds. The required dry strength of the nylon spring is 72,000 x 14/.85 = 1,185,882 pounds. The nylon rope used in the grommet will require a dry strength of: 1,185,882 x % = 658,824 pounds. A 15-inch circumference double-braid nylon rope, with a specified dry breaking strength of 666,000 pounds, will be required for this grommet. The grommet's weight per foot is significantly more than that of the wire (13.24 vs 6.72 lbs./ft) and the grommet will be far more bulky!

5-5.2.5 Pendants, Chain and Other Components. Wire pendants require a higher safety factor than the hawser because of the possibilities of chafing and less care in their handling and storage Chain requires a factor of safety higher than that of the hawser because chain is often intentionally used at chafing points Other components have the same factor of safety as the hawser because of the absence of chafing or other hard use in service

5-5.3 PENDANTS AND BRIDLES. A pendant often is used between the tow and towing hawser to facilitate the rigging problem of connecting heavy components This is called a "lead" or "reaching" pendant. The basic pendant usually is wire rope and should have the same breaking strength as the main hawser unless it is intended to be the weak link, in which case it will be of lower strength

Often, the arrangement of the bow of the tow is such that chafing could occur to the tension member that extends outboard of the bow of the tow. If a wire rope pendant is used in this case, it must be carefully protected from chafing, or a portion of it must be replaced with chain to provide chafing protection Chain pendants frequently are employed when using a single-leg attachment between the hawser and tow This attachment generally runs through a centerline bullnose, chock or fairlead near the tow's centerline.

If the tow has a configurational, operational or directional stability problem that would make a single pendant inadequate, a bridle should be rigged. Barges with square bows are rigged with bridles because of the stabilizing effect produced by the bridle Some barges have a hull form and/or appendages which increase the directional stability of the barge. These barges may be rigged with a pendant, rather than a bridle, attached on centerline. Chain is the preferred material for bridles in deep ocean tow- ing and often complements or substitutes for the wire pendant. Chain's advantage over wire derives from its greater weight per foot, which deepens the catenary, and from its superior resistance to chafing. As a rule of thumb, the size of chain to use for bridles and pendants should be at least equal to the size of chain used to anchor the tow An exception is for larger ships, where the 21/4-inch beach gear chain carried by Navy towing/salvage ships is appropriately sized for the power and hawser size of the tow ship.

Because chain and wire bridles and pendants often are subjected to wear and abrasion during towing, it is recommended practice to "over-design" to allow for wear, particularly for long tows. Tables in Appendices B and D provide the breaking strength and weight per foot of various types of wire and chain. These tables can be used together with the calculated towline tensions and factors of safety obtained from Table 5-4 to determine whether the available selected wire or chain is sufficiently strong.

Emergency tows of merchant ships frequently use the tow's own anchor chain as a tow pendant. Appendix D also includes data describing commercial chains A wire reaching pendant frequently is used with a chain pendant to simplify connecting up the tow.

5-5.4 CONNECTION JEWELRY. The connect- ing components or towing jewelry utilized in rigging the tow system include a variety of shackles, chain detachable links, special fittings such as flounder plates, end terminations for wire and synthetic line, and splices in wire rope and synthetic line.

5-5.4.1 Safety Shackles. General purpose Navy shackles are described in detail in MIL-S-24214A (SHIPS) (Ref 14) and in Appendix D. There are two types, two grades and three classes of shackles Of these twelve categories only four are useable as tow- line connectors. These are as follows:

a. Type I Anchor Shackles
   Grade A-Regular
   Class 3-Safety Bolt and Nut
b. Type I Anchor Shackles
   Grade B-High Strength
   Class 3-Safety Bolt and Nut
c. Type II Chain Shackles
   Grade A-Regular
   Class 3-Safety Bolt and Nut
d. Type II Chain Shackles
   Grade B-High Strength
   Class 3-Safety Bolt and Nut

Navy shackles are permanently and legibly marked in raised or indented lettering on the shackle's body identifying the manufacturer's name or trademark, shackle size and recommended Safe Working Load (SWL). Grade B shackles are further marked with "HS," signifying high strength. SWL of both Grade A and Grade B Navy safety shackles is suitable for sizing hardware for lifting purposes. However, SWL cannot be used as a substitute for, or m addition to, the recommended factors of safety listed in Table 5-4 See also Appendix D for more detail on the application of factors of safety to shackles.

CAUTION

Because of the great difference in strength between Grade A and Grade B shackles, pay particular attention to the presence or absence of the HS mark, indicating a high strength shackle. The user must be sure that proper shackles are used in the system.

Grade B, High Strength shackle pins and bolts are marked by the raised letter "HS" on the head. Grade A shackle pins are not specifically marked.

CAUTION

Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration set up by the hydrodynamic actions on the towline. Although screw-pin shackles are a commonly used type of marine shackle and afford a quick and simple means of connecting and disconnecting, the screw- pin shackle should not be used for connections in a towing rig

WARNING

Cotter keys are not used in towing, despite MIL-S- 24214A (SHIPS) drawings.

CAUTION

Never weld on forged steel shackles. The welding process can weaken the shackle.

Navy shackles are made of forged steel; welding to forged steel shackles can reduce the strength of the shackle by as much as 30 percent Shackles should never be welded on; neither should pins be secured by welding The nuts on safety shackle pins are secured by a small bolt, with two jam nuts to secure the pin nut. Cotter keys are not used in towing, despite MIL-S-24214A (SHIPS) drawings.

5-5.4.2 Other Connecting Links. In addition to safety shackles, there are several other connecting devices used in rigging chain and wire pendants, bridles, etc. These include

a Detachable links (Navy and Kenter-type)
b. Detachable anchor connecting links (Pear- shaped or detachable end link)
c. Plate shackles.

The plate shackles shown in Appendix I are commonly used to make connections to the flounder plate and to connect chain and wire pendants.

CAUTION

Never weld detachable links. The welding process can weaken the links.

NOTE

When inspecting chain, inspect the detachable links to determine whether they have been properly assembled. The key slot must be in the proper place and the match marks must be identical and matched. This is necessary because detachable links are hand-fitted to ensure proper assembly and full strength. All assembled links should be visually inspected and sounded.

The practice of welding detachable links closed to assure security of the towing rig is one that continually plagues towing commands Welding detachable links should never be allowed It is much safer and more cost-effective to use a hairpin to secure the tapered pin in the link This ensures that it will not come apart, while simplifying eventual disassembly and re-use of the link. Details for modifying detachable links for use with hairpins are contained in Appendix D. Detachable links should not be used in instances where they might be subjected to bending or twisting.

5-5.4.3 Wire Rope Termination.

Three types of wire rope terminations normally are

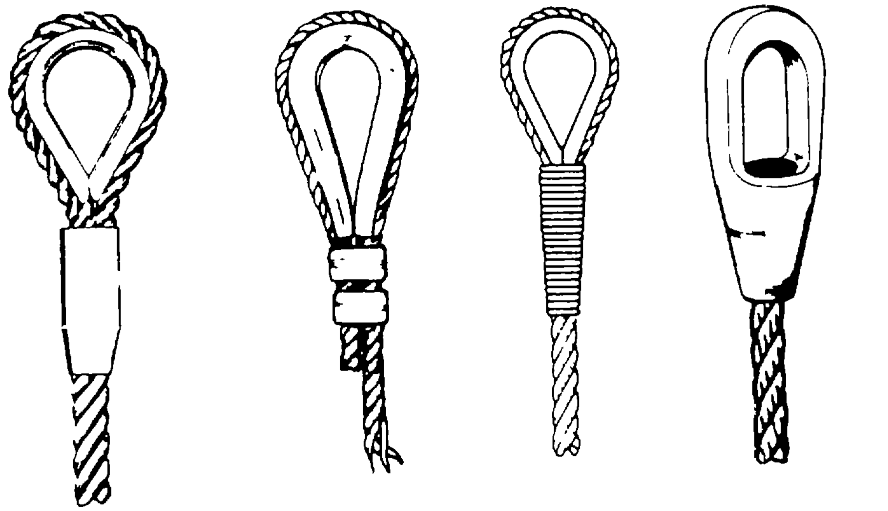


Figure-15. Types of Wire Rope Terminations.

used in Navy towing applications: swaged, spliced and socketed. See Figure 5-15. The hand-spliced eye has less strength than the breaking strength of the wire. For instance, 1%-inch to 2-inch hand-spliced eyes develop 75 percent of the breaking strength of the wire, while 2/4-inch and larger wires have an efficiency of only 70 percent. Nonetheless, hand-splicing enjoys continued popularity because of field repair capability.

A subset of a wire splice is the use of wire clips. These should be used only in an emergency (such as damage to or loss of the normal end fitting). See NAV-SHIPS Technical Manual 613 (Ref. 15) for the proper place- ment and number of wire clips.

Swaged eyes are more common than spliced eyes. Existing swaging technology is so highly-advanced that virtually all types of wire rope terminations can be made. Properly-made swaged eyes develop 100 percent of the strength of the wire. Swaged terminations are applied only to wire rope with wire rope cores A fiber rope core wire can be swaged by replacing the fiber core at the termination with a strand of the wire.

Poured zinc socket terminations are becoming very common and are prepared in accordance with NAV-SHIPS Technical Manual 613. Epoxy-type poured sockets are not suitable for towing purposes

See also Appendix B for data on wire termination efficiencies

5-5.4.4 Synthetic Line Terminations. In general, the same methods are used for splicing synthetic line as for natural fiber line. However, exercise care to maintain the stranded form when splicing a synthetic fiber line. If this is not done, the strand will collapse and form a bundle of tangled yarns. Also, since the felting (tendency to mat together) action of synthetic fiber is considerably less than that of natural fibers, more tucks are needed to produce a safe splice.

The traditional standard end fitting for manila was a tear-drop wire rope thimble. However, with the advent of high-strength synthetics, the eye of the line could stretch sufficiently to allow the thimble to capsize out of the eye. In addition, the higher strength of the synthetic line caused thimbles to crush and fail To resolve these problems, a variety of solid thimbles have been developed. These thimbles have become the standard end fittings used on synthetic line. See Figure 2-42.

SECTION VI

5-6 ATTACHMENT POINTS

Attachment points on tugs and tows transmit the towing load from the tug to the towline and to the tow The tug attachment point will not be considered here since the vessel already will have been designed for towing The attachment point on the tow, how- ever, may not have been designed and fitted for towing. If a tow attachment point exists, it must be checked for adequacy; if it does not exist, it must be designed, fabricated and installed.

Paragraph 2-5 5 of this manual discusses the various types of attachment points on tows and describes the types of loading to which the various types of attach- ments may be subjected. Every possible effort should be made to ensure that the tow's attachment point is subjected to only one type of load at a known point, and in a known direction Horizontal and vertical padeyes should be subjected to a force only perpendicular to the axis of the pin. See Figures 2-21, 2-22 and 2-23 for examples of towing padeyes.

The safety factors to which the attachment points should be designed and built should be in accordance with the General Specifications for Ships of the U.S. Navy (Ref. 16). The criterion generally applied is that the padeye, bitt, cleat, chock, etc., will withstand the breaking strength of the line for which it is sized, while not exceeding 35 percent of the yield strength of the structure

WARNING

If time and the situation permit, a detailed analysis of the padeye and connection shall be made in order to avoid unexpected failure of either.

5-6.1 DESIGN OF A TOWING PADEYE. Figure 5-16 provides an acceptable padeye design for situations where no suitable connection point exists To use Figure 5-16, enter the chart at the estimated force (F) that the padeye is expected to see. The force m the case of a tow attachment point will be the approximate towline tension as determined m Section 6-3 Taking an estimated towline steady state force, move across to the desired plate thickness (t). Reading vertically from the intersection of lines (F) and (t), the minimum hole diameter (d) is read off the top of the chart The minimum distance to the edge (L) is found by reading up from the intersection of (F) and (t) to the intersection of the diagonal line at the upper left side of the chart. Read L at the point where this line is intersected. Read padeye length (1) by entering the chart with force (F) across to the fillet thickness (T), then up to determine (1).

For example, assuming an estimated towline tension of 80,000 pounds, and the plate available for the padeye is 1½ inches thick, the hole/pin size must be at least 2 ¾ inches in diameter with at least 4 inches of plate forward of the hole. The padeye length of over 7½ inches will permit welding to the deck with ¼-inch fillet welds.

The example is satisfactory for an 80,000-pound steady state tension where the tow will be performed using an automatic towing machine The factor of safety requires a 3 x 80,000 = 240,000 pound proof-load shackle, or a 2 ½-inch Grade B shackle The pin for this shackle is 2 ¾ inches and will just fit the hole in the padeye. If the tow were to be performed without an automatic towing machine, but with

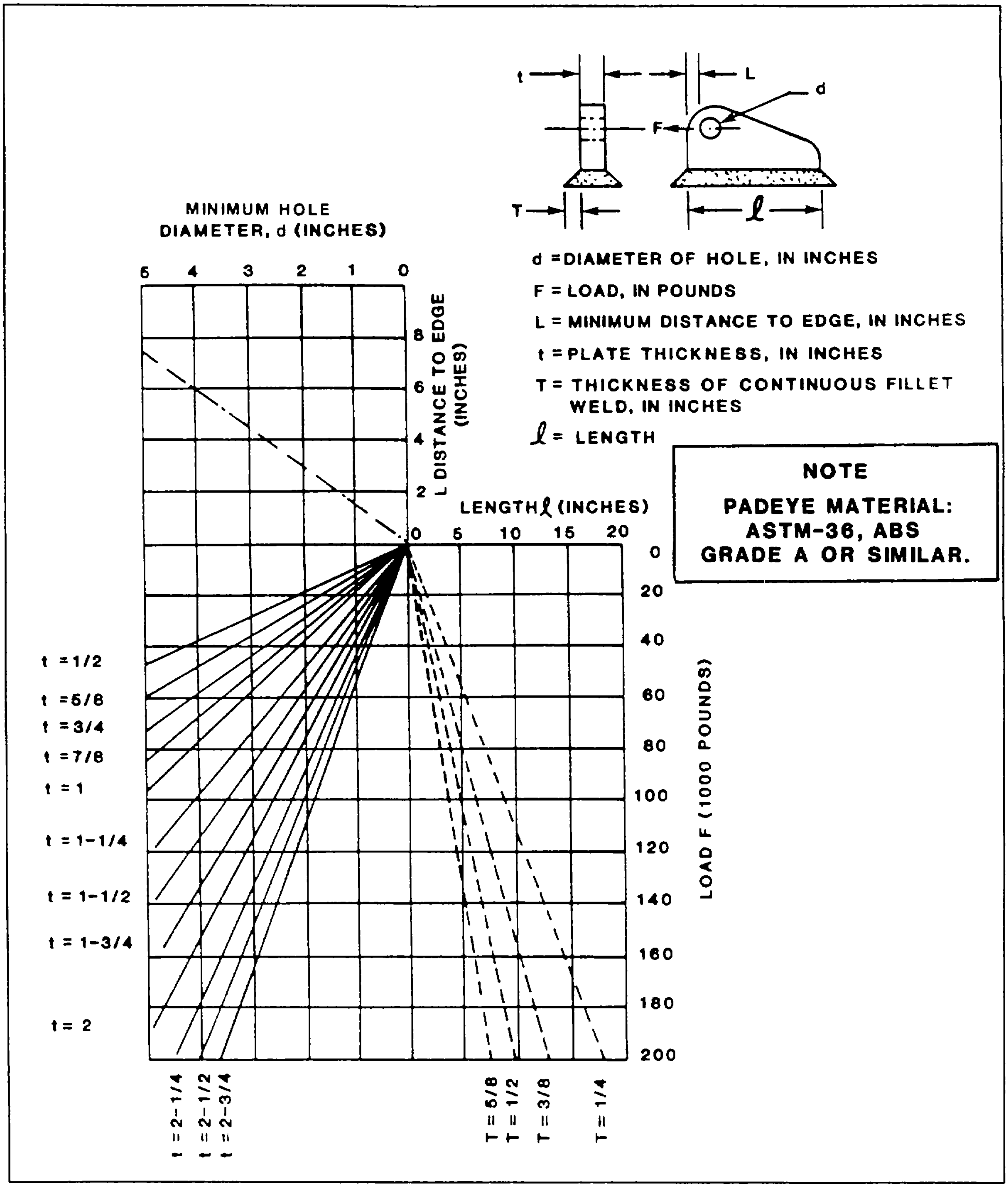


Figure 5-16. Minimum Padeye Design Requirements.

a chain pendant, Table 6-4 would require a shackle factor of safety of 4. Appendix D and Tables D-4 and D-5 show that the minimum Grade B shackle size is 3-inch, with a 3 ¼-inch pin. The 1 ½-inch available plate can be used with a larger hole, taking care to maintain the minimum (L) required by the load and plate thickness

The below-deck structure must be checked or altered to transmit towing stresses to the ship's structurals. Simply welding the padeye to the deck plating is not enough.

5-6.2 EMERGENCY INSTALLATION OF ATTACHMENT POINTS. Suggested attachment points of sufficient strength to tow in an emergency include: using the ship's anchor chain, using installed bitts or padeyes, wrapping a foundation structure such as gun mount or winch with chain, or welding a padeye to the deck. The preferred methods are to use the ship's anchor chain or installed padeyes. The other methods are to be used in emergency situations and may be necessary due to damage to the tow, or other unusual operational constraints.

If there is no designated towing padeye, the ship's anchor chain stopper padeyes are possibilities. See Paragraph 2-5.6 for a description of emergency towing from the tow's anchor chain.

Mooring bitts are a possible choice for securing a tow hawser. U.S. Navy bitts are designed to withstand the breaking strength of double-braid nylon rope for which they are designed, with a factor of safety of 3 on yield strength. Thus, the safe working loads for U S. Navy bitts are as follows.

Bitt Size	SWL
4 inches	23,000 pounds
8 inches	60,000 pounds
10 inches	100,000 pounds
12 inches	164,000 pounds
14 inches	265,000 pounds
18 inches	375,000 pounds

The allowable load can be applied to either barrel (not both), in any direction.

The strength criterion for bitts m commercial ships is similar, except that older ships and Navy support craft often have been designed for manila mooring lines. Consider this when employing bitts for towing of commercial or older Navy ships. In all cases, the strength must be discounted in the presence of obvious corrosion or poor maintenance

Attaching a chain directly to the typical-sized bitts found aboard ships is feasible, but removing slack is difficult. Such a connection is susceptible to shock loading from sudden rendering and has a higher possibility of failure.

An improved connection can be made using wire the same size as the towing pendant. Furthermore, it is easier to minimize slack when rigging with wire and backing up to other bitts is quite feasible. See Figure 5-17.

In Figure 5-17, note that the chain provides the towing chafing protection at the deck edge, but wire is used to make the final connection. The reason for using backup bitts is to share the load. To accomplish this, the loaded part should make only one turn around one barrel of the first bitts. That first turn will absorb 50 to 75 percent of the total load on the wire, depending on the coefficient of friction, and pass along 25 to 50 percent to the backup bitts. The wire can be secured to the second bitts in the normal fashion. Backing up to a third set of bitts is not worthwhile

If two turns had been taken around the first set of bitts, only about 6 to 12 percent of the total load would be passed on to the second bitts, and the whole reason for backing up, i e., load sharing, would have been voided.

The same principles are applicable to fiber rope load sharing.

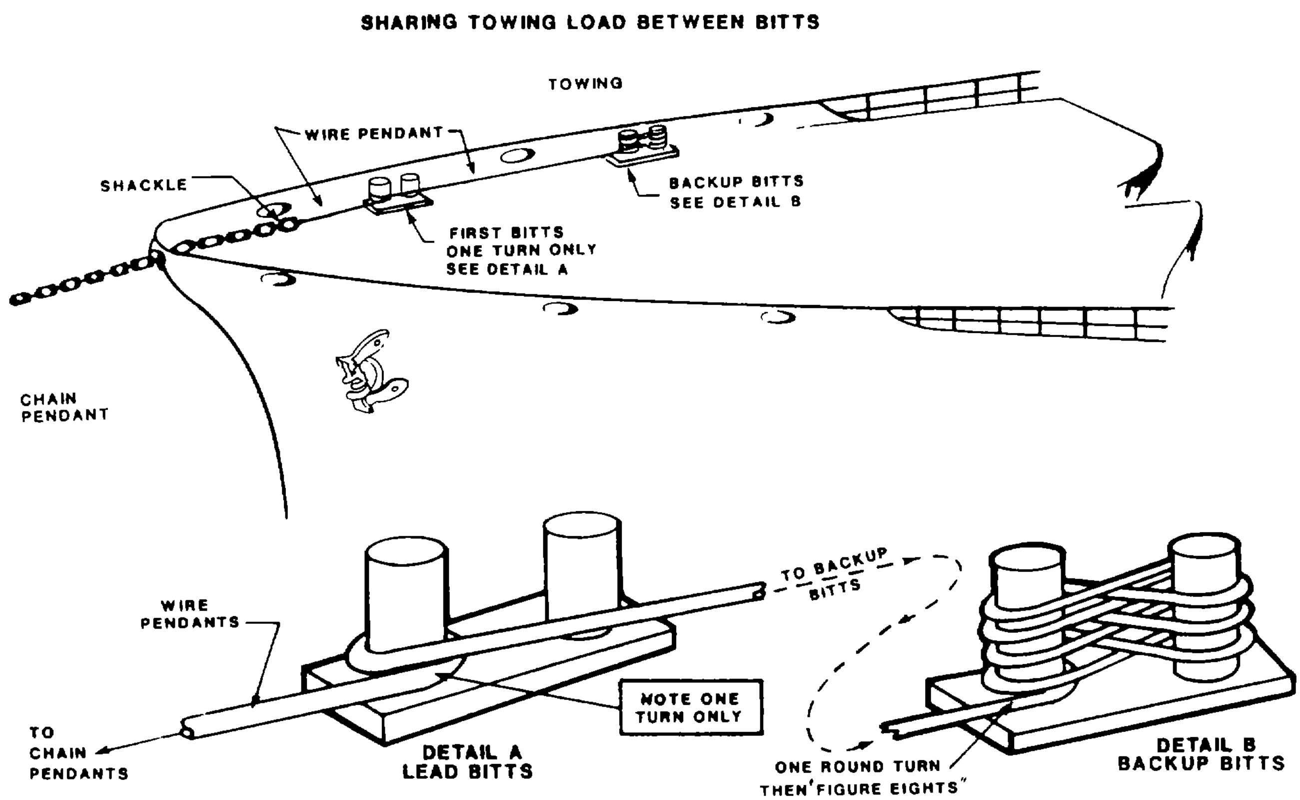


Figure 5-17. Sharing Towing Load Between Bitts.

SECTION VII

5-7 FUSE OR WEAK LINK IDENTIFICATION

Many trade-off decisions must be made in the final selection of the towline system. We know that the peak dynamic loads will be significantly greater than the steady-state, or average, load. The preferred method for mitigation of dynamic towline loads is the use of an automatic towing machine. The next-best method is the use of a long wire-rope hawser with a chain pendant. The elasticity of nylon provides an excellent means for damping out the dynamic effects on towline tension. However, concern over the current state of knowledge regarding synthetic fiber lines, particularly nylon, has led the Navy to discourage the use of an all-synthetic towline system. In addition, the required safety factors require an unreason- ably large synthetic spring See Paragraph 5-5 2.4.

5-7.1 CRITERION FOR FUSE OR WEAK LINK IDENTIFICATION. When a weak link is used as a component m the towing system, its primary purpose is to ensure a known location and mode of towing system failure in the event of an overload. It is unfortunate that the term "weak link" has been used to describe what is really analogous to a safety valve or a circuit breaker Sometimes the term "fuse pendant" is used In all cases, the most probable point of failure must be identified, whether or not it is designated or intended as a weak link.

CAUTION

> Good judgment is required in the use of a weak link. When operational requirements dictate maximum strength, such as a tow along a lee shore, an intentional weak link may jeopardize the mission.

A weak link is the component in a towing rig that is most likely to fail at a predicted load and/or at a known point Whether or not it was designed into the tow system, it always exists It is necessary to know where the weakest part of the system is, and that information be provided to the officer responsible for the tow Some designs intentionally designate the location of the weak link in the towing rig so that a more critical portion of the tow system will be protected from the overload A weak link usually is designed to protect the tow hawser. If a towing system overload occurs, the failure will not damage the tow hawser, which then can be reconnected. A weak link should not fail under the anticipated tensions of a planned tow. The weak link's primary characteristic is its predictability. Tow preparing activities should specify the weakest link in the rig for which they are responsible

When a weak link is intentionally used in the tow design, the towing pendant is the usual selection, being sized to have a 10 to 15 percent lower breaking strength than the main tow hawser. Selection of these figures considers the hydrodynamic resistance of the towline itself, which places a higher tension at the tug end of the hawser Such a pendant shall never be placed in a position subject to chafing or other unusual service.

SECTION VIII

5-8 TUG CAPABILITY. Much too often tug assignments have been based almost completely on availability. A tug must have many special attributes other than availability It must be properly manned by competent personnel and have:

a. Adequate power for the tow at hand

b. Proper towing gear for the towline linkage system from the tow's hard point to the tug's hard point

c. Sufficient endurance to complete the tow

The following paragraphs summarize some of the information on power and towing equipment

5-8.1 TUG POWER. The principal measure of a tug's power is its ability to deliver tow- line pull Generally, a tug's power plant and propeller will have been designed to deliver maximum design power and optimum efficiency at a designated towing speed, which may be anything from zero speed (bollard) to the free route speed. Maximum engine power and design speed were established early in the design evolution In all cases the greatest thrust (bollard pull) is produced at zero speed, with the towline pull diminishing as the towing speed increases. When the tug reaches its maximum free route speed, all its horsepower is used in propelling it. At this point the available towline pull is zero.

5-8.2 ESTIMATED BOLLARD PULL. A rule of thumb for estimating bollard pull for a normal, well- designed tug and propulsion system is: open screw, 25 to 30 pounds per SHP; and Kort nozzle, 30 to 35 pounds per SHP. It is quickly apparent that the nozzle vessel produces better thrust under bollard conditions. This advantage normally is lost as the towing speed increases. Figure 6-1 provides available towline pull vs. speed through the water for Navy tow ships To use Figure 6-1, the ship's speed THROUGH THE WATER must be known. Note the comparison between T-ATF and ATS The low-speed pulling advantage of the T-ATF is reduced as towing speed increases, and finally disappears at higher speeds. This is the result of the propeller nozzles fitted on the T-ATF.

Figure 6-1 can be used directly during towing opera- tions In planning tows, the planner must be aware that a region on the upper left part of the graph may not be achieved by the tug. The reason is that avail- able shaft torque or engine power may be exceeded

Appendices K and L provide additional information on evaluating the capabilities of tugs.

The towing system is the main battery of a towing ship and the towing machine or winch is a major element of this system. These devices must perform several functions. Different machines have different features with which to perform their required functions. The following paragraphs present summary discussions of these functions and features.

5-8.3.1 Functions of Towing Machines and Winches. The principal function of towing machines is to aid in handling and controlling the towline Other functions may be to.

a. Act as a hard point or attachment point for attaching the towline to the tug

b. Serve as a means of paying out and heaving in during the towing operation

c. Serve to transport or stow the towline as it is heaved in

d. Act as a quick-release device for disconnecting the towline if necessary during an emergency

e. Act as an automatic tension control device to limit or relieve the peak dynamic loads in the towline system and thereby enhance the life and utility of that equipment

f. Monitor and read out tow hawser conditions such as tension and scope

5-8.3.2 Features of Towing Machines and Winches. All towing machines and winches in Navy use have features with which to perform the attach- ment, payout and heave-in functions. All of the tow- ing machines and some of the traction winches can act as quick-release mechanisms for disconnecting the towline. However, quick release, automatic ten- sion control and tension/scope measuring and read- out systems will vary

For instance, the diesel-driven SMATCO towing winch on the T-ATFs has no automatic tensioning device and often is operated "on the dog". If an emergency occurs while the winch is on the dog, the dog cannot be released to allow the drum to free-spool and let the towline run out. The diesel engine must be started, brought up to speed and clutched in to move the drum far enough in the heave-in direction to free the dog and permit it to be disengaged The problem is aggravated by the fact that the pneumatic control system on the SMATCO winch can fail in the "open" condition. In this event, there is no way to release the dog. Further, if the winch is not dogged, the loss of air will lead to free-spooling and loss of the towline.

The Almon A. Johnson, Inc design automatic tow- ing machines on the ATSs, ATFs, ASRs, and ARSs have features that make the need to operate "on the dog" rare. Moreover, their all-electric drive can be activated more quickly than a diesel engine to relieve the load and allow the drum to be rotated or disengaged if required.

The drum-type rowing machines and winches all serve as line transport and stowage devices since the in-hauled towline is stowed on the drum. The traction winches perform part of the line transport function, but in each case the line stowage is in a bin below deck. The T-ATF and ARS 50 traction winches have power blocks that back-tension the line and assists m transporting the line to the stowage bin.

The Almon A. Johnson automatic towing machine designs all have features to perform the automatic payout and heave-in functions in response to variations m the towline tension. The ARS 50 traction winch also has features to provide automatic payout function, however, the reclaim feature is not automatic. It requires some monitoring to control the towline tension without gradually paying out all the line, although it does have a "cable-off" device which will secure the winch

SECTION IX

5-9 NAVIGATION LIGHTS, FLOODING AND FIRE ALARMS AND BATTERY REQUIREMENTS

Refer to current COLREGs (Ref 2) for complete information on light requirements

5-9.1 NAVIGATION LIGHTS. Navigation lights, furnished under specification MIL-L-24375 (Ref. 17), have a solar switch built in to increase battery life and meet COLREG requirements. They can be ordered by their Federal Stock Numbers Alternatively, a single solar switch can be added to the system

5-9.2 ELECTRIC CABLE. The towing lights have a 10-foot leader wire for attachment to the batteries. If that length is insufficient, Navy-type DMOF-4 cable is suitable for connection.

5-9.3 NAVIGATION LIGHT BATTERIES. Table 5-5 lists battery capacity, in ampere-hours, required for each side light and the stern light, for tows of various durations. Individual batteries for each light may be used to eliminate the power loss m long cables. Table 5-6 includes battery requirements for both continuous and intermittent 12-hour/day operations.

CAUTION

Batteries should be protected from electrical grounding by mounting them on non-conductive bases or with non-conductive liners in the box.

The battery capacities listed in Table 6-5 correspond to standard Navy 12-volt lead-acid batteries These heavy-duty cells, protected by steel containers, provide the necessary ampere-hour capacity with the smallest size and weight. Table 6-6 lists requirements for a centrally located battery.

5-9.4 PUMPING CAPACITY. For long voyages, tows should have bilge pumping equipment If the permanent bilge pumps on the tow are inoperative, portable lightweight pumps or eductor systems should be provided. They can be handled by the riding crew or inspection party from the tug. Tests should demonstrate that the pumps have adequate suction lift and discharge head.

Table 5-5. Battery Capacity Requirements.

LENGTH OF TOW (DAYS)	12 HR/DAY OPERATION SIDELIGHTS AND STERNLIGHT (Amp-Hr)
5	160
10	320
16	510
21	665
30	950

Table 5-6. Requirements for Centrally-Located Battery.

LENGTH OF TOW (DAYS)	12 HRS/DAY OPER (Amp-Hr)	24 HRS/DAY OPER (Amp-Hr)
5	*1-288	*1-288
10	1-288	1-648
20	1-648	2-648
30	2-648	3-648
40	2-648	4-648
*Shows number of batteries of indicated capacity to be connected in parallel.		

Likewise, there must be pumps for fighting fires Special attention may be required to ensure that portable pumps can obtain a suction from a reliable source of water This may be a particular challenge in the case of a high-sided auxiliary or merchant hull, or a DD 963 Class destroyer.

5-9.5 FLOODING ALARMS. Unmanned tows must be equipped with two alarms (high and low) and independently-wired flooding alarm lights in each space. The low alarm lights should be amber in color and the high alarm lights should be red. In addition, waterline markings, visible from the tug, should be provided. The tow preparing activity is responsible for the installation of flooding alarms. Flooding alarm lights should be checked to ensure their visibility during daylight hours.

A schematic diagram of a typical acceptable flooding alarm is shown in Figure 5-18. No attempt has been made to provide detailed specifications or installa- tion instructions since these vary with the type and size of the tow. The number and location of the electrode blocks or alarm switches to be installed in an unmanned tow are determined by the activity preparing the tow and agreed to by the activity receiving the tow The installation should be sufficient to provide coverage of major hull subdivisions. Alarms should be securely rigged and properly serviced to ensure performance and reliability

A variety of alarm types exist. Choosing one is a matter of judgment The electrical contact alarm that closes its circuit when water makes contact is a workable alarm most of the time. If it is used in an engine room, however, oil in the bilge may coat the wires as flooding progresses and render the alarm useless. Carefully consider the practicality of each proposed alarm location Innovation is advisable.

To supplement the flooding alarm, tug watch personnel should be alert for list, excessive drag, change in roll period or unexpected trim in the tow. All the aforementioned characteristics are possible signs of flooding

5-9.6 SUPSALV ALARM SYSTEM. In early 1988, NAVSEA 00C commenced procurement of a Flooding and Fire Alarms System. Several kits are to be positioned in the Emergency Ship Salvage Material (ESSM) System. Each kit consists of the following:

a. 8 heat detectors

b. 8 low-level, float-actuated water detectors

c. 8 high-level float-actuated water detectors

d. 1 light stand assembly with suitable high- visibility strobe warning lights, visible from 3,000 feet in broad daylight

e. 1 siren audible at 3,000 feet

f. 75 electrical cables, in 100-foot lengths, with waterproof connectors

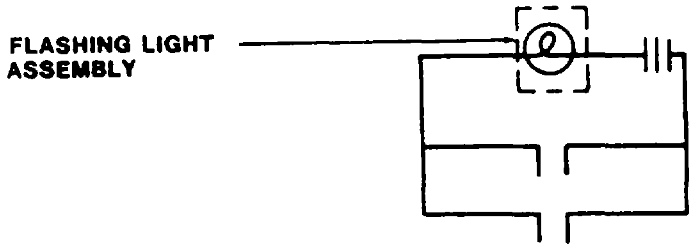
g. 1 self-monitoring control panel to control the sensors and alarms

h. Spare parts.

Each kit is complete, with the exception of the 12- volt battery system to provide power. Power for the alarm system should be separate from the power source for the navigation lights. More than one kit may be required to rig a large tow.

NAVSEA also is developing a companion radio system, using a digitized data to link the control panel on the tow with a terminal on board the tow ship.

The SUPSALV Flooding and Fire Alarm system will be available for loan to Navy activities, on a case basis, for significant tows. Interested commands should contact NAVSEA 00C2, 202-697-7403 or A/V 227-7403.



NOTE: THIS SAMPLE DIAGRAM IS NOT INTENDED TO RESTRICT OR LIMIT THE NUMBER OF ALARMS CONSIDERED NECESSARY TO PROVIDE ADEQUATE PROTECTION TO ALL IMPORTANT WATERTIGHT SPACES.

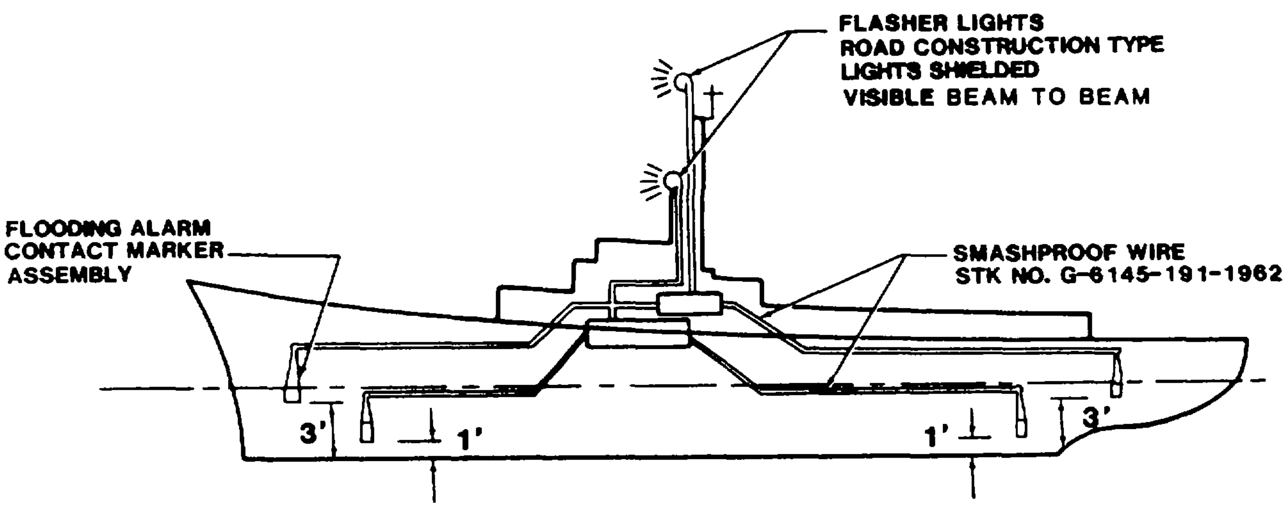


Figure 5-18. Example of a Flooding Alarm Schematic.

APPENDIX A

SAFETY CONSIDERATIONS IN TOWING

A-1 INTRODUCTION

The purpose of this appendix is to supplement the specific safety precautions for towing operations, as listed in this manual, with the general safety precautions as published in OPNAVINST 5100.19A*Navy Safety Precautions for Forces Afloat* (Ref 18).

A-2 SCOPE AND APPLICABILITY

The safety information contained m this Tow Manual is applicable to all afloat Naval Commands which become involved in towing operations. These Commands include the United States Naval Ships (USNS) of the Military Sealift Command (MSC) and its activities and the Marine Corps, when embarked in the aforementioned vessels and to the extent otherwise determined by the Commandant of the Marine Corps. This information, in combination with the OPNAVINST 5100.19A series, comprises the Navy Occupational Safety and Health (NAVOSH) standards for towing operations as required by the OPNAVINST 5100 23B series, Navy Occupational Safety and Health Program (Ref. 19). For additional salvage safety information, consult the Ship Salvage Safety Technical Manual (NAVSHIPS 0994-001- 8014) (Ref. 20).

A-3 BASIC SAFETY PHILOSOPHY

Many safety studies have indicated that human error is a common cause of mishaps. Even though the failure of some item of equipment may be listed as the "cause" of a mishap, the equipment often has failed because of an earlier human error or oversight in design, manufacturing, maintenance or use of the equipment Therefore, all personnel must be trained in the use of, and have ready access to, appropriate Navy technical manuals and other publications to guide them in their operations. Consequently, the approach to achieving safety in towing operations is to:

a Comply with and depend upon existing Navy parent documents such as the OPNAVINST 5100.19A series for general policy and procedural guidelines, and refer to the pertinent Technical Manuals and Planned Maintenance System ((PMS)) cards for specific information on operating commonly-used gear and equipment

b. Comply with and depend upon Navy technical manuals, such as this volume on towing, and manufacturers' operating manuals.

c. Encourage the use of systems safety analyses in which the overall system or activity of concern is planned and reviewed from the standpoint of safety. Thus, such issues as the specific environment in which an operation is to be conducted are considered and accounted for in planning. Consequently, there should be fewer omissions and an increase in safety awareness among all personnel who may be involved. See paragraph 5-5 and Table 6-4 for a discussion of factors of safety in the selection of towing components.

No list of safety precautions in towing can be comprehensive without the principles of good seaman-ship. The precautions stated herein and in the OPNAVINST 5100.19A series are basic and shall be adhered to.

The personnel involved in towing operations must be thoroughly trained, disciplined and equipped not only to perform routine duties, but also to react appropriately to unusual or non-routine situations. The officers and crew of vessels involved in towing operations should continuously conduct safety indoctrination lectures and exercises aimed at reducing unsafe conditions or practices and at reacting appropriately to unusual circumstances through professional knowledge of their duties and towing procedures.

A-4 SPECIFIC SAFETY PRECAUTIONS In addition to the safety precautions in the OP-NAVINST 5100.19A series, many paragraphs within this manual also contain specific notes of safety- related information. Rather than repeat notes from these two sources, the following paragraphs on specific safety precautions discuss the approaches that are recommended in applying these notes and procedures to towing operations.

A-4.1 SPECIFIC APPROACHES.

A-4.1.1 General Specifications. The General Specifications for Ships of the U.S. Navy (Ref. 21) mandates that any ship that is likely to require towing, especially emergency towing, should be equipped to tow or be towed The equipment inventory should be such that in an emergency nothing is required to be brought on board the tow or fabricated on the tow Each ship must be capable of receiving or rigging an emergency towing rig designed so that the ship can tow or be towed

A-4.1.2 Non-Emergency Towing. For non-emergency situations (and for emergencies, to the extent that time permits) the preparation procedures out- lined m Chapter 2 of this manual and in appropriate Type Command Directives or Instructions must be completed. Even for missions that are repetitions of previous tows, it is important that the preparation phase be repeated to ensure that nothing is over- looked. In both the preparation and operational phases of any tow it is essential that full and open communication exist between the preparing activity and the towing vessel.

A-4.1.3 Safety. Safety is paramount in the preparation of individual Command Instructions and Towing Bills, as well as in the preparations for individual towing tasks.

Checklists to assist in the operational planning and preparations for tows are included in Appendix H It must be emphasized and understood by all hands that good planning, preparation for emergency situations, correct shiphandling and good seamanship are all necessary elements of safe towing None is a simple paperwork drill. Rather, this phase of a towing operation demands the same knowledge and seaman- ship skill as the actual at-sea phase. Past experience has amply demonstrated that from the very onset of the tow tasking, it is imperative that the plan for preparing the tow for the transit be thoroughly conducted and reviewed prior to implementation In some instances, such as ocean tows of complex units like drydocks, the plans and the tow may be prepared by a civilian marine contractor and supervised by the Supervisor of Shipbuilding and Repair at an appropriate Navy facility. In a peacetime Navy (or in the early stages of war) there can be wide variations in the availability and quality of "in-house" expertise in the field of towing and tow preparations. The towing unit must therefore monitor the efforts of the activity preparing the tow Continuous inspections must be made and positive action must be taken immediately to correct identified deficiencies. Attendance at any meeting held by the cognizant activity for the tow and the preparing activity, or contractor, should be mandatory for the towing unit Commanding Officer or his representative; and he should not be timid m making any comments or recommendations.

A-4.1.4 Planning. Although the planning procedures are presented in considerable detail in this manual and its appendices, extreme care and judgment must be exercised. Blind dependence upon the results of routine calculation methods, and especially on computerized procedures, without careful cross-checking can lead to major errors and possibly extreme operational difficulties

Even a poor choice of location for conducting pre-tow preparations can lead to major problems. If available, the tow should be prepared at a full-service, easily-accessible location and then moved to a staging area once fully prepared and made ready for sea.

Few tows will be exact duplicates of earlier tows. Even though some tows may appear to be duplicates, there will be differences m season (weather), route and configuration of the towed vessel Thus, the pre-tow planning and preparations must be con ducted each time a towing task is undertaken in order to ensure a minimum of oversights and mishaps

A-4.2 CONTINGENCY PLANNING. Contingency planning is very similar to operational planning except that it concentrates on the aspects of being prepared to respond to emergency conditions. Being prepared includes both knowing what to do and having the appropriate supplies and equipment available for proper response.

APPENDIX B

WIRE ROPE TOWLINE COMPONENTS

B-1 INTRODUCTION

A towing hawser is the key element in the tug-tow connection. For Navy towing ships, the hawser is usually wire rope. It is especially important to keep a wire rope hawser in excellent condition, protect it against excessive wear and inspect and lubricate it regularly.

To provide a written reference of a wire rope towline's history, the Naval Sea Systems Command requires that a Towing Hawser Log be kept by all U.S. Naval vessels regularly engaged in towing operations. An example of this log is shown in Appendix F.

B-2 TRACEABILITY

Traceability, or being able to trace a rope and what has happened to it back to its source, is an important element in accident investigation as well as m efforts for general product-improvement. Some of the needed information is maintained in the Towing Hawser Log American-made wire rope and some brands of foreign-made rope can be identified by special core marker materials used as a part of, or layered around, the core of the wire rope as well as by the metal tags and other data on the reel upon which the rope is wound when delivered Identification of manufacturing source through core markers may be particularly useful in cases where the color coding has not been applied to a strand. Additional information on a specific domestic wire rope producer's core color marking practices is available on request from that manufacturer

B-3 STRENGTH

At present, steel wire rope provides the strongest towing hawser for a given diameter and is usually specified by the Navy as the preferred hawser for towing Target sleds are virtually the only tows for which a synthetic fiber line hawser is currently specified Wire rope strength varies with the type of construction and material as well as with size. Consequently, it is important to be certain that all wire ropes used in towing are of the proper construction, core and required material.

B4 ELONGATION (STRETCH)

WARNING

Wire rope stretches under load far less than most natural and synthetic fiber lines and thus has a smaller zone of danger to bystanders from loose ends "snapping back" in the event that it fails under high loads. The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path.

In addition to the above-noted danger, the sudden release of tension can sometimes cause a popped core or a "bird cage" in the rope when a failure in the towline or its connections allows the rope to rebound from an overload. These conditions also can result from operating a wire rope through an undersized sheave groove See Figures B-1 and B-2 for illustrations of these phenomena.

B-5 MAINTENANCE, CLEANING AND LUBRICATION

Wire rope, like a machine, is made up of many moving parts The individual steel wires slide independently and must be kept clean and protected by adequate lubrication against the effects of movement and pressure.

Corrosion damage is also a danger. There is no way of estimating the exact loss of strength resulting from corrosion of wire rope. Fresh water washdown and lubrication of the tow hawser as it is being retrieved after each use can help retard corrosion This, however, is not a cure-all, since the core remains saturated with salt water.

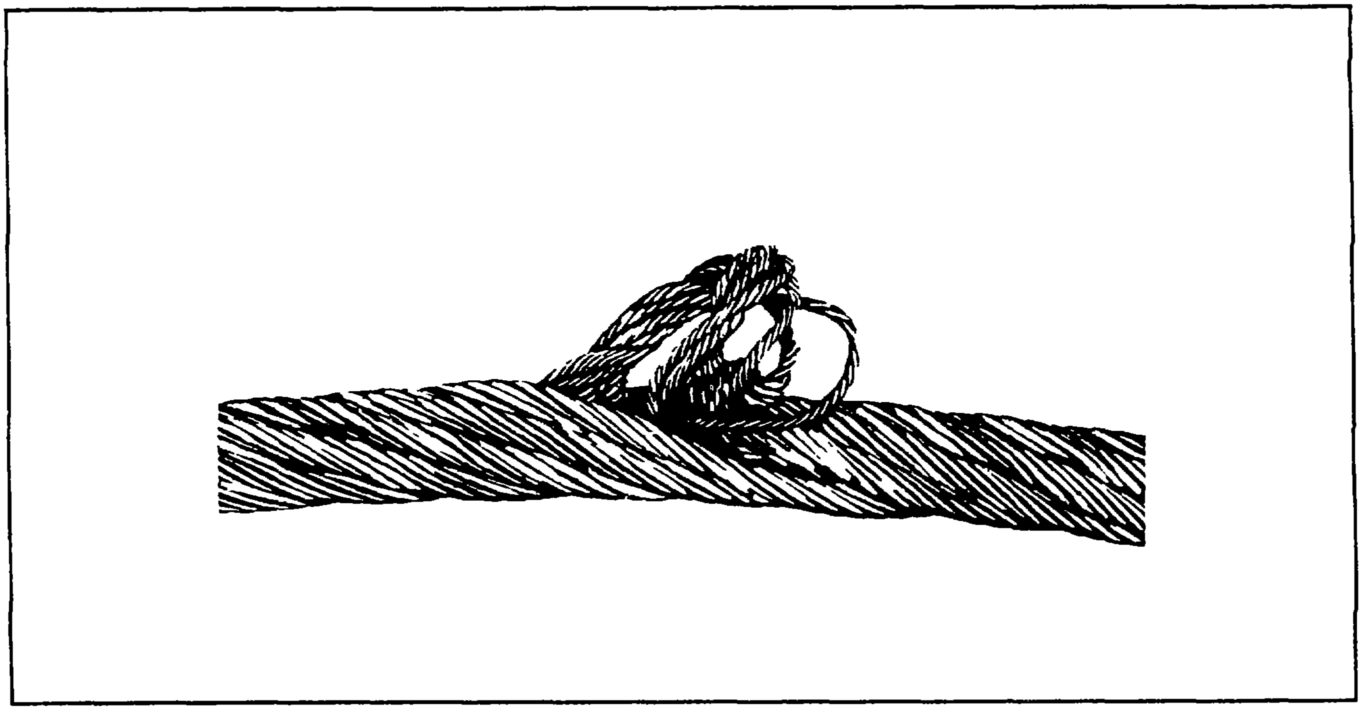


Figure B-1. Popped Core.

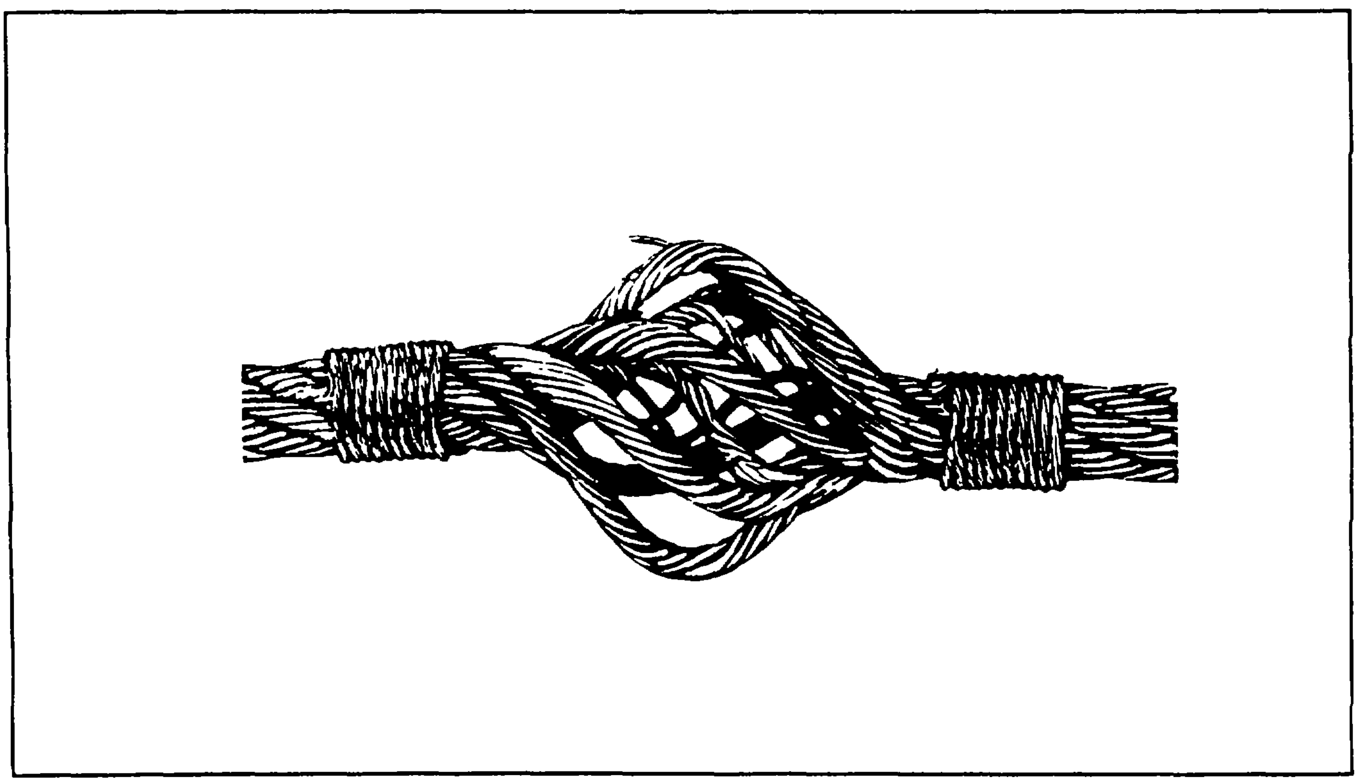


Figure B-2. Bird Caging.

Properly specified and procured wire rope is lubricated during manufacture. The wire may also be protected for shipping storage with a heavy application of Cosmoline. Since the time in storage may not be known, the towing ship should expect to clean and re-lubricate a new towing hawser upon receipt. Re- lubrication will be required, based on frequent inspection, and may be required as often as after each use of the hawser. Inspection of wire and lubrication procedures are detailed m NSTM 613 (Ref. 15) Although a pressure lubricator for wire rope currently is being developed, the use of relatively fluid oil of light viscosity is advisable for field lubrication. Further, heavier, more durable oils may hide wire surface damage and thus make adequate inspection more difficult Grease, (MIL-G-18458), currently is specified This product contains a corrosion preventive and it can be thinned with solvents such as JP-5 or turbine oil-2190 (MIL-L-17331) for cold application The lubricant can be applied by swabbing with a brush. Take care that all sections, including dead layers on the drum, are kept lubricated. These inner layers can be lubricated at such opportune times as.

a. Overhauls

b. When the hawser is reversed, end-for-end, on the drum

c. When towing in good weather, at which time extra line may be run out to expose the inner layers for lubrication.

The Navy procedures for wire rope lubrication currently are being modified. The most recent guidance is contained in NAVSEA *Interim MRC for ARS 50 Class Running Rigging (Ref. 21)* .

B-6 NEW HAWSERS

Wire rope for towing hawsers is shipped in cut lengths on reels. Wire rope for other uses may arrive in coils or on reels

B-6.1 UNREELING.

CAUTION

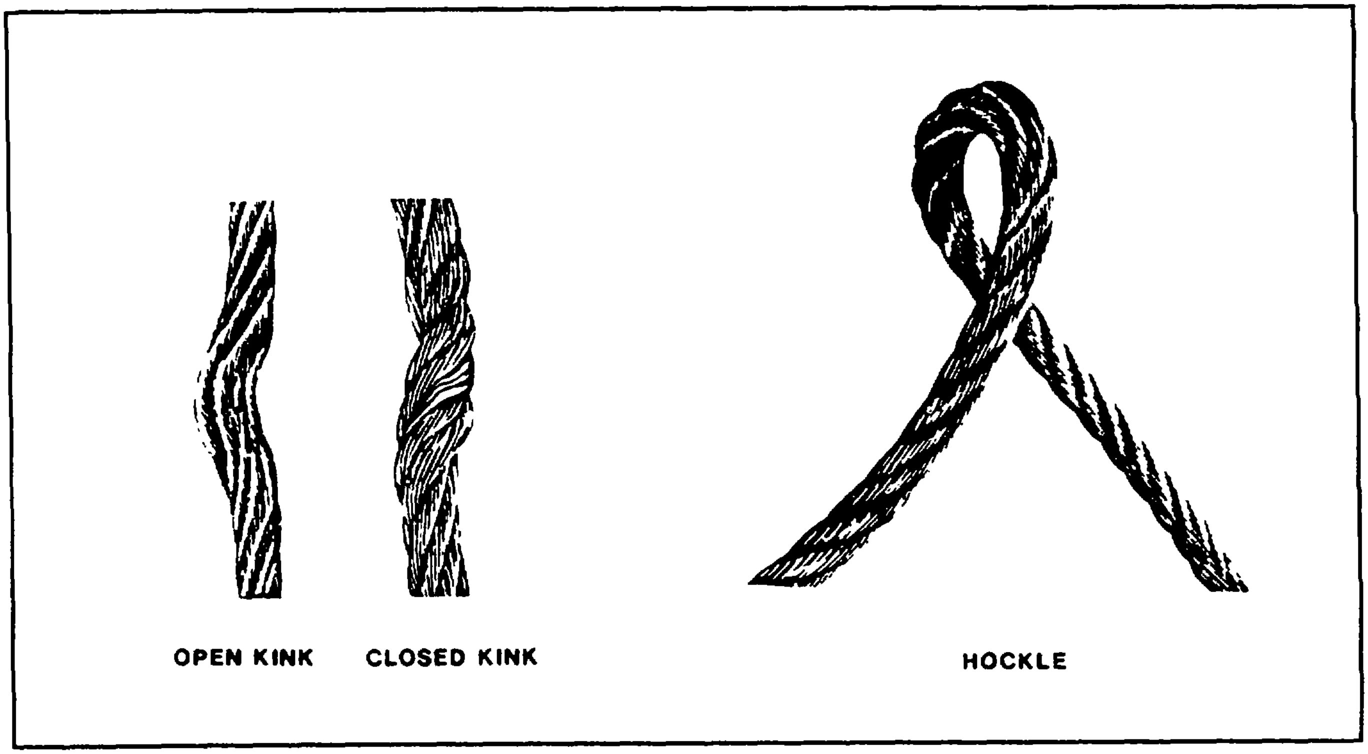
> Great care should be taken when the rope is removed from the shipping package since it can be permanently damaged by improper unreeling or uncoiling. Kinks and hockles, see Figure B-3, may occur with careless uncoiling.

Unreeling wire rope from its reel requires careful and proper procedures There are two methods to perform this step correctly:

a. The reel is mounted on a horizontal shaft supported highenough for the reel to clear the deck. Since the reel is free to rotate, the rope is pulled from the reel by a person holding the rope end and walking away from the reel as it unwinds. A braking device must be employed so that the rope is kept taut and the reel is restrained from over-running the rope. This is necessary particularly with powered unreeling equipment

b. Mount the reel on a vertical reeling stand. It is then unwound in the same manner as described above in Step "a" In this case, however, great care must be exercised to keep the rope under sufficient tension to prevent the accumulation of slack, a condition that will cause the rope to drop below the lower reel flange.

B-6.2 RE-REELING. When re-reeling wire rope from a horizontally-supported reel to a drum, it is preferable for the rope to travel from the top of the reel to the top of the drum, or from the bottom of the reel to the bottom of the drum. See Figure B-4. Re-reeling m this manner will avoid putting a reverse bend into the rope as it is being installed. If a rope is installed so that a reverse bend is induced, it may cause the rope to become less stable and, consequently, more difficult to handle.



FigureB-3. Kinks and Hockles.

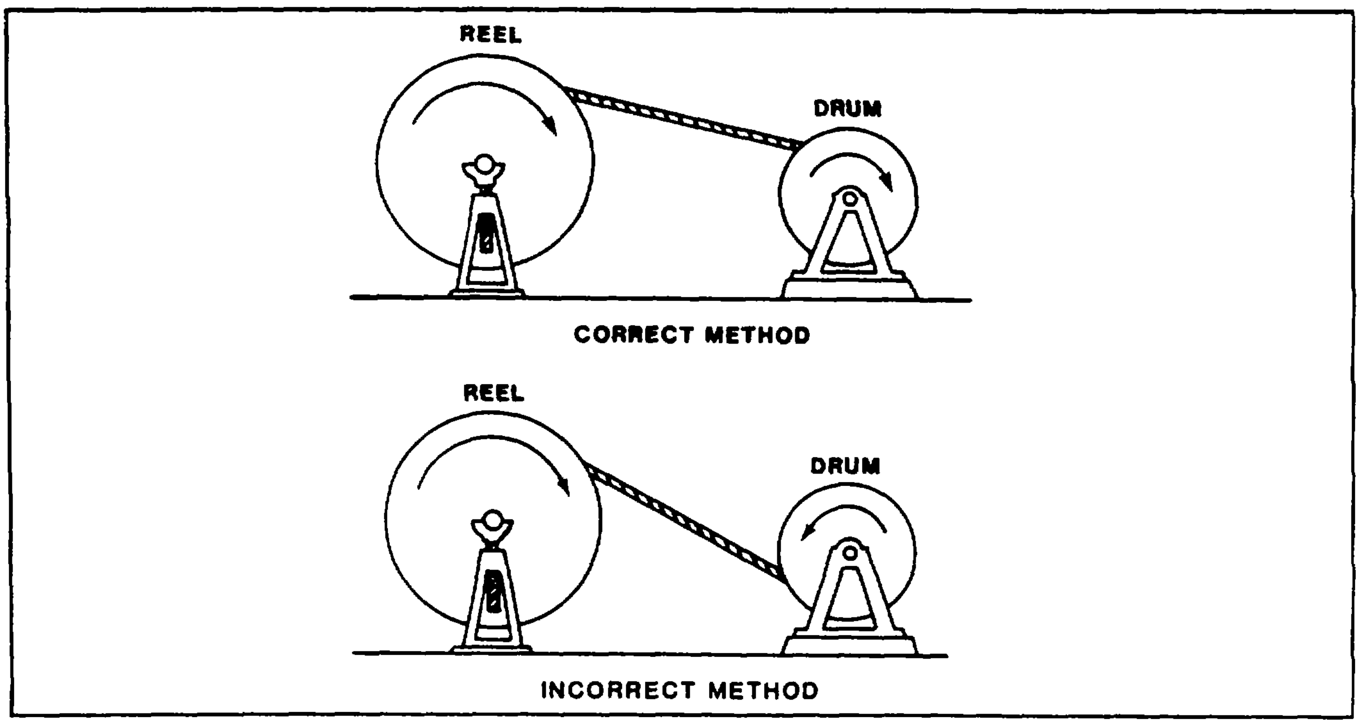


Figure B-4. Re-reeling.

B-6.3 INSTALLATION OF NEW WIRE ROPE. Ideally, new wire rope should be broken in by using it first with a light load. This will help ensure a straight fairlead onto the drum, but the line must be loaded more heavily in order to seat properly on the drum for later heavy use. In each layer of wire rope on the drum, the rope rides in the "grooves" between the wraps on the next lower layer If the wire is wound on the drum under too light a load, the required number of wraps may not go on the drum and the space between the flanges of the drum may not be completely filled The tension load on the wire at the point at which it leaves the drum can force the rope down between the wraps and bury it in the lower layers. Damage to the individual strands and lays of the rope at the contact point and in the lower wrap can occur. See Section B-10 for further information on the relationship of wire lay to tight winding of the first layer on the winch drum.

CAUTION

Sudden application of a load to wire rope by rapid acceleration causes stress much greater than the weight or resistance of the tow. Avoid such strain on the rope by employing gradual acceleration.

NOTE

The need to wind the towline on the drum under fairly high tension, approximately 5 percent of the breaking strength, holds for both smooth and grooved drums.

Using stoppers to load the wire bight by bight is one way to approach the problem but is cumbersome and time-consuming. During the construction of the first four ARS 50 Class ships, a lightweight cable brake was utilized to aid in installing the wire-rope towing hawsers on those ships. This device, called a Wallis Brake, is shown in Figure B-5 and discussed in the following paragraph As designed, this cable brake permitted continuous loading of the wire rope under tension

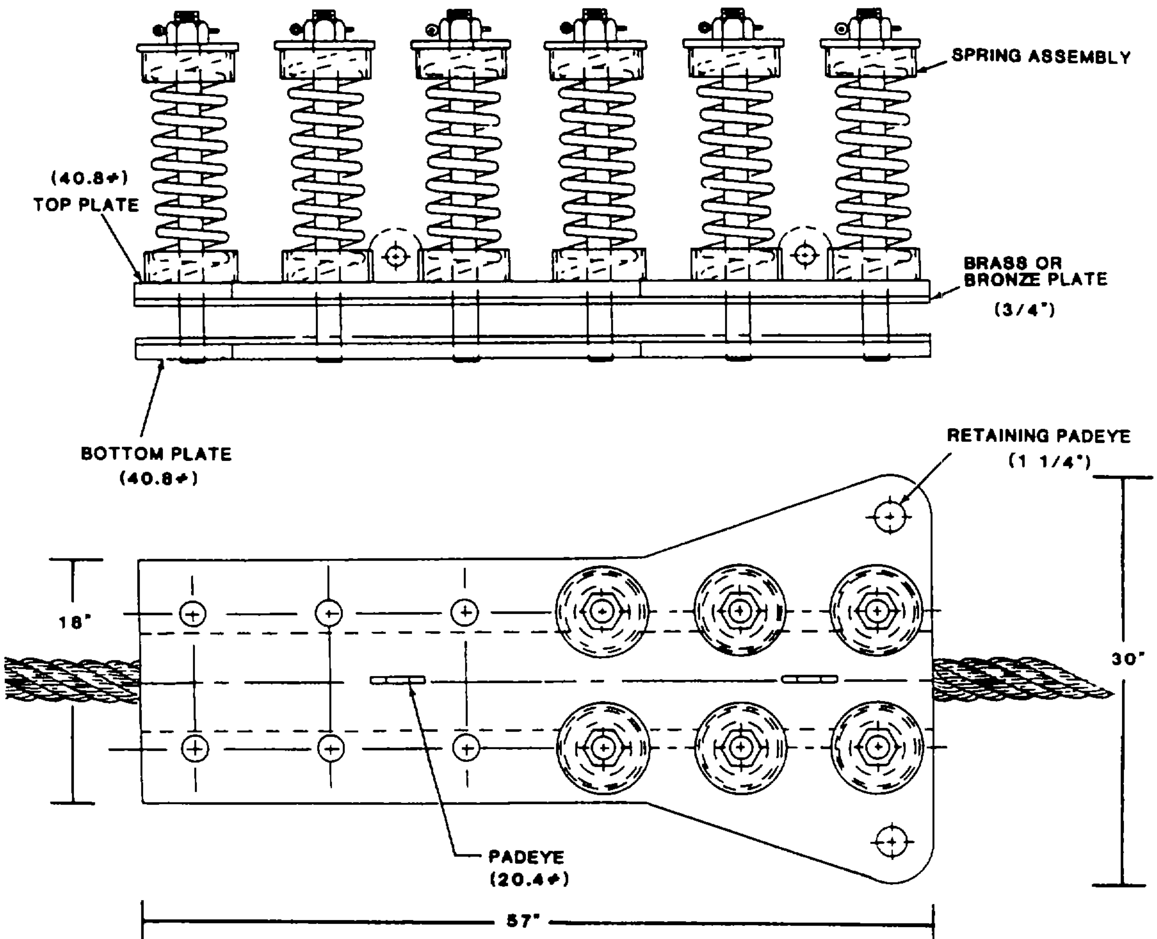
The Wallis Brake is first tied down to a strong point aft of the drum. In the case of a towing machine or winch, there is usually a strong point on the fantail such as an H-bitt or a heavy-lift roller These devices are not intended to be pulled on in the forward direction, but they are built for much heavier loads than they will be required to withstand while sup- porting a cable brake To install the wire, the bitter end is passed through the brake and onto the winch or the brake is opened by removing the spring assembles and the top plate. The wire to be loaded on a winch may then be placed on the bottom plate of the brake The top plate and spring assemblies may then be reinstalled. The spring assemblies may then be tightened with the clamp nuts until the proper ten- sion is reached. Once the cable brake has been properly adjusted, the rope is wound onto the winch in a continuous manner until all the wire is on the winch drum.

When new wire ropes are put m service as towing hawsers or pendants, their identification (see Section B-2) should be recorded in the Towing Hawser Log described in Appendix F

B-7 STOWING

When the towing hawser is to be removed from the drum, it should be wound neatly on a reel and stored in an acid-free, dry, protected location. Whenever a wire rope towing hawser is to be stored for some time, first lubricate it with MIL-G-18458 grease and keep the outer layer lubricated with the same grease throughout the storage period.

Other wire ropes such as beach gear, pendants, etc., may be stowed below deck in open coils in clean, dry, protected bins. If galvanized, these wire ropes may be stowed without the recommended outside protection layer.



NOTE
WALLIS BRAKE SIZED FOR A FAMILY OF WIRE ROPE SIZES. THE APPROXIMATE DIMENSIONS FOR A 2-INCH WALLIS BRAKE ARE SHOWN. CONSULT THE MANUFACTURER FOR DETAILS .

Figure B-5. Wallis Brake.

B-8 INSPECTION

CAUTION

In general, one should wear gloves when handling wire rope except when it is moving under load. The gloves, if snagged, can drag the hands into dangerous locations.

B-8 1 GENERAL. Inspect the rope thoroughly as it is being wound after each use The inspection criteria for general-usage running rope are as follows:

a. Reduction of nominal rope diameter due to loss of core support, internal or external corrosion or wear of individual outside wires

b. Number of broken outside wires and degree of distribution or concentration of broken wires

c. Corroded, pitted or broken wires at end connection

d. Corroded, cracked, bent, worn or improperly- applied end connections

e. Severe kinking, crushing or distortion of rope structure

f. Evidence of heat.

B-8.2 SPECIFIC. Detailed steps for inspection and maintenance of wire rope are specified in NSTM 613

The principal steps in wire rope inspection are:

a. Refer to Figure B-6 for nomenclature of wire rope and Figure B-7 for measuring wire rope.

b. Clean wire rope by wire brushing and wiping with rags.

c. Inspect wire rope for rust, deterioration, corrosion, wear or flattening, broken strands and weakened splices.

d. Count number of broken or protruding wires in each wire rope lay length.

e. Measure wire rope diameter with vernier calipers.

f. Replace wire rope when one or more of the follow- ing conditions exists.
   (1) The nominal rope diameter is reduced by more than the amount shown in Figure B-7 for the applicable size rope for measuring rope diameter
   (2) Six broken wires in one rope lay length or three broken wires in one strand lay length
   (3) One broken wire within one rope lay length of any end fitting
   (4) Wear of one-third the original diameter of outside individual wires
   (5) Evidence of pitting due to corrosion
   (6) Evidence of heat damage
   (7) Kinking, crushing or any other damage resulting in distortion of the rope structure.

B-9 SPECIFIC PRECAUTIONS

WARNING

It is extremely important that wire rope used in critical or potentially dangerous applications such as towing be properly maintained.

Wire rope must be properly maintained when used in critical or potentially dangerous situations It should not be subjected to any of the following common abuses:

a. Chafing

b. Impact loads or rapidly changing loads

c. Incorrect size of groove on drum or sheave

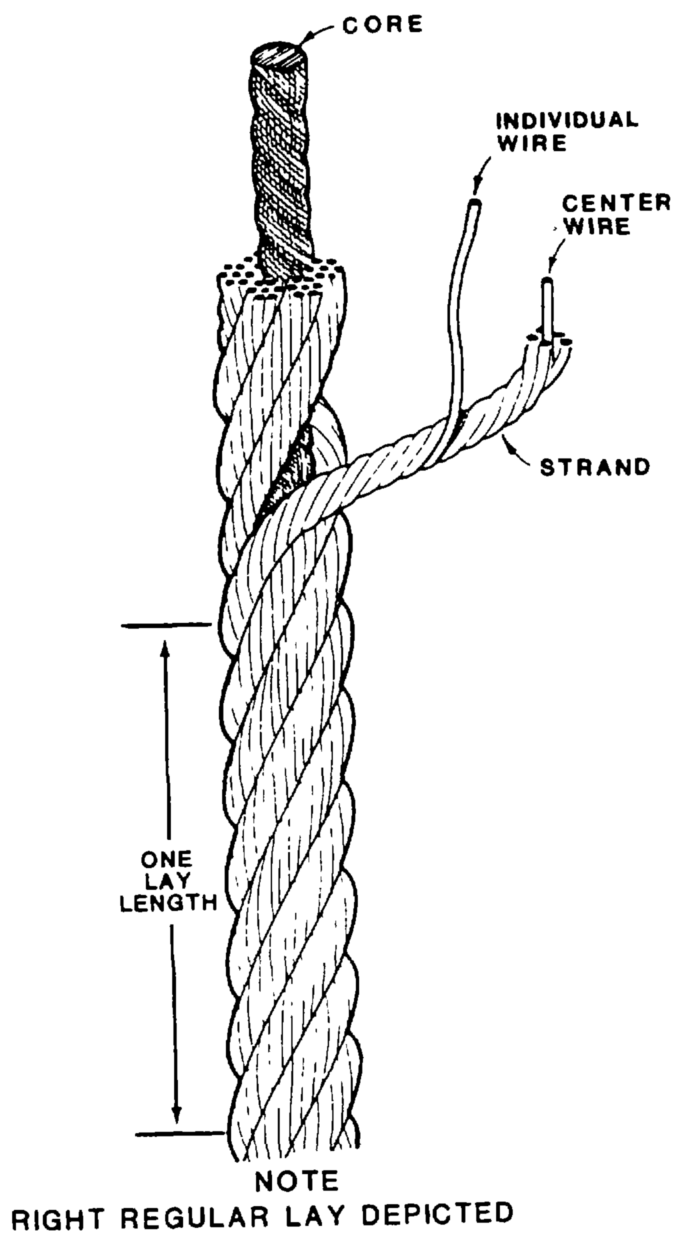
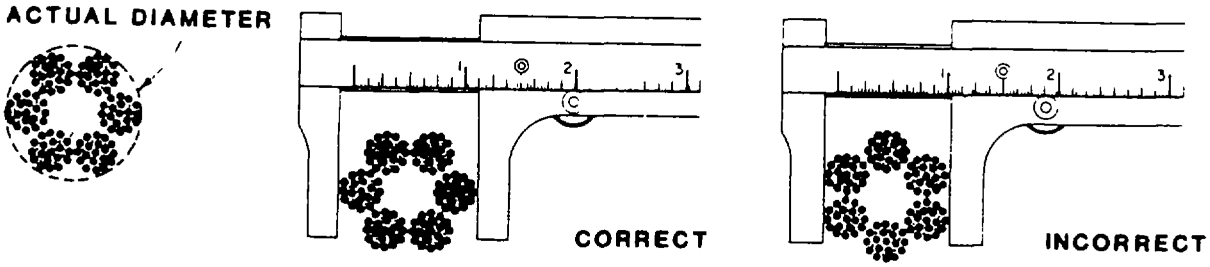


Figure B-6. Nomenclature of Wire Rope.



ROPE DIAMETER (INCHES)	MAXIMUM ALLOWABLE NOMINAL DIAMETER REDUCTION (INCHES)
5/16 AND SMALLER	1/64
3/8 TO 1/2	1/32
9/16 TO 3/4	3/64
7/8 TO 1 1/8	1/16
1 1/4 TO 1 1/2	3/32
1 9/16 TO 2	1/8
2 TO 2 1/2	5/32

Figure B-7. Measuring Wire Rope.

d. Drum or sheave grooves that have become rough or corrugated through wear
e. Inadequate diameter of drum or sheave
f. Improper winding on drum
g. Improper or insufficient lubrication
h. Exposure to corrosive fluids
i. Exposure to excess heat or electric arcing
j. Lack of protection against moisture and salt water
k. Kinks or hockles.

If wire rope is struck by lightning, it should be inspected and considered for replacement.

It is important to maintain a minimum and evenly- distributed wear. Special attention should be given to possible chafing points where the wire rope passes over chocks, bitts, stern rollers, etc. Even though no particular wear may be noticed, it is advisable to freshen the nip at least once a watch in order to change the location of possible wear

B-10 WIRE ROPE SPECIFICATIONS

Navy towing hawsers are invariably 6 x 37 class, pre-formed, right-lay Improved Plow Steel (IPS), coated (galvanized) wire rope. Hawsers should be right-hand lay where the wire winds on the winch drum from the underside and where the bitter end is secured on the port side of the drum This covers most Navy cases since the right-lay wire has the tendency to wind tightly against the preceding wrap in this orientation.

For the port drum on the ATS 1 and ARS 50 Classes, where the hawser is secured to the starboard flange, a left-lay wire be would ideal. To avoid the complication of having different lay hawsers, use a right-lay wire on the port drum, spooling it as follows:

a. Ensure that the wire is pretensioned at 5 percent of its breaking strength.

b. Wind the first layer slowly, ensuring that each wrap is tight against the previous wrap. Use a heavy maul or hammer to obtain a tight fit. Protect the wire as necessary during any hammering action.

c. Do not routinely spool wire off the first layer. Retain the first layer as a semi-permanent foundation for subsequent layers

Navy towing hawsers are of three types:

a. 2-inch diameter, fiber core

b. 2¼-inch diameter, fiber core

c. 2¼-inch diameter, Independent Wire Rope Core (IWRC)

Table B-1 lists the wire hawsers carried by each Navy towing ship class. Table B-2 provides the strength and weight per foot of 6 x 37 class IPS marine ropes. Data is provided for a variety of wire rope sizes for convenience, because pendants, bridles and wire ropes for salvage use are not restricted to the three common sizes.

Attachment A to this appendix provides a procure- ment specification for U.S. Navy towing hawsers. This can be used when procuring a new hawser(s) from manufacturers/vendors, as opposed to purchasing from existing Navy stock. Note that Section 3.1 of Attachment A to this appendix must be adapted to the particular ship involved Also note that drawn galvanized wire is the preferred specification, with strength equal to that of bright, i.e., uncoated, wire.

B-11 WIRE ROPE TERMINATIONS

Wire rope towing hawsers are usually terminated with a closed, poured or "Spelter" socket The dimensions and weights of three common sizes of open and closed Spelter sockets are shown in Figure B-8 The strength of these sockets, properly made, exceeds the strength of the wire rope for which they are designed. The dimensions are given in detail to assist in selecting the appropriate mating jewelry.

WARNING

When using a termination on the tow hawser of less than 100 percent efficiency, the base strength to which the factors of safety are applied must be adjusted accordingly.

See Table B-3 and NSTM 613 for efficiency of wire rope terminations.

Wire terminations are not tested because they are stronger than the safe working strength of the wire. Instead, reliance is placed on the skill of the operator, who is initially qualified and maintains his qualification as described in NSTM 613. Factors of safety listed in Table 6-4 and discussed in Appendix L are applicable to the nominal breaking strength of new wire When terminations other than the poured socket are used, the reduced efficiency of the termination must be included in the allowable load calculations. Furthermore, if the reason for alternate termination is to replace a failed termination or a parted wire, it must be assumed that the balance of the hawser has been overstrained as well. If it is neces- sary to continue use of the questionable hawser, doubling the factor of safety against the lowered system strength would be appropriate.

Table B-1. Wire Hawsers Carried by U.S. Navy Towing Ships.

Ship Class	Wire Rope Hawser Diameter by Length	Core
ATF 76	2" x 2100'	Fiber
ASR 7	2" x 2100'	Fiber
ARS 6	2" x 2100'	Fiber
ATA 120 & 170	2" x 2100'	Fiber
ARS 38	2" x 2100'	Fiber
ATS 1	2 ¼" x 3000'	IWRC
T-ATF 166	2 ¼" x 2500'	Fiber
ARS 50	2 ¼" x 3000'	IWRC

Table B-2. Nominal Breaking Strength of Wire Rope 6x37 Class, Hot Dipped Galvanized.

Fiber Core Note (2) Weight in Air (lbs/ft)*	Fiber Core Note (2) Improved Plow Steel (lbs)**	Nominal Diameter (inches)	Independent Wire Rope Core (IWRC) Note (3) Weight in Air (lbs/ft)	IWRC Improved Plow Steel (lbs)**	IWRC Extra Improved Plow Steel (lbs)**
0.11	4,932	¼	0 12	5,292	6,100
0 16	7,668	5/16	0 18	8,240	9,500
0 24	10,980	⅜	0 26	11,800	13,600
0 32	14,886	7/16	0 35	16,000	18,400
0 42	19,260	½	0 46	20,700	24,000
0 53	24,300	9/16	0 59	26,100	30,250
0 66	30,060	⅝	0 72	32,200	37,100
0 95	42,840	¾	1 04	48,100	53,000
1 29	57,960	⅞	1 42	62,300	71,100
1 68	75,240	1	1 85	80,800	93,000
2 13	94,680	1⅛	2 34	101,700	117,000
2 63	116,280	1¼	2 89	125,000	144,000
3 18	139,860	1⅜	3 50	150,300	172,800
3 78	165,600	1½	4 16	178,000	205,200
4 44	192,600	1⅝	4 86	207,000	237,600
5 15	223,200	1¾	5 67	239,400	275,400
5 91	253,800	1⅞	6 50	273,600	313,200
6 72	288,000	2	7 39	309,600	356,400
7 59	322,000	2⅛	8 35	345,600	397,800
8 51	360,000	2¼	9 36	387,000	444,600
9.48	339,600	2⅜	10 4	430,200	493,200
10 5	439,200	2½	11.6	471,600	543,600
11 6	482,400	2⅝	12 8	518,400	595,800
12 7	525,600	2¾	14 0	565,200	649,800
13 9	570,600	2⅞	15 3	613,800	705,600
15 1	619,200	3	16 6	666,000	765,000
16 4	687,800	3⅛	18 0	718,200	824,400
17 7	718,200	3¼	19 5	772,200	885,600
		3⅛	21.0	826,200	952,200
		3½	22 7	883,200	1,015,206
		3⅝	24 3	941,400	1,083,600
		3¾	26.0	1,002,600	1,153,800

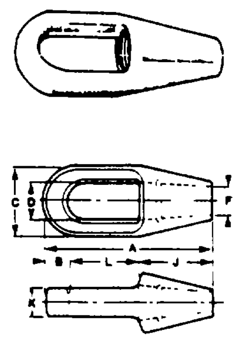
*Weights are given in air. To obtain net weight in water, multiply air weights by 0.87
**Nominal breaking strength in pounds

NOTES

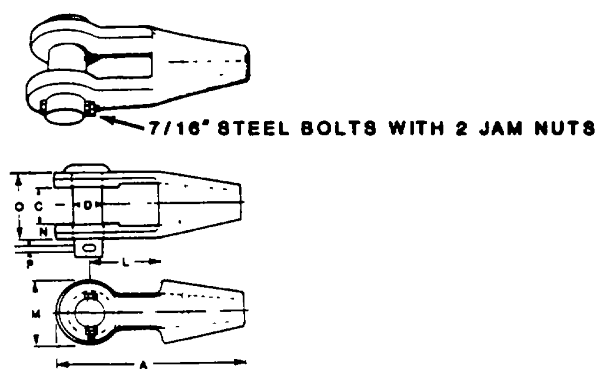
1 All data shown is for hot-dipped galvanized wire. Bright (uncoated) wire strengths are 10% higher and are listed in the same tables in Notes (2) and (3) Drawn galvanized wire rope has the same strength as bright wire.

2 Data for fiber core wire rope is taken from RR-W-410D. Table X.

3 Data for Improved Plow Steel IWRC wire rope is taken from RR-W-410D, Table XI Data for Extra Improved Plow Steel IWRC galvanized wire rope is taken from RR-W-410D, Table XII



WIRE ROPE DIAM INCHES	DIMENSIONS IN INCHES								WEIGHT POUNDS EACH
	A	B	C	D	F	J	K	L	
1 5/8	16.38	2.13	5.75	3.25	1.75	6.50	2.75	5.75	38.25
2-2 1/8	18.75	2.44	7.63	3.75	2.25	8.50	3.25	6.81	77.25
2 1/4-2 3/8	21.63	2.88	8.50	4.25	2.50	9.00	3.63	8.75	108.00
2 1/2-2 5/8	23.50	3.12	9.50	5.50	2.88	9.75	4.00	10.62	140.00



OPEN SOCKET, TYPE A

WIRE & ROPE DIAM INCHES	DIMENSIONS IN INCHES								WEIGHT POUNDS EA
	A	C	D*	L	M	N	O	P	
1 5/8	16.5	3.0	3.0	6.5	5.75	1.31	6.63	0.5	55
2-2 1/8	21.5	4.0	3.75	9.0	7.0	1.81	8.75	0.5	125
2 1/4-2 3/8	23.5	4.5	4.25	10.0	7.5	2.13	10.0	0.5	165
2 1/2-2 5/8	28.5	5.0	4.75	10.75	8.5	2.38	11.0	0.5	252

*PIN SIZE HAS A TOLERANCE OF PLUS OR MINUS 1/32" OTHER DIMENSIONS HAVE A TOLERANCE OF PLUS OR MINUS 1/8", IF UNDER 4" 1/4" IF 4" OR LARGER

Figure B-8. Poured Sockets FED Spec. RR-S-550D Amendment 1.

TABLE B-3. Efficiency of Wire Rope Terminations.

Type Terminations	Efficiency*
Fiege connectors (only suitable up to 1% /" wire size)	85 percent
Wire Rope Clips (See NTSM 613 for number)	80 percent
Mechanical swaging	85 percent
Eye splice (hand-spliced)	
21/4" and larger wire	70 percent
1%" to 2" wire	75 percent
1/8 to 11/2" wire	82 percent
7/. "to 1" wire	88 percent
Flemish eye ("Molly Hogan")	90 percent

*Efficiency is the strength of the termination divided by the nominal breaking strength of the wire

ATTACHMENT A TO APPENDIX B, WIRE ROPE PROCUREMENT

1. SCOPE

This specification establishes the requirements for performance and acceptance of production units of wire rope towing hawsers.

2. APPLICABLE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS.

The following documents, of the issue in effect on the date of invitation for bids or request for proposals, form a part of this specification to the extent specified herein. In the event of conflict between this specification and other documents referenced herein, requirements of thus specification shall apply

SPECIFICATIONS.

Federal
RR-W-410 Wire Rope and Strand
RR-S-550 Sockets, Wire Rope
Manuals
NAVSEA S9086-BK Wire and Fiber Rope and Rigging
NSTM-000/CH 613 NAVSEA Technical Manual
STANDARDS:
Military
MIL-STD-129 Marking for Shipment and Storage
Copies of Military and Federal Specifications and Standards may be obtained from the following facility.

Commanding Officer
Naval Publications and Forms Center (NPFC)
5801 Tabor Avenue
Philadelphia, PA 19120
Tel: (215) 697-3321

STANDARDS:
Reels for all wire shall be steel and shall be constructed according to industry standards for reusable heavy-duty reels. Reels shall be painted.

3. REQUIREMENTS

3.1 WIRE ROPE CHARACTERISTICS

3.1.1 2-Inch Wire Towing Hawsers for ATF 76, ASR 9, ARS 6, ARS 38 and ATA 120 Class Ships

3.1.1.1 Wire rope shall be 2-inch diameter, cut to 2100-foot lengths (see 3 2.1.4 for tolerances in lengths), IPS, drawn galvanized, preformed, regular (R.H.) polypropylene fiber core, Type I, Class 3, Construction 6, 6 x 37 (Warrington-Seale) IAW Specification RR-W-410 Documentation of all test results shall be submitted for the production assemblies (1 data set included with the report m Section 4.4.2).

3.1.1.2 Each of the 2000-foot lengths of 2-inch wire rope shall have a closed zinc poured socket on one end and a permanent seizing on the other end (See Section 3.2.1).

3.1.1.3 Each of the 2000-foot lengths of 2-inch wire rope shall be placed on a steel reel. Reels shall be sized according to the industry standards to accept 2-inch wire. In addition to markings required in RR-W-410, each reel shall be clearly marked on each side with the diameter and length of wire in large 3-inch size letters as follows: "2 " x 2100', w/closed socket termination." Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured.

Presence of the closed socket must be verifiable by visual examination without disturbing the storage of wire on the reel.

3.1.2 2/4-Inch Wire Towing Hawsers for T-ATF 166 Class Ships

3.1.2.1 Wire rope shall be 21/4-inch diameter cut to 2500-foot lengths (see 3.2.1.4 for tolerances in lengths), IPS, drawn galvanized, preformed, regular (R H.) lay, polypropylene fiber core, Type I, Class 3, Construction 6, 6 x 37 (Warrington-Seale) IAW Specification RR-W-410. Documentation of all test results from each Master Reel used in fabrication of wire lengths shall be submitted for the production assemblies (1 data set included with the report m Section 4 4.2).

3.1.2.2 Each of the 2500-foot lengths of 2/4-inch wire rope shall have a closed zinc poured socket on one end and a permanent seizing on the other end (See Section 3.2 1).

3.1.2.3 Each of the 2500-foot lengths of $2\frac{1}{4}$-inch wire rope shall be placed on steel reels. Reels shall be sized according to the industry standards to accept $2\frac{1}{4}$/4-inch wire. In addition to markings required in RR-W-410, each reel shall be clearly marked on each side with the diameter and length of wire in large 3-inch size letters as follows: "21/4 " x 2500' w/closed socket termination." Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured. Presence of the closed socket must be verifiable by visual examination without disturbing the stowage of wire on the reel.

3.1.3 $2\frac{1}{4}$-Inch Towing Hawsers for ATS 1 and ARS 50 Class Ships.

3.1.3.1 Wire rope shall be 2/4-inch diameter cut into 3000-foot lengths (see 3 2.1.4 for tolerances in lengths), IPS (for ATS 1) or EIPS (for ARS 50), drawn galvanized, preformed, regular (R.H.) lay, IWRC, TYPE I, Class 3, Construction 6, 6 x 37 (Warrington Seale) IAW Specification RR-W-410. Documentation of all test results from each Master Reel used in fabrication of wire lengths shall be submitted for the production assemblies (1 data set included with the report in Section 4 4.2)

3.1.3.2 Each of the 3000-foot lengths of 2/4-inch wire rope shall have a closed zinc-poured socket on one end and a permanent seizing on the other end (See Section 3 2.1)

3.1.3.3 Each of the 3000-foot lengths of $2\frac{1}{4}$/4-mch wire rope shall be placed on a steel reel Reels shall be sized according to the industry standards to accept $2\frac{1}{4}$/4-inch wire. In addition to markings required in RR-W-410, each reel shall be clearly marked on each side with the diameter and length clearly marked on each side with the diameter and length of wire in large 3-inch size letters as follows: "21/4" x 3000' w/closed socket termination." Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured.

3.2 Fitting Characteristics

3.2.1 Sockets.

3.2.1.1 Each length of 2-inch and 2/4-inch wire rope described in Sections 3.1 1 through 3.1 3 shall have a closed zinc poured socket on one end and a permanent seizing on the other end.

3.2.1.2 Closed sockets for 2-inch and $2\frac{1}{4}$-inch wire rope shall be Type B, IAW Specification RR-S-550.

3.2.1.3 Closed 2-inch and 21/4" zinc poured sockets shall be attached to the wire in accordance with Naval Ships Technical Manual NAVSEA S9086-BKSTM-000/CH 613, Chapter 613, Wire and Fiber Rope and Rigging. 'Testing shall be as described in Section 4.3 1.

3.2.1.4 Tolerances on 2-inch and 2/4-inch wire rope lengths after sockets have been attached shall be plus or minus 5 feet from the center of socket eye to the bare end of the wire rope.

3.3 LUBRICATION

3.3.1 GENERAL

All wire towing hawsers shall be lubricated with MIL-G-18458 grease in accordance with Naval Ships Technical Manual NAVSEA S9086-BK-STM000/CH613, Chapter 613, Wire and Fiber Rope and Rigging, prior to being placed on steel reels.

4. QUALITY ASSURANCE PROVISIONS

4.1 BASIC REQUIREMENTS

4.1.1 GENERAL.

This section establishes the requirements for verification that the hardware delivered by the contractor conforms to the specified design and performance characteristics. The verification shall be used as the basis for acceptance of the hardware. Failure of any of the test samples to meet the requirements of this specification shall be cause for rejection of the lot represented by the sample.

4.1.2 INSPECTION RESPONSIBILITY.

The contractor is responsible for the performance of all performance tests, acceptance tests, specification tests and inspections. Except as otherwise specified, the contractor may use his own facilities or any commercial laboratory acceptable to the Government The Government reserves the right to perform any or all of the tests and inspections specified herein where such inspections are deemed necessary to assure conformity to prescribed requirements.

4.1.3 GOVERNMENT INSPECTION AND ACCEPTANCE.

It is intended that all government inspections and acceptance tests shall be performed at the contractor's facility by DCAS representatives and/or Navy representatives, however, this does not preclude the contractor from performing his own inspection and acceptance tests as stated in section 4 1.2.

4.2 SPECIFICATION REQUIREMENTS

4.2.1 GENERAL.
All parts of the wire rope assembly shall comply with all the item specifications indicated herein All markings, packaging and testing shall be in accordance with referenced specifications unless otherwise indicated by this modification.

4.3 PERFORMANCE TESTS

4.3.1 POURED ZINC SOCKET TESTS

4.3.1.1 In addition to the specification requirements for testing of the 2 " and 21/4 " wire rope and the 2 " and 24 " closed sockets, the socketed end of the wire rope should be tagged with the date and name of the installation facility.

4.3.1.2 The contractor shall supply certification that the operator installing the poured sockets has had proper training and is experienced at installing sockets on 2" and 21/4" wire and shall also provide certification that his installations have been tested and shown to develop 100% of rated break strength. Certification shall not be more than 1 year old. If operator certification is not available, or has expired, the operator must be certified by the demonstrations described m the following paragraph or by an equally rigorous industry standard.

4.3.1.3 If operator certification or recertification is required, the contractor shall have his operator prepare two sockets on approximately 10-foot sections of the wire using the exact method to be used then be pull tested to 100% of the wire rope nominal breaking strength per RR-W-410. Should the rope or socket failure occur before the nominal breaking strength of the wire is reached, two additional test assemblies shall be prepared and tested and this process continued until required strength is demonstrated m two consecutively fabricated samples. Copies of these test results shall be included with documentation required in Section 4.4 3. All testing shall be completed prior to any fabrication and the DCAS representative and/or Navy representative shall be present to observe and certify the fabrication and testing of the test specimens.

4.4 PRODUCTION
4.4.1 REQUIREMENTS FOR INSPECTION

4.4.1.1 All items shall be checked to ensure proper type, size and marking as required by applicable specifications All data and checks made shall be certified by the DCAS representative and included in the production lot test report (Section 4 4 2)

4.4.1.2 All items not conforming to the specifications shall be replaced at the contractor's expense.

4.4.1.3 Steel cable reels shall be inspected to ensure that modifications to the drums have been made to allow easy socket attachment and to permit external verification of the presence of the socket.

4.4.1.4. The contractor shall keep the DCAS representative informed at all times as to the schedule for required inspections and specification checks in order to ensure complete compliance with specification requirements.

4.4.2 PRODUCTION LOT TEST REPORT
4.4.2.1 Following the production of all items as required by the contract, the contractor shall submit a Production Lot 'Test Report as specified on DD Form 1423.

4.4.2.2 The Production Lot Test Report shall be in accordance with best industry practice and shall contain all data from all tests required by this specification for each piece to be delivered under a Contract Line Item. All certifications by the DCAS representative shall also be included.

4.4.2.3 The entire Production Test Report (3 copies) shall be submitted to the COTR for review as specified on DD Form 1423.

4.4.2.4 The PCO shall within 30 calendar days of receipt of the Production Lot Test Report approve, conditionally approve or disapprove the production lot

4.4.3 DELIVERY

4.4.3.1 All items shall be delivered as required m the procurement request, to the locations specified.

5. PREPARATION FOR DELIVERY
5.1 PRESERVATION AND PACKAGING
5.1.1 GENERAL

5.1.1.1 All shipping containers or other methods of packaging shall be acceptable to the common carrier which will ensure safe delivery in acceptable condition to the destination. Container, packing and method of shipment shall comply with Uniform Freight or National Motor Freight Classification Rules or Regulations, or other carrier rules as applicable to the mode of transportation.

5.1.2 PACKAGING, PRESERVATION AND MARKING

5.1.2.1 All items shall be packaged and preserved in accordance with the applicable specifications, or, in the absence of such specification, to Level "C."

5.1.2.2 Marking for shipment and storage shall be in accordance with the applicable specification and MIL-STD-129

APPENDIX C

SYNTHETIC FIBER LINE TOWLINE COMPONENTS

The material presented here does not supersede any Fleet or NAVSEA directives on the operational use or care of synthetic towlines, particularly concerning nylon line. The user of this manual must keep abreast of such directives which discourage the use of nylon hawsers except for emergency use, training exercises, tow-and-be-towed operations, tow of yard and service craft, ocean tows of ships up to the size of minesweepers, and specially-designed tows where the use of wire is not practical. These proscriptions resulted from increasing numbers of failures of nylon hawsers as their use proliferated. Special circumstances should be discussed with NAVSEA OOC.

NAVSEA and the Fleet commenced pilot programs to evaluate the use of large (14-inch circumference) polyester towing hawsers in early 1988. A key element of this effort is careful control and laboratory analysis of samples periodically taken from active hawsers The purpose of this effort is to develop reliable, practical methods for predicting the useful life of polyester towing hawsers. This has not been practical for nylon hawsers.

C-1 GENERAL

Fiber lines, either natural or synthetic, can be found serving two functions in towline systems. In some systems the main towing hawser is made of fiber lie In other systems the hawser is wire rope and fiber lines are used as springs to provide relief from dynamic tension loads. In both uses, the fiber line should be kept in excellent condition, protected against wear and inspected regularly

When fiber line is used as the main towing hawser or as a spring, a written record of its history is required by the Naval Sea Systems Command in the form of the Towing Hawser Log listed in Appendix F.

C-2 TRACEABILITY

Traceability, the ability to trace a line and what has happened to it back to its source, is an important element m accident investigation as well as in general product-improvement efforts. Some of the needed information is maintained in the Towing Hawser Log. See Appendix F American-made fiber line and some brands of foreign-made rope can be identified by special marker tapes inserted into the fiber lines, special-colored monofilaments and metal tags and other data on the reel upon which the line is delivered Identification of manufacturing source through the marker coding may be particularly useful in cases where the reel markings have been lost. Additional information on a specific domestic rope producer's identification marking practices is available on request from the Cordage Institute, Suite 568, 314 Lincoln Street, Hingham, MA 02043. Telephone (617) 749-1016

C-3 STRENGTH AND LIFETIME

WARNING

The failure of synthetic fiber lines under high tensile loads can be extremely dangerous. Stay out of bights and areas through which the end of a failed line may whip.

C-3.1 GENERAL. Most synthetic fiber lines are stronger than manila (natural fiber) lines, and they usually have longer lifetimes because of their resistance to rot and other forms of environmental deterioration.

C-3.2 SPECIFIC. The primary types of fiber lines in current use by the Navy are nylon, polyester and polypropylene. Of these three, nylon is the strongest for equal size when dry. However, nylon loses strength because of water absorption when wet and becomes weaker than polyester even though it is still stronger than polypropylene. Table C-1 presents a qualitative summary of pertinent characteristics of three fiber lines.

As one may note from Table C-1, nylon's water-absorption characteristic changes its comparative rating from best to intermediate in nearly every category. Consequently, for towing use, the Navy is in the process of phasing out the use of nylon, probably in favor of polyester. Where springs are required in towline systems, nylon will probably continue to be used because of its greater elasticity. Polypropylene will also continue to be used for certain purposes because it is the only one of the three fiber lines that will float.

C-4 ELONGATION

The elongation or stretch of fiber line under tension loads has both advantages and disadvantages. Elongation tends to greatly reduce dynamic loads m the towline such as shock loads and wave-induced loads. But elongation also stores a great deal of energy in ropes under tension and the release of this energy when a rope fails under tension causes a very dangerous whipping or "snapback" of the line. The stored energy, and therefore danger, is much greater in the case of synthetic lines than for wire rope under the same load. For this reason, extreme caution is required when working around fiber lines (especially nylon) which are under load. Braided fiber lines tend to stretch about one-half to two-thirds as much as plaited or stranded ropes of the same size.

Under heavy tension loads, nylon line can snap back at speeds up to 700 feet per second (500 mph)

C-5 MAINTENANCE AND CLEANING

Although fiber lines are not subject to corrosion as wire ropes are, they still require careful maintenance and cleaning. If the line becomes oily or greasy, scrub it with fresh water and a paste-like mixture of granulated soap. For heavy accumulations of oil and grease, scrub the line with a solvent such as mineral spirits, then rinse it with a solution of soap and fresh water.

The three different synthetic fibers show different responses to various chemicals In brief

a. Nylon shows weakening upon exposure to acids, particularly mineral acids. Its resistance to alkalis is good at normal temperatures

b. Polyester line will deteriorate with exposure to hot, strong alkali solutions. It is attacked by very strong acid solutions, therefore, even diluted acid solutions should not be allowed to dry on the rope.

c. Polypropylene is resistant to both acids and alkalis at normal temperatures, but is affected by some organic solvents such as xylene and metacresol and by coal tar and paint-stripping compounds. These types of chemicals are most likely to be found in the paint locker in thinners and cleaning compounds.

All synthetics are weakened by exposure to strong sunlight and should, therefore, be stored out of the sun. Polyester has the best resistance to ultraviolet rays.

C-6 NEW HAWSERS

Synthetic lines are shipped in coils or on wooden reels. They should be unreeled very carefully to avoid abrasion and damage to the fibers.

CAUTION

New synthetic hawsers should not be subjected to heavy strain prior to breaking them in. Limit the towing loads applied to a new hawser until it has been cycled up to its working load.

NSTM 613 (Ref. 15) suggests that a synthetic hawser will be adequately "broken in" after five cycles of loading/unloading up to its working load or to within 20 percent of breaking strength, whichever is less. This permits the construction stiffness to be worked out of the line. When new lines are strained, they some

TABLE C-1. Fiber Comparisons.

Fiber Type	Strength[1]	Cyclic Fatigue2	Bending Fatigue2	Abrasion Resistance	Heat Resistance	Creep
Nylon (dry)	VG	VG	G	E	G	G
Nylon (wet)	G	F	F	F	-	G
Polyester (dry)	VG	VG	VG	VG	G	VG
Polyester (wet)	VG	VG	G	G	-	VG
Polypropylene (dry)	F	F	P	P	P	F
Polypropylene (wet)	F	F	P	F	-	F

E = Excellent VG = Very Good G = Good F = Fair P = Poor

NOTES

1 Tensioned between two limits without bending.

2. Usually running over pulleys. Some line wears out before failing from fatigue because of abrasion between line and pulley

times produce a sharp crackling sound which is the result of readjustment of the line's strands to stretching, and should not be alarming

With new line it is not always possible to get it to lay flat due to turns set into the line during storage on a reel.

Never tow with a nylon hawser to get the hockles or kinks out. Stream the line, controlling its payout with a capstan, until the bitter end is reached. Retrieve it with the aid of the capstan and it will then lay flat as the excess turns will run out of the line as it is being hauled m. The ship should be stopped during retrieval of the line

When new lines are put in service as towing hawsers or springs, their identification, see Paragraph C-2 above, should be recorded in the Towing Hawser Log described in Appendix F

C-7 COILING AND WINDING

C-7.1 GENERAL. Synthetic line is shipped in cut lengths, either in coils or on reels. Great care should be taken when the line is removed from the shipping package since it can be permanently damaged by improper unreeling or uncoiling. Looping the line over the head of the reel or pulling the line off a coil while it is lying on the deck, may create kinks or hockles in the line. Never allow synthetic line to drag over rough surfaces since this will tend to abrade and cut the outer fibers.

C-7.2 SPECIFIC.

CAUTION

A common method of uncoiling wire rope by rolling the coil along the deck is not recommended for fiber lines because of the potential for abrading or cutting the outer fibers, and also because the coil will collapse when the bands are removed.

There are two methods for correctly unreeling synthetic line. These are identical to the methods used for wire rope and are discussed in Appendix B, Section B-6.1.

C-8 STOWING

Stow synthetic line away from strong sunlight, heat and strong chemicals, and cover it with tarpaulins. (Nylon is also sensitive to fluorescent light.) If the line is iced over, thaw it carefully and drain it before stowing. If feasible, store on appropriately treated wooden damage. Nylon is susceptible to a rapid reduction m strength when exposed to rust. Ensure that it is not exposed to rust-prone bare steel surfaces.

C-9 INSPECTION

Regular inspection is essential to ensure that synthetic lines remain serviceable and safe.

It is also emphasized that no matter what has weakened the line, the effect of the same injury will be more serious on the smaller sizes than on the larger sizes of line. Consideration should therefore be given to the relationship of the surface area of the line to its cross section

Examinations of about one foot at a time may prove to be convenient. The line should be turned to reveal all sides before continuing. At the same intervals, the rope should be untwisted slightly to allow examination between the strands of three-strand and plaited rope.

Synthetic lines should be inspected after each use. Look for broken fibers m the outer layer and for discoloration or appearances of melting. In examining between the strands look for these same evidences of wear and, in addition, look for any appearance of a powdery substance between the strands. Broken outer fibers may indicate that the line has been dragged over sharp or rough surfaces. Discoloration or melting may indicate excessive frictional heat from either dynamic loads or from rubbing over smooth surfaces. Internal wear, sometimes indicated as a fuzzed or fused condition between strands, may indicate fatigue damage from repeated or cyclic loads and overloading. If after examination, there is any doubt about the safety of the line, it should be discarded It is again emphasized that the effects of wear and mechanical damage are relatively greater on smaller lines which, therefore, require more stringent standards of acceptance

The following section on types of wear should be helpful during the inspection of synthetic lines.

C-10 TYPES OF WEAR OR DAMAGE

The usual types of wear exhibited by synthetic lines are briefly discussed in the following notes.

a. General external wear. External wear due to dragging over rough surfaces causes surface chafing. In the extreme, the strands become so worn that their outer faces are flattened and the outer yarns are severed In ordinary use some disarrangement or breakage of the fibers on the outside of the line is unavoidable and harmless if not extensive. Generally, nylon and polyester filament lines have a very good abrasion resistance.

b. Local abrasion. This abrasion, as distinct from general wear, may be caused by the passage of the line over sharp edges while under tension and may cause serious loss of strength, especially if accompanied by fused areas signifying high heat generated by rope surges under heavy load. Slight damage to the outer fibers and an occasional torn yarn may be considered harmless but serious reduction in the cross-sectional area of one strand or somewhat less serious damage to more than one strand should merit rejection When such damage is noticed, protective measures should be taken. 'Typical protective steps are to smooth and round off all rough or sharp areas on the surface which are chafing the line and apply chafing gear such as rubber or plastic sleeves or cloth material secured by small stuff around the line.

c. Cuts, contusions, etc. These also may be caused by rough or sharp surfaces. Such careless use may cause internal as well as external damage. This may be indicated by local rupturing or loosening of the yarns or strands. Serious cuts should be removed by cutting the damaged area out and splicing otherwise good rope together.

d. Internal wear. Internal wear caused by repeated flexing of the line, particularly of wet nylon, and by particles of grit which have been picked up, may be indicated by excessive loose- ness of the strands and yarns or the presence of fuzzed or fused internal areas. Ice crystals may be a source of internal wear This condition could result from towing m very cold weather and will most likely occur at the stern of the tug and at the tow where the hawser is occasionally wetted, but generally exposed to the cold air

e. Repeated loading. The resistance of nylon or polyester filament line to damage due to repeated loading is good, but a permanent elongation will occur over time in heavily-loaded ropes. If the original length of the rope is known exactly, a check measurement made under exactly the same conditions will indicate the total extension of the rope although some parts of the rope may escape extension. Measurement of the distance between regularly-spaced indelible markers on the rope may help to reveal severe local permanent elongation which may cause breaking on subsequent loading

WARNING

Surging of synthetic line under tension can cause sufficient frictional heat at the contact surfaces to result in melting the surface of the line. The melting point of polypropylene line, for instance, is 320 °F to 340 °F, while the soften- ing point is around 300 °F. Comparable temperatures for nylon and polyester are only moderately higher. These temperatures are quite quickly produced when a line is surged on a winch or capstan.

f. Heat. Heat may, in extreme cases, cause melt- ing. Any signs of this should obviously warrant rejection, but a line may be damaged by heat without any such obvious warning. The best safeguard is proper care m use and storage. A synthetic line should never be dried m front of a fire or stored near a stove or other source of heat.

g. Strong sunlight Strong sunlight causes weakening of synthetic fibers, but is unlikely to penetrate beneath the surface. Unnecessary exposure should be avoided. Solar degradation should be checked by rubbing the surface of the line with the thumb nail. If degradation has taken place, the surface material will come off as a powder. In addition, the surface of the line will feel dry, harsh and resinous.

C-11 SPECIAL PRECAUTIONS

WARNING

The major special precaution to be taken in the use of synthetic lines that are heavily loaded is to be constantly alert to the danger of line snapback if it fails. Personnel must remain clear of the areas through which the ends of a failed line may whip or snap. This is vital since the end of the broken line can travel at speeds up to 500 mph.

CAUTION

The potential for catastrophe, resulting from the failure of a heavily-loaded synthetic line and the sensitivity of the line to damage from rough surfaces, indicates another major precaution. That is, when towing either alongside or stern-to-bow, with a synthetic hawser, try to keep your line completely outboard. This can be done by shackling into a double synthetic line strap of equal size and type as your line or into a wire rope or chain pendant. This is particularly important on the towed end, as the conditions of those chocks, bitts, etc. are unknown. Barges usually have very rough chocks caused by previous repetitive use of wire rope or chain.

CAUTION

Synthetic lines may slip when eased out under heavy loads since their coefficient of friction is below that of manila. This may cause injury to personnel who have not been thoroughly instructed in these lines' peculiarities. like two or three turns on a bitt before you "figure 8" the line; this provides closer control. Stand well clear of the bitts.

It is important that synthetic line be used and maintained properly It should not be subjected to any of the following common abuses.

a. Chafing

b. Incorrect size of groove on drum or sheave

c. Drum or sheave grooves that have become rough or corrugated through wear

d. Inadequate diameter of drum or sheave

e. Inadequate radius on fairlead or stern roller

f. Rough or abrasive surfaces on fairlead or stern roller

g. Improper winding on drum

h. Exposure to corrosive fluids (oils, acids and bases)

i. Exposure to excessive heat or strong sunlight

j. Accumulation of dirt or grit on the surface of the line

k. Kinks or hockles.

It is important to line life to maintain a minimum and evenly distributed wear. Special attention should be given to possible chafing points where the line passes over chocks, bitts, stern rollers, etc. Even though no particular wear may be noticed, it is advisable to freshen the nip at least once per watch in order to change the location of possible internal wear.

C-12 FIBER ROPE CHARACTERISTICS

Table C-2 provides the strength and weight of several sizes and types of fiber ropes. Manila line characteristics are included for comparison. See NTSM 613, Section 2, for additional data on fiber lines.

TABLE C-2. Synthetic and Natural Line Characteristics.

SIZE (IN)	MANILA FED-T-R-605b TS	WT	POLYPROPYLENE THREE-STRAND MIL-R-24049A TS	WT	DRY NYLON TRIPLE-STRAND MIL-R-17343D TS	WT
3	9,000	27	13,000	20	23,200	25
5	22,500	75	32,000	53	60,000	67
6	31,000	108	44,000	80	90,000	100
7	41,000	146	60,000	111	127,000	141
8	52,000	191	75,000	143	164,000	182
9	64,000	242	94,000	184	209,000	233
10	77,000	299	115,000	233	265,000	295
11	91,000	367	—	—	316,000	351
12	105,000	435	—	—	375,000	417
13	—	—	—	—	—	—
14	—	—	—	—	—	—
15	—	—	—	—	—	—
16	—	—	—	—	—	—
17	—	—	—	—	—	—

SIZE (IN)	DRY NYLON DOUBLE-BRAID MIL-R-24050C TS	WT	POLYESTER DOUBLE-BRAID MIL-R-24677 TS	WT	NYLON 8 STRAND PLAITED MIL-R-24337 TS	WT
3	25,500	25	26,800	32	25,000	28
5	73,000	68	69,900	84	60,000	70
6	102,500	98	106,000	128	86,000	100
7	140,000	132	133,000	161	117,000	136
8	180,000	173	181,000	220	153,000	176
9	225,000	219	236,000	287	192,000	223
10	273,000	270	277,000	337	237,000	277
11	325,000	327	343,000	419	280,000	328
12	385,000	389	417,000	510	345,000	405
13	440,000	450	470,000	576	—	—
14	508,000	524	527,000	646	—	—
15	576,000	600	649,000	798	—	—
16	650,000	685	715,000	879	—	—
17	726,000	770	784,000	965	—	—

TS = Minimum Tensile Strength (lb) WT = Weight (lb/100 ft)

Strength shown for nylon is for new dry nylon Nylon wet strength is about 15% less Multiply figures listed by 0 85 to obtain the new breaking strength of wet nylon

WARNING

Several factors affect line behavior, such as line condition and specific application The tensile loads are tabulated for new line in good condition Normal working loads are not applicable when the line is subject to dynamic loading

NOTE

Figures shown are minimum breaking strength required by the specifications noted Manufacturers may quote "nominal" breaking strength, which may be significantly higher than the figures shown Use the figures in this table for designing towing systems and determining acceptable loads (except for nylon strength, which should be reduced by 15 percent) For special cases, where documentation for a particular hawser certifies a higher minimum breaking strength, this higher figure may be used upon advice of NAVSEA (OOC)

APPENDIX D

ANCHOR CHAIN TOWLINE COMPONENTS

D-1 INTRODUCTION

Chain is an important component in the connection between the towed vessel and the tug. It usually appears m the form of pendants or bridles at the towed-vessel end of the towline The chain components serve one or more of the following purposes:

a. A chafing-resistant strong terminal connection to the towed vessel

b. An equalizing device (bridle) to share the towing load between two strong points located port and starboard of the towed vessel's bow (or stern)

c. A means of absorbing dynamic loads in the tow- line, by virtue of its weight, which increases catenary in the towline.

The traditional Navy die lock chain, with the stud integrally forged into the link, is no longer manufactured. Nonetheless, large amounts of die lock chain remain throughout the Fleet and this type chain is perfectly acceptable for all uses for which it was designed. The Navy now purchases "flash butt welded stud link" chain that is similar in appearance to high quality, commercial anchor chain, usually referred to as "welded" or "stud link" chain. In this appendix, this new Navy chain will be called "stud link" chain for the sake of simplicity. Navy stud link chain is slightly stronger than standard Type 1 die lock chain, they may be used interchangeably.

Until recently, commercial "DiLok " chain was made by one manufacturer, Baldt, and is slightly stronger and heavier than Type 1 standard Navy die lock chain. Section D-11 discusses the strength of the various chains that may be used in towing.

D-2 TRACEABILITY AND MARKING

D-2.1 TRACEABILITY. 'Traceability, or the ability to trace a chain and what has happened to it back to its source, is an important element in accident investigation as well as in general product- improvement efforts For identification, a corrosion- resistant metal tag is attached to the end link at each end of each shot or length of Navy chain. Included among data plainly marked on the tag is a manufacturer's serial number that permits tracing the chain back to its manufacturing source. The manufacturers also provide information with new chain that covers size, type, material, proof tests, certification, etc. This information should be maintained in the Towing Hawser Log, see Appendix F, and updated as necessary for chain that is used as an integral part of the towline connection.

D-2.2 MARKING. Navy chain, whether die lock or stud link, is marked in accordance with MIL-C- 24633 (Ref. 22)

Commercial chain used in marine service, including "DiLok,' is controlled and certified by the various marine classification societies such as the American Bureau of Shipping (ABS), which certifies all US. Flag vessels and many foreign ships. Marine stud link chain is made in three grades, as shown in Table D-2. Grade 2 is most prevalent. ABS requires chain to be marked on the end link of each shot, or every 15 fathoms, if the chain is continuous-i.e., without connecting links. The markings include:

a. Certificate number

b. Chain size

c. Classification society stamp (a Maltese Cross for ABS)

d. Designation of the type of chain, e g., AB/1, AB/2 or AB/3

The other classification societies have similar mark- ing requirements and grading systems as does ABS.

When towing a commercial ship, if it is intended to use the ship's anchor chain for a bridle or pendant, the chain should be carefully inspected m accordance with the requirements of Section D-8. If the classification society grade marking cannot be determined, the chain should be assumed to be Grade 1, which is roughly one-half as strong as standard Navy chain.

Chain from unknown or non-marine sources, which is unmarked and which cannot otherwise be identified, should not be used in towing

D-3 STRENGTH AND LIFETIME

Chain, properly used, should be the strongest and longest-lived element in the towing system. Because of its construction and generally rugged configuration, chain is considerably stronger than wire or fiber rope of the same nominal size

D-4 ELONGATION

The rugged, large-diameter, individual strength members of chain give it the least elongation, or stretch, under load of any towline component This characteristic of chain is one of its prime reasons for being an element in the towline system since working at chafing points, under constantly-changing tension, is minimized. Additionally, the weight and flexibility of the chain promotes the towline catenary and mitigates the effects of dynamic loading on the rest of the towing system.

D-5 MAINTENANCE AND CLEANING

As with other elements of the towline, chain must be properly maintained and cleaned. Perhaps the most important element of chain maintenance is corrosion prevention. Corrosion leads to loss of chain strength directly by reducing the diameter of the load- carrying rods that form the links. Further, for stud link chain, corrosion can loosen the studs and eventually lead to their loss.

Corrosion prevention is best achieved by a fresh- water washdown of the chain after each use, coupled with visual inspection for initial signs of corrosion During the required annual inspection, the chain should be carefully cleaned, inspected and re- preserved as necessary; see NSTM 581 (Ref. 23).

Cleaning should be done by scaling, sand blasting or wire brushing Penetrating oil should not be used to loosen the rust. After cleaning, a careful inspection should be made in accordance with Section D-8. All suspected links should be checked by non- destructive test methods, careful measurement, sounding, etc.

Preservation after cleaning and any necessary repairs should be performed in accordance with Section D-8 and with NSTM 631 (Ref. 4) For most chain, the use of TT-V-51 paint (asphalt varnish) or MIL-P- 24380 paint (anchor chain gloss black solvent type paint) will be satisfactory

D-6 NEW CHAIN AND LINKS

New or re-issued chain or links that will be used as components of towline connections should be treated in the same manner as new towing hawsers. The chain and links should be inspected and pertinent data entered in the Towing Hawser Log. See Appendix F.

D-7 STOWING

No special stowing precautions are needed beyond attempts to prevent corrosion That is, try to avoid moisture, salt, alkalines and acids. Oil and grease also should be avoided since they are difficult to remove and may reduce the effectiveness of corrosion prevention coatings.

D-8 INSPECTION

D-8.1 GENERAL. Annual inspection of chain components of a towline system should follow the Navy practices for anchor chain detailed in NSTM 581 After cleaning by scaling, wire-brushing or sand blasting, each link should be checked by sounding with a hammer. Give particular attention to locating possible loose studs, bent links, excessive corrosion and sharp gouges.

D-8.2 SPECIFIC. Proper reactions to various conditions noted in the inspection are indicated m the following notes, most of which apply to stud link chain.

a. Missing stud: discard link

b. Out-of-plane bending of more than 3 degrees' discard link.

c. Average of the two measured diameters at any point less than 95 percent of nominal diameter, or a diameter in any direction less than 90 percent of nominal diameter: discard link

d. Crack at the toe of the stud weld extending into the base material: discard link

e. Surface cracks or sharp gouges: attempt to eliminate by light grinding. If the chain diameter is reduced to less than 90 percent of the nominal diameter after grinding' discard link.

f. Excessively loose stud: since it is difficult to quantify excessive looseness of chain studs, the decision to reject or accept a link with a loose stud depends on the experience and judgment of the inspector. Consider discarding a link if.

   (1) Stud can move more than 1/8 inch (3 mm) axially or more than 3/16 inch (5 mm) later- ally m any direction,

   (2) A gap of more than 1/8 inch exists between the stud end in a link with a stud welded only on one end.

g. Cracks detected by magnetic particle inspection m the internal locking area of detachable link. discard link. External surface defects m detach- able links are not cause for rejection if they can be eliminated by grinding to a depth of no more than 8 percent of the nominal diameter of the chain.

h. Length over six links exceeding 26.65 times nominal chain diameter or length of individual link exceeding 6 15 times nominal chain diameter. discard links.

i. Excessive wear or deep surface crack on shackles, open links or swivels: Attempt to eliminate by light grinding. If the cross-section area, diameter or critical thickness in any direction is reduced more than 10 percent by wear and grind- ing: discard the chain.

If a substantial number of adjacent links m a chain section meet the discard criteria, the chain section should be removed and the chain joined again by detachable links that have been examined and found to be in acceptable condition

If a large number of links meet the discard criteria and these links are distributed throughout the chain's whole length, replace the chain with a new one.

Re-welding of loose studs in the field is undesirable for the following reasons'

a. Welding m the field may produce hard heat- affected zones that are susceptible to cold cracking.

b. Hydrogen embrittlement may occur from absorption of moisture from the atmosphere or welding electrodes.

Weld repairs on loose studs should be delayed as long as possible Where a few links are found with loose studs in a short section of a chain, it is recommended that this portion of the chain be cut out and a detachable link inserted. If the major portion of the chain has loose studs, the chain should be scrapped.

Any grinding to eliminate shallow surface defects should be done parallel to the longitudinal direction of the chain, and the groove should be well rounded and should form a smooth transition to the surface. The ground surface should be examined by magnetic- particle or dye-penetrant inspection techniques

D-9 TYPES OF WEAR

The rough treatment to which chain items of towing gear are exposed can lead to various chain problems. Eight such common problems for which towing personnel should be alert are described below.

a. Missing studs. the stud contributes about 15 percent of the chain's strength A chain link without a stud may significantly increase the possibility of link failure. High bending stresses and low fatigue life in links are predictable consequences of missing studs

b. Bent links: a bent link is the result of chain handling abuse. The link may have beenexcessively torqued when traversing a sharp, curved surface or the chain may have jumped over the wildcat, making point contacts between the link and the wildcat

c. Corrosion: excessive corrosion increases the possibility of chain failure from corrosion fatigue or overloading due to reduced cross-sectional area.

d. Sharp gouges: physical damage to the chain surface, such as cuts and gouges, raises stress and promotes fatigue failure.

e. Loose studs: loose studs, caused by abusive handling or by excessive stretching of chain, result- ing in lower bending strength of the chain.

f. Cracks: surface cracks, flash weld cracks and stud weld cracks propagate under cyclic loading, and result in premature chain failure.

g. Wear. wear between links in the grip area and between links and the wildcat reduces the chain diameter The diameter reduction decreases the load-carrying capacity of the chain and invites failure.

h. Elongation: excessive permanent elongation may cause the chain to function improperly in the wildcat, resulting in bending and wear of the links. Wear in the grip area of the chain as well as working loads m excess of the original proof load will result in a permanent elongation of chain.

D-10 SPECIAL PRECAUTIONS

Chain generally is the most rugged component of the towline system Because of this, there may be a tendency to become overconfident in its capability and somewhat lax m inspection. Avoid overconfidence when using chain.

Personnel tend not to check carefully enough on such items as:

a Adequate radius of curvature on surfaces of fair- leads, chocks, etc. A ratio of 7:1 is generally accepted as the minimum D:d ratio of bearing surface to chain size for heavy loads when the chain direction is changed significantly over the surface

b. Wear in the grip (partially-hidden contact) area between chain links.

c. Looseness from excessive wear in shackles, swivels and detachable links.

d. Presence of detachable links that are not equipped with safety-lock hairpins.

e. Screw-pin shackles, which should never be used in towline connections

CAUTION

Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration set up by the hydrodynamic actions on the towline.

D-11 CHAIN SPECIFICATIONS

Navy die lock chain characteristics are included in Table D-1. The similar Baldt "DiLok" chain is 11 percent stronger and 1 percent heavier Table D-2 provides the characteristics of Navy stud link chain. Navy stud link chain is equivalent to commercial grade 3 as shown in Table D-3 Grade 3 chain is about 3 percent stronger than Navy Standard die lock, Grade 2 is only about 72 percent as strong as die lock, and Grade 1 is only 51 percent as strong.

D-12 CONNECTING LINKS

Detachable chain connecting links frequently are used in lieu of more traditional shackles, because they will pass through a smaller space and are less likely to "hang up" during the rigging process Pear- shaped detachable links fit two chain sizes. The strength of this link is identical to that of the larger chain size which is designed to accommodate. Figures D-1 through D-3 and Tables D-4 through D-6 describe detachable links and an improved locking system for use with the tapered link pins. End links are special studless links 1/8 inch to 1/4 inch larger than the chain size. They are larger than the chain size to compensate for the lack of a stud They have the same strength as the parent chain system.

D-13 SAFETY SHACKLES

A safety shackle is characterized by a pin that is secured by a bolt on the outside of the shackle For towing use, the bolt itself is secured by a small machine bolt with two nuts jammed together to prevent rotation of the large nut. Screw-pin shackles, which use a threaded pin that screws into the body of the shackle, have no place m towing, even though TB 55-1900-232-10 rotation of the pin might be prevented for a time by a wire mousing through the eye on the large end of the pin.

Navy shackles are manufactured according to MIL-S-24214A (SH) (Ref. 14) which covers two types, two grades and three classes of shackles. Tables D-7 through D-9 provide the physical dimensions and strengths of safety shackles. Note the significant difference in strength between Grade A and Grade B shackles. The shackle size and safe working load will be shown in raised or stamped letters. The pins and bolts of Grade A-Regular Strength-shackles are unmarked, but Grade B pins and bolts are marked "HS."

D-14 PROOF LOAD, SAFE WORKING LOAD AND SAFETY FACTOR

Calculated or predicted design loads are compared to a baseline strength in computing the safety factor Conversely, the baseline strength is divided by the recommended safety factor to determine the allow- able design load. Table 6-4 provides the recommended factors of safety for use in designing towing systems Note that safety factors, for a given type design and service, are referenced to different baselines such as breaking strength, yield strength or proof load

For chain, safety factors are referred to as "proof load;' a load demonstrated as part of the manufacturing process which intentionally introduces a permanent stretch that improves the strength of the chain Proof load for chain is 66 percent of minimum break strength.

For other forged-type hardware, such as shackles, proof load is a load at which no permanent deformation is observed after the load is released This is important where the component must mate with other components or where the component has parts which must fit together In the case of shackles, it is important to be able to remove the pin after use. Unlike chain, however, there is no consistant relation- ship between proof load and breaking load.

The relationship depends upon the metallurgical properties of the material

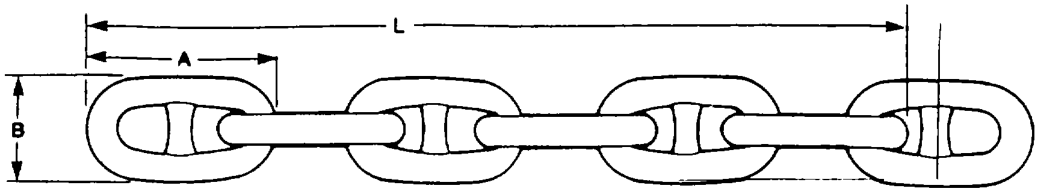
Safe Working Load (SWL) frequently is used for rigging components and systems including such material. The concept of SWL is similar to the use of a "safety factor," and is appropriate where the load is fairly well-known and dynamic loads are limited. The typical use of SWL is for lifting purposes The safety factor inherent m SWL for Navy safety shackles, compared to proof load, is 2 for Grade A and 2 5 for Grade B shackles. This is insufficient for use in towing systems where the dynamic loads are more difficult to predict than for simple rigging purposes However, applying the safety factors from Table 6-4 in addition to SWL is overly conservative and will result in unacceptably large components. Therefore, in designing towing systems for strenuous conditions, the safety factors listed m Table 6-4 for shackles should be applied to proof loads listed m Table D-9

As an example of the above, consider a predicted steady state tow resistance of 80,000 pounds. This is appropriate for a 2-inch fiber core towing hawser under automatic towing machine control Table 6-4 requires a safety factor of 3 for shackles. If this factor is applied to SWL, 4-inch Grade B safety shackles, weighing 310 pounds, would be required m the rig' Applying the required factor of safety to proof load requires more reasonable 22-mnch Grade B shackles

D-15 PLATE SHACKLES

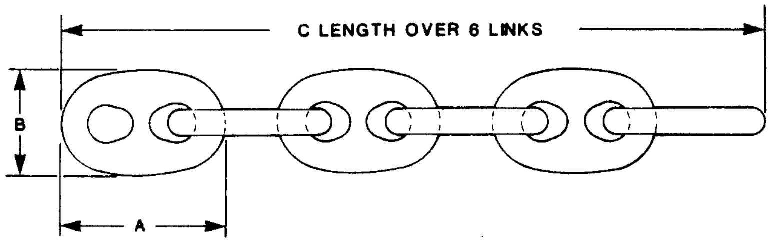
Plate shackles frequently are used in salvage and towing operations because they are simple, efficient and easily fabricated from commonly available materials Plate shackles are efficient because many connections of chain to wire and chain to chain would require two safety shackles, back-to-back, whereas one plate shackle will accomplish the task. The cheeks of towing plate shackles are fabricated from "medium" (ABS Grade A or ASTM A-36) steel, the most readily available classification, and the pins are fabricated from 150,000 psi minimum yield strength bar stock, also readily available. Appendix I includes drawings of plate shackles for use in towing. Certain salvage ships can be outfitted for heavy-lifting operations. In this case, stronger plate shackles than shown in Appendix I, may be required. Check the specific rigging plans for the specified shackles for heavy lifting

Table D-1. Die Lock Chain Characteristics (MIL-C-19944)



CHAIN SIZE Inches	CHAIN SIZE mm	Link Length A	Link Width B	Length Over Six Links C	Links Per 15 Fathom Shot	Links Per 15 Fathom Shot	Approx Weight Per Link	Proof Test in Pounds	Break Test in Pounds
TYPE I STANDARD									
3/4	19	4-1/2	2-5/8	19-1/2	359	490	1 4	48,000	75,000
7/8	22	5-1/4	3-1/8	22-3/4	305	680	2 2	64,000	98,000
1	25	6	3-3/16	26	267	890	3 3	84,000	129,000
1-1/8	29	6-3/4	4	29-1/4	237	1,130	4 8	106,000	161,000
1-1/4	32	7-1/2	4-1/2	32-1/2	213	1,400	6 6	130,000	198,000
1-3/8	34	8-1/4	4-13/16	35-3/4	193	1,690	8 8	157,000	235,000
1-1/2	38	9	5-3/8	39	177	2,010	11 4	185,000	280,000
1-5/8	42	9-3/4	5-7/8	42-1/4	165	2,325	14 1	216,000	325,000
1-3/4	44	10-1/2	6-3/16	45-1/2	153	2,695	17 6	249,000	380,000
1-7/8	48	11-3/4	6-3/4	48-3/4	143	3,095	21 6	285,000	432,000
2	51	12	7-3/16	52	135	3,490	25 9	289,800	439,200
2-1/8	54	12-3/4	7-5/8	55-1/4	125	3,935	31 5	325,800	493,200
2-1/4	58	13-1/2	8-1/8	58-1/2	119	4,415	37 1	362,700	549,000
2-3/8	60	14-1/4	8-3/16	61-3/4	113	4,915	43 5	402,300	607,500
2-1/2	64	15	9	65	107	5,475	51 2	442,800	669,600
2-5/8	67	15-3/4	9-3/16	68-1/4	101	6,050	59 9	486,000	731,700
2-3/4	70	16-1/2	9-7/8	71-1/2	97	6,660	68 7	531,000	796,500
2-7/8	73	17-1/4	10-3/8	74-3/4	93	7,295	78 4	576,000	868,500
3	76	18	10-13/16	78	89	7,955	89 4	623,700	940,500
3-1/8	79	18-3/4	11-1/4	81-1/4	87	8,700	100 0	673,200	1,015,200
3-1/4	83	19-1/2	11-11/16	84-1/2	83	9,410	113 4	723,700	1,089,000
3-3/8	86	20-1/4	12-1/8	87-3/4	79	10,112	128 0	776,000	1,166,400
3-1/2	90	21	12-5/8	91	77	10,900	141 6	829,800	1,244,800
3-3/4	95	22-1/2	13-3/8	97-1/2	71	12,500	176 1	1,008,000	1,575,000
4-3/4	121	28-1/2	17-1/8	122-1/2	57	20,500	359 7	1,700,000	2,550,000
TYPE II HEAVY DUTY									
2-3/4	70	16-1/2	9-7/8	71-1/2	97	7,000	72 2	584,100	882,900
3	76	18	10-13/16	78	89	8,100	91 0	685,800	1,035,000
3-1/2	90	21	12-5/8	91	77	12,000	155 8	97,200	1,530,000
TYPE III HIGH STRENGTH									
3/4	19	4-1/2	2-5/8	19-1/2	359	550	1 5	67,500	91,100
1	26	6	3-3/16	26	267	1,000	3 8	116,100	156,700
1-1/8	29	6-3/4	4	29-1/4	237	1,270	5 4	145,000	195,000
1-3/8	34	8-1/4	4-15/16	35-3/4	193	1,900	9 9	211,500	285,500
1-1/2	38	9	5-3/8	39	177	2,260	12 8	252,000	340,200
1-5/8	42	9-3/4	5-7/8	42-1/4	165	2,620	15 9	292,500	395,000

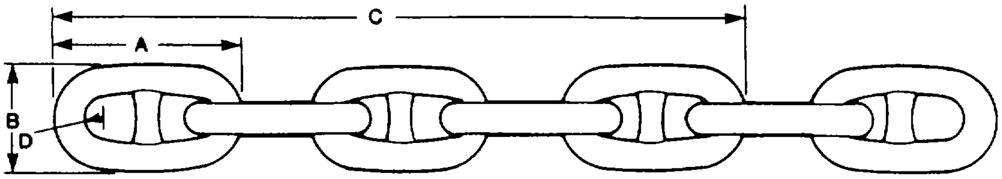
Table D-2. Navy Stud Link Chain Characteristics (MIL-C-24633)



Chain Size Inches	Link Length Inches (A)	Length Over 6 Links in Inches (L)			Link Width Inches (B)	Number of Links per 15-Fathom Shot	Proof Test Load (lb.)	Break Test Load (lb.)	Nominal Weight per 15-Fathom Shot (lb.)*
		Minimum	Nominal	Maximum					
3/4	4-1/2	19-3/8	19-1/2	19-13/16	2-5/8	359	48,000	75,000	480
7/8	5-1/4	22-5/8	22-3/4	23-1/16	3-1/8	305	64,400	98,000	660
1	6	25-7/8	26	26-3/8	3-9/16	267	84,000	129,000	860
1-1/8	6-3/4	29-1/16	29-1/4	29-5/8	4	237	106,000	161,000	1,080
1-1/4	7-1/2	32-5/16	32-1/2	32-15/16	4-1/2	213	130,000	198,000	1,350
1-3/8	8-1/4	35-9/16	35-3/4	36-1/4	4-15/16	193	157,000	235,000	1,630
1-1/2	9	38-13/16	39	39-1/2	5-3/8	177	185,000	280,000	1,940
1-5/8	9-3/4	42	42-1/4	42-7/8	5-7/8	165	216,000	325,000	2,240
1-3/4	10-1/2	45-1/4	45-1/2	46-1/8	6-5/16	153	249,000	380,000	2,590
1-7/8	11-1/4	48-1/2	48-3/4	49-1/2	6-3/4	143	285,000	432,000	2,980
2	12	51-11/16	52	52-3/4	7-3/16	135	318,800	454,000	3,360
2-1/8	12-3/4	54-15/16	55-1/4	56-1/8	7-5/8	125	357,000	510,000	3,790
2-1/4	13-1/2	58-3/16	58-1/2	59-3/8	8-1/8	119	396,000	570,000	4,250
2-3/8	14-1/4	61-7/16	61-3/4	62-3/4	8-9/16	113	440,000	628,000	4,730
2-1/2	15	64-11/16	65	66	9	107	484,000	692,000	5,270
2-5/8	15-3/4	67-7/8	68-1/4	69-1/4	9-7/16	101	530,000	758,000	5,820
2-3/4	16-1/2	71-1/8	71-1/2	72-9/16	9-7/8	97	578,000	826,000	6,410
2-7/8	17-1/4	74-3/8	74-3/4	75-7/8	10-3/8	93	628,000	897,000	7,020
3	18	77-5/8	78	79-3/16	10-13/16	89	679,000	970,000	7,650
3-1/8	18-3/4	80-13/16	81-1/4	82-1/2	11-1/4	87	732,000	1,046,000	8,320
3-1/4	19-1/2	84-1/16	84-1/2	85-3/4	11-11/16	83	787,000	1,124,000	9,010
3-3/8	20-1/4	87-5/16	87-3/4	89	12-1/8	79	843,000	1,204,000	9,730
3-1/2	21	90-9/16	91	92-5/16	12-5/8	77	900,000	1,285,000	10,500
3-5/8	21-3/4	93-13/16	94-1/4	95-5/8	12-15/16	73	958,000	1,369,000	11,300
3-3/4	22-1/2	97-1/16	97-1/2	98-7/8	13-3/8	71	1,019,000	1,455,000	12,000
3-7/8	23-1/4	100-1/4	100-3/4	102-3/16	14	69	1,080,000	1,543,000	12,900
4	24	103-1/2	104	105-1/2	14-3/8	67	1,143,000	1,632,000	13,700

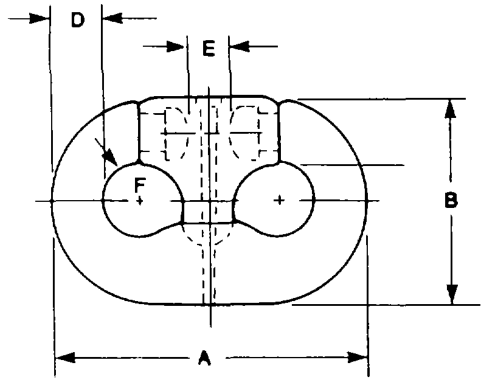
*Not mandatory, for information only.

Table D-3. Commercial Stud Link Anchor Chain



Chain Size Inches	Chain Size mm	Link Length (A)	Link Width (B)	Length Over Five Links (C)	Grip Radius (D)	Approx Weight per 15-Fathom Shot	No of Links per 15-Fathom Shot	ABS Grade 1 Proof Test	ABS Grade 1 Break Test	ABS Grade 2 Proof Test	ABS Grade 2 Break Test	ABS Grade 3 Proof Test	ABS Grade 3 Break Test
3/4	19	4-1/2	2-5/8	16-1/2	1/2	480	357	23,800	34,000	34,000	47,600	47,600	68,000
13/16	20	4-7/8	2-7/8	17-7/8	17/32	570	329	27,800	39,800	39,800	55,700	55,700	79,500
7/8	22	5-1/4	3-1/8	19-1/4	37/64	660	305	32,200	46,000	46,000	64,400	64,400	91,800
15/16	24	5-5/8	3-5/16	20-5/8	5/8	760	285	36,800	52,600	52,600	73,700	73,700	105,000
1	25	6	3-9/16	22	21/32	860	267	41,800	59,700	59,700	83,600	83,600	119,500
1-1/16	27	6-3/8	3-3/4	23-3/8	11/16	970	251	47,000	67,200	67,200	94,100	94,100	135,000
1-1/8	28	6-3/4	4	24-3/4	25/32	1,080	237	52,600	75,000	75,000	105,000	105,000	150,000
1-3/16	30	7-1/8	4-1/4	26-1/8	25/32	1,220	225	58,400	83,400	83,400	116,500	116,500	167,000
1-1/4	32	7-1/2	4-1/2	27-1/2	25/32	1,350	213	64,500	92,200	92,200	129,000	129,000	184,000
1-5/16	33	7-7/8	4-3/4	28-7/8	7/8	1,490	203	70,900	101,500	101,500	142,000	142,000	203,000
1-3/8	34	8-1/4	4-15/16	30-1/4	7/8	1,630	195	77,500	111,000	111,000	155,000	155,000	222,000
1-7/16	36	8-5/8	5-3/16	31-5/8	15/16	1,780	187	84,500	120,500	120,500	169,000	169,000	241,000
1-1/2	38	9	5-3/8	33	63/64	1,940	179	91,700	131,000	131,000	183,500	183,500	262,000
1-9/16	40	9-3/8	5-5/8	34-3/8	1-1/32	2,090	171	99,200	142,000	142,000	198,500	198,500	284,000
1-5/8	42	9-3/4	5-7/8	35-3/4	1-1/16	2,240	165	108,000	153,000	153,000	214,000	214,000	306,000
1-11/16	43	10-1/8	6-1/16	37-1/8	1-3/32	2,410	159	115,000	166,500	166,500	229,000	229,000	327,000
1-3/4	44	10-1/2	6-5/16	38-1/2	1-5/32	2,590	153	123,500	176,000	176,000	247,000	247,000	352,000
1-13/16	46	10-7/8	6-1/2	39-7/8	1-3/16	2,790	147	132,000	188,500	188,500	264,000	264,000	377,000
1-7/8	48	11-1/4	6-3/4	41-1/4	1-1/4	2,980	143	140,500	201,000	201,000	281,000	281,000	402,000
1-15/16	50	11-5/8	7	42-5/8	1-9/32	3,180	139	149,500	214,000	214,000	299,000	299,000	427,000
2	51	12	7-3/16	44	1-5/16	3,360	133	159,000	227,000	227,000	318,000	318,000	454,000
2-1/16	52	12-3/8	7-7/16	45-3/8	1-3/8	3,570	129	168,500	241,000	241,000	337,000	337,000	482,000
2-1/8	54	12-3/4	7-5/8	46-3/4	1-27/64	3,790	125	178,500	255,000	255,000	357,000	357,000	510,000
2-3/16	56	13-1/8	7-7/8	48-1/8	1-15/32	4,020	123	188,500	269,000	269,000	377,000	377,000	538,000
2-1/4	58	13-1/2	8-1/8	49-1/2	1-1/2	4,250	119	198,500	284,000	284,000	396,000	396,000	570,000
2-5/16	59	13-7/8	8-5/16	50-7/8	1-17/32	4,490	117	209,000	299,000	299,000	418,000	418,000	598,000
2-3/8	60	14-1/4	8-9/16	52-1/4	1-9/16	4,730	113	212,000	314,000	314,000	440,000	440,000	628,000
2-7/16	62	14-5/8	8-3/4	53-5/8	1-5/8	4,960	111	231,000	330,000	330,000	462,000	462,000	660,000
2-1/2	64	15	9	55	1-5/8	5,270	107	242,000	346,000	346,000	484,000	484,000	692,000
2-9/16	66	15-3/8	9-1/4	56-3/8	1-11/16	5,540	105	254,000	363,000	363,000	507,000	507,000	726,000
2-5/8	67	15-3/4	9-7/16	57-3/4	1-11/16	5,820	103	265,000	379,000	379,000	530,000	530,000	758,000
2-11/16	68	16-1/8	9-11/16	59-1/8	1-3/4	6,110	99	277,000	396,000	396,000	554,000	554,000	792,000
2-3/4	70	16-1/2	9-7/8	60-1/2	1-13/16	6,410	97	289,000	413,000	413,000	578,000	578,000	826,000
2-13/16	71	16-7/8	10-1/8	61-7/8	1-27/32	6,710	95	301,000	431,000	431,000	603,000	603,000	861,000
2-7/8	73	17-1/4	10-3/8	63-1/4	1-7/8	7,020	93	314,000	449,000	449,000	628,000	628,000	897,000
2-15/16	75	17-5/8	10-9/16	64-5/8	1-7/8	7,330	91	327,000	467,000	467,000	654,000	654,000	934,000
3	76	18	10-13/16	66	2	7,650	89	340,000	485,000	485,000	679,000	679,000	970,000
3-1/16	78	18-3/8	11	67-3/8	2	7,980	87	353,000	504,000	504,000	705,000	705,000	1,008,000
3-1/8	79	18-3/4	11-1/4	68-3/4	2-1/16	8,320	85	366,000	523,000	523,000	732,000	732,000	1,046,000
3-3/16	81	19-1/8	11-1/2	70-1/8	2-1/16	8,660	85	380,000	542,000	542,000	759,000	759,000	1,084,000
3-1/4	83	19-1/2	11-11/16	71-1/2	2-1/8	9,010	83	393,000	562,000	562,000	787,000	787,000	1,124,000
3-5/16	84	19-7/8	11-15/16	72-7/8	2-1/8	9,360	81	407,000	582,000	582,000	814,000	814,000	1,163,000
3-3/8	86	20-1/4	12-1/8	74-1/4	2-3/16	9,730	79	421,000	602,000	602,000	843,000	843,000	1,204,000
3-7/16	87	20-5/8	12-3/8	75-5/8	2-3/16	10,100	77	435,000	622,000	622,000	871,000	871,000	1,244,000
3-1/2	90	21	12-5/8	77	2-5/16	10,500	77	450,000	643,000	643,000	900,000	900,000	1,285,000
3-5/8	92	21-3/4	12-15/16	79-3/4	2-5/16	11,300	73	479,000	685,000	685,000	958,000	958,000	1,369,000
3-3/4	95	22-1/2	13-3/8	82-1/2	2-15/32	12,000	71	509,000	728,000	728,000	1,019,000	1,019,000	1,455,000
3-7/8	98	23-1/4	14	85-1/4	2-15/32	12,900	69	540,000	772,000	772,000	1,080,000	1,080,000	1,543,000
4	102	24	14-3/8	88	2-5/8	13,700	67	571,000	816,000	816,000	1,143,000	1,143,000	1,632,000
4-1/8	105	24-3/4	14-7/8	90-3/4	2-11/16	14,600	65	603,000	862,000	862,000	1,207,000	1,207,000	1,724,000
4-1/4	108	25-1/2	15-5/16	93-1/2	2-3/4	15,400	63	636,000	908,000	908,000	1,272,000	1,272,000	1,817,000
4-3/8	111	26-1/4	15-3/4	96-1/4	2-7/8	16,200	61	669,000	956,000	956,000	1,338,000	1,338,000	1,911,000
4-1/2	114	27	16-3/16	99	2-15/16	17,100	59	703,000	1,000,400	1,000,400	1,405,000	1,405,000	2,008,000

Table D-4. Commercial Detachable Chain Connecting Link.



Chain Size		A	B	C	D	E	F	Proof Test	Break Test	Weight per Link (lbs)
Inches	mm									
3/4	19	4-1/2	3	1-3/64	3/4	27/32	1/2	67,500	91,100	2 1
13/16- 7/8	21–22	5-1/4	3-1/2	1-7/32	7/8	63/64	19/32	88,200	119,000	3 4
15/16-1	24–25	5	4	1-25/64	1	1-1/8	21/32	116,110	156,700	5 1
1-1/16-1-1/8	27-28	6-3/4	4-1/2	1-9/16	1-1/8	1-17/64	47/64	145,000	195,000	7 2
1-3/16-1-1/4	30–32	7-1/2	5	1-47/64	1-1/4	1-13/32	13/16	178,200	240,600	9 9
1-5/16-1-3/8	33–34	8-1/4	5-1/2	1-29/32	1-3/8	1-35/64	29/32	211,500	285,500	13 3
1-7/16-1-1/2	36–38	9	6	2-5/64	1-1/2	1-11/16	83/84	252,000	340,200	17 3
1-9/16-1-5/8	40–42	9-3/4	6-1/2	2-1/4	1-5/8	1-63/64	1-1/16	292,500	395,000	22 0
1-11/16-1-3/4	43–44	10-1/2	7-1/2	2-7/16	1-3/4	2	1-3/16	352,000	476,000	27 5
1-3/16-1-7/8	46–48	11-1/4	7-1/4	2-1/2	1-7/8	2-5/32	1-1/4	285,000	432,000	32
1-15/16-2	50–51	12	7-3/4	2-1/2	2	2-5/16	1-5/16	322,000	488,000	36
2-1/16-2-1/8	52–54	12-3/4	8-1/4	2-21/32	2-1/8	2-1/2	1-13/32	362,000	548,000	44
2-3/16-2-1/4	56–58	13-1/2	8-23/32	2-13/16	2-1/4	2-5/8	1-1/2	403,000	610,000	52
2-5/16-2-3/8	59–60	14-1/4	9-7/32	3-1/16	2-3/8	2-3/4	1-9/16	447,000	675,000	61
2-9/16-2-5/8	66–67	15-3/4	10-3/16	3-1/4	2-5/8	3-1/16	1-3/4	540,000	813,000	82
2-11/16-2-3/4	68–70	16-1/2	10-13/16	3-11/16	2-7/8	3-1/4	1-13/16	649,000	981,000	100
2-13/16-2-7/8	71–73	17-1/4	11-1/8	3-19/32	2-7/8	3-11/32	1-29/32	640,000	965,000	107
2-5/16-3	75–76	18	11-5/8	3-3/4	3	3-17/72	1-31/32	693,000	1,045,000	120
3-1/16-3-1/8	78–79	18-3/4	12-1/8	4	3-1/8	3-5/8	2-3/64	748,000	1,128,000	138
3-3/16-3-1/4	81–83	19-1/2	12-5/8	4-1/16	3-1/4	3-5/8	2-5/32	804,100	1,210,000	161
3-5/16-3-3/8	84–86	20-1/4	13-3/32	4-7/32	3-3/8	3-15/16	2-1/4	862,200	1,296,000	177
3-7/16-3-1/2	87–89	21-1/8	13-25/32	4-13/16	3-3/4	4-1/8	2-13/32	1,080,000	1,700,000	205
3-9/16-3-5/8	90–92	21-3/4	14	4-9/16	3-5/8	4-3/16	2-5/16	1,021,100	1,566,000	215
3-11/16-3-3/4	94–95	22-1/2	14-1/2	4-11/16	3-3/4	4-11/16	2-7/16	1,120,000	1,750,000	256
3-1/16-3-7/8	97–98	23-1/4	15	5	3-7/8	4-1/2	2-5/8	1,205,000	1,863,400	271
3-7/16-4	100–102	24	16-1/2	5-3/16	4	4-5/8	2-11/16	1,298,000	1,966,000	288
4-1/8	105	24-3/4	16-1/2	5-7/8	4-1/8	5	2-25/32	1,347,000	2,062,500	384
4-1/4	108	25-1/2	17-3/8	6-1/2	4-3/8	5-1/4	2-7/8	1,393,700	2,134,000	422
4-3/8	111	26-1/4	18-3/8	7-1/4	4-1/2	5-5/8	2-15/16	1,569,700	2,398,000	460
4-1/2	114	27	19-3/8	8	4-5/8	6	3	1,672,000	2,508,000	500

All specifications in pounds and inches, unless otherwise stated

Table D-5. Commercial Detachable Anchor Connecting Link

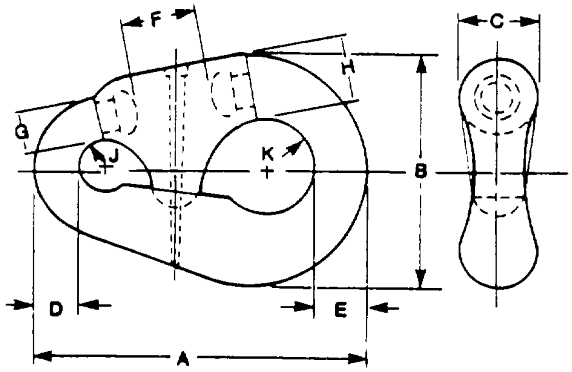


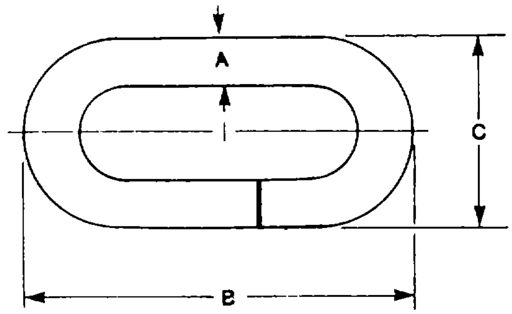
TABLE D-5. COMMERCIAL DETACHABLE ANCHOR-CONNECTING LINK

Small End Chain Size			A	B	C	D	E	F	G
No	Inches	mm							
2	3/4–15/16	19–24	7-5/8	5-3/16	1-1/2	15/16	1-1/4	2-1/4	15/16
3	1-1-3/16	25–30	9-3/8	6-9/16	1-13/16	1-3/16	1-1/2	2-19/32	1-5/16
4	1-1/4–1-9/16	32–40	11-3/4	8-1/8	2-5/16	1-9/16	1-7/8	3-1/4	1-9/16 x 1-3/4
5	1-5/8–2	42–51	14-7/8	10-1/4	3	2	2-1/2	3-15/16	2-15/16 x 2-3/8
6	2-1/16–2-3/8	52–60	17-7/8	12-5/16	3-5/8	2-3/8	3	4-3/4	2-7/16 x 2-7/8
7	2-7/16–3-1/8	62–79	22-1/8	14-13/16	4-5/8	3-1/8	3-3/4	5-7/8	3-3/8 x 3-1/8
8	3-3/16–3-5/8	81–92	25-3/4	16-1/2	5-1/4	3-5/8	4-7/8	5-7/8	4-3/8 x 4
9	3-11/16–3-3/4	94–95	27-1/4	17-1/8	5-3/4	3-7/8	5-1/8	6-1/4	4-7/8 x 5-3/8
10	3-13/16–4	97–102	35	22-1/2	7-1/2	4-3/4	6-1/2	7-1/2	5-1/8
11	4-1/16–4-1/4	103-108	37	24	8	5	6-7/8	8	6-1/8

Small End Chain Size			H	J	K	Proof Test	Break Test	Weight per Link (lbs)
No	Inches	mm						
2	3/4– 15/16	19–24	1-3/8	21/32	1-3/16	74,000	113,500	7
3	1-1-3/16	25–30	1-3/4	3/4	1-3/8	118,000	179,500	14
4	1-1/4–1-9/16	32–40	2-7/32	1-1/32	1-11/16	200,500	302,500	28
5	1-5/8–2	42–51	2-29/32	1-1/4	2-1/16	322,000	488,000	60
6	2-1/16–2-3/8	52–60	3-15/32	1-15/32	2-17/32	447,000	675,000	107
7	2-7/16–3-1/8	62–79	4-3/8	1-29/32	3	748,000	1,128,000	208
8	3-3/16–3-5/8	81–92	5-1/8 x 5-1/4	2-1/8	3-1/8	1,021,000	1,566,000	328
9	3-11/16–3-3/4	94–95	5-9/16	2-1/4	3-1/4	1,120,000	1,750,000	520
10	3-13/16–4	97–102	7-1/8	2-7/8	4-1/4	1,298,000	1,996,500	850
11	4-1/16–4-1/4	103–108	7-7/8	3	4-3/8	1,440,000	2,220,000	920

All specifications in pounds and inches, unless otherwise stated
See Figures D-2 and D-3 for hairpin locking details

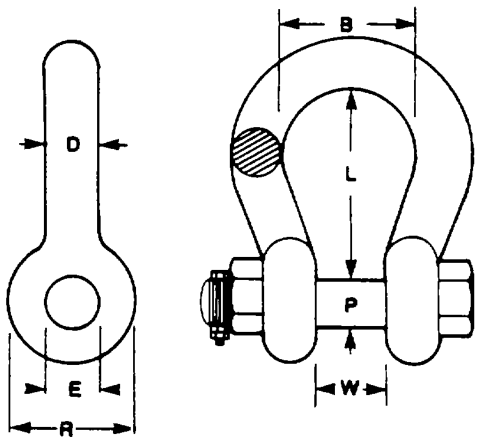
Table D-6. Commercial End Link.



Chain Size		A	B	C	Weight per Link (lbs)	Proof Test
Inches	mm					
11/16- 3/4	17-19	13/16	5-5/8	2-7/8	1 8	48,000
13/16-1	21-25	1-1/16	7-1/2	3-3/4	4 0	84,000
1-1/16-1-1/4	27-32	1-3/8	9-3/8	4-7/8	8 0	130,000
1-5/16-1-1/2	33-38	1-5/8	11-1/4	5-3/4	14 2	185,000
1-9/16-1-3/4	40-44	1-7/8	13	6-5/8	21 6	249,000
1-13/16-2	46-51	2-1/8	15	7-5/8	34 2	322,000
2-1/16-2-1/4	52-58	2-1/2	16-7/8	8-3/4	45 4	403,000
2-5/16-2-1/2	59-64	2-3/4	18-3/4	9-3/4	62 0	492,000
2-9/16-2-3/4	66-70	3	20-1/2	10-3/4	81 0	590,000
2-13/16-3	71-76	3-1/4	22-1/2	11-5/8	105 0	693,000
3-1/16-3-3/8	78-86	3-5/8	25-1/4	13	148 0	862,200
3-7/16-3-3/4	87-95	4	28	14-1/2	202 0	1,120,000
3-13/16-4	97-102	4-1/4	30	15-1/4	258 0	1,298,000

All specifications in pounds and inches, unless otherwise stated

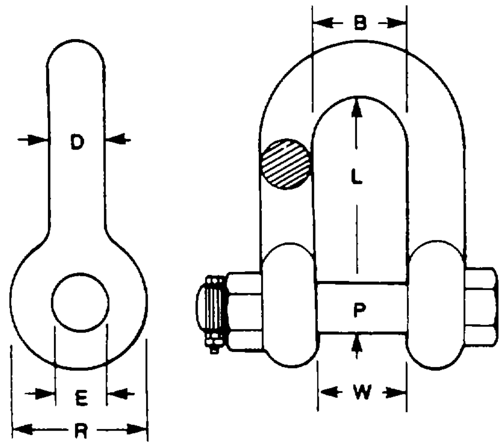
Table D-7. Type I, Class 3 Safety Anchor Shackle (MIL-S-24214A (SHIPS))



Size (D) Minimum	Diameter Bolt (P) Minimum	Diameter Inside Eye (E) Maximum	Width between eyes (W)		Length inside (L)		Width Minimum	Diameter Outside Eye (R) Maximum	Approx Weight per 100 Shackles
			Nominal	Tolerance (+)	Nominal	Tolerance (+)			
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
1/2	5/8	23/32	13/16	1/16	1-7/8	1/8	1-3/16	1-3/8	82
5/8	3/4	27/32	1-1/16	1/16	2-13/32	1/8	1-1/2	1-7/8	158
3/4	7/8	31/32	1-1/4	1/16	2-27/32	1/4	1-3/4	2-1/8	280
7/8	1	1-3/32	1-7/16	1/16	3-5/16	1/4	2	2-3/8	395
1	1-1/8	1-7/32	1-11/16	1/16	3-3/4	1/4	2-5/16	2-5/8	560
1-1/8	1-1/4	1-11/32	1-13/16	1/16	4-1/4	1/4	2-5/8	2-7/8	785
1-1/4	1-3/8	1-15/32	2-1/32	1/16	4-11/16	1/4	2-7/8	3-1/4	1,120
1-3/8	1-1/2	1-5/8	2-1/4	1/8	5-1/4	1/4	3-1/4	3-1/2	1,520
1-1/2	1-5/8	1-3/4	2-3/8	1/8	5-3/4	1/4	3-3/8	3-3/4	1,950
1-5/8	1-3/4	1-7/8	2-5/8	1/8	6-1/4	1/4	4	4-1/8	2,410
1-3/4	2	2-5/32	2-7/8	1/8	7	1/4	4-1/2	4-1/2	3,130
2	2-1/4	2-13/32	3-1/4	1/8	7-3/4	1/2	5-1/4	5-1/4	4,630
2-1/4	2-1/2	2-21/32	3-7/8	1/8	9-1/4	1/2	5-1/2	5-3/4	5,650
2-1/2	2-3/4	2-29/32	4-1/8	1/8	10-1/2	1/2	6-3/4	6-1/4	9,400
3	3-1/4	3-13/32	5	1/8	13	3/4	7-3/8	6-3/4	14,500
3-1/2	3-3/4	3-29/32	5-3/4	1/4	15	3/4	9	8-1/2	25,000
4	4-1/4	4-13/32	6-1/2	1/4	17	3/4	10-1/2	9-1/2	35,800

See Table D-9 for Shackle strengths

Table D-8. Type II, Class 3 Safety Chain Shackle (MIL-S-24214A (SHIPS)).



Size (D) Minimum	Diameter Bolt (P) Minimum	Diameter Inside Eye (E) Maximum	Width between eyes (W) Nominal	Width between eyes (W) Tolerance (+)	Length inside (L) Nominal	Length inside (L) Tolerance (+)	Diameter Outside Eye (R) Maximum	Approx Weight per 100 Shackles
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
1/2	5/8	23/32	13/16	1/16	1-5/8	1/8	1-3/8	76
5/8	3/4	27/32	1-1/16	1/16	2	1/8	1-7/8	156
3/4	7/8	31/32	1-1/4	1/16	2-3/8	1/4	2-1/8	262
7/8	1	1-3/32	1-7/16	1/16	2-13/16	1/4	2-3/8	365
1	1-1/8	1-7/32	1-11/16	1/16	3-3/16	1/4	2-5/8	535
1-1/8	1-1/4	1-11/32	1-13/16	1/16	3-9/16	1/4	2-7/8	727
1-1/4	1-3/8	1-15/32	2-1/32	1/16	3-15/16	1/4	3-1/4	1,020
1-3/8	1-1/2	1-5/8	2-1/4	1/8	4-7/16	1/4	3-1/2	1,335
1-1/2	1-5/8	1-3/4	2-3/8	1/8	4-7/8	1/4	3-3/4	1,850
1-5/8	1-3/4	1-7/8	2-5/8	1/8	5-1/4	1/4	4-1/8	2,310
1-3/4	2	2-5/32	2-7/8	1/8	5-3/4	1/4	4-1/2	2,850
2	2-1/4	2-13/32	3-1/4	1/8	6-3/4	1/2	5-1/4	4,110
2-1/2	2-3/4	2-29/32	4-1/8	1/8	8	1/2	6-1/4	8,450
3	3-1/4	3-13/32	5	1/8	9	3/4	6-3/4	12,300
3-1/2	3-3/4	3-29/32	5-3/4	1/4	10-1/2	3/4	8-1/2	21,800
4	4-1/4	4-13/32	6-1/2	1/4	12	3/4	9-1/2	31,000

See Table D-9 for Shackle Strengths

Table D-9. Mechanical Property of Shackles (MIL-S-24214A (SHIPS)).

Size D	Recommended Safe Working Load (Maximum)		Proof Load (Maximum)		Breaking Load (Minimum)	
Inches	Pounds		Pounds		Pounds	
	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
3/16	520	900	1,040	2,250	2,600	4,500
1/4	710	2,000	1,420	5,000	3,550	10,000
5/16	1,060	3,120	2,120	7,800	5,300	15,600
3/8	1,590	3,800	3,180	9,500	7,950	19,000
7/16	2,170	5,180	4,340	12,950	10,850	25,900
1/2	2,830	6,500	5,660	16,250	14,150	32,500
5/8	4,420	10,000	8,840	25,000	22,100	50,000
3/4	6,360	13,800	12,720	34,500	31,800	69,000
7/8	8,650	18,700	17,300	46,750	43,250	93,500
1	11,310	24,400	22,620	61,000	56,550	122,000
1-1/8	13,360	28,600	26,720	71,500	66,800	143,000
1-1/4	16,500	36,000	33,000	90,000	82,500	180,000
1-3/8	19,800	41,400	39,600	103,500	99,800	207,000
1-1/2	23,740	48,800	47,480	122,000	118,700	244,000
1-5/8	27,900	57,400	55,800	143,500	139,500	287,000
1-3/4	32,320	65,000	64,640	162,500	161,600	325,000
2	42,220	85,040	84,440	212,600	211,100	425,200
2-1/4	54,000	—	108,000	—	270,000	—
2-1/2	67,600	121,400	135,200	303,500	338,000	607,000
3	96,200	150,000	192,400	375,000	481,000	750,000
3-1/2	131,100	200,000	262,200	500,000	655,500	1,000,000
4	171,140	260,000	342,280	650,000	855,700	1,300,000

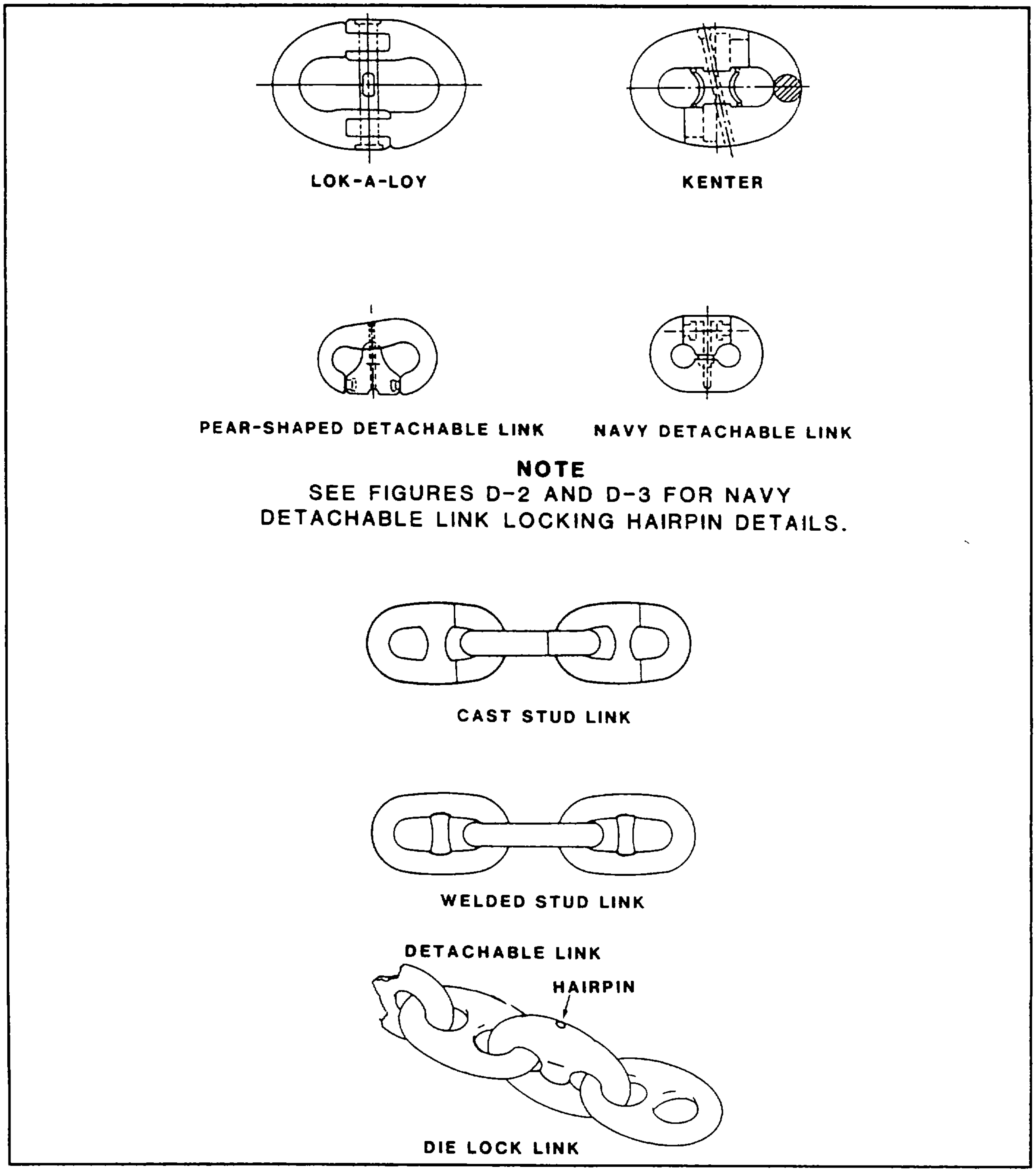


FIGURE D-1. Types of Chains and Connecting Links.

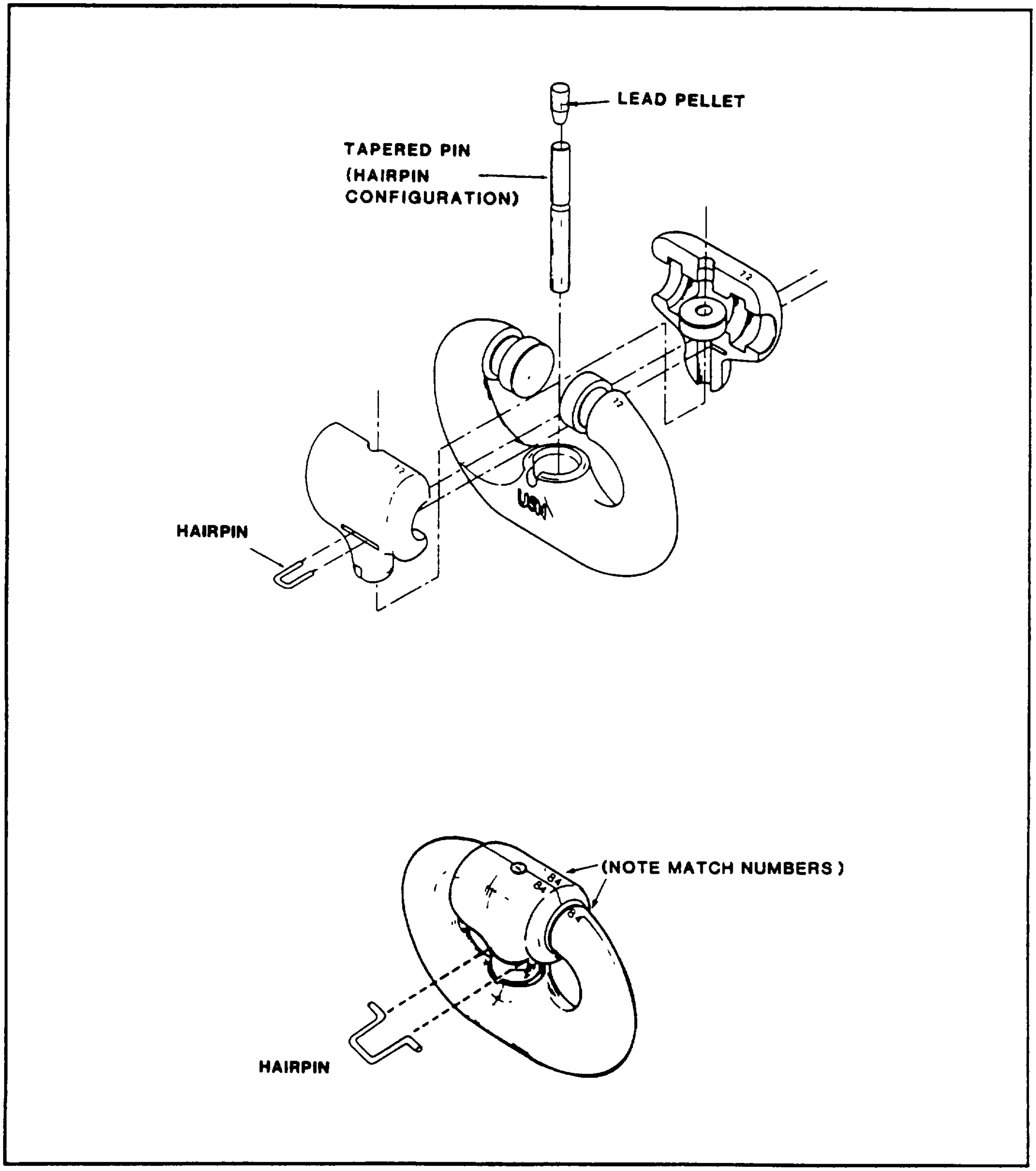
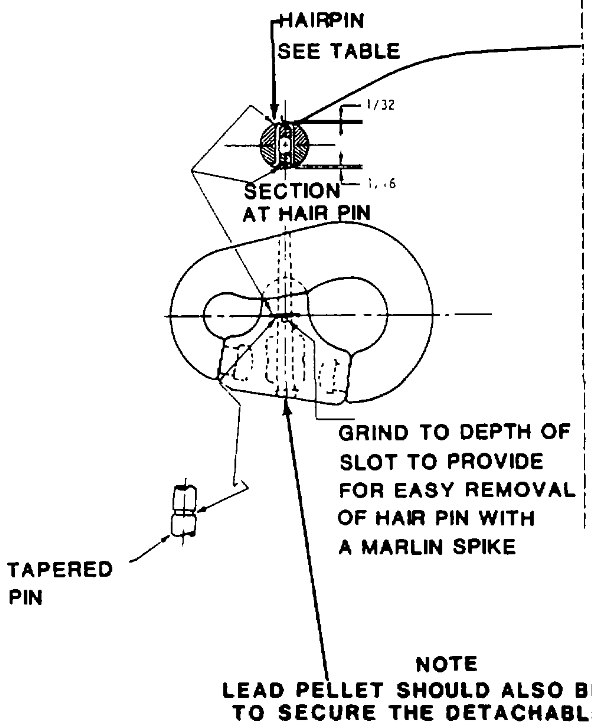
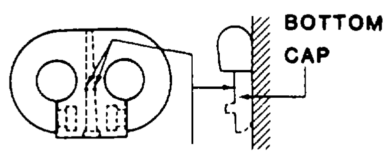


Figure D-2. Detachable Line with Identifying Marks for Assembly.



HAIRPIN DATA

Detachable Size	Hairpin Diameter	Cut Length
3/4 - 15/16 P S	3/32	4
1-1/8 H S	3/32	4-5/8
1-3/8 H S	1/8	5-1/2
1-5/8 H S	1/8	6-5/8
1-11/16 - 1-7/8	3/16	7
1-15/16 - 2	3/16	7-1/2
2-9/16 - 2-5/8	1/4	9
1 H S	3/32	4-3/8
1-1/8 H S	3/32	4-5/8
1-3/8 H S	1/8	5-1/2
1-5/8 H S	1/8	6-5/8
1-3/4 H S	3/16	7
2-3/16 - 2-1/4	1/4	8
1-1/8 H S	3/32	4-5/8
1-3/8 H S	1/8	5-1/8
1-3/4 H S	3/16	7
1-7/8	3/16	1-1/2
2-1/4	1/4	9
2-7/8	5/16	12
1 - 1-3/16 P S	1/8	4-7/8
1-1/4 - 1-9/16 P S	5/32	6-1/8
1-5/8 - 2 P S	1/4	8
2-1/16 - 2-3/8 P S	1/4	9-5/8
2-7/16 - 3-1/8 P S	5/16	12-1/4



STEP 1. LOCATE AND DRILL PILOT HOLES IN BOTTOM CAP

STEP 2. ASSEMBLE CAPS WITH PIN AND DRILL THROUGH PILOT HOLES TO SUIT

STEP 3. SLOT CAPS AS INDICATED

STEP 4. GROOVE TAPERED PIN TO SUIT HAIRPIN

Figure D-3. Typical Method for Modifying Detachable Chain Connecting Links for Hairpin Installation.

APPENDIX E

STOPPERS

E-1 INTRODUCTION

The term "stopper,” as used in seamanship, describes a device or rigging arrangement that is used to temporarily hold a part of running rigging or ground tackle that is, or may come, under tension. The stopper is an indispensable tool in a towing operation.

E-2 TYPES OF STOPPERS

There are many types of stoppers and methods of attaching them to the tension members that are to be stopped off. Most stoppers cannot be released under load, and require the held line to be heaved in to slack the stopper and allow its removal. On the other hand, some stoppers, such as the pelican hook and carpenter stopper, can be released when under load.

There is no single "best" type of stopper for all situations. However, for the three basic types of tension members-chain, fiber line and wire rope- the following is recommended:

a. Chain The attachment to a tension member should be made by means of a suitably-sized, jaw-type chain stopper . See Figure 3-22

b. Fiber Line . Fiber line always should be stopped off with fiber stoppers

c Wire Rope Stopping a wire rope can be accomplished with a carpenter stopper, Klein grip, chain stopper or fiber stopper using Kevlar

E-3 PREVENTION OF DAMAGE

When passing a stopper, a major consideration is prevention of damage to the tension member that is being stopped off This priority is second only to safety of personnel.

A dedicated towing ship's towing hawser is its "main battery" If the towing hawser is damaged, the ship essentially is out of action

Properly using a stopper on a towing hawser entails considerably more than merely passing the stopper It requires very close coordination between the Conning Officer on the bridge and the Boatswaiun's Mate in charge of the stopper-passing evolution on the fantail.

E-4 STOPPING OFF A WIRE TOWING HAWSER

WARNING

Never pass a stopper on a tension member that is under a strain greater than the safe working load of the stopper, or on a tension member that might be subjected to a heavier loading condition while the stopper is in place.

A properly-fitted carpenter stopper should always be used when stopping off a wire rope towing hawser. See technical manual on carpenter stoppers (Ref. 24)

In a situation where a carpenter stopper is not readily available, the hawser can be stopped off with a chain . If a chain stopper is selected, great care must be exercised so as to prevent damage to the hawser

E-5 SYNTHETIC LINE

In recent years synthetic fiber line has replaced virtually all large natural fiber line in the Navy. Synthetic fiber has many good qualities, such as its superior strength and elasticity.

Its prime weakness when compared to other types of tension members is its susceptibility to physical damage . It is very intolerant of mechanical mistreatment such as cutting by sharp objects, melting of the fibers due to friction or abrading by rough surfaces. Damage of all three types may occur from the action of a poorly-passed stopper.

When stopping off a synthetic towing hawser, a synthetic fiber stopper should be used.

E-6 STOPPER BREAKING STRENGTH

Ideally, the strength of the passed stopper would be equal to the strength of the tension member, thus eliminating the stopper as the weak link in the system.

When stopping off relatively small lines such as fiber boat falls, this ideal strength condition may be achieved.

The prime factor limiting breaking strength of a large stopper is the physical size that can be manually handled by the deck seaman. As an example, a stop- per of 1/2-inch chain can be passed fairly easily and one of 3/4-inch chain with some difficulty. However, if one were to try to match the breaking strength of a large towing hawser of 2- to 2 1/2-inch wire, he might come up with a stopper of 1 1/2-inch or 2-inch chain. From an engineering point of view, the numbers would match up, but from a practical seamanship point of view the deck force would be faced with an impossible task.

In cases of heavy rigging, the stopper indeed becomes the weak link. Thus, all personnel who are involved in a towing hawser/stopper passing evolution must be aware of inherent dangers.

During the period the stopper is in use on the towing hawser or pendant, the Conning Officer should not increase speed or radically change course without first notifying the afterdeck of his intention, and requesting concurrence from the Afterdeck Supervisor that it is safe to do so. Direct communication between the deck work area and the bridge is mandatory.

The Conning Officer should be well-versed in the use of stoppers, especially concerning their applications and limitations.

E-7 FIBER STOPPERS

Fiber stoppers, shown in Figure E-1, are the simplest and most commonly used type of stopper.

One version, called a rat tall stopper, may be merely a length of fiber line with an eye in one end, with the section of the stopper that is to make contact with the tension member flattened.

When using a 3-strand line, this flattening is accomplished by passing a seizing, unlaying the line and then weaving it back together m a 3-strand braid.

In the case of double-braided line, the flattening may be accomplished by shipping the cover back and removing a section of the core.

E-8 STOPPER HITCHES

Attaching the stopper to the tension member may be accomplished by any one of a number of methods, such as:

a. A rolling hitch backed up with half hitches (see Figure E-1).
b A long series of half hitches, known as a crossover or Chinese stopper (see Figure E-2).
c. A series of crisscrosses formed by weaving the stoppers over and under the tension member (see Figures E-3 and E-4)--this method is the most preferred.
d. Two long series of half hitches formed by half hitching a double stopper to the hawser (see Figure E-5).
e. Any desirable number of combination of the above.

There is no universal best stopper hitch. The decision as to which hitch arrangement to use is dependent upon the size and composition of the line to be stopped, the size and composition of the available stoppers and the personal.

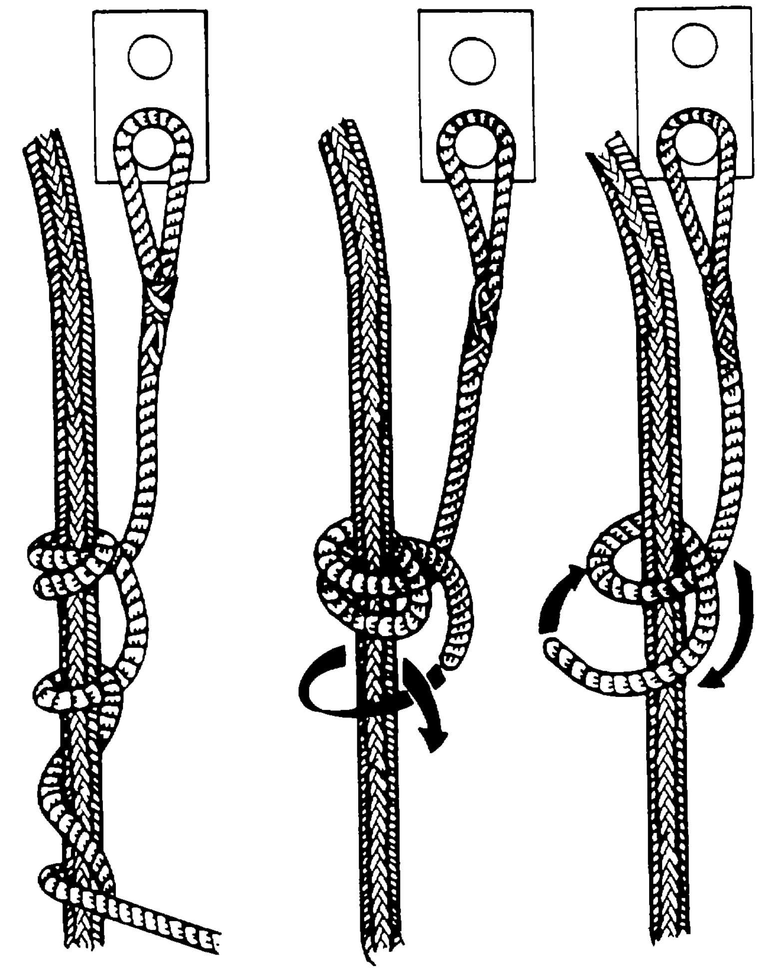


Figure E-1. Typical Stopper.

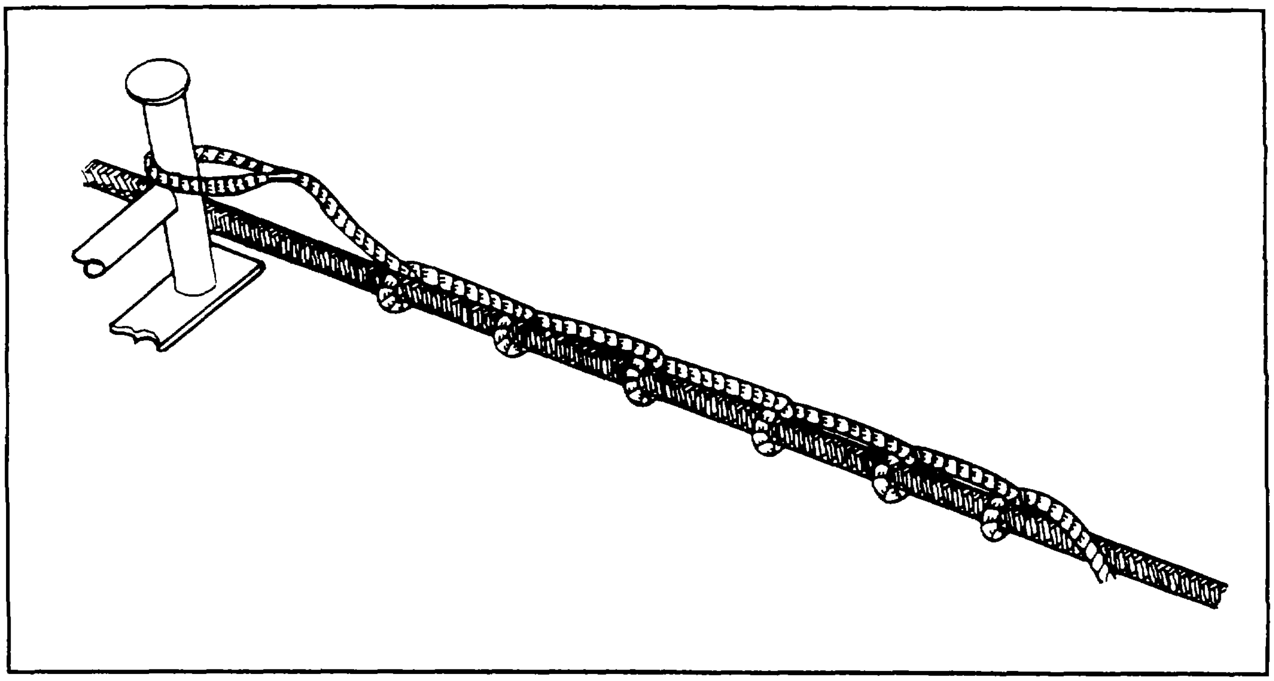


Figure E-2. Half Hitches.

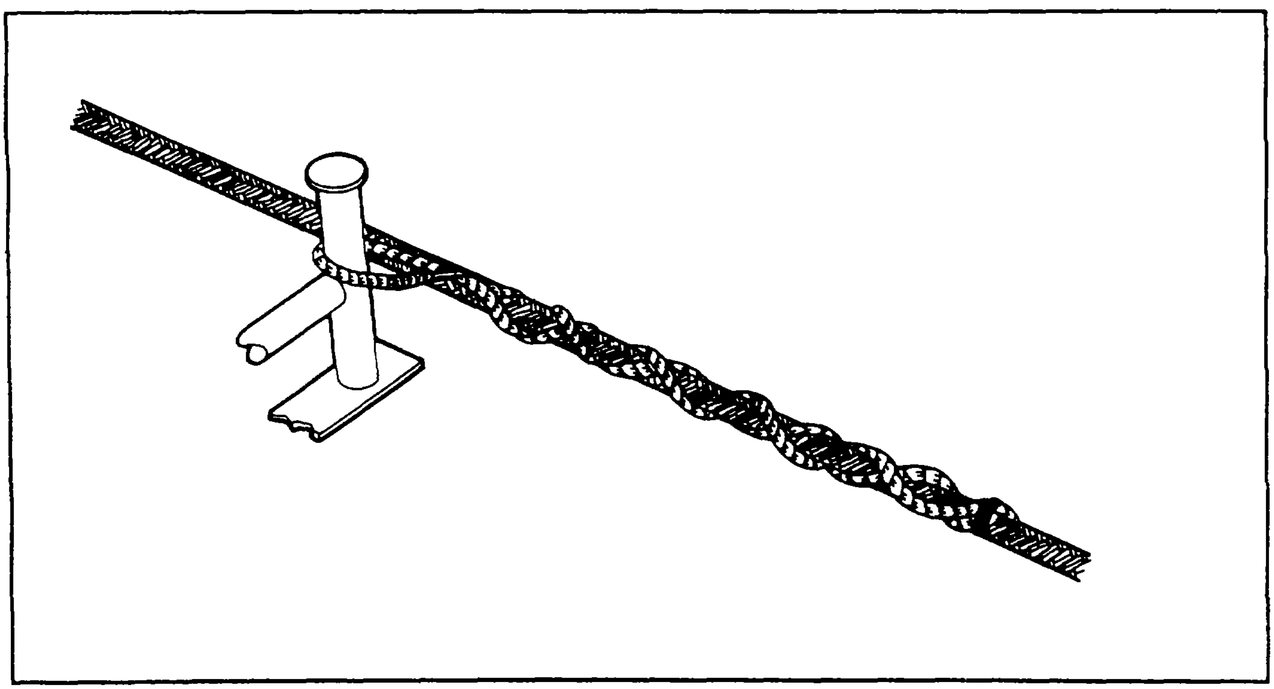


Figure E-3. Crisscross Fiber Stopper.

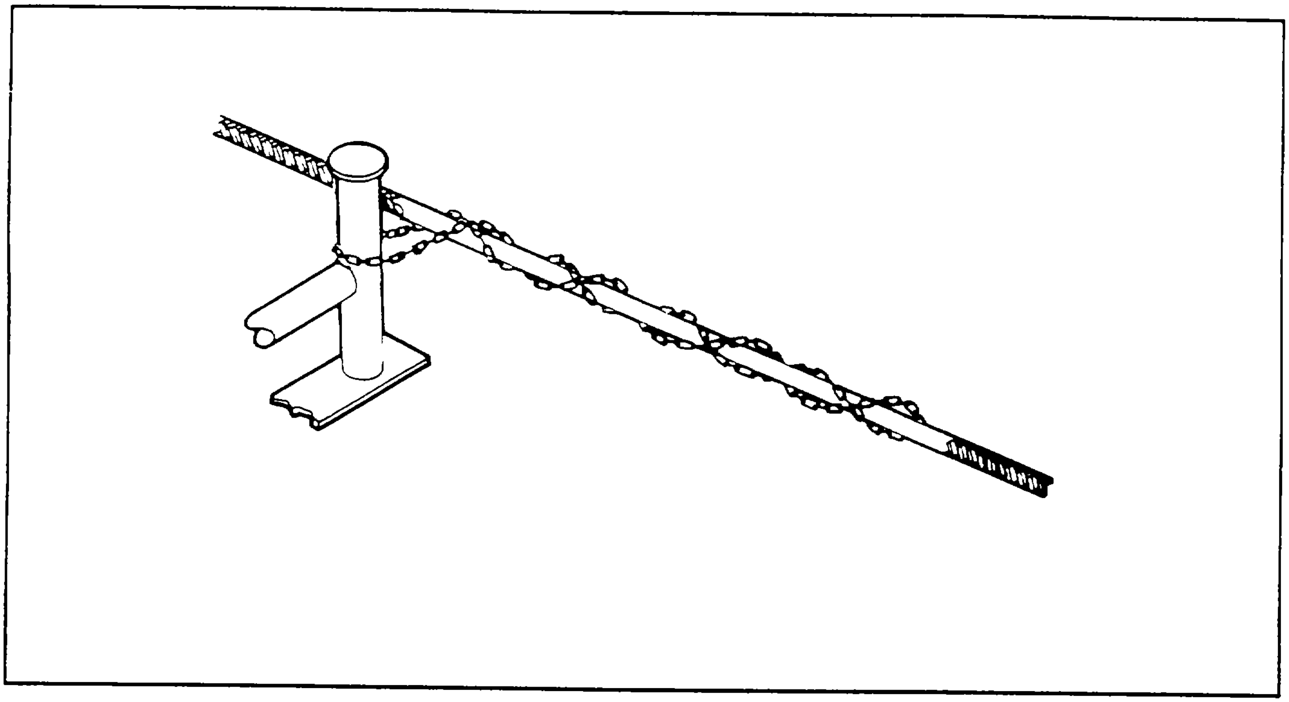


Figure E-4. Crisscross Chain Stopper.

preference and judgment of the Boatswain's Mate in charge.

E-9 SECURING THE PASSED STOPPER

When securing a passed stopper to a part of relatively small, low-tension rigging, such as a boat fall, the end of the stopper is usually held in place by hand.

To secure a passed stopper to a large tension member, such as a towing hawser, the ends of the stopper should be securely seized to the hawser with small stuff.

E-10 SETTING THE STOPPER

Once the stopper is m place and all personnel are safely out of the way, the tension member should be very slowly and carefully eased out. This should continue until a determination can be made whether the stopper is holding or not This critical determination normally is made by the Boatswain's Mate.

If the stopper is slipping, or shows any indication that it might slip, the stopper should be removed and re-attached.

The Conning Officer must be made aware of any overloading of a towing hawser stopper so that he may take corrective action, such as easing the tension by slowing or stopping the ship.

E-11 NEW TYPE SYNTHETIC LINE STOPPER

Stoppers made of Kevlar are now available and are acceptable for use on fiber line.

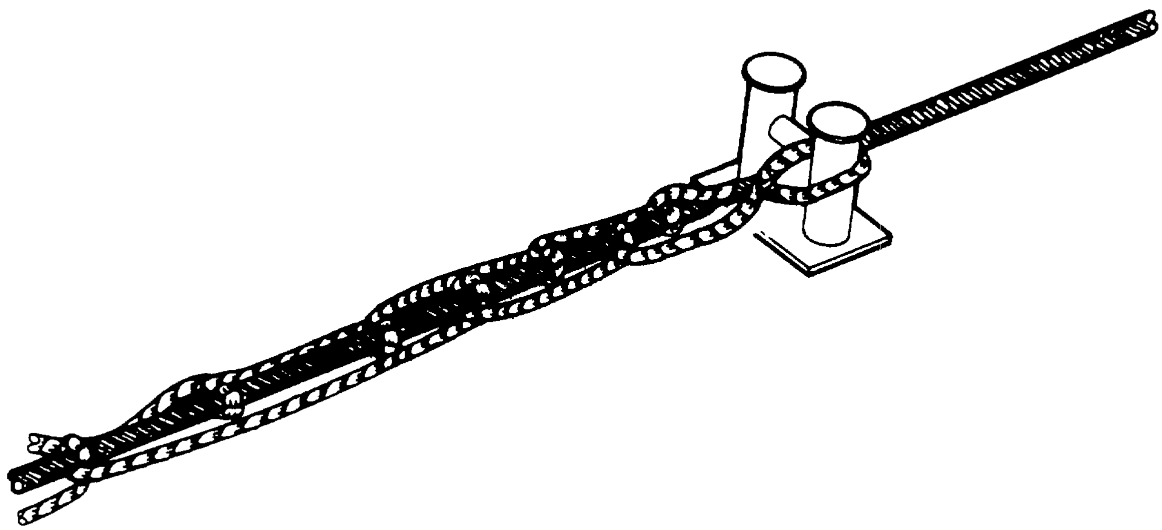


Figure E-5. Double Half-hitch Stopper.

APPENDIX F

TOWING HAWSER LOG

F-1 INTRODUCTION
The purpose of this appendix is to establish the requirement for towing ships to keep a Towing Hawser Log . Entries in this log will be useful in the evaluation of past hawser usage and will assist in evaluating the present condition of the hawser and in the decisions concerning replacement. The log provides a documented reference for the Commanding Officer's use in evaluating the condition of readiness of the hawser The condition of the hawser may not be apparent, even to the experienced operator, and thus the record of usage may become a decisive factor in evaluating operational readiness and overall system safety. This appendix replaces the NAVSEAINST 4740 series regarding hawser logs.

F-2 BACKGROUND
Historically, there have been fewer towline component failures on ships where close attention has been paid to the condition and history of the hawser and other tensile components of the towline. Life of towline components depends less on age than on care, use and history of failures. Fiber lines of all types, including natural and synthetic fiber, deteriorate with age, shelf life and usage The fiber core m wire ropes, particularly if it is natural fiber, also deteriorates with age. Old wires and those with no documentation should be treated with suspicion

F-3 DISCUSSION
In some instances when hawsers and other components fail, it has been impossible to ascertain usage, manufacture and installation data because a log had not been kept. This lack of data precluded a meaningful analysis of the failure.

NSTM 613 (Ref. 15) describes the fabrication, conditions of use, care and preservation of wire rope, fiber rope and cordage . Additionally, the Wire Rope Users' Manual (Ref. 13), as well as handbooks and catalogues published by major wire and rope manufacturers, are useful.

Keeping a hawser log is mandatory for all towing ships Selection and identification of other components that should be similarly logged and administered is left to the discretion of the Commanding Officer. In general, ships may find it beneficial to keep a similar log on mooring lines. Salvage ships may also find it prudent to keep logs on beach gear components, chain and connecting hardware.

F-4 LOG
Salvage ships, fleet tugs, submarine rescue ships and other Navy ships which normally engage in towing operations must maintain a Towing Hawser Log m the format of Attachment A to this appendix. Ships may also keep similar logs on other towline components.

The log should record a comprehensive history of all towing hawsers on the ship. This includes the main wire rope hawser and target towing hawsers.

It is the responsibility of the command to maintain the log . Periodic review is mandatory.

Type Commanders should include the requirement for keeping hawser logs as a check-off item in their Operational Readiness and Administrative Inspection Lists.

F-5 FAILURES
Ships experiencing failure of hawsers and other logged towline components should advise NAVSEA (Attention SEA OOC and SEA 56W), giving details which may be needed for technical evaluation. Fifteen-year-old hawsers are definitely suspect

Whenever a hawser or other logged component breaks under suspicious conditions, save the broken ends and at least 12 feet of good rope (or three links in the case of chain) on each side of the break. Save end fittings as appropriate. Serve the broken ends to prevent unlaying of fiber line or oil them to prevent corrosion of wire rope Log and describe details of the break . Save fragments and pieces for analysis.

When synthetic fiber line fails, it is important that an adequate length be saved. If the break occurs in the vicinity of an end fitting, the end fitting also should be sent for test and evaluation, with the broken end wrapped in plastic.

ATTACHMENT A to APPENDIX F: TOWING HAWSER LOG

1. The Towing Hawser Log is intended for use m connection with both wire rope and fiber line hawsers. It may be used to record other towline components as well. The Towing Hawser Log should be kept in a standard record book. A separate book or separate section of the same book should be kept for each component.
2. The log for any towing hawser or other component consists of three parts, as detailed below.

NOTE

In measuring any rope length and identifying (mapping) a spot along the hawser, always measure back from the original outboard end. If hawser is end-for-ended, do the same, but carefully measure the entire length when end-for-ending and precisely log the conversion technique to be used in subsequent mapping. If the hawser is shortened to install a new end fitting, hold to original measuring system; that is, measure as if it were still all there, but note in the comments section that the hawser has been shortened for installation of a new end fitting.

PART A: NEW ROPE (HAWSER OR COMPONENT) ENTRY

Record data as follows.

1. Date and place of installation.
2. Identification of installer (ship's force, yard, etc.).
3. Method of installation. Was line put on drum under back tension? If so, what was tension? How was tension applied? If not applied, what was done to ensure a tight spool?
4. Comprehensive description of new item. In the case of wire rope and fiber line, include material (wire: IPS, EIPS, stainless, etc, fiber: manila, polypropylene, etc.); size (wire: rope-diameter, fiber line: circumference), and breaking strength. Ensure that the Federal Stock Number and any other specifications are included.
5. Details of line construction as found on tag attached or tacked onto shipping reel. Paste tag in log if possible, or add Xerox copy to towing log, as appropriate.
6. Manufacturer of rope or line (obtain from tag or shipping reel).
7. Date of manufacture of basic rope/line/chain. Also, date of any rigging loft work.
8. Source of rope (NSC; private supplier; etc).
9. Details of end fittings, both ends. Paste a Polaroid photo in log. Provide details of splices and servings for synthetic hawsers and springs.
10. Record any other observations of the hawser, component or pendant, such as degree of lubrication or appearance of light film of rust, discoloration, damage, etc Include observations from internal inspection of rope or line.

PART B: OPERATIONS ENTRY

Record for every employment of the hawser or component:

1. Description of basic employment, such as: towing a DD, hauling on a wreck, etc.
2. Duration of use (days/hours).
3. Scope of tow hawser used (if varied, cite maximum and minimum scopes).
4. Maximum strains experienced by hawser or component. This may come from towing machine or other strain measuring instrumentation . Include notations of weather on trip.

5. Map and complete description of all chafe, bearing or nip points and any chafing gear used. Include Polaroid photos when practical.
6. Description of use of carpenter stopper, chain stopper or other hardware on rope. Where (lengthwise) was stopper placed on rope?
7. For fiber line hawsers, how it was secured on towing vessel' e.g, wrapped around main traction sheave/drum, stopped on the H-bitts, etc.
8. Give minimum depth of water traversed. Did hawser drag bottom9 Give details.
9. If hawser was passed to a wreck, was it:
   a. Floated
   b. Dragged across bottom
      (1) Distance dragged
      (2) Type of bottom.
10. Other experiences of note (surging against hawser/components, fouling on rocks or ship's appendages, etc.).
11. Between-tow maintenance; give information on type of lubricant used, how used and by whom applied.

PART C: POST-OPERATIONS ENTRY

Record after every use:

1. Specific inspection of hawser for wear points such as carpenter or chain stopper wear points, caprail/nipping chafe area, shock bearing points, sheaves and fairleads, etc. Include photographs.

2. Quantification of wear:
   a. General and wire rope. Include count of fish hooks and record and identify (map) spots. Count fish hooks per strand lay. Count all broken wires, not just those that protrude from the rope. Record maximum number of broken wires per lay (total) and maximum number of broken wires per strand lay Include information on any birdcaging, kinking, broken surface wires and surface wire flattening. Indicate surface corrosion. Include photographs. Periodic inspection/ maintenance of hawser or components, which includes opening the lays and internal inspection, need not be performed after every employment, but when undertaken, it should be logged When lubrication is performed, carefully log stock number and manufacturer's data on lubricant as well as who performed the maintenance and inspection.
   b. Fiber line. Include information on surface chafing and abrasion wear, kinking or any other visible damage. Include photographs.
   c. Chain. Pay particular attention to the link bearing points (the "grip" area). Pay special attention to places along the chain where it passed through or bore against chocks or fairleads. In these latter places a straight edge should be laid against the flat face of the link to ensure that the link is not bent in this plane. Any bending is to be reported as failure and requires replacement.
   d. Joining links and shackles of all kinds. Inspect the mechanical joints and screw threads. In the case of safety shackles, measure the mortice to ensure that the bow is not sprung. If sprung, dispose of the shackle. Ensure that all detachable link pieces have serial numbers and are matched in sets. Ensure also that the hairpins fit snugly.

3 General comments . Include as a minimum a general post-operations observation of hawser, component and end-fitting.

APPENDIX G

CALCULATION PROCEDURE FOR TOW RESISTANCE DETERMINATION

This appendix provides a means of calculating towing resistance for various ships and craft. Data for ships, barges and drydocks have different sources and, therefore, are presented in different formats.

The calculation often is a trial-and-error process. Resistance is computed for several assumed towing speeds and different wind and sea conditions. The resulting values are then compared to tow hawser sizes and towing capabilities of available tow ships.

The towing connection-bridles, chain pendants, etc.- are then selected, towing hawser length determined, catenary checked and towline hydrodynamic resistance estimated. This process may result in a towing ship pull requirement or total hawser tension that will require an adjustment to the assumed tow speed.

G-1 SELF-PROPELLED SURFACE SHIPS

The following method combines hull, propeller, wind and sea state resistance into one calculation for determination of the total tow resistance of a ship. Resistance of the towline is considered. Paragraph 6-3.2 and Table 6-1 provide a method for estimating towline resistance. Table G-1 is used to determine the resistance of the tow itself by following the step-by- step procedure below.

Item/Procedure

1. Identify the ship class, or select a class as close as possible to the one under consideration from Table G-2.
2 Select displacement (A) in long tons from table G-2. If the ship is known to be lighter than full load, adjust the full load figures from Table G-2 accordingly.
3. List frontal windage area (A_T) in square feet from Table G-2. A_T is estimated for ships not listed.
4. List wind drag coefficient (C_w) from Table G-2.
5. List projected area of all propellers (Ap) in Feet^2 from Table G-2. This assumes that propellers are locked. If propellers are trailing, reduce the A_p by one-half. If propellers have been removed, use A_p of zero.
6. Select curve number for hull resistance from Table G-2. See Section G-1.1
7. List curve number for sea state resistance (R_s) from Table G-2 . See Section G-1.2.
8. Determine Beaufort wind force number based on expected or measured wind velocity or observation of the sea state with the aid of Table G-3. The estimate should be conservative and should account for anticipated changes of weather.
9. List relative wind speed (V_R) in knots. (For worst condition, use tow speed plus true wind speed.)
10. Select a heading coefficient (K). If the relative wind is dead ahead, use 1 0. If the relative wind is 20 to 40 degrees off the bow, use K = 1 2. For 40 to 90 degrees relative wind, use K = 0 4. There is higher wind resistance to ahead movement when the wind is broad on the bow than when directly ahead, because of the larger ship area presented to the wind. As the wind veers farther aft, however, the wind effect on the ahead direction falls off faster than the increase of the area presented to the wind. See Section G-1.3 for additional guidance.

11. Using the appropriate curve as specified by Item 7, determine the sea state resistance (R_s), from Figure G-2, using the wind and sea conditions specified by Item 8. See Note 1 at the end of this section.
12. Select tow speed (V_{TOW}) in knots.
13 Select tow course.
14. Using the curve number as specified by Item 6, enter Figure G-1 to find the value for R_H/Δ for the tow speed selected in Item 12. See Note 2 at the end of this section.
15. Calculate the hull resistance (R_H) by multiplying 1.25 times Item 14 times Item 2. (The factor 1.25 accounts for hull roughness and other variables).

$R_H = (1.25)x(R_H/\Delta x(\Delta)$

$= (1.25) \times (\text{Item } 14) \times (\text{Item } 2)$

16 Calculate the propeller resistance (R_p) by multiplying 3.737 times Item 5 times Item 12 squared:

$R_p = (3.737) \times (A_p) \text{ X } (V_{tow})^2$

$= (3.737) \times (\text{Item } 5) \times (\text{Item } 13)^2$

See Note 3 at the end of this section.

17 Calculate the wind resistance (R_w) by multiplying 0.00506 times Item 4 times Item 3 times Item 10 times Item 9 squared:

$R_w = (0.00506) \times (C_w) \times (A_t) \times (K) \times (V_R)^2$

$= (0.00506) \times (\text{Item } 4) \times (\text{Item } 3) \times (\text{Item } 10) \times \quad (\text{Item } 9)^2$

See Note 4 at the end of this section.

18. Calculate the total steady-state tow resistance (R_t) by adding Item 11 plus Item 15 plus Item 16 plus Item 17.

$R_T = R_s + R_H + R_p + R_w$
$= (\text{Item } 11) + (\text{Item } 15) + (\text{Item } 16) + (\text{Item } 17)$

19 Estimate the resistance of the tow hawser from Table 6-1 or 10% of tow resistance, Item 18.
20 Calculate horizontal tow hawser tension, Item 18 plus Item 19.

Pages G-5 through G-10 contain sample calculations.

Note 1: The method of estimating the added resistance from waves, at tow speeds, is not well developed . The data herein are developed from stationary (anchored) theory and include no correction for tow course or speed. However, from the shape of the curves it can be seen that there is little effect in seas up to State 4 or 5 The added resistance increases rapidly m heavier seas, which probably will require the tow to head into the seas Furthermore, the effect of the additional speed of the tow will be small compared to the speed of the seas m this case and can be ignored . Therefore, the amount of error introduced by assuming head seas and neglecting tow speed is small, and, in any event, provides a conservative answer for most tow courses.

Following wind and seas will reduce the tow resistance. However, the dynamic effects of ship motions on the tow hawser may preclude towing down-wind under strenuous sea conditions. See Appendix O. Likewise, stability of the tug and tow may preclude towing across the wind and seas under strenuous conditions.
Note 2: These hull resistance curves are plotted on a per-ton-displacement basis. Thus they are applicable to similar hull shapes. Hull shapes are largely influenced by speed/length ratio $V/\sqrt{L}$. Assume that it is necessary to estimate the towing resistance of a large tanker with the following design characteristics:

Displacement	110,000 long tons
Length	850 feet
Speed	15 knots

Compute speed length ratio as 0.51. Using the same units (speed/length and feet), inspect Table G-2 for a similar hull. With the help of one of the many publications providing data on Navy ships, note the T-AGM 20 (14 kts/595 ft) has a speed/length ratio of 0.57. This is close enough for the purpose intended. Enter curve 5 for the T-AGM 20 (Figure G-1) at the assumed tow speed and read resistance per ton. For instance, at 6 knots, read 0.70 lb/LT . If the disabled ship is loaded fully, its hull resistance is 1.25 x 0.75 x 110,000 = 103,125 lbs.

Even without estimating propeller, wind or sea state resistance, by inspecting Figure 6-1, it is apparent that towing this ship at this speed is impractical for all single Navy tow ships except the T-ATF and ATS Classes. Vessels of the latter class can accomplish such tows only under very favorable wind and sea conditions. While working on curve 5, it will save time to also compute hull resistance for 5, 4, and 3 knots as well, for future use. The resulting hull resistance values are 66,000, 42,600 and 20,600 pounds, respectively.

Note 3: Ships of comparable size and speed have comparable propeller size . For ships not listed in Table G-2, select a comparable listed ship for propeller projected area . In this case, there is no comparable ship listed in Table G-2 . For a ship of comparable speed-the T-AGM-20, propeller size projected area is 150 ft^2 . The ship in question is 4.4 times the size of the sample, so it will require roughly 4.4 times the power for the same speed. Therefore, estimate the propeller projected area as 4.4 x 150 ft^2 = 660 ft^2.

Note 4: At higher wind strengths, Force 5 to 7 (the latter with winds of 28 to 33 knots), the tow will be forced to head into the wind because of the sea conditions. Therefore, the most severe weather expected should be checked for head wind and seas to confirm tug and especially tow hawser selection.

G-1.1 HULL RESISTANCE CURVES. Those familiar with previous editions of this towing manual will recall that a large number of hull resistance curves formerly were displayed. Figure G-1 has only five curves. This simplification is the result of the following factors:

a. The hull resistance curve for ships tends to become unique at higher speeds where wavemaking resistance predominates. At low speeds usually associated with towing, there is not a wide variance m the curves when plotted on a per-ton basis. Five curves were found to cover the ships of interest. It was found that some divergence from the simplified curves used here commenced at seven-or eight-knot speeds. Even at 10 to 12 knots, the error introduced is modest.

b. Additional accuracy is not justified in view of the rather gross assumptions made elsewhere, e.g, 25 percent fouling allowance.

c. The methods for predicting additional resistance due to waves are not well developed for the low speeds associated with towing. The degree of accuracy of estimating the added resistance due to waves, see Figure G-2, does not justify relatively higher accuracy in the other components of total tow resistance

d Most towing ships have the capability of measuring towline tension. These observed resistance figures will supersede any computed values in the Captain's operational decision-making process.

Nevertheless, the ability to predict tow resistance is extremely important in tow planning, and should continue despite the comparative lack of precision in the process.

(Text continued on page G-17.)

TABLE G-1: Calculation of Steady State Towing Resistance

SHIP: ______________________ **BY:** __________

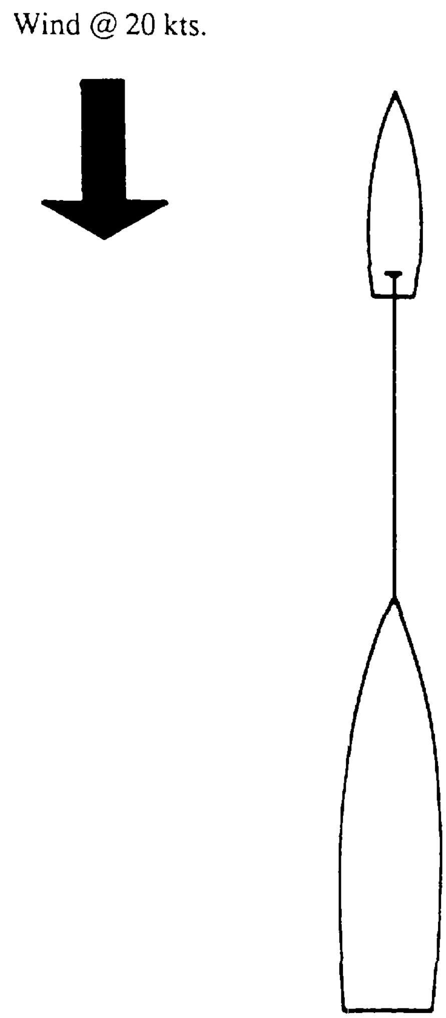
Item	Description	Units	
1	Ship Class (AE, CV, etc)		
2	Tow Displacement, $\triangle$ (See Table G-2)	Long tons	
3	Frontal Windage Area, A_T, (See Table G-2)	Sq Feet	
4	Wind Drag Coefficient, C_W, (See T *able G-2)*		
5	Total Projected Area of Propellers, A_p, (See Table G-2)	Sq feet	
6	Curve Number for Hull Resistance, $R_H/\triangle$, (See Table G-2)		
7	Curve Number for Sea State Resistance, R_S, (See Table G-2)		
8	Beaufort Number (Wind)—(See Table G-3)		
9	Relative Wind Speed, V_R; (If unknown assume worst condition, i e , tow speed plus true wind speed)	Knots	
10	Heading Coefficient K, (See paragraph G-1 procedures) (If unknown, assume K = 1 2)		
11	Sea State Resistance R_s (See Figure G-2 for curve identified in item 7 and wind/sea state listed item 8)	Pounds	
12	Select a Tow Speed, V_{TOW}	Knots	
13	Tow Course γ	Degrees	
14	$R_H/\triangle$ (See Figure G-1)		
15	Hull Resistance = R_H = (1 25) x (Item 14) x (Item 2)	Pounds	
16	*Propeller Resistance* = R_p = (3 737) x (Item 5) x (Item 12)^2	Pounds	
17	Wind Resistance = R_w = (0 00506) x (Item 4) x (Item 3) x (Item 10) x (Item 9)^2	Pounds	
18	Total Steady State Tow Resistance = R_T = (Item 11) + (Item 15) + (Item 16) + (Item 17)	Pounds	
19	Tow Hawser Resistance (R_{wire}) from Table G-1 or 10% of Item 18	Pounds	
20	Total Tow Hawser Tension = (Item 18) + (Item 19)	Pounds	

Example 1: Filled-in Form for Calculation of Steady State Towing Resistance for DDG 2.

SHIP: DDG 2 BY: PP

Item	Description	Units	
1	Ship Class (AE, CV, etc)		**DDG 2**
2	Tow Displacement, △ (See Table G-2)	Long tons	**4,500**
3	Frontal Windage Area, A_T, (See Table G-2)	Sq Feet	**2,256**
4	Wind Drag Coefficient, C_W, (See Table G-2)		**.70**
5	Total Projected Area of Propellers, A_p, (See Table G-2)	Sq feet	**176**
6	Curve Number for Hull Resistance, $R_H/\triangle$, (See Table G-2)		**2**
7	Curve Number for Sea State Resistance, R_S, (See Table G-2)		**1**
8	Beaufort Number (Wind)—(See Table G-3)	**Force 7**	**28 kts.**
9	Relative Wind Speed, V_R, (If unknown assume worst condition, i e , tow speed plus true wind speed)	Knots	**36**
10	Heading Coefficient K, (See paragraph G-1 procedures) (If unknown, assume K = 1.2)		**1.0**
11	Sea State Resistance R_s (See Figure G-2 for curve identified in item 7 and wind/sea state listed item 8)	Pounds	**20,000**
12	Select a Tow Speed, V_{TOW}	Knots	**8 kts.**
13	Tow Course γ	Degrees	**000° T**
14	$R_H/\triangle$ (See Figure G-1)		**2.40**
15	Hull Resistance = R_H = (1 25) x (Item 14) x (Item 2)	Pounds	**13,500**
16	Propeller Resistance = R_p = (3 737) x (Item 5) x (Item 12)^2	Pounds	**42,093**
17	Wind Resistance = R_w = (0 00506) x (Item 4) x (Item 3) x (Item 10) x (Item 9)^2	Pounds	**10,356**
18	Total Steady State Tow Resistance = R_T = (Item 11) + (Item 15) + (Item 16) + (Item 17)	Pounds	**85,949**
19	Tow Hawser Resistance (R_{wire}) from Table G-1 or 10% of Item 18	Pounds	**1,800**
20	Total Tow Hawser Tension = (Item 18) + (Item 19)	Pounds	**87,749**

Example 1-Worksheet.



Towed ship: DDG 2

Full load displacement 4,500 LT

Desired speed—8 kts

Course—000° T

Relative wind: 28 kts @ 000° R

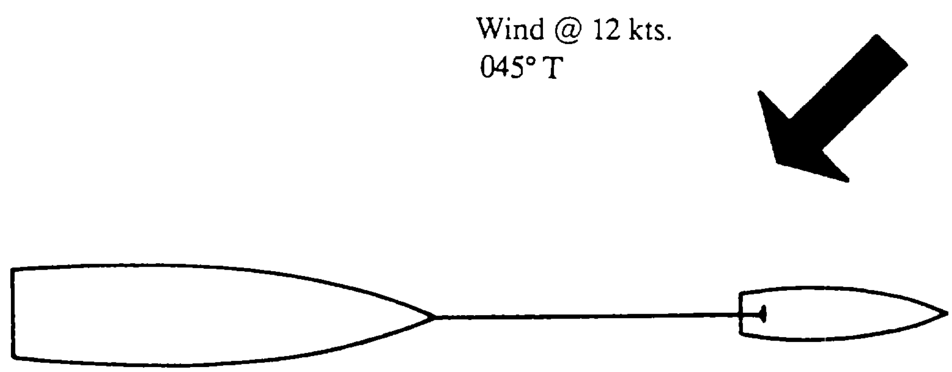
The predicted tow resistance is 85,949 lbs Assuming an 1,800-ft 2-inch hawser with 90 feet of 2¼-inch chain pendant, the tow hawser resistance will be approximately 1800 lbs. The total tug requirement is 87,749 lbs Inspection of Figure 6-1 shows that both the T-ATF 166 and ATS 1 Classes can perform this tow. The other tugs can tow at a slower speed.

Example 2: Completed Form for Calculation of Towing Resistance for CVA.

SHIP: CV 64 BY: PP

Item	Description	Units		Second Trial
1	Ship Class (AE, CV, etc)		**CV 64**	**CV 64**
2	Tow Displacement, △ (See Table G-2)	Long tons	**75,200**	**75,200**
3	Frontal Windage Area, A_T, (See Table G-2)	Sq Feet	**15,000**	**15,000**
4	Wind Drag Coefficient, C_W, (See Table G-2)		**.45**	**.45**
5	Total Projected Area of Propellers, A_p, (See Table G-2)	Sq feet	**1028**	**1028**
6	Curve Number for Hull Resistance, $R_H/\triangle$, (See Table G-2)		**5**	**5**
7	Curve Number for Sea State Resistance, R_S, (See Table G-2)		**3**	**3**
8	Beaufort Number (Wind)—(See Table G-3) **4**	**045° T**	**4 (12 kts)**	**4 (12 kts)**
9	Relative Wind Speed, V_R, (If unknown assume worst condition, i e , tow speed plus true wind speed)	Knots	**16**	**14**
10	Heading Coefficient K, (See paragraph G-1 procedures) (If unknown, assume K = 1.2)		**1.2**	**1.2**
11	Sea State Resistance R_s (See Figure G-2 for curve identified in item 7 and wind/sea state listed item 8)	Pounds	**3,000**	**2,000**
12	Select a Tow Speed, V_{TOW}	Knots	**5**	**3**
13	Tow Course γ	Degrees	**090**	
14	$R_H/\triangle$ (See Figure G-1)		**.45**	**.20**
15	Hull Resistance = R_H = (1 25) x (Item 14) x (Item 2)	Pounds	**42,300**	**18,800**
16	Propeller Resistance = R_p = (3 737) x (Item 5) x (Item 12)^2	Pounds	**96,041**	**34,575**
17	Wind Resistance = R_w = (0 00506) x (Item 4) x (Item 3) x (Item 10) x (Item 9)^2	Pounds	**10,492**	**8,033**
18	Total Steady State Tow Resistance = R_T = (Item 11) + (Item 15) + (Item 16) + (Item 17)	Pounds	**151,833**	**63,408**
19	Tow Hawser Resistance (R_{wire}) from Table G-1 or 10% of Item 18	Pounds	**2,500**	**2,900**
20	Total Tow Hawser Tension = (Item 18) + (Item 19)	Pounds	**154,333**	**66,308**

Example 2-Worksheet



Towed Ship: CVA 64

Lightly Loaded At 75,200 LT

Desired Tow Speed 5 kts

Course—090° T

Relative Wind: 15.9 kts. from 327.8° R

The predicted towing resistance in this case is 151,833 lbs., to which about 2,500 lbs.* of hawser resistance should be added. Examination of Figure 6-1 shows that the T-ATF 166 Class tug is the only Navy tow ship capable of towing the CVA 64 at speeds approaching 5 knots under the assumed conditions.

A second computation for 3 knots shows the total hawser tension of 66,308 lbs., which can be achieved by all Navy tow ships except the ARS 38 Class. In practice, tow speeds of 2, 3, 4, 5 and 6 knots could have been assumed, and the results plotted on Figure 6-1. This method would provide the predicted two speed capability of each type tow ship.

*Based on 2,000 feet of 2¼-inch hawser with a pendant of 270 feet of the carrier's 4¾-inch anchor chain

Example 3: Filled-in Form for Calculation of Steady State Towing Resistance for DD 963.

SHIP: DD 963 BY: PP

Item	Description	Units		Second Trial
1	Ship Class (AE, CV, etc)		DD 963	DD 963
2	Tow Displacement, △ (See Table G-2)	Long tons	7,500	7,500
3	Frontal Windage Area, A_T, (See Table G-2)	Sq Feet	4,400	4,400
4	Wind Drag Coefficient, C_W, (See Table G-2)		.7	.7
5	Total Projected Area of Propellers, A_p, (See Table G-2)	Sq. feet	254	254
6	Curve Number for Hull Resistance, R_H/Δ, (See Table G-2)		3	3
7	Curve Number for Sea State Resistance, R_S, (See Table G-2)		1	1
8	Beaufort Number (Wind)—(See Table G-3) **25—**	**Force 6**	25 kts	25 kts
9	Relative Wind Speed, V_R, (If unknown assume worst condition, i e , tow speed plus true wind speed)	Knots	35	33
10	Heading Coefficient K, (See paragraph G-1 procedures) (If unknown, assume K = 1 2)		1.0	1.0
11	Sea State Resistance R_s (See Figure G-2 for curve identified in item 7 and wind/sea state listed item 8)	Pounds	13,000	8,500
12	Select a Tow Speed, V_{TOW}	Knots	10	8
13	Tow Course γ	Degrees		
14	R_H/Δ (See Figure G-1)		5.05	3.20
15	Hull Resistance = R_H = (1 25) x (Item 14) x (Item 2)	Pounds	47,344	30,000
16	Propeller Resistance = R_p = (3 737) x (Item 5) x (Item 12)^2	Pounds	94,919	60,749
17	Wind Resistance = R_w = (0 00506) x (Item 4) x (Item 3) x (Item 10) x (Item 9)^2	Pounds	19,091	16,973
18	Total Steady State Tow Resistance = R_T = (Item 11) + (Item 15) + (Item 16) + (Item 17)	Pounds	174,354	116,221
19	Tow Hawser Resistance (R_{wire}) from Table G-1 or 10% of Item 18 **Assume 2000′ of 2¼″ wire w/ 90′ of 2¼″ chain**	Pounds	1,100	1,900
20	Total Tow Hawser Tension = (Item 18) + (Item 19)	Pounds	175,454	118,121

Example 3-Worksheet

DD 963 @ 7500 LT displacement

What is the maximum speed each Navy tug can achieve?

Solution: Compute hawser tension at 10, 8, 6, 4 knots and plot in Figure G-1

Tow Speed	Tow Resistance	Hawser Resistance	Total Pull Required
10 kts	174,354 lbs	1,100 lbs.	175,454 lbs.
8 kts	116,221 lbs	1,900 lbs	118,121 lbs
6 kts	70,711 lbs	2,500 lbs.	73,211 lbs.
4 kts	37,093 lbs.	3,100 lbs.	40,193 lbs.

The attached Table G-1 work-up shows hawser tensions for the 8- and 10-knot cases.

Plotting a curve on Figure 6-1 provides the following likely maximum tow speeds for each of the tug types listed, with total hawser average tension.

	Max Tow Speeds	Average Tension
T-ATF 166	7.75 kts	113,000
ATS 1	7.4 kts	106,000
ARS 50	7.2 kts	98,000
ATF 76	5 7 kts	68,000
ARS 38	4.4 kts	47,000

TABLE G-2. Characteristics of Naval Vessels (sheet 1 of 3).

CLASS	DESCRIPTION	△ FULL LOAD DISPLACEMENT (L TONS)	A_T LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	C_W WIND COEFF	A_P TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-1	CURVE FOR WAVE RESISTANCE SEE FIGURE G-2
BB 61-64	BATTLESHIPS	59,000	8,500	70	664	5	3
CVN 68-73, 65	AIRCRAFT CARRIERS	91,000	16,600	45	895	5	3
CV 59-64, 66, 67	AIRCRAFT CARRIERS	81,000	15,000	45	1028	5	3
CV 41-43	AIRCRAFT CARRIERS	65,000	9,500	45	615	5	3
CV 14-34	AIRCRAFT CARRIERS	42,000	9,000	45	300	5	3
CVS 9-39	ASW AIRCRAFT CARRIERS	40,600	9,000	45	300	5	3
CA 68-124	GUN CRUISERS	17,500	5,300	70	308	5	2
CA 134-148	GUN CRUISERS	20,950	4,500	70	324	5	2
CGN 38-41 (DLGN)	GUIDED MISSILE CRUISERS	11,000	4,000	70	207	4e	1
CGN 36-37 (DLGN)	GUIDED MISSILE CRUISERS	10,450	4,000	70	238	4e	1
CGN 35 (DLGN)	GUIDED MISSILE CRUISER	9,127	2,960	70	239	3	1
CGN 25 (DLGN)	GUIDED MISSILE CRUISER	8,592	3,040	70	239	3	1
CGN 9	GUIDED MISSILE CRUISER	17,525	7,900	70	312	4	2
CG 47-56	GUIDED MISSILE CRUISERS	9,600	7,000e	70	254	4e	1
CG 26-34 (DLG)	GUIDED MISSILE CRUISERS	8,250	3,675	70	296	4	1
CG 16-24 (DLG)	GUIDED MISSILE CRUISERS	8,250	3,000e	70	243	3	1
CG 10-12	GUIDED MISSILE CRUISERS	19,500	5,300	70	308	5e	2
DDG 51-53	GUIDED MISSILE DESTROYERS	8,300	6,900	70	254	4e	1
DDG 993-996	GUIDED MISSILE DESTROYERS	8,300	5,000e	70	254	4e	1
DDG 37-46 (EX-DLG 6/9)	GUIDED MISSILE DESTROYERS	6,150	3,000e	70	228	3	1
DDG 2-24	GUIDED MISSILE DESTROYERS	4,500	2,256	70	176	2	1
DDG 31-34	GUIDED MISSILE DESTROYERS	4,150	2,100	70	194	3	1
DD 963-992, 997	DESTROYERS	7,810	4,400	70	254	3	1
DD 931-951	DESTROYERS	4,200	2,100	70	194	2	1
DD 445 CLASS	DESTROYERS	3,040	1,400	70	134	3	1
DD 692 CLASS	DESTROYERS	3,400	1,400	70	158	3	1
DD 710 CLASS	DESTROYERS	3,540	1,450	70	158	3	1
DE 1006 CLASS	DESTROYER ESCORT	1,914	1,342	70	79	1	1
FFG 7-61	GUIDED MISSILE FRIGATES	3,585	2,200	70	170e	2e	1
FFG 1-6 (DEG)	GUIDED MISSILE FRIGATES	3,426	1,715	70	131	2	1
FF 1052-1097 (DE)	FRIGATES	3,900	2,020	70	131	2	1
FF 1040-FF 1051 (DE)	FRIGATES	3,400	1,715	70	131	2	1
LCC 19-20	AMPHIBIOUS COMMAND SHIPS	18,650	7,360	70	220e	5	2
LHA 1-5	AMPHIBIOUS ASSAULT SHIPS	39,300	11,500	70	262	5	3
LPH 2-12	AMPHIBIOUS ASSAULT SHIPS	18,800	6,700	75	155	5	2
LPD 4-15	AMPHIBIOUS TRANSPORT DOCKS	17,000	8,350	75	175	5	2
LPD 1-2	AMPHIBIOUS TRANSPORT DOCKS	14,665	8,300	75	175	5e	2
LSD 41-48	DOCK LANDING SHIPS	15,730	8,000e	75	360e	5e	2
LSD 36-40	DOCK LANDING SHIPS	13,700	7,450e	75	348	5	2
LSD 28-35	DOCK LANDING SHIPS	12,000	6,150	75	174	5	2
LST 1179-1180	TANK LANDING SHIP	8,450	5,200	75	108	4	2
LST 1171-1178	TANK LANDING SHIP	7,100	3,400	75	82	4	2
LST 47-1088	TANK LANDING SHIP (WWII)	4,000	2,000	75	30	4	1
LKA 113-117	AMPHIBIOUS CARGO SHIPS	20,700	7,650	75	312	5e	2
MCM 1-14	MINE COUNTERMEASURE VESSELS	1,040	1,500	75	40	2e	1
MSO 427-511	OCEAN MINESWEEPERS	735	1,340	75	40	2	1
T-ACS 1-12	AUXILIARY CRANE SHIPS	31,500	5,300e	75	300e	5e	3

"e" REPRESENTS BEST ESTIMATE

TABLE G-2. Characteristics of Naval Vessels (sheet 2 of 3).

CLASS	DESCRIPTION	△ FULL LOAD DISPLACEMENT (L TONS)	A_T LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	C_W WIND COEFF	A_P TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-1	CURVE FOR WAVE RESISTANCE SEE FIGURE G-2
AD 15-19	DESTROYER TENDERS	18,400	6,200	75	136	5	2
AD 37-44	DESTROYER TENDERS	20,500	8,000	75	136	5	2
AE 21-25	AMMUNITION SHIP	16,000	6,490	75	187	5	2
AE 26-35	AMMUNITION SHIP	18,000	7,800	75	216	5	2
T-AF 58	STORE SHIP	15,540	5,400	75	198	4	2
AFS 1-7	COMBAT STORE SHIPS	18,000	6,350	70	216	5	2
T-AFS 8-10 (ex RN/RFA)	COMBAT STORES SHIPS	16,792	4,000e	75	156e	4e	2
T AG 194 (ex AGM-19)	MISC	21,626	5,020	70	150e	4	2
AGF 11 (ex LPD-11)	MISC COMMAND SHIP	16,912	8,350	75	175	5	2
AGF 3 (ex LPD-1)	MISC COMMAND SHIP	15,000	8,300	75	175	4	2
T-AGM 10 (ex AP 145)	MISSILE RANGE INST	17,120	5,000e	1 0	200e	5e	2
T-AGM 20 (ex AD-114)	MISSILE RANGE INST (T2-SE-A2)	24,710	5,020	70	150e	5e	2
T-AGM 23 (ex AG 154)	MISSILE RANGE INST (C4-S-A1)	17,015	5,550	1 0	200e	5	2
AGOR 14-15	OCEANOGRAPHIC RESRCH SHIPS	1,915	1,800e	75	30e	4e	1
AGOR 21-22	OCEANOGRAPHIC RESRCH SHIPS	1,437	1,080e	75	40e	4e	1
AGOR 23	OCEANOGRAPHIC RESRCH SHIPS	2,433	1,500e	75	45e	4e	1
AGOR 3, 9-10	OCEANOGRAPHIC RESRCH SHIPS	1,370	1,100	75	35e	4e	1
T-AGOR 16	OCEANOGRAPHIC RESRCH SHIPS	3,860	4,500e	75	100	4e	1
T AGOR 7, 12-13	OCEANOGRAPHIC RESRCH SHIPS	1,370	1,100	75	35e	4e	1
T-AGOR 8, 11	OCEANOGRAPHIC RESRCH SHIPS	3,886	2,400e	1 0	50e	4e	1
T-AGOS 1-26	OCEAN SURVEILLANCE SHIPS	2,285	2,800e	75	55	4e	1
T-AGS 21-22	SURVEYING SHIPS (VC2-S-AP3)	13,050	2,900e	75	120	5e	2
T-AGS 26-27, 33-34	SURVEYING SHIPS	2,800	2,000e	75	55e	4e	1
T-AGS 29, 32	SURVEYING SHIPS	4,330	2,500e	75	90e	4	1
T-AGS 38	SURVEYING SHIP	21 235	4,050	75	200e	4e	2
T-AGS 39-40	SURVEYING SHIPS	15,800	3,500e	75	150e	4e	2
AH 17	HOSPITAL SHIP	15,500	4,900	75	115	5	2
T AH 19-20	HOSPITAL SHIPS	44 875	8,400e	1 00	330e	5e	3
AK 283	CARGO SHIPS (C2-S-B1)	11,000	4,375	75	106	5	2
T-AK 1010	MPS-CARGO SHIP	22,600e	5,600e	75	220e	5e	2
T-AK 2043	MPS-CARGO SHIP (C4-2-66a)	24,300e	5,000e	75	210e	5e	2
T-AK 2046	MPS-CARGO SHIP (LASH TYPE)	49,000e	9,000e	1 0	320e	5e	3
T-AK 267	CARGO SHIPS (C4-S-B1)	22,056	4,200	75	150e	5e	2
T-AK 271	CARGO SHIPS (C1-ME2-13a)	3,886	1,600	75	50e	5	1
T-AK 280-282	CARGO SHIPS (VC2-S-AP3)	11,300	4,100	75	119	5	2
T-AK 284-286, 295	CARGO SHIPS (C3-S-33a)	15,404	3,800e	75	130e	5e	2
T-AKB 1015, 2049	MPS-CARGO SHIPS (BARGE CARRIER)	53,000e	9,000e	1 0	300e	5e	3
T-AKR 287-294	MPS-VEHICLE CARGO SHIPS (SL-7)	55,000e	10,000	1 0	500e	5e	3
T-AKR 7	VEHICLE CARGO SHIP (C3-ST-14A)	18,286	4,000e	75	180e	5	2
T-AKR 9	VEHICLE CARGO SHIP (C4-ST-67A)	21,700	4,100e	75	200e	5	2
T-AKR (new)	VEHICLE CARGO SHIP	24,500	6,200e	75	400e	5e	2
T-AKX 3000-3004	MPS-VEHICLE CARGO SHIPS	44,086	9,800	1 0	280e	5e	3
T AKX 3005-3007	MPS-VEHICLE CARGO SHIPS	51,612	10,000	1 0	380e	5e	3
T AKX 3008-3012	MPS-VEHICLE CARGO SHIPS	46,111	9,800	1 0	350e	5e	3
AO 177-186	OILERS	26,110	6,300	1 00	220	5e	3
AO 51, 98-99	OILERS	34,040	5,480	1 00	346	5	3
T-AO 105-109	OILERS	35,000	5,480	1 0	346	5e	3

"e" REPRESENTS BEST ESTIMATE

Table G-2. Characteristics of Naval Vessels (sheet 3 of 3).

CLASS	DESCRIPTION	Δ FULL LOAD DISPLACEMENT (L TONS)	A_T LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	C_W WIND COEFF	A_P TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-1	CURVE FOR WAVE RESISTANCE SEE FIGURE G-2
T-AO 143-148	OILERS	36,000	5,000e	1 0	400e	5e	3
T-AO 187-204	OILERS	40,000	6,750e	1 0	420e	5e	3
T-AO 57, 62	OILERS	25,500	5,480	1 0	346	5e	3
AOE 1-4	FAST COMBAT SUPPORT SHIPS	53,500	9,750	1 00	456	5	3
T-AOG 78	GASOLINE TANKERS (T1-M-BT2)	6,047	2,500e	1 0	70e	4e	1
T-AOG 81-82	GASOLINE TANKERS (T1-MET-24a)	7,000	2,500e	1 0	67	4e	1
AOR 1-7	REPLENISHMENT OILERS	37,700	7,590	1 00	274	5	3
T-AOT	TRANSPORT OILERS (T5 type)	39,000	5 000e	75	180e	5e	3
T-AOT 1203-1205	MPS-TRANSPORT OILERS	44,000e	4,500e	1 0	270e	5e	3
T-AOT 134	TRANSPORT OILERS (T2-SE-A2)	22,380	3,600e	1 0	135e	5e	2
T-AOT 149-152	TRANSPORT OILERS (T5-S-12A)	32,953	4,000e	1 0	200e	5e	3
T-AOT 165	TRANSPORT OILERS (T5-S-RM2A)	31,300	4,600e	1 0	210e	5e	3
T AOT 168-176	TRANSPORT OILERS	34,100	4,600e	75	200e	5e	3
T-AOT 181	TRANSPORT OILERS	35,000	4,700e	75	270e	5e	3
T-AOT 50-76	TRANSPORT OILERS (T2-SE-A1)	21,880	3,600e	1 0	120e	5e	2
AP 110	TRANSPORTS	20,175	6,800	75	200	5e	2
AP 121-127	TRANSPORTS	22,574	6,300e	75	216	4e	2
AR 5-8	REPAIR SHIPS	16,300	5,460	75	136	5	2
T-ARC 2, 6	CABLE REPAIR SHIP (S3-S3-BP1)	8,500	2,250e	75	72e	5	1
T-ARC 7	CABLE REPAIRING SHIP	14,157	4,700e	1 0	300e	5e	2
ARL 24	SMALL REPAIR SHIP	4,325	2,320	75	30	4	1
ARS 38-43	SALVAGE SHIP	2,045	1,500	75	56	5	1
ARS 50-53	SALVAGE SHIP	2,880	2,000e	75	80	5e	1
AS 11, 17, 18	SUBMARINE TENDERS	17,000	6,200	75	136	4	2
AS 19	SUBMARINE TENDERS	19,200	6,200	75	136	4	2
AS 31-32	SUBMARINE TENDERS	19,000	6,440	75	140	4	2
AS 33-34	SUBMARINE TENDERS	21,089	7,550	75	136	5e	2
AS 36-41	SUBMARINE TENDERS	23,000	7,550	75	136	5	2
ASR 21-22	SUBMARINE RESCUE SHIPS	3,411	4,500e	75	100	3e	1
ASR 9,13-15	SUBMARINE RESCUE SHIPS	2,320	1,200	75	50	5	1
ATF 91-160	FLEET TUGS	1,640	1,100	75	43	2	1
T-ATF 166-172	FLEET OCEAN TUGS	2,260	1,700e	75	120e	4e	1
ATS 1-3	SALVAGE & RESCUE SHIPS	2,929	2,500	75	110	5e	1
T-AVB 3-4	MPS-AVIATION MAINTENANCE SUP	23,800	6,000e	1 0	370e	5e	2
AVM 1	GUIDED MISSILE SHIP	15,170	5,300	75	136	4	2
WAGB 10-11	(CG) ICEBREAKERS	12,087	4,500	75	280e	4e	3
WAGB 281-282	(CG) ICEBREAKERS	6,515	3,150	75	182	5e	2
WAGB 4	(CG) ICEBREAKERS	8,449	3,400	75	300e	5e	2
WHEC 35, 37	(CG) HIGH ENDURANCE CUTTERS	2,656	1,600	70	50e	1e	1
WHEC 379	(CG) HIGH ENDURANCE CUTTERS	2,800	1,600	70	47e	1e	1
WHEC 715-726	(CG) HIGH ENDURANCE CUTTERS	3,050	2,000	70	154e	2e	1
WMEC 165-166	(CG) MED ENDUR CUTTERS (ATF)	1,731	1,200	75	43	2e	1
WMEC 615-623	(CG) MEDIUM ENDUR CUTTERS	1,000	1,400	70	40e	2e	1
WMEC 76, 85, 153	(CG) MED ENDUR CUTTERS (ATF)	1,731	1,500	75	56	2e	1
WMEC 901-913	(CG) MEDIUM ENDUR CUTTERS	1,780	1,300	70	55e	1e	1
WMEC 6, 167, 168	(CG) MED ENDUR CUTTERS (ARS)	1,745	1,500	75	56	5e	1
YTB 752-836	LARGE HARBOR TUGS	350	560	75	22e	2e	1

"e" REPRESENTS BEST ESTIMATE

Table G-3. Beaufort Scale.

BEAU-FORT NO	KNOTS	DESCRIPTION	AVG HT (FT)	SIGNIFICANT 1/3 HIGHEST (FT)	AVG WAVE LENGTH (FT)	MINIMUM DURATION (HOURS)	AVERAGE WAVE HEIGHT (FT)*
0	less than 1	Calm					
1	1-3	Light air	<1	<1	10 IN	18 MIN	
2	4-6	Light breeze	<1	<1	6 7 FT	39 MIN	
3	7-10	Gentle breeze	<1	<1	20-27	1 7-2 4 HR	2 (3)
4	11-16	Moderate breeze	1 8-2 9	2 9-4 6	52-71	4 8-6 6	3 1/2 (5)
5	17-21	Fresh breeze	3 8-5 0	6 1-8 0	90-111	8 3-10 0	6 (8 1/2)
6	22-27	Strong breeze	6 4-9 6	10-15	134-188	12-17	9 1/2 (13)
7	28-33	Moderate gale (high wind)	11-16	18-26	212-285	20-27	13 1/2 (19)
8	34-40	Fresh gale	19-28	30-45	322-444	30-42	18 (25)
9	41-47	Strong gale	31-40	50-64	492-590	47-57	23 (32)
10	48-55	Storm	44-59	71-95	650-810	63-81	29 (41)
11	56-63	Violent storm	64-73	103-116	910-985	88-101	37 (52)
12	Above 63	Hurricane	>80	>128			45 (-)

NOTES

1 Figures shown are associated with the low and high wind speed within each force range.

2 Except for far right column, figures are for fully-developed seas Note that the more strenuous seas require a progressively longer duration to develop The fully-developed seas associated with 50-kt or stronger winds rarely occur Average heights listed in the right-hand column are more representative of waves actually encountered under the stated wind conditions

* For tow planning purposes, use "average height" column in computing added resistance due to waves These are the more usual wave heights encountered, due to the long duration required to achieve the "fully-developed sea" for the stated wind conditions Figures in parentheses represent the occasional highest wave in the average spectrum These occasional highest waves have little long-term impact on the towing resistance

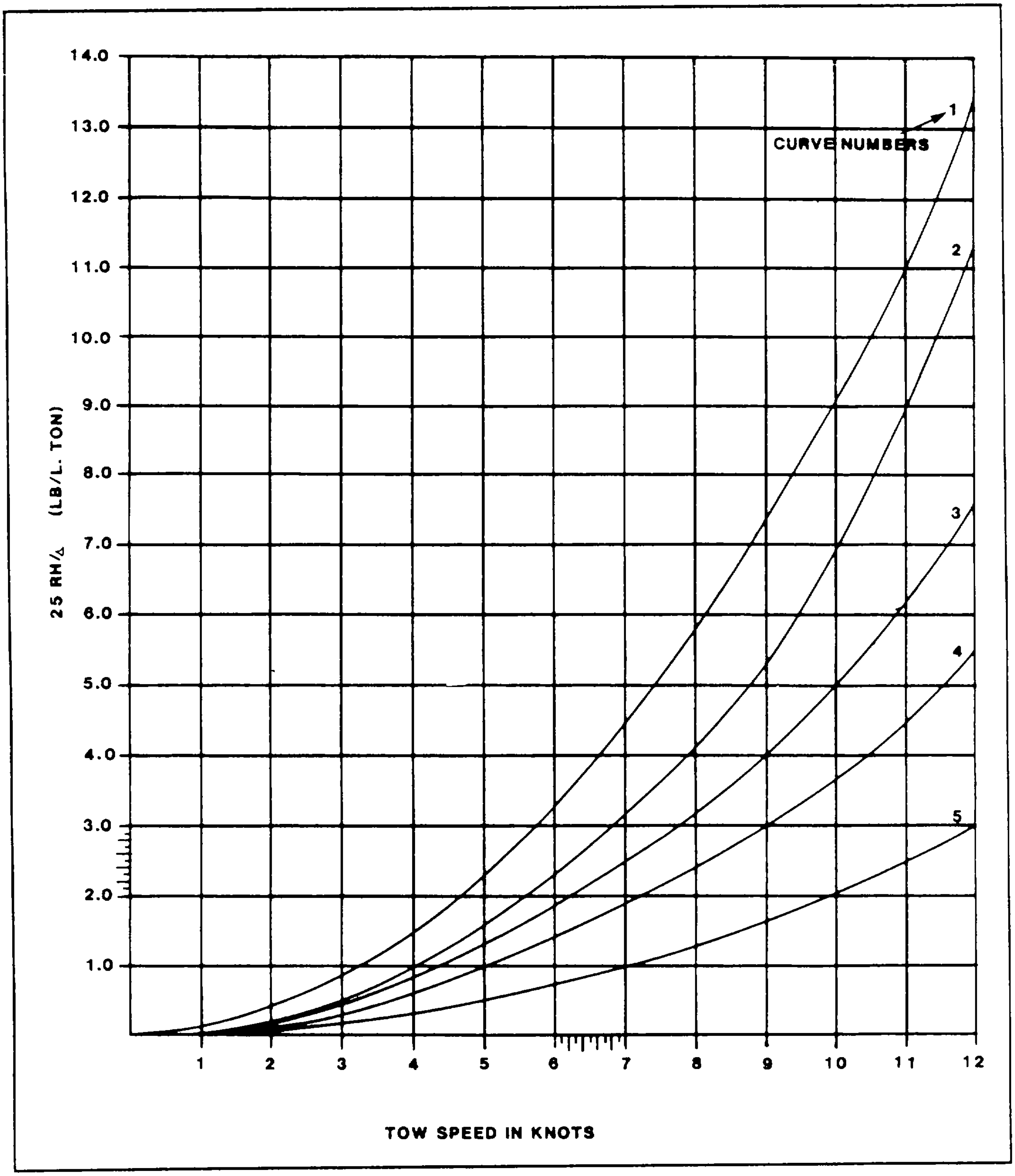


Figure G-. R_H /D vs. Tow Speed.

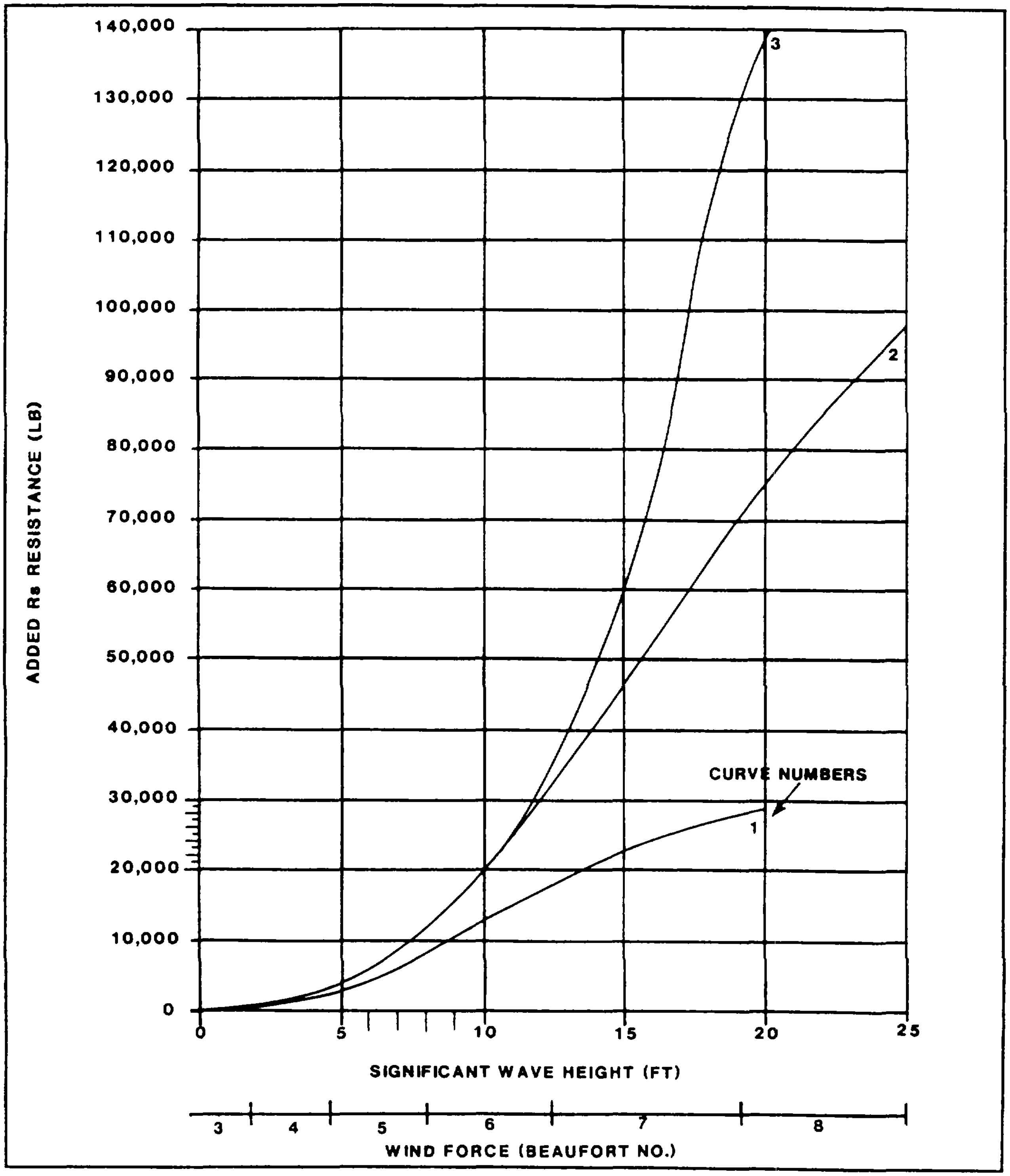


Figure G-2. R_S vs. Wave Height and Wind Force.

(Text continued from page G-3)

G-1.2 ADDITIONAL RESISTANCE DUE TO WAVES . As in the case of smooth water hull resistance curves, it was found that three curves adequately covered the expected range of weather and tows. Furthermore, the data are considered qualitative only.

Note that there is no method provided for estimating the effect of other than head seas. Under the more benign sea conditions, where the tug has total freedom in course-setting, the effect of the waves on the tow and tug is modest. In more strenuous cases, the tug will have to set a course into the seas for stability purposes as well as for relief of effects on the hawser. Under the more strenuous conditions, it is unlikely that the tug will be able to take advantage of following seas.

For the larger ships represented by curves 2 and 3 in Figure G-2, the added resistance is significant at the higher sea states. However, under these conditions the tug itself may experience difficulty and may simply have to reduce power to maintain steerageway. Speed over the ground of the tug and tow may well be sternward in this case and this is perfectly appropriate in the open sea.

G-1.3 WIND RESISTANCE. The prediction of wind resistance is also simplified in this manual. The sea conditions associated with the most significant winds generally dictate towing into or close to the wind. The ability to precisely predict the reduction of tow resistance from a Force 10 wind off the quarter is not very important. Furthermore, in those cases where there is insufficient reach or duration of the strong winds to raise fully-developed waves, the tug will base operational decisions on actual observations of the towline, not on the predicted assistance from strong stern winds.

G-2 FLOATING DRYDOCKS

The following method for determining the total tow resistance of non-self-propelled floating drydocks is based on the now out-of-circulation. Technical Publication NAVDOCKS TP-DM-26, 1 October 1953,*Towing Non Self-Propelled Floating Structures.* This procedure, which has been successfully used for many years, is recommended for estimating tow resistance for these types of craft . Table G-4 contains the various constants used in the following formulae.

TABLE G-4. Drydock Towing Coefficients.

Ship Class			f1	S	f2	B	f3	C
AFDB-1	Section	256′ x 80′	45 to .8	23,000	.3	720	7	3,800
AFDB-4	Section	240′ x 101′	45 to .8	26,000	.3	900	7	4,500
AFDM-1	3-Piece	496′ x 116′	.45 to .8	50,000	6	750	67	7,000
AFDM-3	3-Piece	488′ x 124′	45 to 8	52,000	.6	800	.67	7,800
ARD-1	1-Piece	390′ x 60′	.45 to 8	20,000	2	250	.61	2,000
ARD-2	1-Piece	486′ x 71′	.45 to 8	34,000	.2	370	.61	3,700
ARD-12	1-Piece	492′ x 81′	.45 to 8	40,000	.2	480	.61	4,400
AFDL-1	1-Piece	200′ x 64′	45 to 8	13,000	.4	220	7	1,400
AFDL-7	1-Piece	288′ x 64′	.45 to .8	19,000	.4	210	7	1,500
AFDL-35	1-Piece	389′ x 84′	45 to .8	38,000	3	780	.67	1,900
AFDL-47	1-Piece	448′ x 97′	.45 to .8	46,000	5	420	7	2,500
AFDL-48	1-Piece	400′ x 96′	45 to .8	48,000	4	1,350	7	2,540
YFD-7	3-Piece	488′ x 124′	.45 to 8	52,000	6	800	67	7,800
YFD-68 to 71	3-Piece	474′ x 118′	45 to 8	48,000	6	750	67	7,300

G-2.1 FRICTIONAL RESISTANCE. The data used for determining frictional resistance are based upon a series of experiments on modeled and actual conditions. The resistance caused by the friction of water on the vessel's wetted surface depends upon.

a. Area of surface below the waterline
b. Nature of the surface
c. Speed of tow.

Thus the formula for frictional resistance of a vessel passing through water is:

$$R = f_1 \times Sx(V/6)^2 \quad (1)$$

where:

R = resistance in pounds

f_1 = a coefficient depending on the shape of the vessel's hull (from Table G-4)

S = area of the vessel's wetted surface below the waterline, in square feet (from Table G-4)

V = speed of tow in knots relative to still water.

G-2.2 WAVE-FORMING RESISTANCE.

Data for wave-forming resistance are based on model tests and depend upon:

a. Area below waterline (maximum cross section)
b. Form of bow and stern
c. Speed of tow.

Thus the formula for wave-forming resistance of a body passing through water is'

$$G = 2.85xBxf_2xV^2xK \quad (2)$$

where:

G = resistance in pounds

B = cross-sectional area of vessel below waterline in square feet (from Table G-4)

f_2 = a coefficient depending upon the configuration of vessel's bow and stern (from Table G-4)

V = speed of tow in knots relative to still water

K = 1.2, which is a 20 percent increase in resistance resulting from rough water and eddies

G-2.3 WIND RESISTANCE. Data used for determining wind resistance are based on a series of experiments on models. The resistance caused by wind blowing against a vessel depends upon:

a Cross-sectional area of vessel above waterline subjected to wind
b. Speed of wind
c. Speed of tow
d. Shape of vessel subjected to wind.

Thus the formula for frictional resistance caused by wind is'

$$W = C \times .004\ (V_w + V)^2 X\ f_3 \quad (3)$$

where:

W = resistance in pounds

C = cross-sectional area of vessel above waterline in square feet (from Table G-4)

V_w= speed of wind in knots

V = speed of tow in knots, relative to still water

f3 = a coefficient depending on the shape of vessel subjected to wind (from Table G-4)

G-2.4 TOTAL RESISTANCE. The total resistance is determined by solving formulas 1, 2 and 3 and adding the results. This tow resistance then is used in selecting the tow ship and designing the tow connection as described in Chapter 6

G-2.5 EXAMPLE. The following example is given to show the use of the three resistance formulas already outlined.

The problem is to determine the extreme requirements for towing AFDL 1 Class floating drydock under all weather conditions To Illustrate this design, the following known factors have been selected:

a. Hurricane wind speed 69 knots
b. Towing speed during hurricane: 6 knots
c Bottom condition of drydock-moderately rough and in need of cleaning use fl coefficient of 0 65

Substitute into resistance formulas, using above factors and coefficients from Table G-4

R = fl x S (V/6)2
= 0 65 x 13,000 x (6/6)2
= 8,450 lbs

G = 285xBxf2xV2xK
= 2 85 x 220 x 0.4 x 62 x 1.2
= 10,835 lbs

W = C x 0.004 x (Vw + V)2x f3
= 1,400 x 0.004 x (69 + 6)2 x 0.7
= 22,050 lbs

Total resistance
- R+G+W
= 8,450 + 10,835 + 22,050
= 41,335 lbs

G-3 TOWING RESISTANCE OF BARGES

The previous section on towing resistance of drydocks can be adapted for computing the total resistance of barges.

G-3.1 FRICTIONAL RESISTANCE. The method is identical to the one used in Section G-2.1. The wetted surface (S), is simply the barge's length times width plus perimeter times draft

G-3.2 WAVE FORMING RESISTANCE The cross section area (B), is width times draft. For the typical rake-ended barge, use f2 = 0.2. This also is applicable to the comparatively blunt ship-shaped bow of some barges such as YFBNs and APLs For square-ended barges, use f2 = 0.5.

This treatment probably understates the added resistance due to waves m Sea States above 4 or 5 In these cases, the tow direction may have to be changed to avoid excessive slamming of the bow structure of the tow, assuming adequate stability of the barge Thus, added barge resistance in heavy seas tends to be limited by other factors. However, if the barge has a ship-shaped bow or otherwise can withstand ahead wave heights over 8 to 10 feet, Curve 1, Figure G-2, can be used to estimate the added resistance from waves

G-3.3 WIND RESISTANCE. Use the formula contained in Section G-2.3. The cross sectional area (C), is the freeboard times beam plus height times width of the deck house or any deck cargo. Use f3 = 0 60 as an average barge figure m the formula

G-3.4 TOTAL BARGE RESISTANCE. Add the results of frictional wave forming and wind resistance from the previous three sections.
G-3.5 EXAMPLE. Assume a berthing barge (YRBM) is to be towed Dimensions are:

Length	265 feet
Width	65 feet
Draft	7 feet
Hull Depth	12 feet
Deck house	220 ft x 55 ft x 25 ft

Desired tow speed is 10 knots, maximum head wind IS 20 knots Bottom conditions are average. The hull has rake-shaped ends.

G-3.5.1 Frictional Resistance. Estimate the average length below the waterline as 250 feet, with the bottom being 245 feet.

S = 7 x 2 x (250 + 65) + (245 x 65)
= 20,335 ft2

R = 65 x 20,335 x (10/6)2
= 36,716 lbs

G-3.5.2 Wave Forming Resistance.
B = 65 x 7 = 455

G = 2.85 x 455 x 0 2 x 102 x 1 2
= 31,122 lbs.

In this case a 20-knot wind could have generated an average wave height of 5 feet. Curve No. 1, Figure G-2 predicts an added resistance of 2,500 pounds. This is well within the 5,187 pounds catch-all correction included in the formula's 1 2 factor, so do not add the additional 2,500 pounds.
If the tow encountered 10-foot average wave height, and was structurally adequate to continue, the added resistance of 12,000 pounds would be added to the total resistance.

G-3.5.3 Wind Resistance.

C = 65 x (12-7) + (25 x 55)
= 1,700 ft2

Where:

C = frontal area

W = 1,700 x .004 (20 + 10)2 x .6

= 3,672 lbs.

G-3.5.4 Total Resistance.

R + G + W = 36,716 + 31,122 + 3,672

= 71,510 lbs

Inspecting Figure 6-1 shows that this tow is within the capability of the T-ATF and ATS 1 Classes, at the assumed towing speed of 10 knots Clearly, other towing ships, ag., the ARS 50 and ATF 76 Classes, would be adequate for this tow at lower speeds

APPENDIX H

CHECK-OFF LIST FOR PREPARING AND RIGGING A TOW

H-1. CHECK-OFF LIST FOR PREPARING AND RIGGING A TOW

1. The following check-off list is to be used by the preparing activity to aid m preparing a tow for sea and acceptance by the towing unit. It lists general requirements, most of which must be completed before the towing unit will accept it for sea. If the preparing activity has questions concerning this check-off sheet or preparations required to ready the tow, it should communicate via message or phone with the towing unit or its Immediate Superior in Command (ISIC) The preparing activity must fully complete this check-off list. Items which are not applicable or cannot be accomplished must be cleared through the towing unit's ISIC or the towing unit.

2. A preliminary pre-tow inspection should be conducted by the command conducting the tow as soon as possible to preclude misunderstandings and rework. In special situations, the standards reflected in this checklist can be relaxed and a calculated risk tow accepted. The Commanding Officer of the towing ship and his ISIC must agree to all calculated risk tows, as they do not relieve them of responsibility or safe practice. Calculated risk tows are not routine.

3. The Commanding Officer of the towing ship will conduct a final inspection of the tow in company with a representative of the preparing command. Upon satisfactory completion of this inspection, condition ZEBRA will be set on the tow by the preparing activity and the tow accepted and signed for by the towing ship's Commanding Officer

4. General Characteristics:

a. Is craft designed and authorized to be ocean-towed IAW the U S Navy Towing Manual?__________________
If not, why not?____
____
____

(Use separate sheet if additional space is needed.)

b Nomenclature of unit being towed____

c Departure from what activity and port____

d. Name of craft being towed____________________

e. Length____________Beam____________

Draft fwd______Draft aft________Mean draft__________

Freeboard forward________mid________aft__________

f. Maximum designed draft (include sonar dome, propellers, etc.)__________

g. Displacement____________________

h. Does craft have a fixed rudder or a skeg?____________

i. Is the booklet of general plans available?____________

Where is the booklet located?____________

j. Are instructions posted in after steering for lining up hydraulic steering systems to hand pump?

____

k. Are plans and date of last drydocking available?____________

Date?____________________

l. Were hull thickness recordings taken during last drydocking?__________
Provide record of sonic drill or test.____________

m. Is damage control book, curves of forms or other stability data available?________

Where?____________________

n. MTI____________________

o. TPI____________________

p. Preparing activity to provide a list of equipage assigned to the craft which is pilferable and is required to be on board at destination. Preparing and towing representatives' signatures are required. (Provide list on separate sheet; if there is none, so state)____________

q. If craft is a floating drydock, has it been inspected by a representative of NAVSEA? If yes, when? ____________________

r Do you hold a signed copy of the inspection? ____________________

s. Are ladders available for boarding on both port and starboard sides on the after one-third of the tow?

____ For unmanned ships with freeboard over 10 feet, are rungs welded to the sides? ____________________

5. Riding Crew:

a. Is a riding crew necessary? ____________ (Note Riding crews are not ordinary practice for open ocean tows.)

Attach a copy of the directive (message, letter, etc.) ____________________

If so, proceed with the following checks.

b. Which authority has authorized that a riding crew be on board? ____________________

How many men? ____________________

c. Is there a sufficient number of life rafts on board with emergency rations and water to accommodate the riding crew in the event that they are required to abandon ship? ____________________

Where are they located? ____________________

d. Date life rafts were last tested/inspected ____________________

e Are life jackets and life rings on board? ____________________

How many? ____________ Type? ____________________

Date last tested/inspected ____________________

f. Are at least two P-250s and all other necessary firefighting equipment on board? ____________________

Is there a sufficient quantity of P-250 fuel on board? ____________________

g Is storage of fuel adequate? ____________________

h What means of communications with the towing ship will be provided? ____________________

____

(Both visual and radio are recommended)

i. Provide list of riding crew to enter in towing ship's diary (name, rate, SSN, and NOK; address and phone number of rider and NOK for civilians).

j. If the preparing activity normally is responsible for training the crew m damage control and support systems, are they trained?____

k. Is habitability and sustenance sufficient from on-board assets?______________________

6. Seaworthiness'

a. Is the craft in proper trim?____

(Note. For a ship/craft to be in proper trim for towing, it should draw approximately one foot morewater aft than it does forward for each 100 feet of length. Deep draft tows use somewhat less than one foot. Before trimming excessively, ensure that drafts obtained will allow sufficient clearing of thebottom at point of departure, transit, and point of delivery, and that stability of tow is not impaired)

b. Will craft require ballast?____

c. If so, what type of ballast?____

d. Describe where ballast will be placed and how much____________________________

____

____

e. Draft after craft is in proper trim': fwd________aft __________max navigational draft______________________

f. GM after craft is in proper trim____

g. KG after craft is in proper trim____

h. If GM is not known, "sally ship" to establish period of roll.
Normally T = 2V Beam (ft) is maximum period. The measured period of roll will be useful in detecting deteriorating stability during the tow

T = 2Beam (ft)____

T (observed)____

i. Are all sea valves closed and wired shut?__________________________________

Is there a two-valve protection from the sea for all sea openings?______________________

j. Is a list of sea valves attached?____

(Note. Two-valve protection consists of either two valves wired shut or one valve and a blank flange. A list of all valves should be attached.)

k. Closely inspect, below decks, all drain piping which originates above the water-line and terminates within 20 feet of the waterline. Are there any loose connections or badly deteriorated spots in the piping? Are all sea valves closed and wired shut with steel wire?____________________________________

l. Are all sounding tubes capped?____

m. Is a list of all sounding tubes attached? (Required)__________________________________

n. Are all between-tank sluice valves closed?______________________________________

o. Are all normally dry compartments dry?____

p. Are all bilges free of oil and water?____

q. Are there any broken, cracked or weak frames, longitudinal, plates, welds or rivets?________________

Have repairs been made?____

r. Has the hull been inspected to the best of your ability?________________________________

s. What type(s) of inspection was/were conducted and where? (e.g., ultrasonic interior, exterior, voids, etc.)____

(Note. All compartments should be entered and inspected)

t. Has steel wire or cable been used to secure all equipment to prevent any movement m heavy weather?_____

(Note. All moveable equipment must be secured by welding or secured with wire m place No fiber rope or line will be accepted)

u. Is/are rudder(s) locked?____

(Note: The rudder(s) should be locked by using a structural steel of acceptable size and quantity. The lock should transfer the rudder load from the yoke to structural members of the tow's hull Refer to Chapter 4 of the U S Navy Towing Manual for typical configurations and sizing)

v. What type of locking device is used?____

w Is/are shaft(s) locked m accordance with the U.S. Navy Towing Manual?______________________________

x. Is/are propeller(s) removed?______________________________

y. Are shafts equipped with extra rings of packing in the gland to allow emergency repair during transit, and is the gland tightened to its tightest position?______________________________

z. Ensure that there is no leakoff at the stern tube Can the stern tube packing gland be tightened at least two more inches before it is two-blocked?______________________________

aa. Are locking nuts tight on packing glands to prevent their backing off?______________________________

bb. Are all portholes sealed and covered with metal to prevent breakage?______________________________

cc. Are all vents subject to heavy-weather flooding (e.g., air, fresh water, fuel tank, etc) sealed?______________

Wood covers are not considered adequate

(Note Recommend remove completely and blank flange or weld closed)

dd. Are all hatches, scuttles, doors and other watertight closures provided with pliable gaskets?______________

ee. Have weather decks and main transverse bulkhead watertight closures been chalk tested?______________

ff. Are all dogs on watertight closures operable and functioning as designed?______________________________

gg. Are all main spaces accessible for adequate dewatering capability?______________________________

hh. Location of pumps/generators/eductors______________________________

____

____

____

ii. Amount/location/size of hose______________________________

____

____

jj. Is adequate fuel available for pumps/generators?____

kk. Is forward one-fifth of craft designed to withstand constant pounding during transit?______________________
If not, shore m accordance with the U.S. Navy Towing Manual.

ll. If the craft to be towed is a barge, and inspection reveals signs of serious deterioration, or the barge is suspected of being weakened, it may require shoring, particularly in the forward one-fifth of its length Is shoring required?____

mm. Is steel "K " shoring installed on all longitudinal m forward and after compartments?______________________

nn. For LST-type tows, the following questions must be answered in the affirmative, or the vessel will not <u>be accepted for ocean tow</u>, even as a calculated risk:

(1) Do the bow doors have hydraulic rams connected?____

(2) Are mud flaps at the bottom of the doors secured?____

(3) Are all dogs, heavy weather shackles, ratchet-type turnbuckles and strongbacks in place, tight and secure so that they cannot work free?____

(4) Are bow ramp operating instructions posted in the hydraulic control room?________________________

oo. If craft is equipped with a bow or stern ramp, is it secured in accordance with notes on LSTs listed below?___

YFU/LCUs are inherently unseaworthy due to wide beams and flat bottoms. A lift of opportunity should be used whenever possible. If it is absolutely necessary to tow these craft, the following must be strictly adhered to':

(1) The bow ramp will be secured with a minimum of four angle straps on each side, welded on the outside of the ramp. The size of these straps should be a minimum of 4 " x 3/8 " and overlap the bow ramp and sides of the craft a minimum of 10"

(2) All normal securing devices (1 e., ramp chains, dogs and turnbuckles) are in place and in good mechanical condition

(3) All hatches, scuttles and doors have good gaskets and all securing devices are in proper operating condition

pp. Are 1-foot by 3-foot international orange stripes or inactive ship flooding markers painted on the sides of the hull forward, aft and midships at the water's edge to allow visual inspection for proper trim during transit?___

qq. Are all lifelines m place and in good condition?____

rr. Is condition ZEBRA set throughout the tow?_______________If not, list exceptions on separate sheet

ss. Are liquid load diagrams and damage control flooding plates available on board?______________________

If yes, where?____

tt. Are damage control inspection routes marked by paint/diagrams?___________________________________

7 Flooding

a. Are amber (lower) and red (upper) alarm lights installed?____

b. Are flooding alarm lights visible from at least 90 ° and centered forward on the tow?____________________

(Note. 360 of visibility is preferable for a high-value, escorted tow)

c. Are both the 1-foot and 3-foot flooding alarm lights rigged with two bulbs each?_______________________

d. Are flooding alarm lights rigged with a separate battery source?_____________________________________
(Must not be connected to navigational lights.)

e. Total amperage capacity____

f. Are flooding alarm lights rigged with flasher-type units?____

g. Is all wiring connected to sensor indicator lights run below decks insofar as possible?___________________

h Is all wiring secured and protected from any chafing?____

i Is all topside wiring protected from weather damage?____

j Are flooding alarms rigged in all major compartments closest to the keel?________________________________

k. Attach a list of below-waterline areas that do not have alarms Tanks and voids which can be flooded without sounding an alarm should be identified and the decision not to install alarms justified.

l. In large craft or in barges where compartments run athwartships, are flooding alarms rigged on both port and starboard sides?____________________

m. Are flooding alarm sensors well-secured to fixed objects such as stanchions, drainage pipes or ladders?____

n. Is the lower indicator light wire rigged to the 1-foot flooding alarm sensors?____________________

o. Is the upper indicator light wire rigged to the 3-foot flooding alarm sensors?____________________

p. Are the batteries secured for heavy weather? (If topside, they must be in a watertight box) Is battery ventilation adequate?____________________

8. Navigation:

a. Are proper navigation lights installed for towed unit?____________________

b. Is each light rigged with two bulbs, so that if one burns out the craft still complies with the Rules of the Road?

c. Is all wiring well-secured and protected from damage by the elements?____________________

d. Is the tow equipped with a solar switch or time switch?____________________

e. Are the batteries in a watertight box and secured for heavy weather?____________________

f. Is battery ventilation adequate?____________________
(If topside, batteries must be in a watertight box. The location should be carefully considered and secured from heavy seas. If possible, they should be inside the ship)____________________

g. Are the batteries charged with sufficient amperage available to keep the lights burning brightly for the duration of the trip?____________________

h. Total ampere capacity of the bank____________________

Sufficient battery amperage must be calculated and available to cover the following.

(1) Wattage of the bulbs serviced
(2) Distance of bulbs from battery resistance
(3) Duration of tow (taking into consideration the solar/time switch and length of the period of darkness)

(Note' Current requirements are listed in Section 6-9 of the U.S. Navy Towing Manual.)

9. Cargo.

a. Will craft have cargo on board?____________________

b. If liquid cargo, give location and type____________________

c Is solid cargo stowed below the main deck secured in position?____________________

If so, list location and type____________________

____

d. Is solid cargo stowed topside secured in position?____________________

If so, list location and type.____________________

____

(Note: All solid cargo on board must be well-secured from heavy weather. All cargo topside must be secured with wire straps and properly-secured turnbuckles or equivalent securing devices. In some cases, shoring will be required.)

e. Will cargo stowed on board adversely affect the stability of craft?____________________

(Note: If so, revise stability calculations m Section 6 of this check-off list.)

f. Has a manifest of all cargo been prepared for the towing ship?____________________

10. Towing Gear'

a. Have towing attachment points and fairleads (including chocks/bullnose) been non-destructively tested?_____

b. Date of last test____________________

c Test procedures used____________________

d Has all chain in the towing bridle been measured in accordance with NSTM 581 and the U.S. Navy Towing Manual?

(Note. The towing bridle is normally chain on all ocean tows. On some service craft, especially barges, wire has been successfully used. Wire should be used with extreme caution, due to problems with chafing)

e. Is towing bridle of sufficient size and length? The following restrictions apply:

(1) For service craft up to 500 tons, no less than 1 1/4-inch chain.

(2) For service craft above 500 tons, no less than 1 5/8-inch chain.

(3) For ships, the bridle must be equal in size to the ship's anchor chain, but not less than 1 1/4inch. Large ships do not need chain larger than 2 1/4 inches when towed by U.S. Navy towing ships More powerful commercial tugs will require larger chain bridles.

(4) Non-magnetic chain and attaching hardware will not be used for towing bridles.

(5) The length of each leg of the bridle from the towing attachment point to the flounder plate after rigging is completed must be equal to or greater than the horizontal distance between the attachment points.

(6) A bridle apex angle should be between 30 and 60 degrees, with 60 degrees the optimal angle

(7) On some ships with high bows (e.g., CVA, AD, AOR, AFS, etc.), it may be necessary to rig a one or two-shot chain pendant between the bridle flounder plate and the towing hawser.

f. Are all detachable links in the bridle legs and chain pendant locked with a hairpin?______________________
If not, towing bridle is unsatisfactory. See Appendix D of the U S. Navy Towing Manual.

g. Are the bridle legs of the same size chain and equal in length when rigging is complete?_________________
Link count____

(Note: To ensure accuracy, counting links prior to rigging and painting bench marks is the only positive method Total links per bridle leg should be equal at the attachment point on the tow)

h. If a wire bridle is used, is there a point of chafe on the tow?____
If so, strongly reconsider the decision to use wire. If there is a point of chafe and wire is used, sufficient and adequate chafing gear must be installed on the wire

i. If towing pads do not exist and bitts or cleats must be used, are they substantial enough to handle the strain of towing?____
See Chapter 6 of the U.S. Navy Towing Manual.

j. Are fairlead chocks and/or bullnose substantial enough to handle strain of towing?______________________

k. Is the deck area surrounding bitts or cleats in good condition?______________________________________

(Note. If not, consider non-destructive testing)

l. Is the tow bridle fairlead angle sufficiently straight to preclude excessive side loading to fairlead points?____

m. If mooring bitts are used, state the condition of bitts and surrounding deck area. If any doubt exists, request that the area be non-destructively tested.____

____

n. All towing bridles, when rigged correctly, must have a backup securing system. This Is normally accomplished by using wire rope of appropriate size (able to lace through chain links) and taking sufficient bights of wire from a second securing point (bitts, heavy cleats, etc.) and lacing the wire rope through the after end of links in the chain bridle (no less than four bights). Size and number of bights or wire should equal the strength of the chain used in the bridle. If a towing pad is used to connect the bridle to the tow, the backup wires must be laced forward of the towing pads. If a set of mooring bitts is used as a securing point for the bridle on the tow, the wire should be laced through the chain links that remain astern of the bitts after the three or more "figure eights " are secured on the bitts. There must be at least 3x diameter plus one wire clip on each bitter end of the backup wire, aligned in the same direction with "U " on bitter end side placed 6 rope diameters apart. Is the towing bridle rigged as stated above?____

o. Type of backup, cleats, bitts, padeye____

p. Distance from towing pad or bitts to backup point____

q. If mooring bitts are used, with sufficient strength to withstand the entire towing load, does the towing bridle have a round turn followed by three or more complete "figure eights" around bitts before the end of the chain is laced with the backup wire?____

____

r. When using a chain bridle and sets of bitts as the towing point, it is preferable to terminate the chain before reaching the bitts, using wire to make the connection to the bitts. When load-sharing between two sets of bitts, take only one round turn around one barrel of the first set and lead the wire to the second set, where it is terminated with a round turn followed by "figure eights" Has this been done?________________________________

s. Has all slack been taken out of the "figure eights "?________________________________

t. Has all the slack been removed from the backup wires so that all parts will take an equal strain if the attachment points fail?________________________________

u. In most cases, the bridle legs are run through closed chocks before being connected to the towing pads or bitts. The lead angle from the connecting point to the chocks must be fairly straight to prevent bending and failure of the chain where it passes through the chock. Does the towing rig conform to the above?________________

v. Is there sufficient and adequate metal thickness at all potential chafing points to prevent the bridle from cutting into the chocks, gunwale or hull?________________________________

w. If mooring bitts are used as bridle attachment points, heavy channel iron must be welded across the bitts to prevent the chain from jumping out. Has this been accomplished?________________________

(Note A minimum of 4-inch channel iron is recommended.)

x. Is the size of the bridle retrieving pendant adequate (i.e., providing a 4.1 safety factor in lifting bridle weight, but no less than 5/8-inch wire rope)?________________________________

y. Is there an adequate number of wire clips securing the retrieval pendant (3 x diameter of wire plus 1)?_______

(Note Install wire clips aligned in the same direction with "U" on bitter-end side, placed 6 rope diameters apart)

z. When attached from the bow of the tow to the flounder plate, is there sufficient slack to allow the retrieval pendant to droop slightly with no strain when the unit is being towed?________________________

aa. Are flounder plates and plate shackles of approved design, and rigged in accordance with the U S Navy Towing Manual"

bb. If there is a clearance in excess of 1/16" in securing pins in plate shackles, flounder plates and other towing jewelry, the rig is unacceptable. Is the towing rig jewelry within acceptable clearance limits?
____

cc. All plate and safety shackle pin nuts must be locked with a minimum of a 5/16-inch machine bolt through a drilled hole in the plate shackle nut and pin. Secure the machine bolt in place with jam nuts Has this been accomplished?______________________________

(Note. Welding is not acceptable.)

dd. Lateral movement must be removed from the plate shackle connections by using washers or welding bosses on the plates Has this been accomplished?______________________________

ee. Are all safety shackles of the approved types and materials listed in the U.S. Navy Towing Manual?

____

ff. If multiple tows are planned, and you are the preparing activity, have you checked to ensure that all the necessary equipment is available to rig and stream the appropriate towing method?

Standard U S Navy practice allows three possible versions: the Christmas Tree, Honolulu, and Tandem rigs Any rig selected must be rigged in accordance with the U.S. Navy Towing Manual. Rig selected

(Note: Preparing activity should check with the towing activity as to desired rig.)

gg. Is shoring required to prevent damage to deck fittings, wiring, scuttles, doors, etc.?______________________________

hh. Does craft have the equipment on board to anchor in 60 feet of water with at least a ratio of 3.1, scope to depth?______________________________

Is anchor of sufficient size and anchor cable ofsufficient size and length to accomplish this?

____

ii Has the anchor windlass brake been tested?______________________________

jj. If plans have been made to anchor the tow at port of delivery, is power available to raise the anchor?

____

kk Major ocean tows are normally rigged with a secondary emergency towing system to recover the tow in case of failure of the primary system. Is such a system rigged?______________________________

ll. Are the secondary towing system's attachment and fairlead points adequate to tow the vessel?______________________________

____

mm. Is adequate chafing protection provided for the vessel's primary and secondary towing systems?
____

nn. Is the secondary towing pendant at least 1 5/8-inch wire rope?____________________

oo. Is the secondary towing pendant stopped off in bights on one side of the tow?____________________
____

pp. Are the stops sufficient to hold in heavy weather, but accessible to allow cutting and light enough to be broken without damaging the towing pendant or tow?____________________

qq. Will the secondary pendant fall free without turns that willcause kinking as they pull out?____________________
____

rr. Is the secondary towing pendant fitted with a synthetic line messenger to facilitate passing it to the tug?_____

ss. If the tow is unmanned, is a polypropylene floating retrieval line attached to the end of the messenger with a small buoy secured at its end?____________________

tt. Normally, an open-ocean tow has solid connecting jewelry, but m cases of damaged and some calculated risk tows (such as some SINKEXs), an emergency quick-disconnect method such as a pelican hook is advisable If this is such a tow, is an emergency quick disconnect provided?____________________
If so, what?____________________

uu. If an emergency disconnect is provided, will all jewelry fit through all fairleads through which it must pass (e.g, the bullnose)?____________________

vv. What is the weakest element in the towing rig?____________________What is its strength?____________________

11. Special Considerations.

a. Some types of tows require special considerations. For instance, YTBs, YTMs and other self- propelled service craft were not designed to go to sea and are not very seaworthy. In these craft, the watertight envelope must be absolutely complete; they have low freeboards and water will constantly be breaking over them even in moderate seas. Topside weight must be reduced to an absolute minimum Barges must be in excellent condition and, in most cases, reinforced on the inside of the bow because of the constant pounding of the seas caused by their flat bottoms Submarines are not designed with towing in mind Generally, a towing padeye is installed near the sail as a single towing point See Chapter 4 and Appendix J of the U S. Navy Towing Manual for data concerning submarine tows

b. There are many hulls whose design will require special towing rigs. Additional work may be required to rig an applicable bridle to ensure safe delivery of a craft from port to port. This will require additional lead time to prepare the tow(s) for ocean transit. Submarines, wooden-hull mine sweepers, sailing craft, etc, fall into this category.

c. When towing a sharp "V-shaped" hull that has a bullnose and a bulbous bow/sonar dome, the single leg bridle is the preferred method of rigging. Rig using at least two shots of the tow's anchor chain, if that chain is acceptable, m accordance with the U S Navy Towing Manual

12. Remarks':____

13. The tow described above is certified as seaworthy m all respects. The material condition is noted. Copies of the master inventory and storage keys are receipted for.

Representative of command having prepared the tow for sea. Date

H-2. SAMPLE CERTIFICATE OF SEAWORTHINESS/DELIVERY LETTER

FIRST ENDORSEMENT

1 Upon inspection of the tow described above, the following unsatisfactory conditions were found, which render the tow unseaworthy or not ready for towing (if none, so state).

a.

b.

C

d

2 (Cross out the statement which is not applicable)

a I find the tow described above in a condition satisfactory for towing, and hereby assume responsibility for delivery to the port of destination prescribed m my sailing orders.

b. I will accept the tow as a calculated risk only upon authorization of my operational commander. I have notified my operational commander of the reasons for this action.

Commanding Officer, USS	Date

SECOND ENDORSEMENT (To be accomplished only if calculated risk tow is acceptable to delivering authority)

1. The following conditions listed in the first endorsement remain uncorrected.

a

b.

2. It is requested that you accept this tow in the above condition as a calculated risk

Representative of command having cognizance of towed unit.	Date

THIRD ENDORSEMENT

1. As authorized by____
(DTG reference of operational commander's message)

I accept this tow, with conditions existing as described in the second endorsement, as a calculated risk for delivery to the port designated in my Sailing Orders.

_______________________________________ _______________________________
Commanding Officer, USS_______________________ Date

SAMPLE DELIVERY LETTER

From: (Receiving Activity)

To: (Commanding Officer of Towing Vessel)

1. Received custody of (describe tow) this date.

_______________________________________ _______________________________
Representative of Receiving Activity Date

APPENDIX I

TOWING PLANS

Towing plans and drawings of towing equipment and rigging associated with towing operations are included in this appendix

The enclosed drawings are intended to serve as both guidance and examples of typical tow configurations. Exercise care in selecting compatible components. Important considerations include the following:

a. Each leg of a bridle should be strong enough to assume the entire resistance of the tow.

b. For a Christmas Tree rig, using chain bridles and pendants will promote a deeper underrider and minimize interference with intermediate tows.

c. Towing flounder plates and plate shackles are designed to be fabricated easily. Flounder plates and cheeks of plate shackles can be fabricated from common steel (1 e., ABS Grade A or ASTM A-36). Pins must be machined from 150,000 psi minimum yield material such as AISI 4140. When pins are fabricated, it is recommended that a material certification be required

d. Plate shackles shown herein are not necessarily suitable for beach gear or heavy lifting rig applications

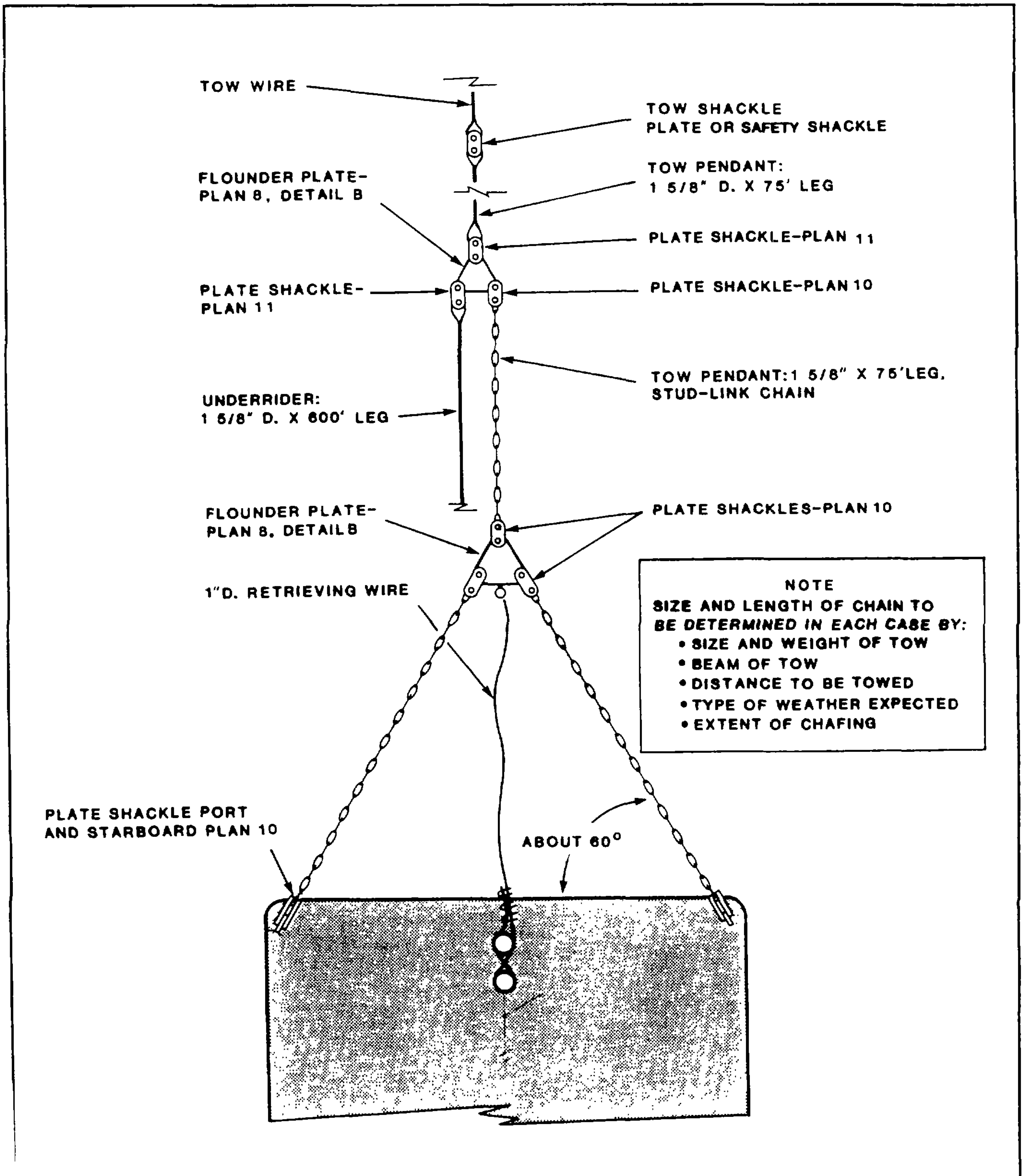


Figure I-1. Towing Plan No. 1-Chain Bridle with Chain Pendant.

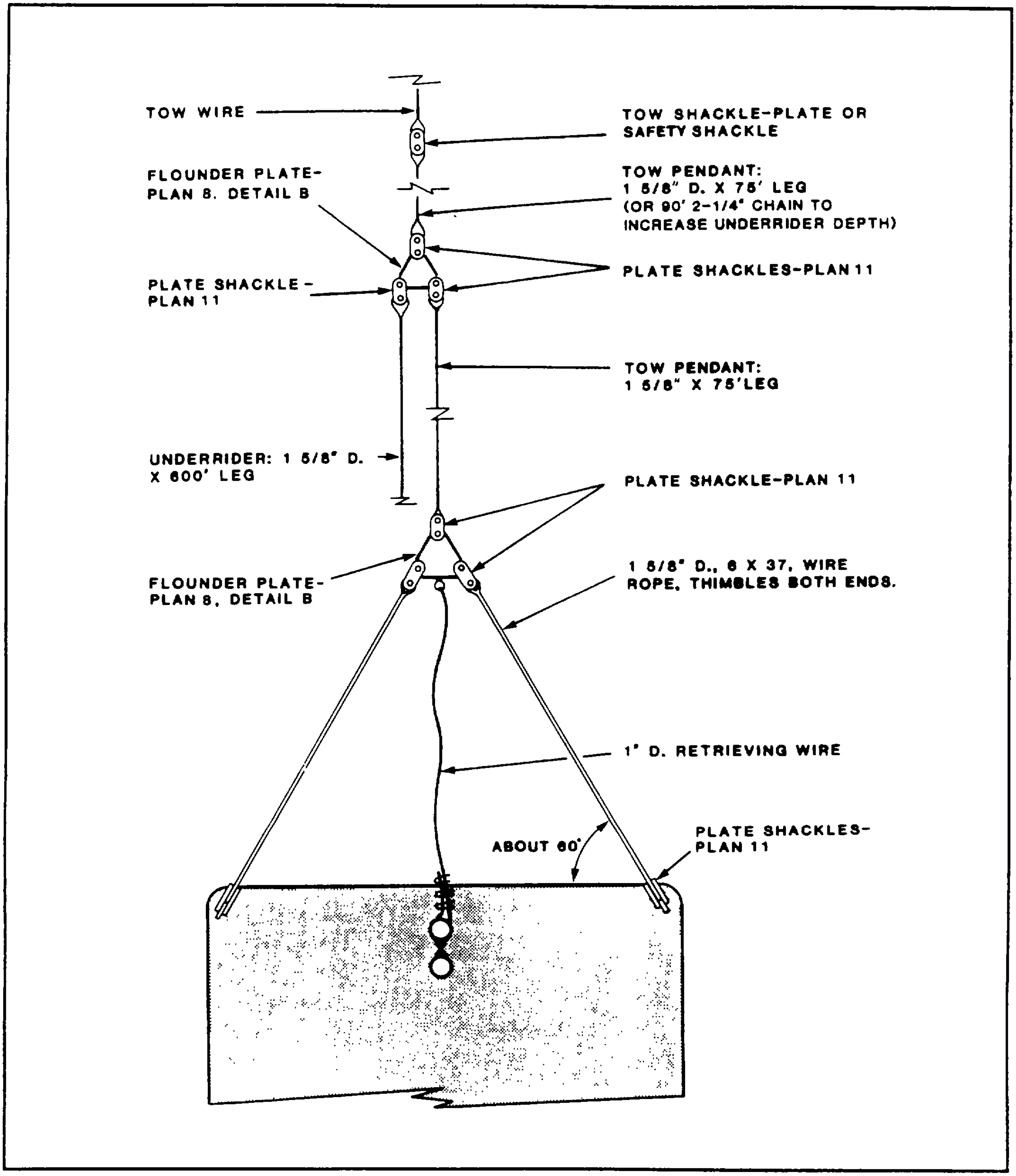


Figure I-2. Towing Plan No. 2-Wire Bridle with Wire Pendant.

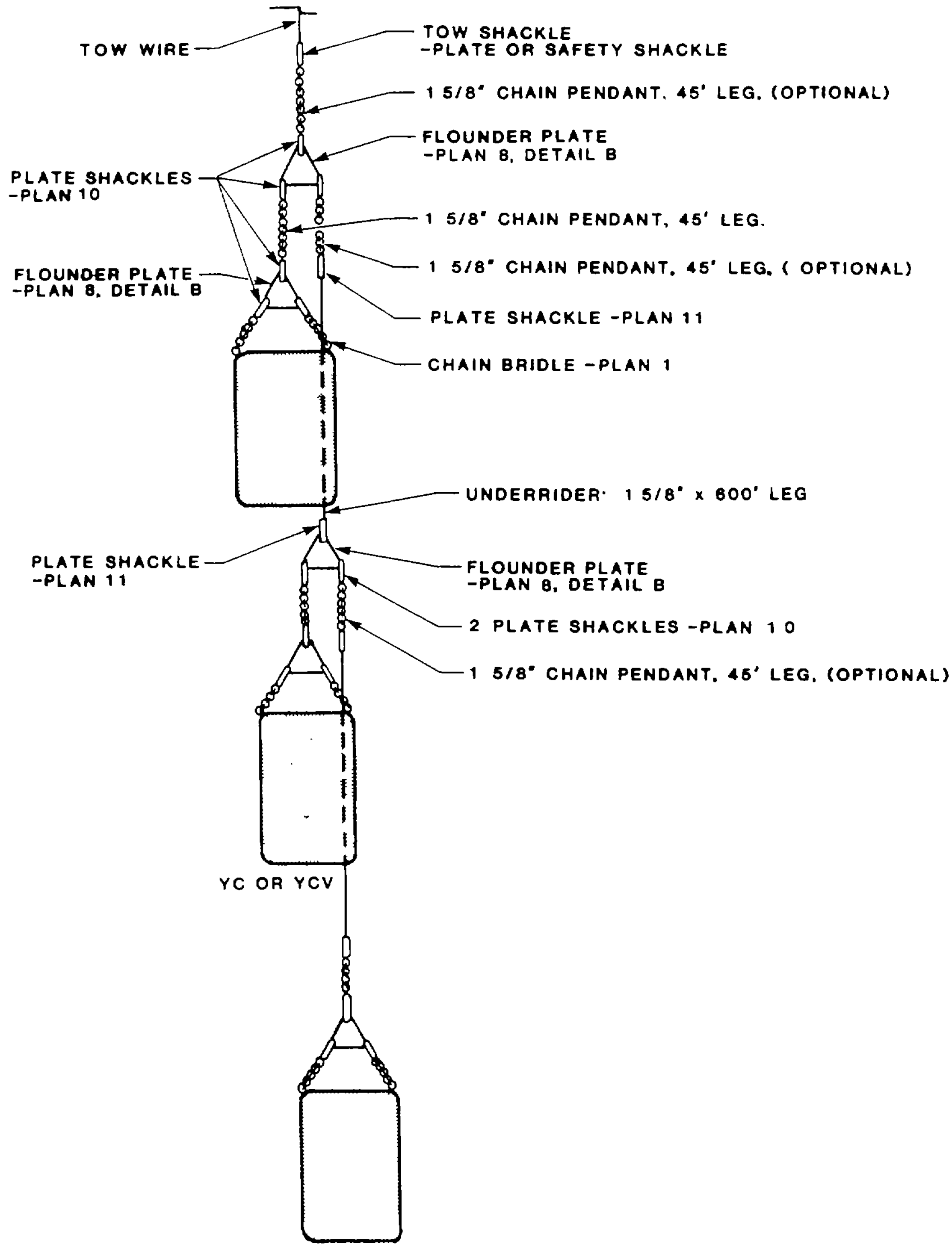


Figure I-3. Towing Plan No.3-Christmas Tree Rig, Chain Bridle.

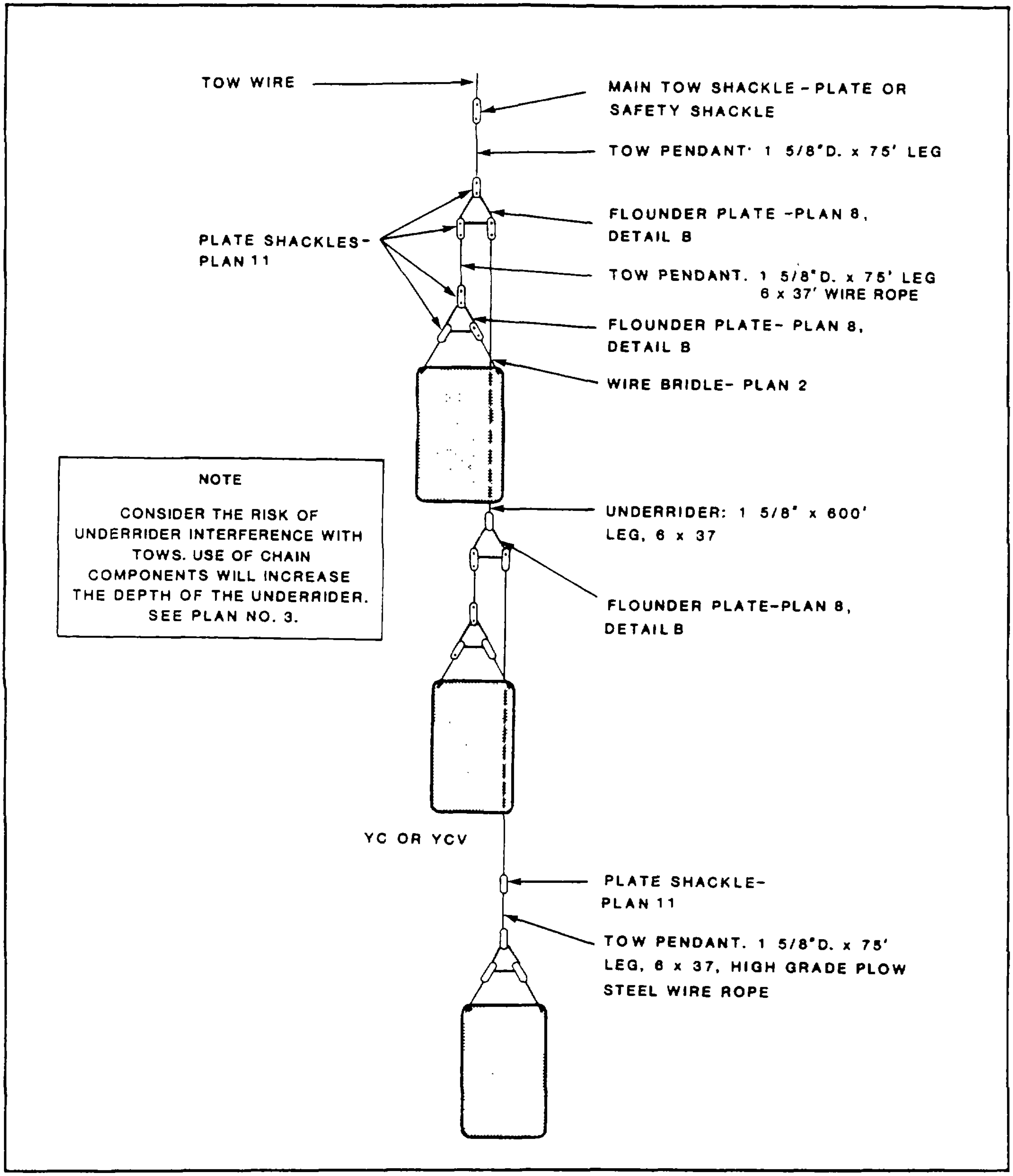


Figure I-4. Towing Plan No.4-Christmas Tree Rig, Wire Bridle.

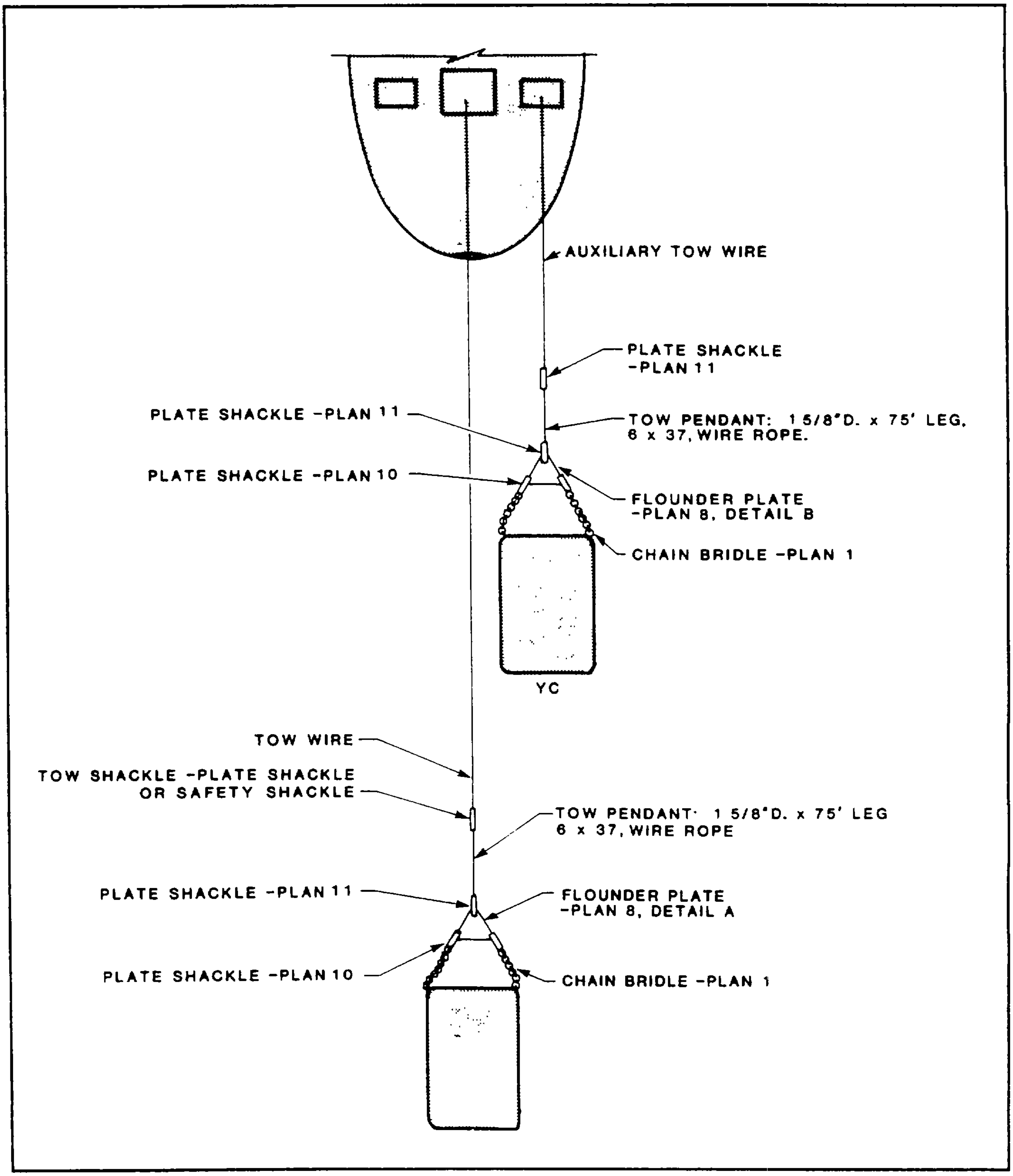


Figure I-5. Towing Plan No. 5-Honolulu Rig.

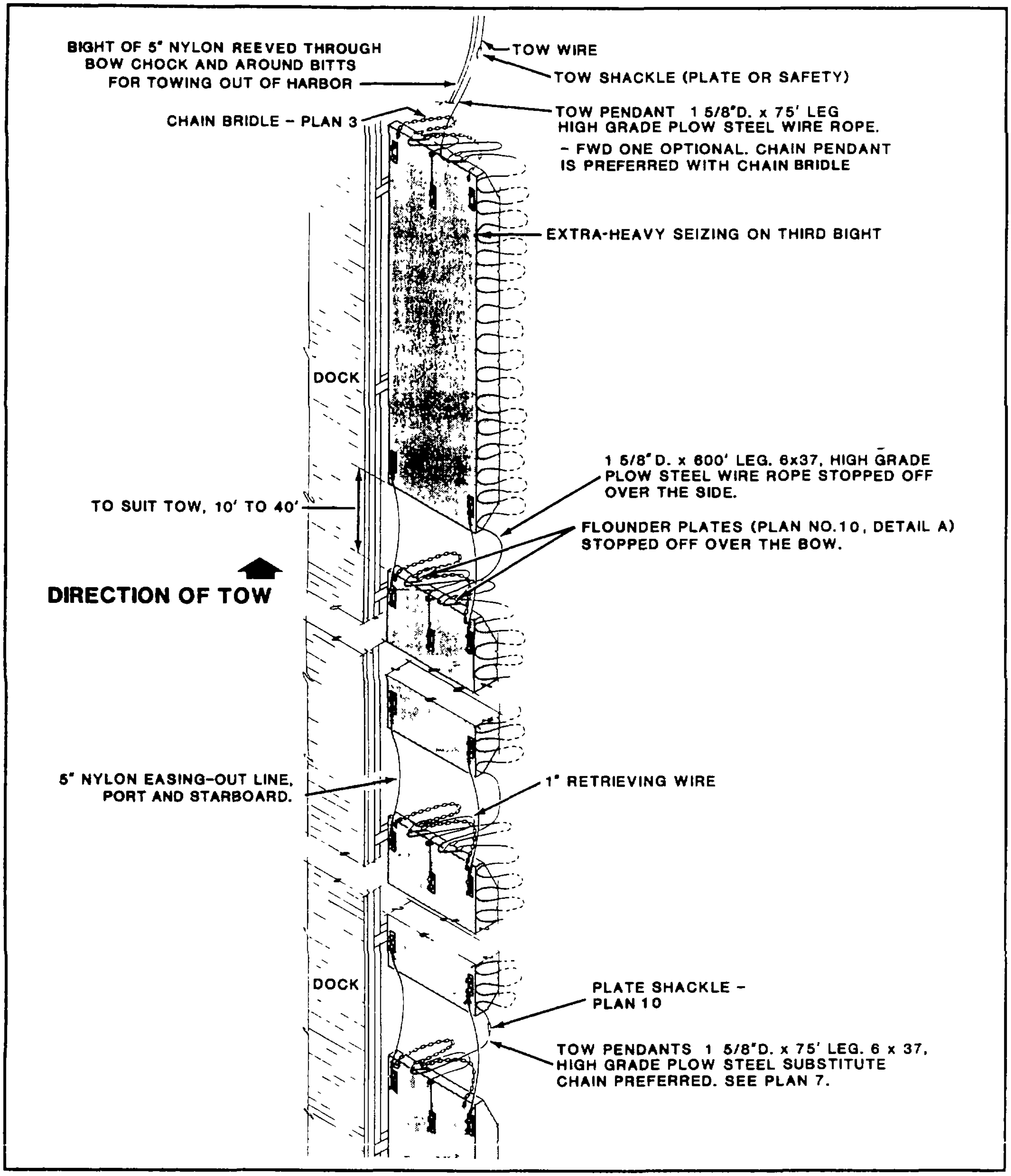


Figure I-6. Towing Plan No. 6-Four Barge Tow Ready for Streaming.

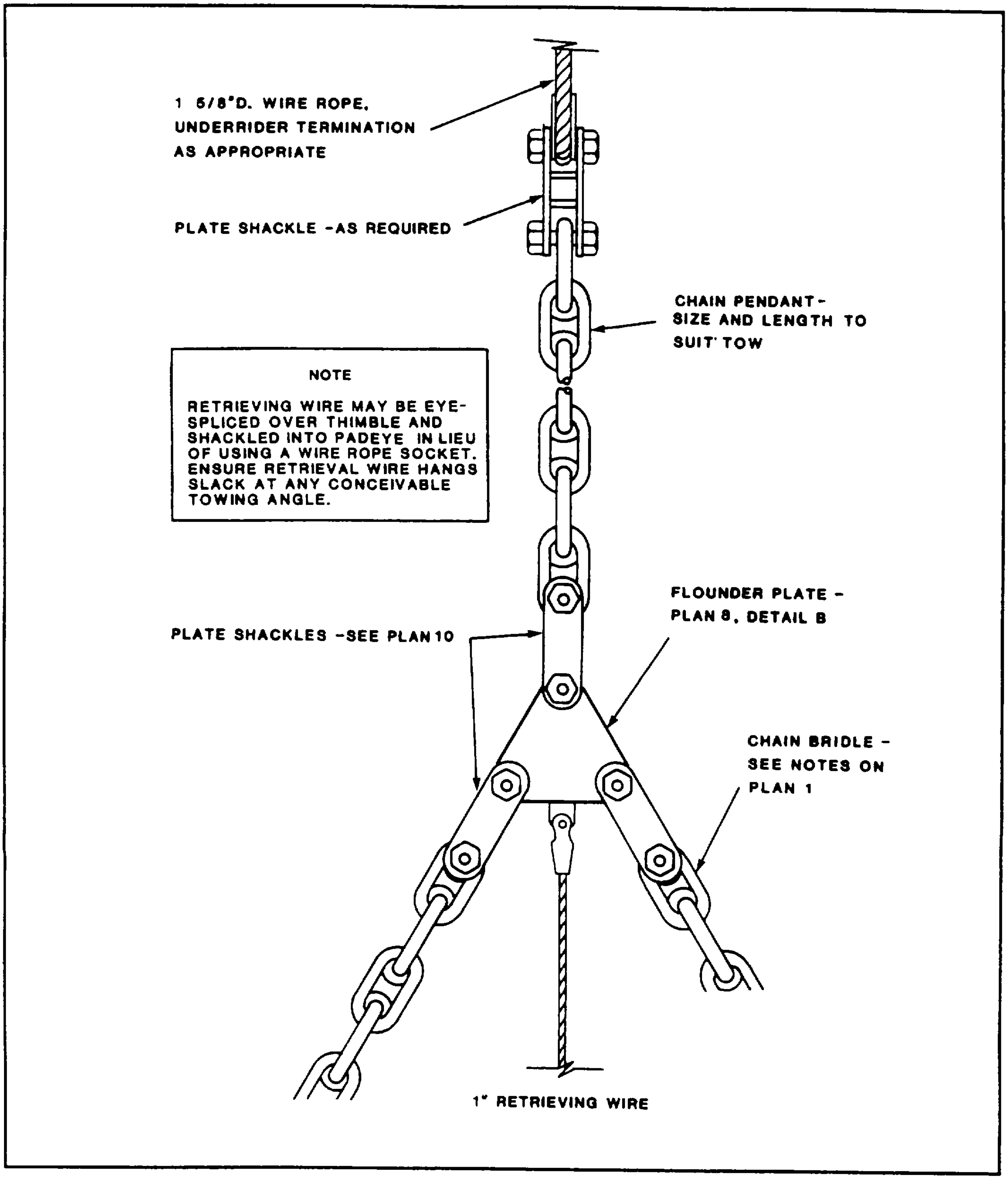


Figure I-7. Towing Plan No.7-Chain Bridle and Pendant in Christmas Tree Rig.

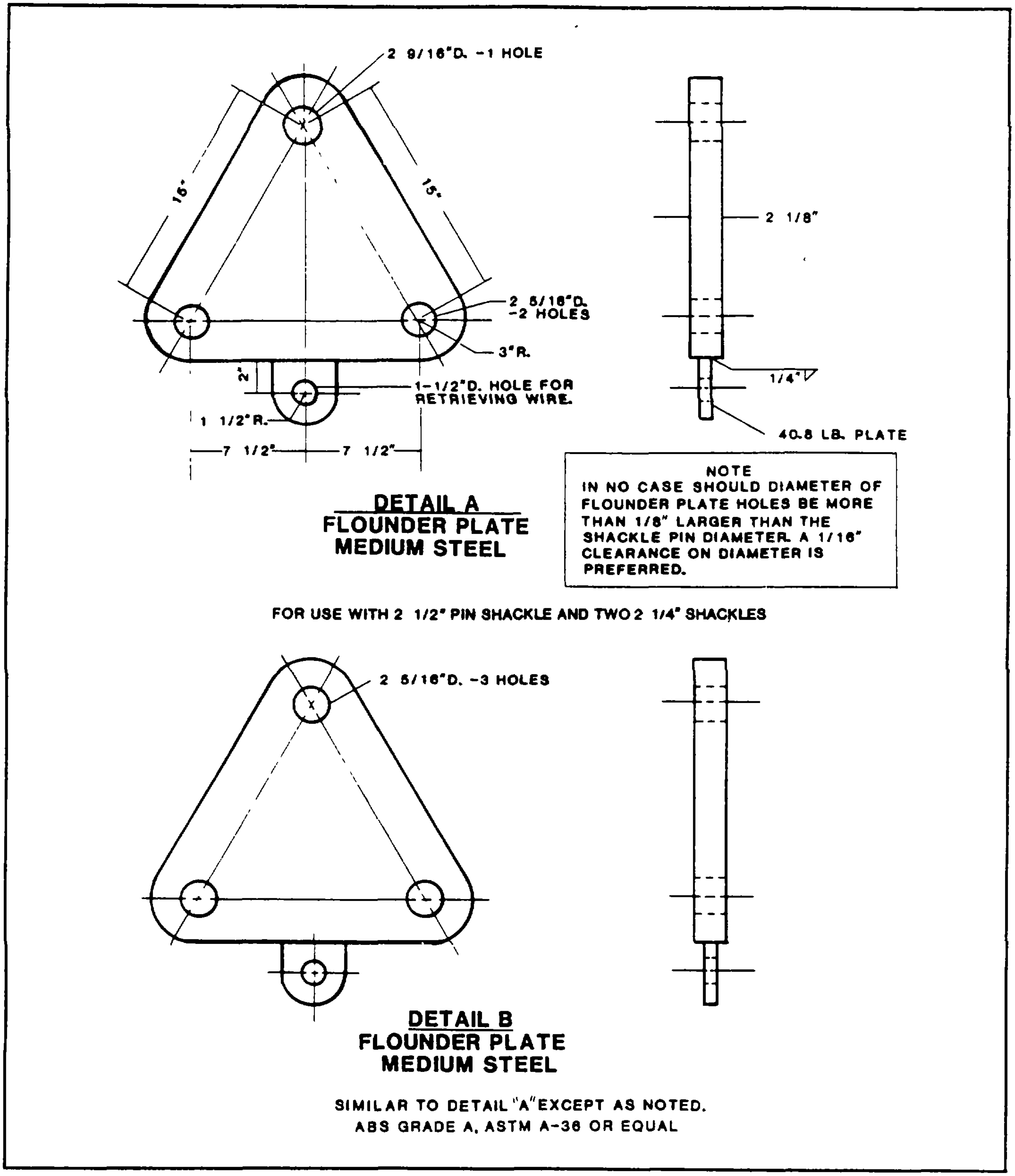


Figure I-8. Towing Plan No. 8-Flounder Plate.

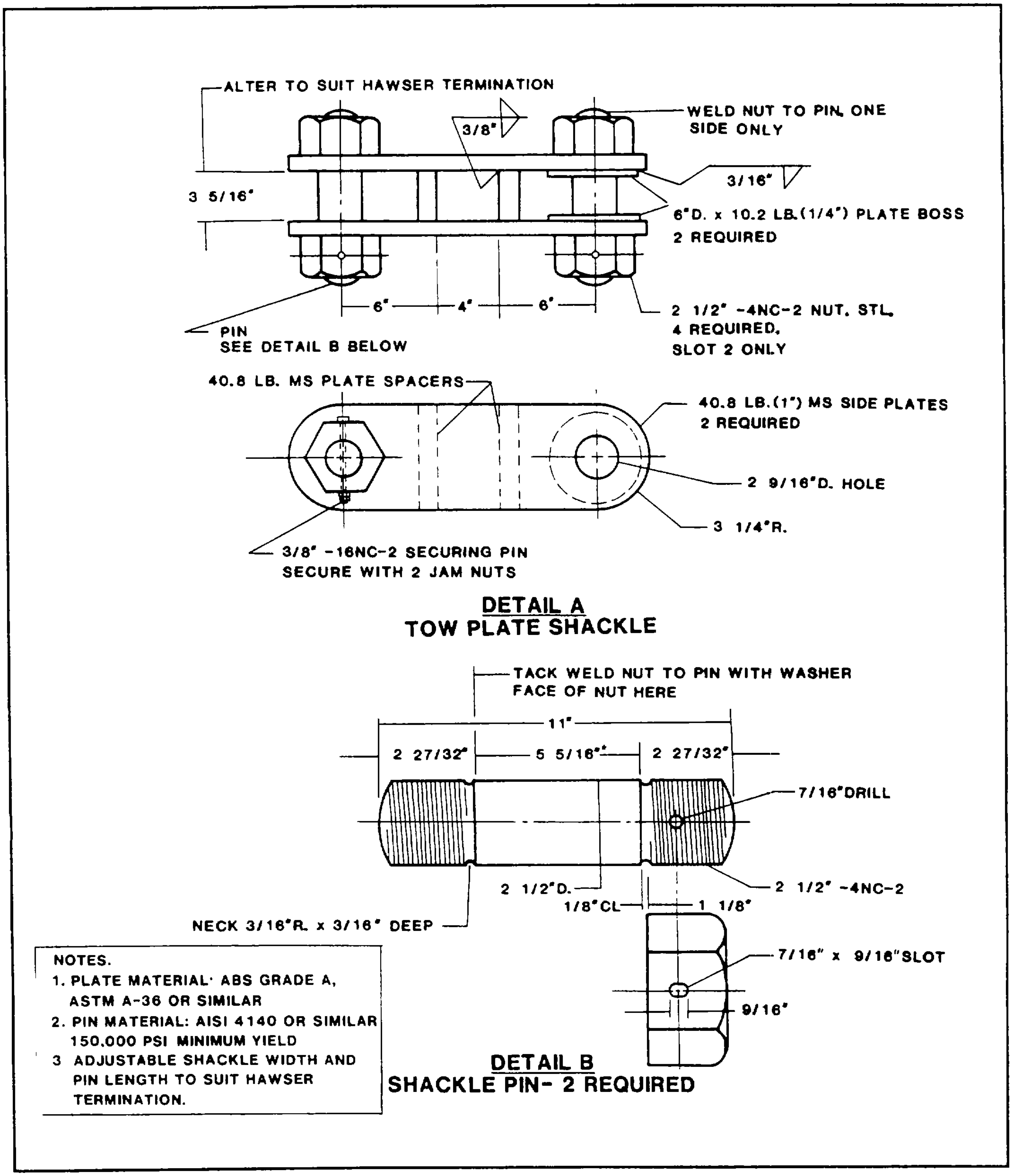


Figure I-9. Towing Plan No. Plate Shackle and Pin for 2-inch Closed Socket.

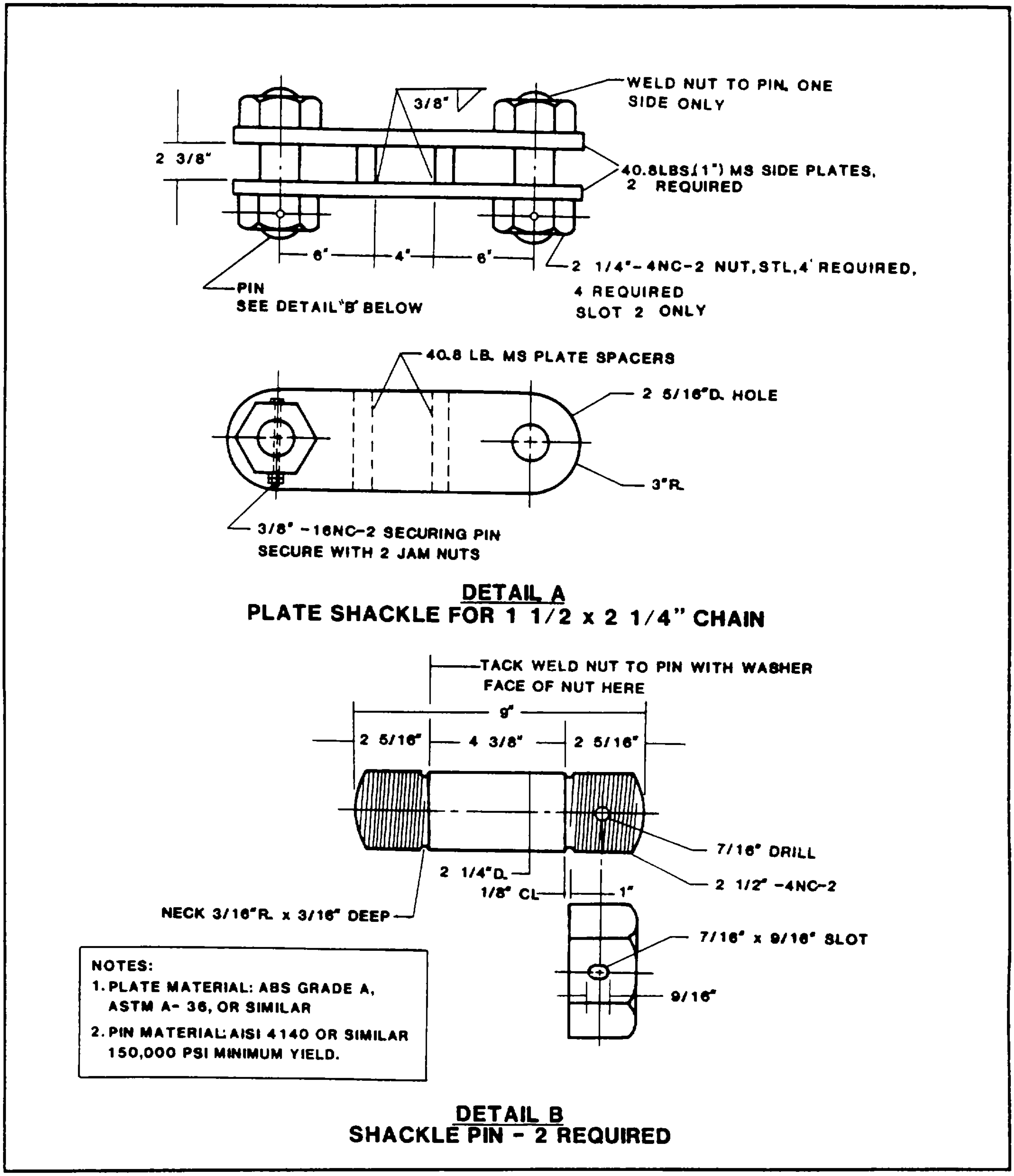


Figure I-10. Towing Plan No. 10-Plate Shackle and Pin.

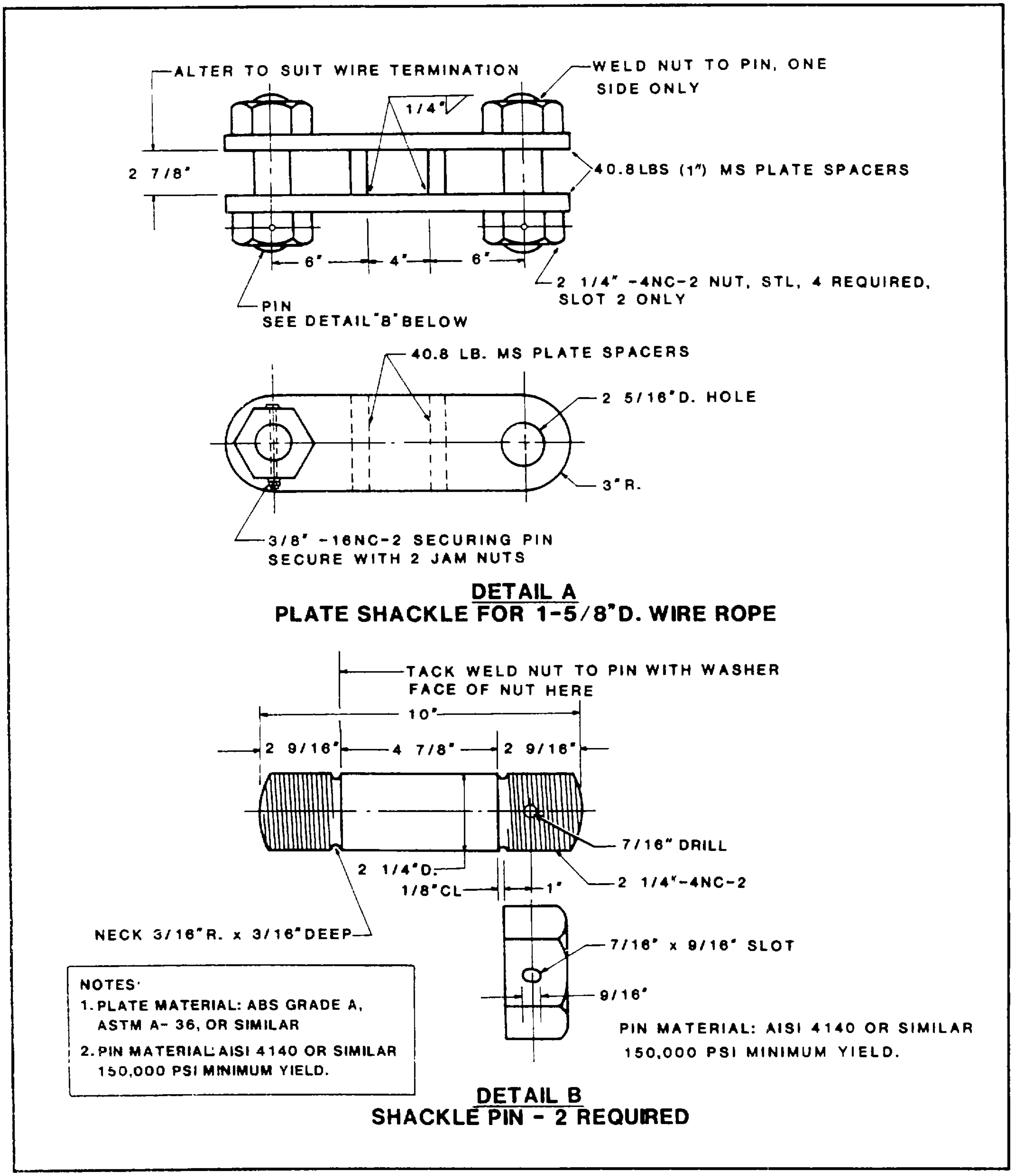


Figure I-11. Towing Plan No.11-Plate Shackle and Pin.

APPENDIX J

TUG CAPABILITIES

This appendix is intended to assist the tow planner by addressing considerations and features of commercial ocean-going tugs, foreign and domestic, that may be called upon for planned or emergency use by the U.S. Navy. Reasons are provided to encourage care in the selection of commercial tugs to fulfill Navy requirements

J-1 TUG CHARACTERISTICS

This section addresses features of ocean-going tugs, with emphasis on salvage tugs. This does not suggest that other types of tugs are not capable of safely executing assigned tasks. In fact, they usually will be more economical to hire than a fully-equipped and fully-manned salvage tug. The salvage tug is used as the benchmark by which to compare others, since it is the most capable and versatile type of tug.

J-l.1 SALVAGE TUG ATTRIBUTES. Salvage tugs are large, powerful and extremely seaworthy tugs They can perform many different tasks and carry a wide variety of equipment and material, as well as a relatively large crew They have the crew and equipment to execute a salvage task and the high power needed to refloat a stranded vessel. They are excellent in a rescue mission, they possess excellent seaworthiness and sufficient speed to reach the casualty promptly, the extra manpower and gear to make the tow connection under strenuous conditions, and the power to tow the casualty to safety Finally, salvage tugs have the power, stores and fuel capacity to make them excellent for long-distance tows of large ships and heavy objects In terms of capital cost and operating expenses, each of the three salvage tug missions-salvage, rescue and towing- probably could be accomplished more economically and efficiently by a tug specializing in only one of these areas. However, no other type of tug can fulfill all three missions, under all kinds of circumstances, as well as the salvage tug

Not surprisingly, the lines separating the classes of tugs are sometimes blurred by overlapping design features, and often by what an owner chooses to call his tug There is no universal acceptance of the salvage tug description used in the preceding para- graph. In fact, few owners actually refer to their salvage tugs as such, preferring simply to list them as "tugs"' Some that are called "salvage tugs" may be low-powered vessels intended for support of salvage operations, often inshore, and would be totally unsuited for a rescue mission, long ocean tow or stranding on an unprotected shore.

The problem of identifying tugs by type is further complicated by the advent of many high-powered but very specialized support craft involved in the offshore oil industry. Thus, there are anchor-handling tugs, supply tugs and anchor-handling/supply tugs. These can be useful in an emergency situation, but have minimum crew sizes, may have limited cruising range, and usually do not carry the wide assortment of gear useful in rescue towing or salvage.

The following sections describe the attributes of salvage tugs

J-1.1.1 Length. Length is a major contributor to seaworthiness and provides for good arrangements and ample storage for crew, stores and equipment. Length promotes efficient free-running speed. The disadvantages of incremental length are higher construction cost and less maneuverability. Salvage tugs generally are well over 200 feet long, with the largest approaching 300 feet.

J-1.1.2 Draft. Draft promotes seaworthiness and directional stability against off-center towing forces, and provides for efficient propeller, design and placement. However, salvage tugs must work in shallow water around strandings, so their drafts represent compromises. Salvage tugs generally have a draft of 16 to 18 feet, with the deepest approaching 20 feet

J-1.1.3 Freeboard/Depth. High freeboard forward improves seaworthiness. Freeboard aft is a compromise between the desire to provide a work space that is safe and dry, versus one that is located conveniently close to the work site, which often is near the waterline.

J-1 1.4 Beam. Beam improves stability, provides the internal volume for storage and other functions, and promotes efficient work spaces. Too much beam, however, handicaps free-running speed and increases fuel consumption. Salvage tug beams are 45 feet or more, with the largest over 50 feet.

J-1.1.5 Crew. The crew of a salvage tug is significantly larger than crews of other tugs. Commercial salvage tug crews will vary from 15 to 25. Less tangible is the experience level of the crew. The best salvage and towing people often gravitate toward the salvage tugs, man-for-man, the experience level often is superior in these ships.

J-1.1.6 Towing Equipment. Towing equipment, as described in Appendix N, is the "main battery" of a salvage tug. Some salvage tugs have automatic tow- mg machines Most commercial salvage tugs have an automatic rendering winch, at a minimum This is an important clue to the capabilities of salvage tugs. Appendix N has a more complete discussion of tow- mg machines and winches. Section 5.5 discusses strength of towing hawsers and related equipment.

J-1.1.7 Power. Power obviously is an attribute for tugs because it provides for prompt transit to the location of the casualty, assists in refloating the stranded ship, and facilitates towing the casualty. The citation of horsepower rating for tugs varies, and this must be understood to make a valid comparison between tugs. This subject is addressed in Section J-1.2.

J-1.1.8 Bollard and Towline Pull. Bollard and towline pull are measures of maximum pull while dead in the water and available pull when the tow is under- way. These attributes are also discussed in Section M-1 2 since they are closely related to power.

J-1.2 POWER, BOLLARD PULL AND TOWLINE PULL. Towing is a very competitive endeavor, with business often sold on the basis of tug power. Custom, with regional differences, results in different methods of reporting a tug's attributes, as follows.

J-1.2.1 Power. The power of a tug can be quoted in shaft horsepower, horsepower, indicated horsepower or kilowatts, as follows:

Shaft Horsepower (SHP) is the power delivered to the propeller. Generally, only Navy tugs utilize SHP to describe their power; however, this is the truest measure of power delivered by the tug.

Horsepower (HP) generally is the Brake Horsepower (BHP) of its propulsion engines-i e., the power delivered at the engine’s shaft This description ignores the reduction gear and propeller shaft losses, which may be considerable. Most American owners and the offshore oil industry, worldwide, use the HP description for tugs. Some foreign shipowners use kilowatts as units of power. Kilowatts (1 KW = 1.341 HP) may be assumed to be measured at the engine.

Indicated Horsepower (IHP) derives from the days of reciprocating steam engines and ignores heat, friction, valve and engine-driven auxiliary losses within the engine Furthermore, some owners may add the generator engines and thruster power to the total, so IHP may exceed HP by a factor of 1.2 to 1.6 or more. Of course, an owner reporting in HP also may add generators and other power sources/users to his total Most European and Asian salvage operators report tug power in IHP and no one wants to be the first to report otherwise, for fear of losing a competitive advantage. It has been noted, however, that more owners are now reporting in kilowatts to avoid the confusion of HP vs. IHP.

J-1 2.2 Bollard Pull. Bollard pull is the zero speed pulling capability of the tug. It is a measure of the usefulness of the ship in a stranding scenario or in holding a large tanker or aircraft carrier off a lee shore. However, the bollard pull figure must be under- stood

Ideally, bollard pull is tested when a tug is built and certified by one of the classification societies. Bollard pull tests sometimes are performed after major engine overhauls Tug owners whose tugs have been tested usually provide a copy of the certificate attesting to the bollard pull figure

Bollard pull, like horsepower, is a selling point for tugs and is sometimes overstated. For instance, there are rules of thumb for converting propeller power (SHP) to bollard pull, such as one ton pull per 100 horsepower for a conventional propeller, or 1.2 to 1.5 tons pull per 100 horsepower for a propeller fitted with a nozzle. The owner may save the cost of a bollard pull test and simply apply one of the factors to convert propeller power to bollard pull without ever knowing what the real figure is It is unlikely that this owner will ever select a conservative conversion factor

European owners generally report bollard pull in their literature and reputable salvage tug owners generally are able to produce a certificate to document the test. American owners, and the worldwide offshore oil support industry, rarely report bollard pull. When they do, the figure may not have been validated by a test. Horsepower is probably a more reliable measure among ships of these types.

Bollard pull is not the only useful measure of the puling capability of a tug. Except in the case of a stranding, the objective of the tug is to move its tow. In this case, some of the tug's power is expended on overcoming the hull resistance of the tug itself, and some on the hydrodynamic resistance of the towing hawser Bollard pull can be maximized by propeller and nozzle design, but at the expense of towline pull at towing speeds This adversely impacts free- running speed and fuel usage. Most tug designs, however, are optimized for towing.

Tugs generally are expected to operate in the 4- to 8-knot speed range. Modern tugs usually use propeller nozzles so that bollard pull still is quite high, but with a significant disadvantage in tug speed and fuel consumption A tug optimized for rescue towing probably would not employ nozzles, being most concerned with high speed running to the casualty, and accepting some loss in efficiency of the tow itself. Appendix L provides additional information on the tradeoffs involved in tug design. Figure M-1 displays towline pull vs. speed for typical tug designs using controllable-pitch propellers turning inside nozzles. The figure is adapted from Blight and Dai, *Resistance of Offshore Barges and Required Tug Horse-power, OTC 3320, 10th Offshore Technology Conference Proceedings, 1978 (Ref. 26).*

The foregoing aspects of tug design and owners' claims demonstrate that a tug should be considered as a balanced design, with some being more suitable for some tasks, others for other tasks. The balance extends to the task as well Chartering a 20,000 IHP salvage tug to tow a 200-foot barge would be just as inappropriate as sending a 5,000 HP platform supply ship, with no tow hawser or winch, on a rescue tow mission.

J-2. OCEAN-GOING TUGS FOR HIRE.

This section provides sample specifications for typical ocean-going tugs and statistics on the number of tugs available for hire.

J-2.1 OCEAN-GOING TUG EXAMPLES.

Figures J-2 through J-4 are drawings of typical salvage tugs, point-to-point towing tugs and anchor- handling/supply tugs. Table J-1 provides data on these and other tugs

J-2.2 DECLINE IN SALVAGE TUG AVAILABILITY . Traditionally, salvage and towing companies maintained their best ships "on station" waiting for a casualty to occur. The "station" could be a semi- permanent strategic location such as Jamaica, Gibraltar, Aden or Singapore, with backup by a shore

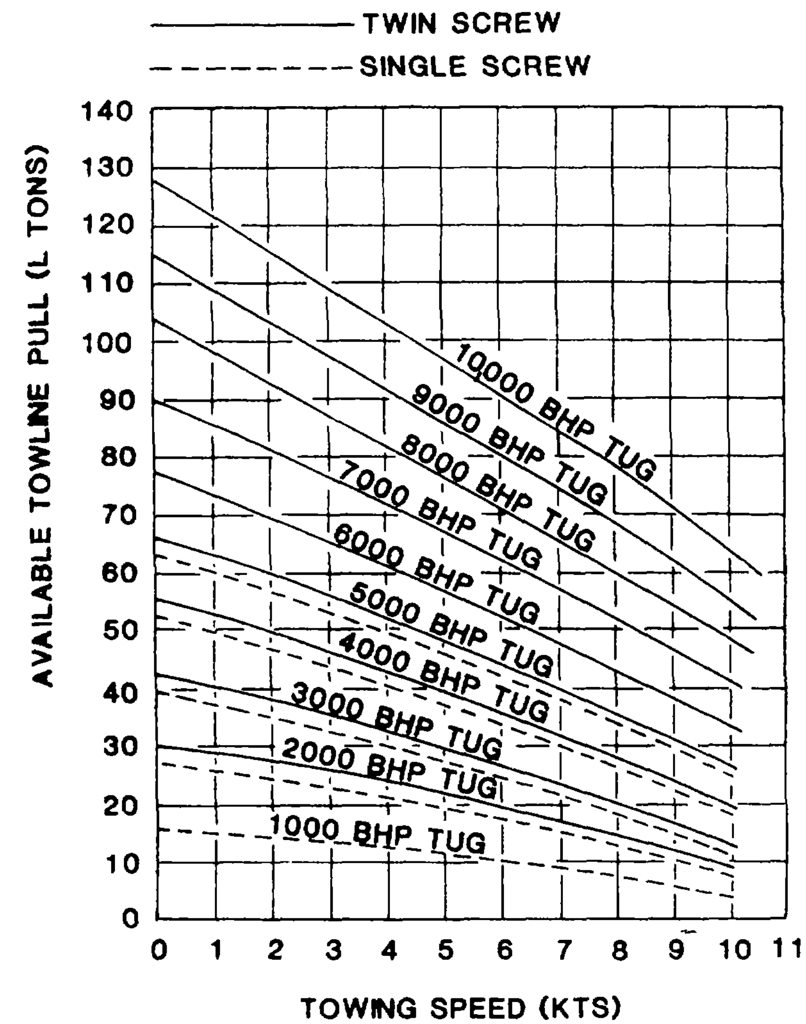


Figure J-1. Tug Bollard Pull Vs. Towing Speed for Tugs with Controllable-Pitch Propellers and Nozzles.

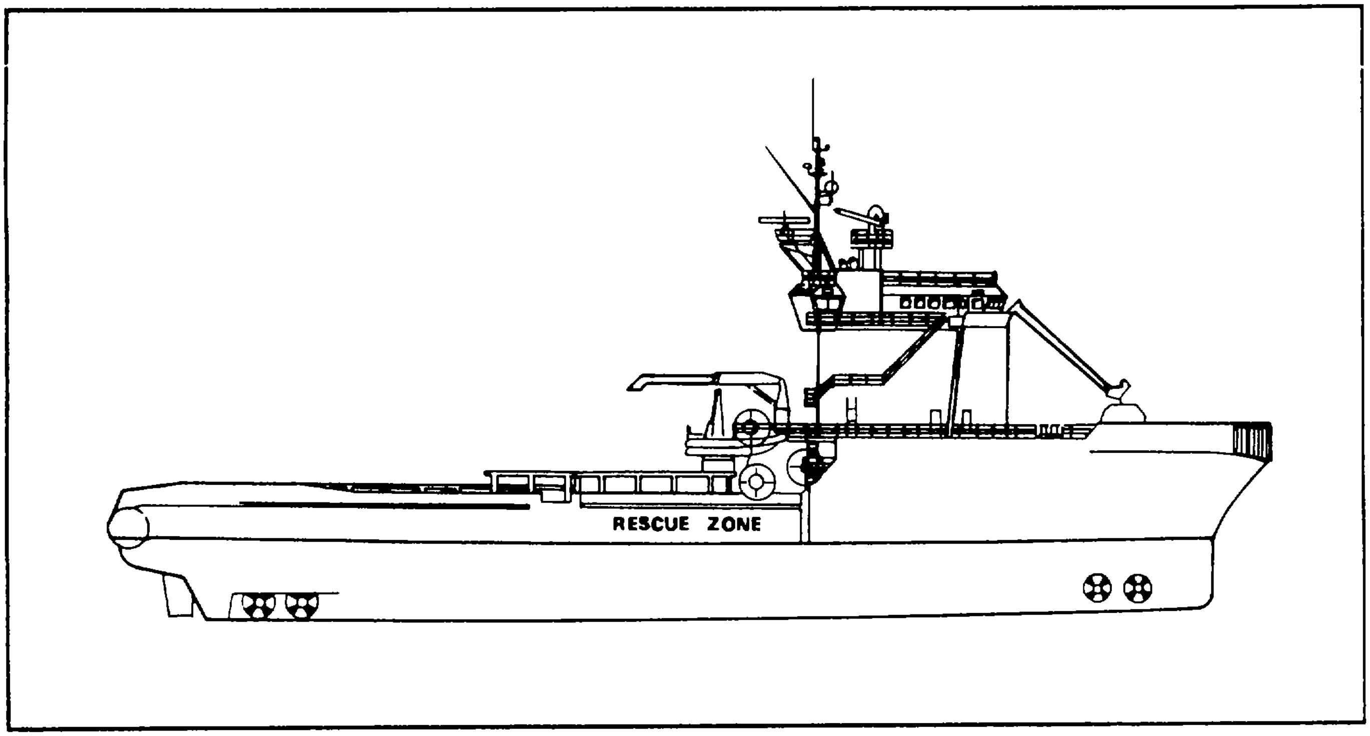


Figure J-2. Anchor-Handling/Supply Tug.

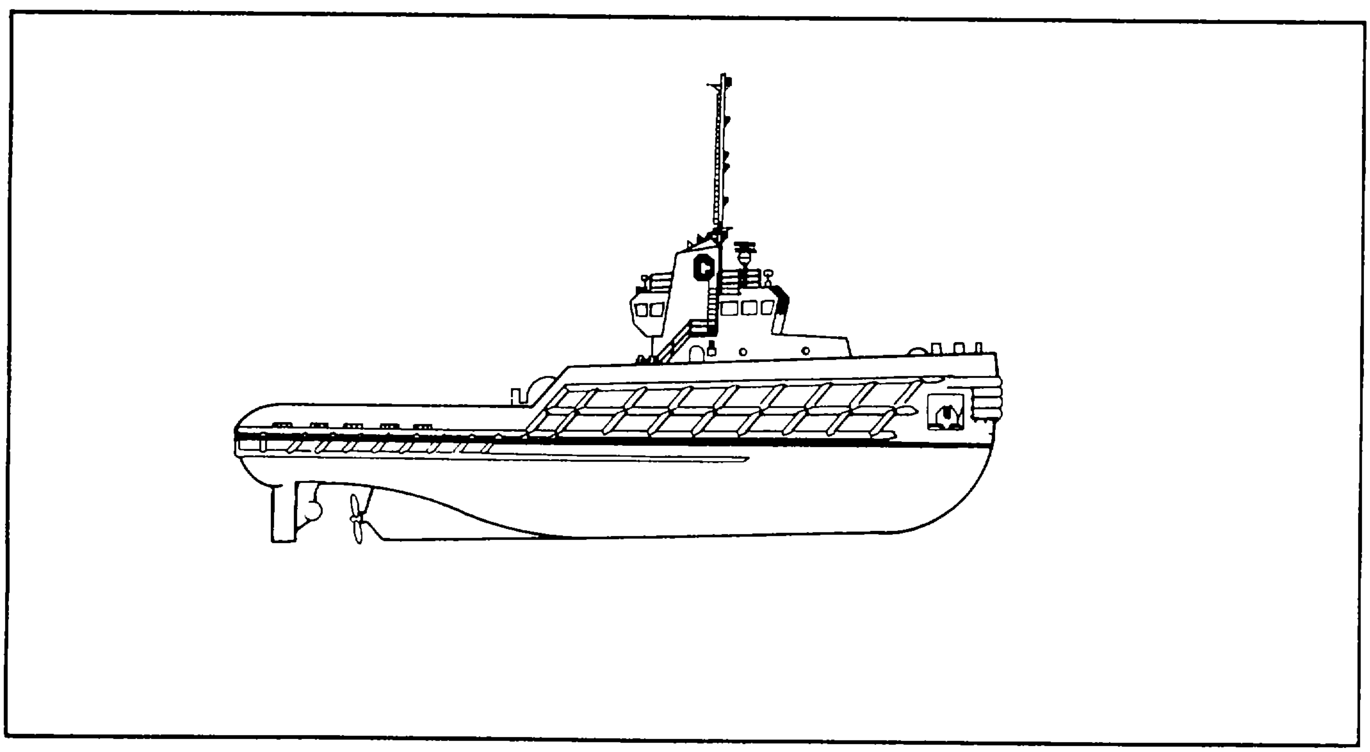


Figure J-3. Point-to-Point Towing Tug.

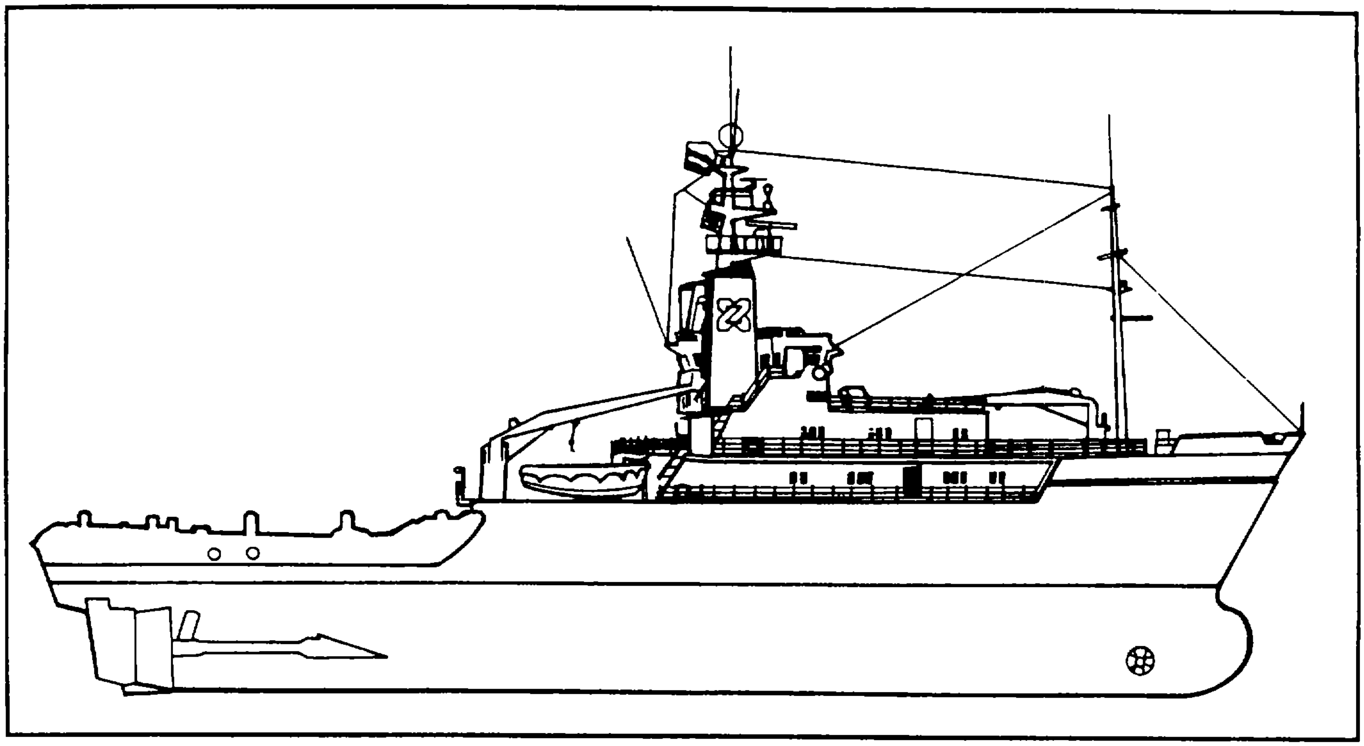


FIGURE J-4. Salvage Tug.

base; or it could be a seasonal location such as the North Sea in winter or the Cape of Good Hope during the Southern Hemisphere's winter. Work was contracted on the well-understood "Lloyds Open Form- No Cure-No Pay," and usually went to the first tug to arrive. Several factors have led to the decline of the traditional "fire-house" nature of the salvage and towing business. To list a few:

a. Improved navigational aids resulted in fewer casualties.

b. The advent of large offshore oil structures and VLCC and ULCC tankers required construction of large, very powerful and expensive salvage tugs.

c. Increased ship size resulted in fewer ships to potentially suffer casualties. Further, since fewer ships were operating, marginal operators and crews gradually were forced out

d. Crew demands for improved habitability, working conditions and wages.

e. The worldwide reduction in oil consumption caused a reduction in shipping and, therefore, casualties, in the early 1980s

f. Owners of casualties tended to avoid the "no cure-no pay" contract in favor of more price competitive bidding. This placed the traditional salvage tug operator at a disadvantage because of his higher equipment, labor and standby costs.

Consequently, tug owners sought routine, long- distance towing tasks to keep their expensive assets at work Others laid up their ships or went out of business. Thus, except for unique circumstances such as the Persian/Arabian Gulf during the 1980s, the traditional salvage stations, with professional salvors staffing the best salvage tugs, have largely disappeared. Those that remain largely are subsidized by governments.

Table J-1. Typical Commercial Salvage/Towing Vessels for Hire.

NAME	USS SAFEGUARD 1985	ZWARTE ZEE 1963	ATLANTIC 1975	SMIT SINGAPORE 1984	JOHN ROSS 1975	OTTO CANDIES 1986	STAR SIRIUS 1986
TYPE	U S NAVY RESCUE SALVAGE	TOWING/ SALVAGE	TOWING/ SALVAGE	TOWING/ SALVAGE/ ANCHOR HANDLING	RESCUE/ SALVAGE	TOWING	ANCHOR HANDLING/ SUPPLY
LOA (FT)	256′	254′3″	255′	246′6″	310′	140′	213′
BEAM (FT)	57′	40′6″	43′6″	51′5″	51′10″	42′	47′6″
DRAFT (FT)	16′6″	18′10″	20′0″	21′		18′	17′
DISPLACEMENT (LT)	3193	2619		4833			
RANGE (NM)	10,000	14,000	14,000				10,000
HORSEPOWER IHP BHP	4400 SHP	9,000 IHP EST 6000 BHP	16,000 IHP EST 10,000 BHP	22,000 IHP EST 18,000 BHP	26,000 IHP EST 22,000 BHP	5850 BHP	9180 BHP
BOLLARD PULL (TON)	64		135	189	200		150
MAX SPEED (KTS)	14 5		17				16
PROPELLERS	2 CPP w/nozzles	1	2 CPP w/nozzles	2 CPP w/nozzles	1 CPP w/nozzle	3 w/nozzles	2 CPP w/nozzles
WORK BOATS	2	1	2	2	2	0	0
ACCOMMODATIONS	99		26	38		14	26

J-2.3 AVAILABILITY OF OCEAN-GOING TUGS. Nonetheless, there are a large number of tugs available throughout the world A 1985 survey reported 965 tugs and 733 supply tugs over 1,000 horsepower Of these, 99 tugs and 171 supply tugs claim 6,000 to 10,000 IHP and 28 tugs and 27 supply tugs list over 10,000 IHP The total numbers are probably under- stated, since some well-known salvage/towing firms are not listed in the survey and there are few Communist bloc ships listed. On the other hand, the ships were listed as reported by the owners, without comment. Many of the smaller, less-powerful tugs are unsuited for any but the most benign tows In addition, many quite powerful tugs, in the 4,000 to 8,000 IHP range, are well under 150 feet in length. The ships are optimized beautifully for point-to-point towing but may be handicapped seriously m a rescue tow scenario under strenuous sea conditions.

This section again demonstrates that care must be exercised in the selection of a tug for a particular mission.

J-3 OBTAINING TUG ASSISTANCE.

This section provides guidance in obtaining commercial tug assistance.

J-3.1 EMERGENCY TUG ASSISTANCE. Since the Navy ship requiring emergency towing assistance will communicate with its operational and administrative superiors by designated means, it will be helpful, subject to security restrictions, to query the UHF and VHF emergency channel frequencies to determine whether competent assistance is available close by Salvage tugs always, and most other tugs frequently monitor the distress frequencies and will make their presence known. Knowledge of such avail- ability, along with pertinent data on the tug and its owners, will be useful to the operational superiors in resolving the problem.

J-3.2 RESTRICTIONS IN CONTRACTING.
U S Navy ship Commanding Officers are not authorized to commit the US. government to indefinite obligations or claims. A Lloyds Open Form contract requires arbitration in, and is subject to, the laws and courts of Great Britain. The United States will not permit itself to be subject to such requirements Further, even a per diem (fixed rate) salvage contract involves an indefinite value. The net result is that the Commanding Officer of a U.S. Navy ship is severely restricted in arranging for emergency assistance

J-3.3 CONTRACTING FOR EMERGENCY COMMERCIAL TOWING ASSISTANCE. If Navy towing assets are not available, the appropriate superior in the chain of command can arrange for emergency commercial towing assistance in two ways:

a. The cognizant U S Government procurement office can be contacted and provide data on any potential nearby assistance. That activity can arrange for an appropriate per-diem-type con- tract with the tug's owners, who will immediately advise the tug

b. The U.S Navy Supervisor of Salvage (Director of Ocean Engineering-NAVSEA OOC) can be contacted by message and/or telephone at 202-697- 7386 or -7403 (AUTOVON 227-7386 or -7403). SUPSALV maintains standing salvage con- tracts that can respond immediately. Frequently, the response is m the form of the Navy salvage contractor sub-contracting with the most appropriate salvage/towing firm anywhere m the world Thus, an available commercial tug can be directed to provide emergency assistance with very little delay, and without subjecting all par- ties to protracted legal efforts after the fact

J-3.4 ARRANGING FOR ROUTINE (NON- EMERGENCY) TOWS BY COMMERCIAL TUGS. The tow planner normally will request the tow from the appropriate Navy operational Surface Force Commander who will arrange for a U.S. Navy or Military Sealift Command tow. If neither is available, the tow should be arranged through the local supply/procurement agency In the latter case, if tows are arranged infrequently, or the tow is technically unusual, obtaining advice from SUPSALV is recommended.

APPENDIX K

TOWING MACHINES AND TRACTION WINCHES

The purpose of this appendix is to provide a brief overview of the functions and types of towing machinery installed in U.S. Navy tugs and towing ships. It is intended to assist in tow planning by providing an understanding of the capabilities and limitations of the towing machinery in these ships. This appendix is not a substitute for specific design or operating data contained in the technical manuals for the equipment installed in an individual ship.

K-1 BACKGROUND

While some ocean towing is now performed by tug-barge combinations where the tug is mechanically attached to the tow, this manual addresses the classic towing arrangement of the tug attached to the tow by a fiber or wire hawser. The towing machinery must be considered the "main battery" of the tug and deserves appropriate care in selection, design, operation and maintenance. An example of the importance of the towing machinery is provided by the president of a major privately-owned European salvage and towing company who reports that, for modern, high power tugs, the cost of the towing machinery at least equals the cost of the ship's entire main propulsion plant.

K-1.1 NOMENCLATURE. Automatic towing machinery derives from the original "towing winch" Application of steam power to the towing winch resulted in frequent use of the term "towing engine'." Today, "towing machine" is the preferred term for automatic towing machinery and is the one used in the NAVSHIPS TECHNICAL MANUAL. A non-automatic towing winch appropriately is called the "towing winch." The terms traction "machines" or "winches" are both used, depending upon the number of automatic features installed.

K-1.2 FUNCTIONS OF TOWING MACHINERY.

All towing ships need a means of handling the towing hawser. Functions to be performed include:

a. Attaching the hawser to the tug

b. Adjusting the deployed length of the hawser

c. Stowing of the unused portion of the hawser

d. Providing for quick release while the hawser is under tension

e. Minimizing damage and wear to the hawser while in use and while stowed.

K-1.2.1 Attachment to the Tug. Older, smaller tugs may have no more than a bollard or bitts for attaching the hawser. Smaller, European tugs often use a towing hook which swivels about a strong bearing on a platform. More modern tugs generally combine the hawser securing function with the storage and/or transport system.

K-1.2.2 Adjusting the Deployed Length of the Hawser. Paying out additional hawser when secured to bitts can be accomplished by hand, but at considerable personnel risk. When using a towing hook, which uses a permanent eye at the end of a hawser, paying out hawser requires inserting a specific length of additional hawser. In each case, shortening the length of deployed hawser is much more difficult and necessitates power assistance if the hawser is under strain. More modern ships incorporate the hawser adjustment function into a powered winch or traction machine

K-1.2.3 Storage of Unused/Undeployed Hawser. On smaller, older tugs, hawsers may be simply faked down on deck or stored on a reel which may be powered. Since the advent of wire hawsers, larger ocean tugs generally combine the hawser securing, adjusting and storing functions into a self-contained winch.

More recently, two phenomena have led to development of traction machines that overcome problems inherent in the typical winch:

a. The use of large, long, generally synthetic fiber hawsers The poor compression rigidity of the fiber hawsers precludes transmitting the tensile load directly to a storage reel because the hauling part would embed itself in the preceding layers of stored rope. Furthermore, this fiber's large bulk, compared to that of comparable wire hawsers, requires a relatively large storage volume which is impractical for reel-type storage. The unused fiber hawser generally is stored in a bin or dedicated compartment, which may be adjacent to the traction machine. The traction mechanism operates on the hawser and separates the hawser's unloaded, stored portion from its deployed, tensioned portion.

b. The second phenomenon, not yet seen in the U.S Navy, is the advent of very powerful tugs (on the order of 10,000 horsepower and larger) which require very long, heavy, wire hawsers. These ships often have two hawsers and towing machines. Each hawser may be 72 mm (2 7/8-inch) diameter and as much as 1,800 M (5,900 feet) in length. Each such hawser weighs about 38 long tons and requires a massive reel to store it, while also being robust enough to withstand direct application of tensile loads carried by the hawser. Optimal location of the towing point is at the main deck, on centerline, close to mid-length of the ship. This is prime space for arrangement purposes and presents a significant drawback to stability when large weights are needlessly located at that height. Consequently, these large tugs frequently use traction machines to transport and hold the wire, while the unused wire is stored at more appropriate locations on relatively light storage reels. These reels need only sufficient power to take up the slack between reel and traction machine. Wire hawser traction machines are similar in principle and appearance to the fiber line machines familiar to the U. S. Navy.

K-1.2.4 Quick Release of the Hawser under Tension. Emergency conditions, such as the tow's sinking or being set toward danger, require quick release of the hawser, often while under strain Fiber hawsers may be cut with an axe. Wire hawsers may be cut with an oxyacetylene torch or power cutters Each is hazardous and may be impossible in a heavy seaway. The towing hook has an advantage in that it can be tripped, often remotely, to release the hawser. For the typical reel-type towing winch, the reel can be disconnected from the driver mechanism so that it will free-wheel, allowing the hawser simply to pull itself off the reel. The bitter-end connection of the wire to the reel is easily defeated by the momentum of the wire coming off the reel. Traction winches generally are able to be disconnected, and can be overhauled by the tensioned hawser. However, a rapidly-running, large-diameter fiber hawser presents significant hazards to personnel and equipment. Unless the bitter end of the hawser is very close to the traction mechanism, the unloaded portion of the hawser may have to be cut.

K-1.2.5 Protection of the Hawser. There are two principal concerns The first is minimizing damage and wear to the hawser because of scuffing, abrasion, small-diameter bending, crushing of stored layers under loaded turns on a reel and protection from adverse environmental conditions. The second principal concern is protection of the hawser from overload due to surges caused by relative movements of tug and tow in a seaway. The former considerations are addressed by careful design of arrangement of towing machines and deck equipment. The latter concern (overload) is met in part by proper operating parameters (speed, scope of hawser and course) and often by inclusion of automatic payout and retrieval features in towing machinery. Both concerns are further eased by use of towing machinery instrumentation that provides hawser tension and scope readouts. This instrumentation may operate independently of towing machinery. The next section expands on the reasons for including automatic features on towing machinery.

K-2 TOW HAWSER SURGE LOADING AND AUTOMATIC TENSIONING

This section provides a historical perspective and brief discussion of surge loading of towing hawsers and the advantages of automatic-tensioning towing machinery.

K-2.1 SURGE LOADING. Most seamen are unaware of the surge motions of ships at sea because there is no reference from which to measure the motion. However, connecting two ships by a tow hawser does provide a reference, and towing people long have been aware of the relative motion of tug and tow in ocean wave systems For small tugs and/or tows, the hawser itself exerts considerable restraint to the motion of the ships from their completely independent states. If the tug and tow are both relatively large, it is apparent that a strenuous sea state can easily impart sufficient relative motion to cause hawser failure.

K-2.1.2 Early Automatic Towing Machinery.
Experienced tug seamen have known the dangers of load surges for at least a century. Steam power led to larger, more powerful tugs and to wire hawsers as manila hawsers grew to unmanageable sizes. As steam deck machinery was developed, it was naturally applied to a winch for the towing hawser. The throttle to the winch steam engine could be cracked open by trial and error to provide an automatic feature to the winch. When the steam pressure behind the pistons was overcome by the tension of the hawser, the winch would pay out; likewise, slack would be taken in automatically when the load was eased. Simple controls were added to quantify the set point and to limit the total amount of wire paid out, or taken in, without human intervention Through this arrangement, large potential surges in hawser loading were significantly reduced with the "automatic" steam towing winch This improved safety and wire wear, and permitted use of more power than would be available otherwise.

K-2.1.3 Electric Towing Machinery. Dieselization of large tugs, commencing in the 1930s, was a major advancement for propulsion power and endurance. But it was a setback for automatic towing machinery because the steam-powered winch no longer was an option Electric-driven automatic towing machinery was developed, but it tended to be relatively expensive and complex. While the U.S. Navy was a leader in the use of automatic towing machinery, commencing early in World War II, much of the rest of the world returned to non-automatic towing machinery for its non-steam-powered tugs, and much of it remains there today!

The arguments against automatic towing machinery are many. To list a few:

a. "My seaman's eye is more accurate and reliable than any automatic winch."

b. "Automatic towing machines are too heavy and too expensive."

c. "Automatic towing machines are unreliable, difficult to understand and Impossible to maintain."

d. "Automatic towing machines are noisy, making it difficult for the crew to sleep at night."

Each reader will be able to add other often-heard complaints. Nevertheless, the arguments for automatic towing machines are even more compelling, as described in the following paragraph, which quantify the magnitude of surge tensions.

K-2.1.4 Wire Surge Example. Section 6-4 provides data on catenaries of wire towing hawsers. As the strain increases, the catenary becomes flatter, with less spring available. In fact, if it were not for stretch of the wire itself, it can be shown that a 1,000-foot, 2-inch FC hawser, with a steady tension of 50,000 pounds, would break if the tug and tow were separated by only an additional 2 feet! Fortunately, the hawser has considerable elasticity Figure 5-3 compares tug-tow separation to hawser tension for

1,000-foot and 1,800-foot hawser scopes. A 1,000-foot length of 2-inch wire, with initial tension of 50,000 pounds, will have tension increasing to the wire's safe working limit of 187,000 pounds (.65 x 288,000) when the tug and tow are separated by an additional 9 feet, still a relatively low figure. Further stretch will permanently damage the wire, and it will break when increased separation has reached a total of 15 feet beyond the separation characterized by the 50,000-pound initial tension. The same wire, with initial tension of 100,000 pounds, can absorb increased tug-tow separation of only approximately 10 feet.

The figures for 1,800 feet of the same hawser at 50,000 pounds initial tension are somewhat more advantageous. The system can absorb 19 feet of increased tug-tow separation before reaching its safe working limit. Overall, the ability of wire hawsers to absorb changes in the distance between tug and tow is relatively limited, compared to probable ship motions under strenuous sea conditions.

K-2.2 AUTOMATIC FEATURES ON TOWING MACHINES-GENERAL . The full-featured automatic towing machine can be set to maintain hawser tension within a pre-selected range. It will pay out hawser if the hawser tension exceeds the set point, and will recover hawser when tension falls below a second set point. Typically, there are limitations on the total amount of hawser allowed to be paid out or retracted. Some towing machinery will pay out, but not retract, automatically.

K-2.3 LIMITATIONS IN QUANTITATIVE UNDERSTANDING . The responsiveness of U.S. Navy automatic towing machines to actual dynamic loading of their towing hawsers is not well-understood at present. The automatic payout feature reduces the potential peak tension. However, quantitative data on towing machine time constants and responsiveness need study. The landmark work leading to the data contained in Appendix N is very recent. It significantly improves the understanding of the dynamic demands placed on the towing system.

Further work is needed in understanding the process with the automatic towing machine as part of the dynamic situation. At-sea testing will undoubtedly be required as well, to validate the model predictions There is a distinct possibility that this work will ultimately result in lowering traditional factors of safety, which are really "factors of ignorance," while maintaining or improving efficiency and safety in towing operations.

K-3 TYPES OF TOWING MACHINES

This section provides an overview of the types of towing machines in use in the U S Navy, with additional reference to other types of machines for technical interest.

K-3.1 CONVENTIONAL TOWING WINCHES AND MACHINES. These units, which store the unused wire hawser on a horizontal drum, are the most prevalent.

K-3.1.1 Drum Arrangements. There may be either one or two main drums, one for each hawser if there is more than one In the U.S. Navy, two-drum units locate the drums side-by-side. Commercial tugs often locate the second drum forward of and above the first drum in a "waterfall" arrangement. The drums are always powered, but capabilities of independent operation of the drums vary. They may be equipped with a level-wind apparatus and may be strong enough to withstand the breaking tension of the wire applied directly onto the drum. Some U.S. Navy units are equipped with one or two auxiliary drums to accommodate work on mooring lines or long, target-towing hawsers.

K-3.1.2 Drum Securing Features. Towing hawser drums generally can be positively locked with a pawl or dog. For control purposes, a brake system is also provided.

K-3.1.3 Drum Prime Movers. The more sophisticated units use DC electric motors to provide infinitely - variable speed control. It is quite conceivable that hydraulic drives will find increased future application. The double-drum units may have two-drive units which can be clutched separately, one to each drum, or in tandem to a single drum for increased power. Less-sophisticated units use a self-contained diesel engine drive connected through a torque converter and/or an appropriate mechanical transmission.

K-3.1.4 Automatic Features. All machines have brake systems that will slip at some point. However, the set level may not be very reliable, and the drum is often locked by a dog or pawl. The next level of sophistication is an automatic payout capability when the tension exceeds a set level. There may be a limit on the total length of hawser permitted to be paid out automatically. Finally, the most sophisticated machines have an automatic reclaim capability, with a limitation on the net allowable length to be reclaimed.

K-3.1.5 Instrumentation and Controls. All units have local control capability and many have a remote operation station. Instrumentation generally includes cable tension, length of cable paid out, motor speed indicator and automatic payout/reclaim set points. Some of the instrumentation may be repeated on the bridge.

K-3.2 TRACTION WINCHES. In the U.S. Navy, traction winches were introduced for use with the large synthetic hawsers that gained popularity in the 1960s. Traction winches also are finding application with wire hawsers in powerful commercial tugs.

K-3.2.1 General Description. Traction winches always have two parallel cylinders with grooves sized to accept the intended hawser. There are four or more complete wraps of the hawser around the two cylinders. Both cylinders are powered to transport the hawser. The orientation of the cylinders or drums can be either horizontal or vertical In principle, traction winches are similar to capstans. The two-drum arrangement eliminates the axial skidding of the rope inherent in capstans, and permits the grooving that improves support and reduces wear on the rope.

In contrast to requirements of drum-type winches, a long line can be loaded onto a traction winch at any point within its total length. This is useful for mooring purposes and was the reason for their first marine use-for control of mooring lines on large ships and for Single Point Moorings used in the offshore oil industry.

K-3.2.2 Hawser Storage. Conventional winch designs are not used with fiber towing hawsers for two reasons-the large size required and problems inherent in wrapping and storing a tensioned, highly elastic line on itself. Storing the untensioned fiber hawser on a drum is feasible, but storage bins are universally used. The traction winch can easily pull the hawser from its storage location, via appropriate fairleads. Re-stowing the hawser as it is recovered is more difficult and sometimes requires hands-on effort.

K-3.2.3 Traction Winch Operation. Traction winches are motor-driven, sometimes with variable speed capabilities. They have brakes and clutches for control When de-clutched, they can be overhauled by the hawser to provide for free release of the hawser in emergency. Some traction winches have an automatic tension payout capability, but automatic reclaim is rare on fiber line systems because of the hawser storage system described in the previous sub-section.

K-3.2.4 Controls and Instrumentation. Traction winches have local and/or remote station controls. Most have tension readouts and some have hawser scope (without stretch compensation) instrumentation. Some traction winches will have end-of-hawser warning or shutdown systems.

K-4 U.S. NAVY TOWING MACHINERY

This section provides a more detailed description of specific towing machinery installations on U.S. Navy towing ships. This is not intended to substitute for, or supplement, technical manuals for the specific machines. Towing machinery installed in mine warfare ships and in ice breakers is not addressed. In the following sections, "AAJ" refers to Almon A. Johnson, Inc., a major designer and builder of towing machines.

K-4.1 AAJ "222 SPECIAL" AUTOMATIC TOWING MACHINE (ATF 76/110 CLASSES). This towing machine has a main towing drum and two auxiliary drums The main drum can spool 2,100 feet of 2-inch diameter wire rope. It operates in an automatic range of up to 80,000 pounds line pull and a manual range of up to 100,000 pounds line pull, on the second layer of the drum. Tension settings are adjusted by manually setting the desired maximum tension level on the Direct-Acting Tension Controller mounted on the towing machine. The machine is powered by a 75 HP DC electric motor The main towing drum is equipped with an automatic spooling device (level wind) and a cable indicator, which shows the length of cable remaining on the drum This indicator has an electric interlock which will shut down the machine if too much wire is paid out.

The two auxiliary drums may be operated singly or simultaneously, either with or without the main drum, but are not under automatic tension control The starboard side auxiliary drum has capacity to spool 5,000 feet of 1-inch diameter wire in 15 layers. It has an automatic spooling device to spool the wire tightly onto the drum This drum has a maximum line pull heave-m of 26,000 pounds at 80 feet per minute on the eighth layer The port side auxiliary drum is designed to spool 1,800 feet of 1 1/8-inch diameter wire rope in 13 layers It does not have a level wind.

The towing machine system includes a 93.6 HP/62 8 KW DC/DC electric motor-generator set with a DC motor starter, variable voltage control panel and a set of armature loop resistors. These items are located inside the ship, since they are not waterproof. The towing machine is driven by a 75 HP DC motor and is operated from a control stand located next to the machine on the main deck.

K-4.2 AAJ "260 SPECIAL" AUTOMATIC TOWING MACHINE (ASR 9 CLASS). This machine is identical to the AAJ "222 Special" model installed in the ATF 76 Class except, that the two auxiliary drums are designed to spool 750 feet of 9-inch circumference nylon line or 4,500 feet of 1 1/8-inch wire rope.

K-4.3 AAJ "250 SPECIAL" AUTOMATIC TOWING MACHINE (ARS 6/38 CLASS). This machine is similar to the 222 and 260 AAJ machines. Its main drum has the same capacity of 2,100 feet of 2-inch wire and the same automatic setting up to 80,000 pounds and a maximum pull under manual control of 100,000 pounds. An upgrade of an earlier version, the "250 Special" uses a smaller motor with different gearing to provide the same hawser tensions, but at a slightly lower line speed Some of these machines also have a single auxiliary drum, with a level wind, capable of spooling 5,000 feet of 1-inch wire.

K-4.4 AAJ SERIES 322 AUTOMATIC TOWING MACHINE (ARS 50 CLASS). See Figure 2-29 for a drawing of this towing machine. It is equipped with two side-by-side main drums, each capable of spooling 3,000 feet of 2 1/4-inch wire. Level winds are provided which can be adjusted to spool 2 1/2 -inch wire as well. Power is provided by two 125 HP DC electric motors which can be connected singly or together to either drum. Each drum can heave a maximum 110,000 pounds at 37 FPM. Maximum line speed is 100 FPM Each drum can be set for automatic operation within the range of 25,000 to 115,000 pounds Automatic operation includes payout and reclaim, with limits on maximum and minimum hawser scope.

The ARS 50 has a Series 400 traction machine located adjacent to, and forward of, the Series

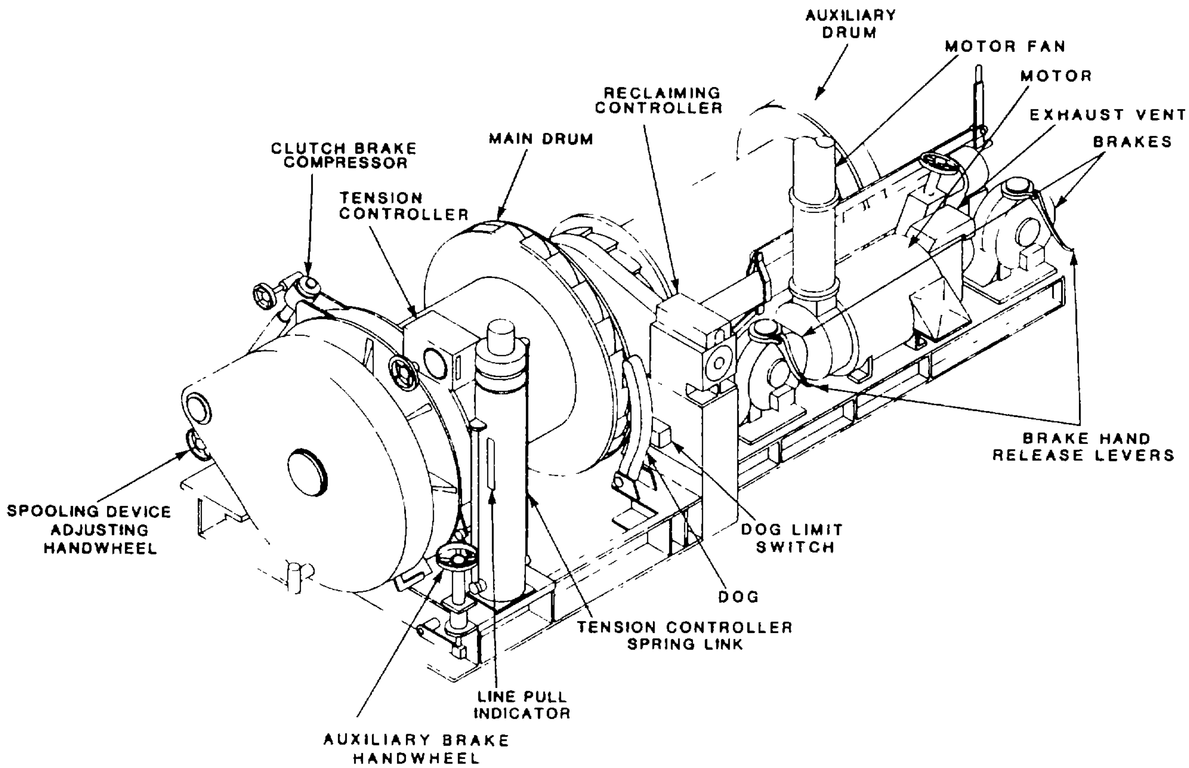


FIGURE K-1. AAJ, Inc., “250 Special” Automatic Towing Machine (ARS6/38 Class).

322 machine. The traction winch is designed for use with 3 1/2-inch to 14-inch circumference fiber line. The traction winch has an automatic payout capability, with a set range of 15,000 to 110,000 pounds. There is no automatic reclaim capability. Maximum heave is 110,000 pounds at 20 FPM; maximum line speed is 90 FPM

Both machines are totally enclosed within the ship's deck house. Normal operation is from an enclosed operating station in the after portion of the space, which is equipped with all controls and instrumentation. Much of the instrumentation is repeated in the pilot house Emergency shutdown controls are located in the towing machine compartment. The ARS 50 towing machinery has no auxiliary drum incorporated into the design

K-4.5 STOTHERT & PITT TOWING MACHINE (ATS 1 CLASS). This machine was built in the U.K to AAJ specifications. It has two side-by-side main drums, each capable of spooling 3,000 feet of 2 1/4-inch wire. The level wind apparatus is adjustable for use with 1 5/8-inch, 2-inch and 2 1/2-inch wire as well. Two 75 HP DC motors can drive the main drums in any combination. With both motors engaged to one drum, line pull varies from 30,000 pounds at 120 FPM to 200,000 pounds at 20 FPM. Both main drums are outfitted with automatic payout and reclaim features with maximum and minimum scope limits Automatic tension can be set at any desired level from 15,000 to 96,000 pounds.

The Stothert & Pitt Towing Machine has an auxiliary drum, located on centerline forward of the main drums, capable of spooling 5,000 feet of 1-inch wire. The level wind is adjustable for 5/8-inch, 1-inch and 1 5/8-inch wire. Power is derived from one or both of the main motors at a maximum pull of 30,000 pounds at 250 FPM Slack line speed is 400 FPM on the auxiliary drum.

All drums are equipped with tension and cable scope readouts, but they are calibrated for only 2 1/4-inch and 1-inch wires, respectively, on the main and auxiliary drums.

The ATS 1 has no traction winch.

K-4.6 SMATCO TYPE 1 TOWING WINCH AND LAKE SHORE TRACTION WINCH (T-ATF 166 CLASS). The SMATCO winch, see Figure 3-30, is a single-drum machine capable of spooling 2,500 feet of 2 /4 -inch wire A level wind is provided. There is no automatic payout or reclaim capacity. Wire tension measurement is provided by strain gauges in the winch foundation. There is a remote tension readout, but no scope-of-wire-out instrumentation. Maximum hawser heave-in is 179,000 pounds at 14 FPM; maximum hawser speed is 280 FPM at 18,000 pounds tension on the first wrap. At the top wrap (twelfth layer) maximum line speed is 775 FPM at 6,000 pounds tension. Maximum pull on the twelfth layer is 64,000 pounds at 38 FPM.

A major difference between the SMATCO towing winch and those found on other Navy towing ships is that the SMATCO is diesel-driven through an air operated clutch, a torque converter and a gear train. For various reasons, towing is frequently accomplished with the drum locked on the "dog," rather than riding the brake In order to increase hawser scope, or even let it run free in an emergency, the engine must be started, engaged and the load taken off the dog before the dog can be released. Managing the hawser with this system is more difficult than with the other U S Navy towing machines.

The T-ATF 166 Class has a separate Lake Shore traction winch suitable for fiber hawsers up to 15inch circumference. See Figure 3-31. The hawser is stored in a below-deck storage room with appropriate fairleads to the winch. The winch has no automatic functions. The Lake Shore Traction Machine is electric motor-driven, with infinite speed adjustment available. Maximum line pull is 175,000 pounds at 12 FPM. No-load maximum line speed is 370 FPM in payout, 134 FPM heaving in. The unit can be declutched to permit the lines to run free in emergencies. There is a manual brake to control disconnected payout. The winch will hold and structurally withstand the breaking strength of a 15-inch-circumference double-braided nylon hawser.

APPENDIX L

ESTIMATION OF DYNAMIC TOWLINE TENSIONS

L-1 INTRODUCTION

This appendix addresses recent developments in quantifying the impact of relative motion between a tug and its tow on the towline connecting the ships. Data are provided that will be useful to the tow planner, given the sea conditions expected during the tow. More importantly, the data will be of immediate use to the U.S Navy towing ship in predicting an acceptable risk of extreme dynamic towline loadings, rather than assuming that sufficient margin exists in the traditional factors of safety applied to steady state tensions.

L-2 BACKGROUND

This section describes the problem of towline dynamics.

L-2.1 SHIP DYNAMICS. All seamen are well aware of ship motions in a seaway, particularly rolling, pitching and yawing. But there are three additional types of ship motion that are less apparent - heave, sway, and surge, for a total of six independent ship motions In a towing scenario, the tug and tow both experience their own motion, for a total of twelve degrees of freedom acting on the towline connecting them. The towline also acts on both ships. These dynamic effects can cause the failure of the towline at unexpected times, when average tensions are well within acceptable limits. Traditionally, the complex problem has been unquantifiable, and still is addressed through the traditional method where not all variables are quantified-the use of a factor of safety. In towing, the factors of safety are applied to the steady-state towline tensions, as described in Chapter 5, and the new strength of the towline. The factors of safety used are those determined through experience, primarily to account for the dynamic effects in the towline. Nonetheless, failures still occur.

L-2.2 WIRE TOWLINE MOTION. A heavy wire hawser forms a catenary between the tug and tow. In the steady-state condition, the shape of the catenary is easily estimated. Further, the catenary acts as a spring, flattening and deepening to compensate for relative motions between the tug and tow. Questions have been raised recently, however, concerning the cross-flow hydrodynamic resistance on the wire as it rises and falls. It has been suggested that, for the motion frequencies encountered in most towing situations, the wire towline does not have time to fully resume its former deep catenary when the tension eases, before the next surge in tension occurs. The net result over time is that the wire catenary flattens out, thereby providing somewhat less spring than previously thought. In this scenario, more of the spring remaining in the system can be attributed to the elastic stretching of the wire itself. See Paragraph 5-4.5.2 for a discussion of the stretch of wire hawsers.

L-2.3 SYNTHETIC TOWLINE BEHAVIOR. Fiber hawsers are much lighter than wire hawsers, and do not form an appreciable catenary. They rely almost totally on their elastic stretch in the towing scenario. The advent of strong, highly elastic synthetics, especially nylon, was expected to be a boon to towing, because their elasticity easily absorbed relative ship motion. Such hawsers could be man-handled and employed with neither a dedicated towing winch nor an automatic towing machine. However, as the use of nylon became more prevalent, unexplained failures were reported, often under towing tensions far below the supposed strength of the towline. Factors of safety were increased to take into account the unsolved problems to the point where the advantages of nylon over wire hawsers were lost.

A separate problem with nylon was caused by its elasticity. The large amount of energy stored in the stretched hawser is released explosively when the hawser falls. This often has disastrous effects, especially on personnel Ul-

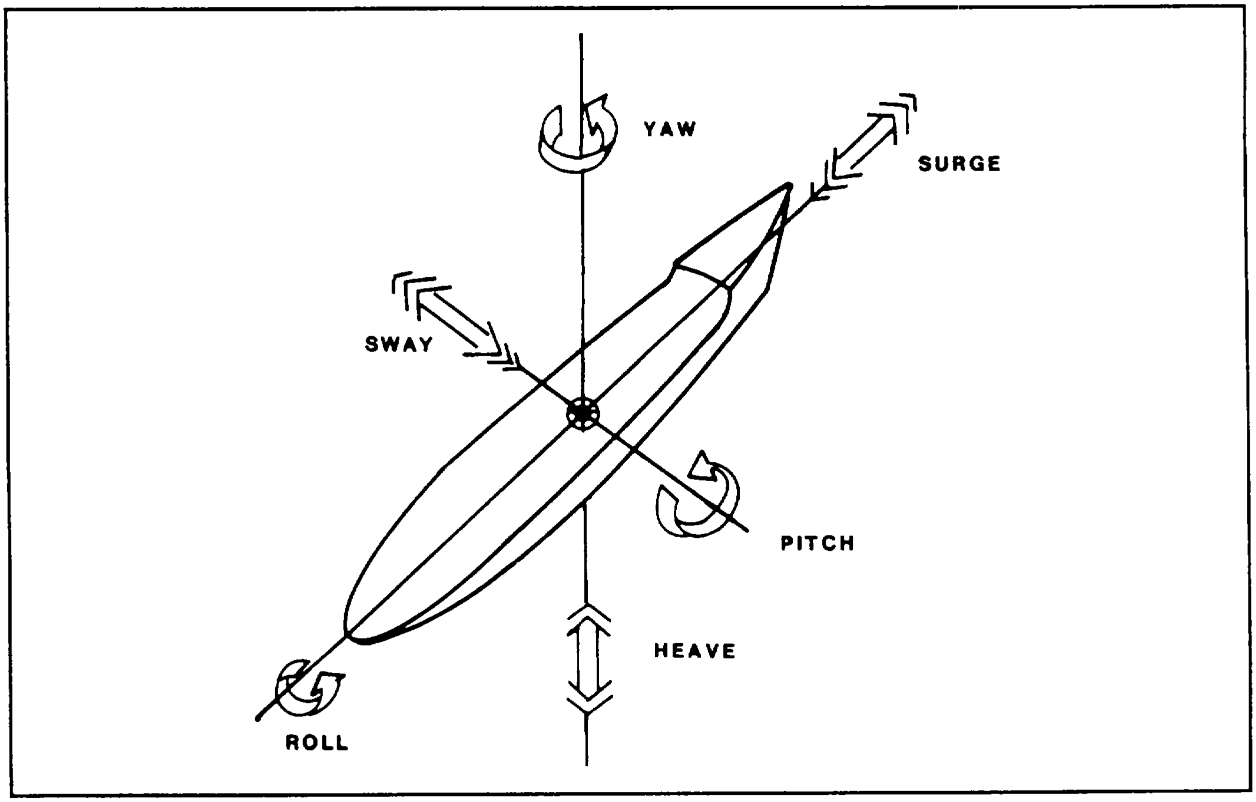


FIGURE L-1. Six Independent Ship Motions.

timately, use of synthetic towlines was restricted in the U.S. Navy.

The problems with nylon hawsers have resulted in major studies of mechanical properties of rope construction and chemical properties of the materials Basically, the strength of such ropes has been found to be affected by sunlight, chemicals, salt water and-above all-the cyclic load history of the rope. Current research may result in better ropes and more reliable methods of predicting their strength, thereby permitting re-introduction of synthetic ropes into towing. This work is a major ongoing effort, and will not be discussed further in this appendix.

L-3 EFFECTS OF TUG AND TOW MOTIONS ON TOWLINE DYNAMICS

This section briefly describes the project to quantify towline dynamics. The behavior of a wire stretched in water between variably-distant endpoints is discussed first, because the hawser effects on the tug and tow must be known in order to solve the ship motion problem. The ship motion problem is then discussed

L-3.1 WIRE TOWLINE BEHAVIOR. Methods for predicting five degrees of ship motion in response to wave action have been in use for some time. The sixth degree, and the most important to towing-surge-normally was not addressed. Surge has been included in the most recent work The special towing problem of examining the motions of two ships connected by a towline required a significant es calation of the ship motion problem. A mathematical model was developed to predict the behavior of a wire towline and account for the wire's normal mechanical properties plus the following factors:

a. Cross-flow hydrodynamic drag on the wire that tends to flatten out the catenary and increase dynamic tensions

b The changing spring constant of the wire.

Tests were conducted in a towing tank where the towline was modeled so that it could be pre-tensioned and one end point moved longitudinally to simulate the varying separation between tug and tow The test results validated the numerical model describing the behavior of a wire towline. This work was a prerequisite to the ship motion studies, because it was necessary to know the coupling forces between the two ships, caused by the towline.

L-3.2 MOTIONS OF THE TUG AND TOW. The computer provides the capability to predict statistics of ship motion in a seaway, given ship characteristics, size and frequency of the ocean waves, angle of encounter with the waves and ship speed. For towing, the motions of two ships connected by the towline model, described above, are examined. This twelve degree-of-freedom problem does not provide the towline tension directly, since the motions of both the seas and the ships are random. However, the statistical nature of the effort can provide the probability that a tension will be exceeded during a 24-hour period of towing. Given a steady-state tension, and selecting a probability of 0.1 percent, the program provides the extreme tension that has one chance in a thousand of being exceeded in 24 hours of towing. This is comparable to once in 1000 days of towing-a very small risk. (Of course, the "once" can occur in the first hour. It is not risk-free.) However, with the low probability involved, extreme tensions can be compared to the strength of the towline using a lower factor of safety than is otherwise required when the dynamic effects are unquantified. A factor of safety of 1 5, based on new wire strength, is appropriate for this effort.

There is no reason to doubt the accuracy of these data. However, until experience is gained in applying the data to real-life tows, two factors of safety are applicable to towing operations-1.5 when dynamic effects are quantified, and the appropriate factor of safety from Table 6-4. Both must be checked, as one will control in some cases, the other in others.

L-3.3 DESCRIPTION OF PHYSICAL VARIABLES AND INFLUENCES ON EXTREME TENSION . The numerical model describing wire hawser behavior is included in the twelve-degree-of-freedom ship motion program. Thousands of individual computer simulations were performed, using the following variables:

a. Respective characteristics-displacement and length of tug and tow

b. Wave size, angle and frequency

c. Towline used

d. Average towline tensions

e. Towing speed.

Each of these is discussed in the following subparagraphs.

L-3.3.1 Size of Tug and Tow. Sea motions of both the tug and its tow are unique. It was therefore necessary to study the problem for the T-ATF 166, ARS 38, ARS 50 and ATS 1 Classes. To provide a range of tow sizes, each tug was examined while towing the following:

a. 650-ton YRBM berthing barge

b. 3,200-ton FFG 1 Class frigate

c. 6,707-ton DD 963 Class destroyer

d. 20,000-ton AE 26 Class ammunition ship

e. 40,000-ton LHA 1 Class assault carrier

It was found that the motion characteristics of the ARS 50 and ATS 1 were sufficiently alike to eliminate separate studies for these two towing ships.

L-3.3.2 Wave Size, Angle and Frequency. The motions of the tug and the tow, caused by ocean waves, result in variations in towline tension. The ship motion having the most influence on towline tension is surge, but the other motions-sway, heave, roll, pitch and yaw-play a role as well Generally, the larger waves cause the greatest tension, but it is not only the size of any one wave that counts; ship position and motion at any point in time depend on the most recent several waves. In addition to wave size, the wave frequency is influential. For very high frequencies, ships do not have time to respond to the waves, so the motions resulting from such waves are small. At very low frequencies, ships move significantly, but there is sufficient towline catenary adjustment that ship motion is accommodated by geometric changes in catenary depth. At somewhat higher frequencies, changes in catenary depth are restricted by the cross-flow drag of the water on the catenary as it tries to rise and fall. Thus, at these medium frequencies, the frequencies of interest, ship motions cannot be accommodated by geometric changes in catenary. This results in larger extreme tensions.

The wave height estimated by an experienced seaman has been found to be approximately the average height of the third-highest waves, called $H^{1/3}$. Values of $H^{1/3}$ used in the computer program for predicting extremal tensions are as follows:

Wind Speed	$H^{1/3}$
15 knots	4.0 feet
20 knots	7.2 feet
25 knots	9 1 feet
30 knots	16.4 feet

L-3.3.3 Influences of Towline and Average Towline Tension . For a wire rope towline, the average (mean) towline tension has a major effect on the extreme tension, since it is the base to which the dynamic tension effects are added in the analyses. When average tension is low, the towline hangs in a deep catenary which can change its depth to accommodate large ship motions without large changes in the tension. When the average tension is high, the towline is nearly straight and can accommodate ship motions only by stretching, which requires large increases in the tension of wire rope. Of course, the catenary depends upon the weight and scope of the wire used. All of the computations were based on the actual hawsers used by each towing ship and an assumed 70 feet of 2 1/4-inch chain pendant extending outward from the tow's bow Computations were made for hawser scopes of 1,000, 1,200, 1,500, 1,800 and 2,100 feet.

Methods for estimating average towline tension appear in Chapter 6 and Appendix G of this manual One of the effects influencing average tension, the added resistance due to waves, cannot be estimated with great accuracy. Results for added resistance, obtained from the methods of Appendix G, are approximate. Because average tension can have such a pronounced effect on extreme tension, especially for wire rope towlines, it is preferable to use mean tension measured with an accurate tension meter for entering the extreme tension graphs, rather than using calculated mean tension.

L-3.3.4 Influence of Tow Speed. The greatest influence of tow speed on extreme tension derives from its impact on mean towline tension. Both mean tension and dynamic tension contribute to extreme tension Speed also affects the frequencies at which waves are encountered, providing a second-order effect on tension. All these effects have been included in the analysis.

Because of the association between mean tension and extreme tension, estimates of the latter must be based on accurate estimates of mean tension. This is facilitated by presenting data in the form of curves relating these two forms of tension. These curves "automatically" include the primary effect of speed-its influence upon mean tension. To account for the less important influences of speed, different curves are specified for different speeds.

L-3.3.5 Yawing and Sheering. In towing nomenclature, sheering is the movement of the tow off to the side of the towing track This motion can be steady, with the tow staying to one side. Alternatively, it can be unsteady, with the tow moving from one side to the other, taking several minutes to go through a complete cycle. Occasionally, sheering is called "yawing." This term should not be confused with "yawing" in seakeeping nomenclature, which is a wave-driven variation in heading that occurs at the frequency of the waves. The effects of yawing are included in the computations, but effects of sheering are not.

L-3.4 DISPLAY OF THE DATA. The computations use fully-developed wave characteristics associated with wind speeds of 15, 20, 25 and 30 knots. For every combination of speed, wave characteristic and angle, ship combination and tow speed, the computation procedure assumes a tow speed of 3, 6 or 9 knots. Mean towline tensions were assumed to be the following:

a. 10,000 pounds

b. 20,000 pounds

c. 40,000 pounds

d. 80,000 pounds

e. 120,000 pounds

A very large amount of data is developed and is displayed in Tables L-1 through L-15. To simplify the presentation, from 100 different curves a "standard" curve is selected (Figures L-2 through L-5) that provides the best fit to the results of comparing extreme tension to average tension. When there is not an obvious choice, the program selects the curve that best minimizes the error at higher tension ranges-
i.e., at about 70 percent of the strength of the wire used by the tug. Precise accuracy at higher tension levels is not needed, since there is too much risk associated with towing at these tensions. Errors at lower levels are not a problem, since the wire is not highly-loaded.

For each tug/tow combination, the data are presented in 12 tables-one for each of three tow speeds at each of four different wind speeds (therefore, wave characteristics). Within each table, data are listed for five towline scopes against each of four wave-encounter angles. The individual data point identifies the standard curve that best describes extreme tension vs. average (computed or observed) towline tension.

As an example, for a T-ATF using 1,800 feet of hawser, towing a ship comparable to a 40,000-ton LHA at 3 knots, into head seas generated by 30-knot winds, the table identifies curve number 6. If the predicted average towline tension is 52,000 pounds, curve 6 predicts that there is only a 0.1% probability that a tension of 140,000 pounds will be exceeded in a day of towing. Assume that the tow now sheers out to one side, remaining off the tug's quarter for a significant period. The tug's towing winch tension-meter now reads 70,000 pounds. Curve 6 predicts the extreme tension of 195,000 pounds still well below the allowable tension for the T-ATF's towing hawser.

L-4 USE OF EXTREME TENSION DATA

This section presents the extreme tension curves and tables for various tug/tow combinations and provides guidelines on their use.

L-4.1 ALLOWABLE EXTREME TENSION. The tables and curves presented are based on computations that modeled the actual wire towing hawsers associated with the tugs involved See Table B-1. Computations assume that the final connection to the tow uses one shot of 2 1/4-inch chain, 20 feet of which is on the deck of the tow

Given a steady-state or average towline tension, the curves provide an extreme tension (dynamic plus average) that has only one chance in a thousand of being exceeded in 24 hours of towing. The allowable tension for a given wire can therefore be much closer to the hawser's ultimate strength than can tension computed relying on the traditional factors of safety described in Chapter 5. For a wire in good condition, limiting the extreme tension to 67 percent of new breaking strength is reasonable. This is equivalent to a factor of safety of 1.5. Each ship might draw a horizontal line on each of Figures L-2 through L-5 at 67 percent of the catalogue strength of its towing hawser. This represents the limit of acceptable extreme towline tension for that tug.

The 1.5 safety factor described above does not supersede factors of safety listed in Table 6-4. These latter factors of safety, which describe limits on average or steady-state tension, still must be checked. Either criterion may control. The more severe criterion must be considered the limit until significant quantitive experience is gained with the dynamic theory.

L-4.2 INTERPOLATION WITHIN THE TABLES. The following sub-paragraphs will assist in applying different conditions to the criteria used in developing the extreme tension predictions.

L-4.2.1 Ship Size. Generally, smaller ships will be affected more by a given sea state than larger ships. For tugs different from those described (T-ATF 166, ARS 38, ARS 50, ATS 1) use the next-smaller ship listed. For towing ships smaller than the 2,000-ton ARS 38, use the ARS 38 as the basis for evaluating dynamic tension Similarly, for tows different from the examples used, use the next-smaller tow unless the actual tow's displacement is within 25 percent of that of the next larger vessel.

L-4 2.2 Average Tension. Estimation of additional tow resistance due to waves, at normal tow speeds, is not well-understood. Consequently, the total tow resistance predicted in accordance with Chapter 5 and Appendix G is always suspect. Whenever there is a difference between computed versus observed towline tension, use the observed towline tension. This assumes that there is confidence in tension instrumentation onboard the tug.

L-4.2.3 Tow Speed. Speed contributes to extreme tension for two reasons. First, the wave encounter frequency, for head seas, increases with incremental speed, thereby raising slightly the added resistance due to tensions. Secondly, the far more significant effect of increased speed is creation of higher average towline tension. This increases dynamic factors by raising the base to which purely dynamic parameters are added, and by providing a stiffer (i e., having less catenary) towline system. A stiffer system also increases dynamic effects Fortunately, the method of data presentation dilutes an incorrect prediction of speed since entry into curves 0 through 99 is through average tension rather than speed. Examination of the curves and tables will show that the effect of speed, at a given average tension, is not great. Thus, without resulting in major error, the table values for 3 knots can be applied to speeds from 1.0 to 4.5 knots; similarly, the 6 0 knot table values can be applied to speeds from 4.5 to 7.5 knots, etc. To reiterate, it is far more important to know the actual average tension than the actual speed. To find the maximum allowable speed for a given scope, interpolation or extrapolation is acceptable.

L4.2.4 Towing Hawser Scope. Shorter hawser scope results in a "stiffer" hawser system and higher dynamic components To be conservative, enter the tables with the next-lower scope-e g., 1,500 feet for a 1,700-foot hawser scope. Extrapolating beyond 2,100 feet is acceptable.

L-4.2.5 Wave Angle. Data in the tables are presented for relative wave directions of dead-ahead and 60, 120 and 180 degrees. The data for 0 degrees can be used for head seas and seas to angles of 40 degrees relative The 60-degree results can be used for seas from 40 to 70 degrees relative. Results are not provided for predominantly beam seas between 70 and 110 degrees relative, because the tow's rolling and sheering present much larger difficulties than towline dynamics for these angles The 120-degree results can be used for quartering seas between 110 and 140 degrees relative, respectively, whereas the 180-degree results are appropriate for following seas between 140 and 220 degrees relative.

L-4.2.6 Wind Strength and Wave Height. If the seas are not fully-developed, the relationship between wind speed and wave characteristics will be different from that used in the computer program. Factors for which seas would not be fully-developed include small fetch or changes in wind speed or direction, since it takes many hours for the sea state to reach equilibrium with the wind.

When seas are not fully-developed, data for wind speeds corresponding to actual wave heights should be used, as listed in Paragraph O-3 3.2, instead of data for existing wind speeds. For example, a sudden 45-knot wind can develop waves estimated at 9 feet. Enter the tables at the 25-knot wind speed, which assume H 1/3 at 9 1 feet.

L-4.3 RESPONSE TO WORSENING SEA CONDITIONS. When encountering rising seas, the towing ship Commanding Officer has several options.

L-4.3.1 Reduce Speed. This probably is the single most effective action, because of the multiple effects in extreme tension' reduction of towline stiffness, with consequent dynamic component reduction; and reduction of the base to which the dynamic components are added.

L-4.3.2 Increase Towline Scope. While not as effective as a reduction in tow speed, increasing towline scope usually is the first action taken, assuming that water depth and towline total length permit. This reduces the stiffness of the system, and therefore the dynamic component of the extreme tension.

L-4.3.3 Change Course. Examination of the tables and curves reveals many examples of changing course to encounter the waves on a different relative heading. Sometimes head seas are better; and at other times, seas from 60 degrees relative are better For instance, examine the ARS 50/DD 963 tow, 30 knot head wind, 1,500-foot hawser scope at 3 and 6 knots tow speed, and 9 knots with 1,200-ft. Scope. In general, stern seas at a given average tension are worse, but in this case, the tug can reduce RPM and might still achieve headway over the ground with acceptable extremal tensions. Specific examples will have to be worked out carefully.

L-4.3.4 A Sheering Tow. A tow sheering badly to one side or the other will raise the average tension. This is due to significantly increased hydrodynamic resistance of the towline and (possibly) increased resistance of the tow because of a relatively long-term yaw angle from the course of the tug. Such sheering movements generally occur at a low frequency, so that they in themselves do not generate dynamic effects. The tug, typically with a constant-torque engine setting, will simply slow down to compensate for the increased average resistance. Sheering is not allowed for in the extreme tension model, which assumes that the tow yaws about the track of the tug With a sheering tow, the tow ship should observe the average tension over a minimum of 30 seconds, when the tow is at its extreme deviation from the tug's track. This figure should be used to enter the curves to determine the extreme tension. If a badly-sheering tow is also rolling heavily, and has a high bow, increasing the dynamic factor of safety to 2 0 is appropriate.

L-5 EXTREME TENSION EXAMPLES

Tables L-1 through L-15 identify the appropriate extreme tension vs average tension for various tug/tow combinations, wind forces, relative wave directions, speeds and hawser surges. Figures L-2 through L-5 provide 100 standard curves predicting extreme tensions based on average resistance The following section provides examples of use of the tables and curves.

Use of the extreme tension charts and curves first requires a predicted or observed mean towing hawser tension. Tb simplify the description of using the tables and figures, the following examples are based on the tow of a 7500 LT DD 963 Class destroyer into seas generated by a 25-knot wind Example 3, page G-10, predicts the hawser tension for several speeds, including the hydrodynamic resistance of 2,000 feet of 2'/4-inch wire towing hawser with one shot of 2 1/4 -inch chain.

Note that the example shows fairly modest changes in hawser hydrodynamic resistance over the tension range of interest. For the following examples, the effects of different scopes and different hawsers can be ignored Alternatively, tow resistance alone can be considered and the wire resistance of the specific hawser in use added back at the appropriate points. However, the method used here is simpler and will make the results somewhat conservative.

Using the example from Appendix G, the maximum safe speed for each of the most common Navy Towing ships will be determined.

The tables are developed for each towing ship class towing a DD 963 Class destroyer displacing 6,707 LT. The assumed tow, being heavier at 7,500 LT, will experience somewhat less motion, the results will slightly overstate extreme tensions, but are sufficient for estimating purposes.

L-5.1 ATS 1 CLASS Appendix G predicts a maximum tow speed of 7.4 knots with a total hawser tension of 106,000 lbs.

Enter Table L-8 at the 25-knot/6-knot section. Pick off the curve number for several hawser scopes, enter the curves at 106,000 pounds to find several predicted extreme tensions as follows.

Wave Direction	Scope	Curve No	Extreme Tension
0	1,200	5	270,000 lbs.
0	1,500	4	234,000 lbs.
0	1,800	3	203,000 lbs.
0	2,100	29	177,000 lbs
60	1,200	33	235,000 lbs
60	1,500	31	198,000 lbs
60	1,800	30	217,000 lbs
60	2,100	29	177,000 lbs.

The ATS 1 Class towing hawser has a new breaking strength of 360,000 pounds Using a 1.5 dynamic factor of safety for evaluating extreme tensions, the allowable extreme tension is 240,000 pounds Note that the tension with only a 0.1 percent probability of being exceeded in a 24-hour period is less than the 240,000-pound figure for hawser scopes of at least 1,500 feet. Note also that predicted extreme tension is reduced in some cases when the seas are met at 60 percent relative, rather than head-on.

Not shown here is the extreme tension when towing downwind under these conditions Assume tow speeds up to about 9 knots with the same tension, because of the following wind and seas. Predicted extremal tension is beyond the curve display limits of 400,000 pounds for all towline scopes listed.

The steady state, or mean, tensions must also be checked against the safety factors listed in Table 5-4. When towing on automatic tension control, the minimum factor of safety is 3, and the allowable tension is.

$$360,000/3 = 120,000 \text{ lbs}$$

This is greater than the mean tension of 106,000 pounds, so the tow described is within limits, the actual control being the towing capacity of the ATS 1 at the speed of 7 4 knots.

L-5.2 ARS 50 CLASS. This class uses the same tables as the ATS 1 Class. Therefore, the curve numbers will be the same. But the ARS 50 can tow the 7500 LT DDG 963 Class destroyer at only 7.2 knots with a mean hawser tension of 98,000 pounds. Therefore, extremal tensions will be less than for the ATS 1 at 7.4 knots. For example, with a wire scope of 1,800 feet, the extremal tension prediction is 186,000 pounds. The ARS 50 has a stronger hawser than the ATS 1, and the example needs to be carried no further to check factors of safety. The tow will be limited by the maximum towing speed attainable by the ARS 50.

L-5.3 T-ATF 166 CLASS. The Appendix G example predicts that the T-ATF can conduct the tow at 7 75 knots with a hawser tension of 113,000 pounds. However, the T-ATF towing winch has no automatic tension feature. The minimum factor of safety, from Table 5-4, therefore is 4, and the allowable mean tension is

360,000/4 = 90,000 lbs

This will limit the towing speed to about 6 9 knots.

The extreme tension must also be checked with a mean tension of 90,000 pounds using Table O-3.

Wave Direction	Wire Scope	Curve No	Extreme Tension
0	1,200	4	195,000 lbs
0	1,500	3	170,000 lbs
0	1,800	30	162,000 lbs
0	2,100	29	148,000 lbs.

Applying the dynamic factor of safety of 1.5, the maximum allowable predicted extremal tension is 240,000 pounds. Therefore, predicted extreme tensions from ship motion theory is satisfactory for this tow at 6 9 knots. The 90,000-pound steady-state tension condition limits this tow.

L-5.4 ATF 76 CLASS. New hawser strength for this class is 288,000 pounds. When towing with the automatic tension feature engaged, the allowable mean tension is:

288,000/3 = 96,000 lbs

The maximum allowable tension predicted from ship motion theory is:

288,000/1.5 = 192,000 lbs.

The Appendix G example predicts the ATF 76 can tow the 7,500 LT DDG 963 destroyer at 5.7 knots into 25-knot wind and seas, with a steady-state hawser tension of 68,000 pounds. This is less than the allowable mean tension, so the extremal tension predictions should be examined. The tables do not include ATF 76 Class tows Use the ARS 38 tables, since that is the ship closest in size, and remember that the extreme tension predictions may be slightly understated. Enter Table L-13 in the 25-knot wind/6knot speed block to develop the following data for an average tension of 68,000 pounds

Wave Direction	Wire Scope	Curve No	Extreme Tension
0	1,000	4	149,000 lbs.
0	1,200	3	128,000 lbs.
0	1,500	30	134,000 lbs
0	1,800	29	121,000 lbs

All of these predictions are less than the 192,000 pounds allowed, and the tow can be performed with acceptable risk at 5.7 knots at 68,000 pounds mean tension

Note that the tables and curves predict an increase in extreme tension when increasing hawser scope from 1,200 to 1,500 feet. This does not occur frequently in the tables, but does happen sometimes when shifting between different families of curves on Figures L-2 through L-5. This is caused by the curve-fitting program, which attempts to provide the best fit at about 70 percent of hawser strength, accepting some error at lower tensions.

The hawser tension trends for the previous examples do not experience the abnormality demonstrated here. It may be assumed that the extreme tension probability with 1,800-foot scope of wire will be better than, or certainly no worse than, at 1,200-foot scope.

L-5.5 ARS 6/38 CLASS. The ARS 6 and 38 Classes have the same hawser as the ATF 76. Limits of mean and extreme tension are 96,000 and 192,000 pounds, respectively.

The Appendix G example predicts a tow speed of 4.4 knots at 47,000 pounds hawser tension. Mean tension is satisfactory in this case. Because of the lower speed, enter Table L-13 at the 25-knot wind/3-knot tow speed section.

Wave Direction	Wire Scope	Curve No.	Extreme Tension
0	1,000	6	131,000 lbs.
0	1,200	4	103,000 lbs.
0	1,500	31	117,000 lbs.
0	1,800	30	105,000 lbs.

These predicted extremal tensions are well under the allowable dynamic tension of 192,000 pounds, and the tow may be performed with acceptable risk. Towing speed is limited by the available power of the towing ship.

As in the previous case, note that there is an apparent increase in predicted extreme tension as the table shifts from one family of curves (straight lines in figure L-2) to another family. These differences should not be taken literally; it can be assumed that longer scope will reduce the risk of extremal tensions resulting from ship motions.

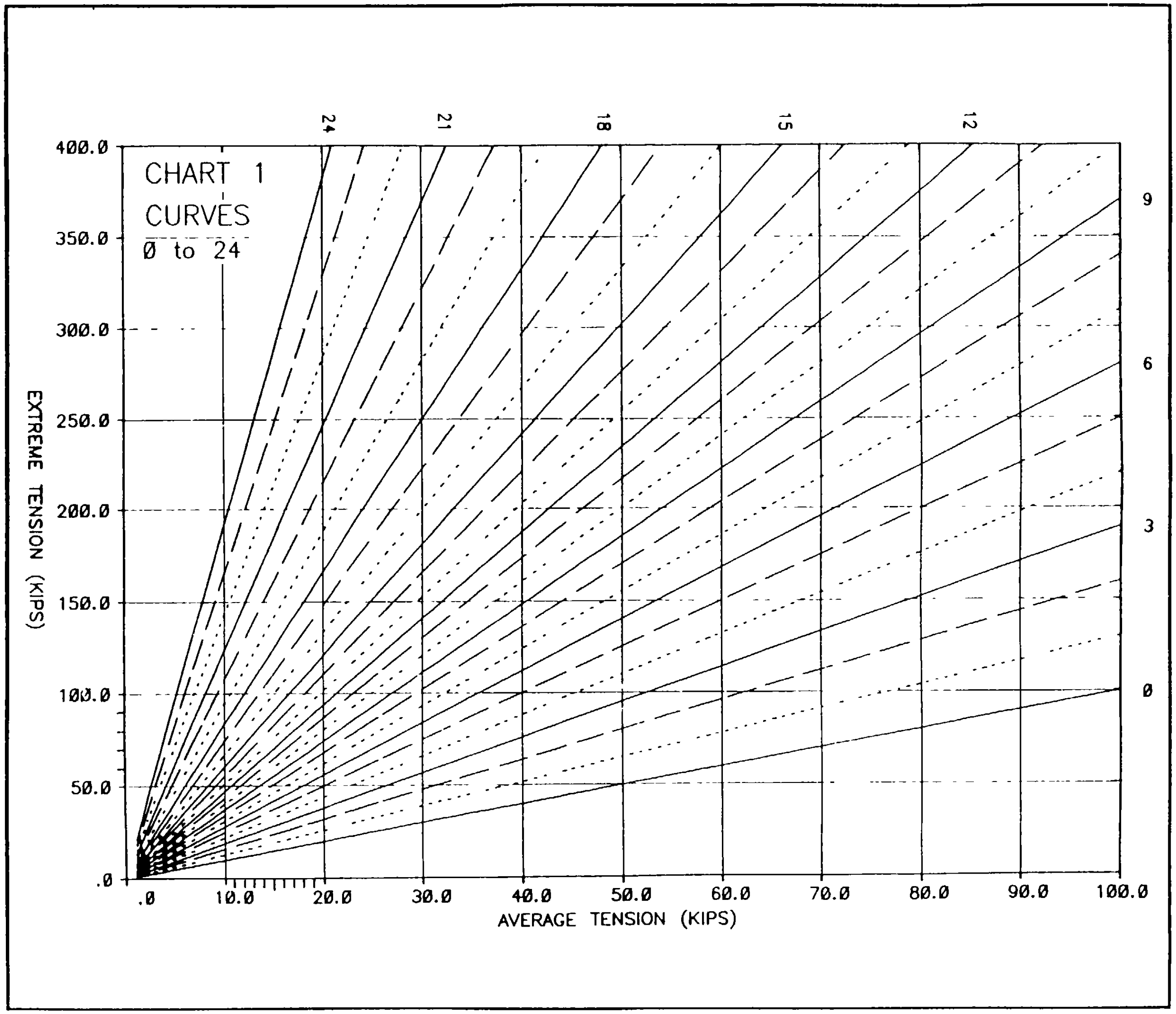


FIGURE L-2. Extreme Tension (Curves 0 to 24).

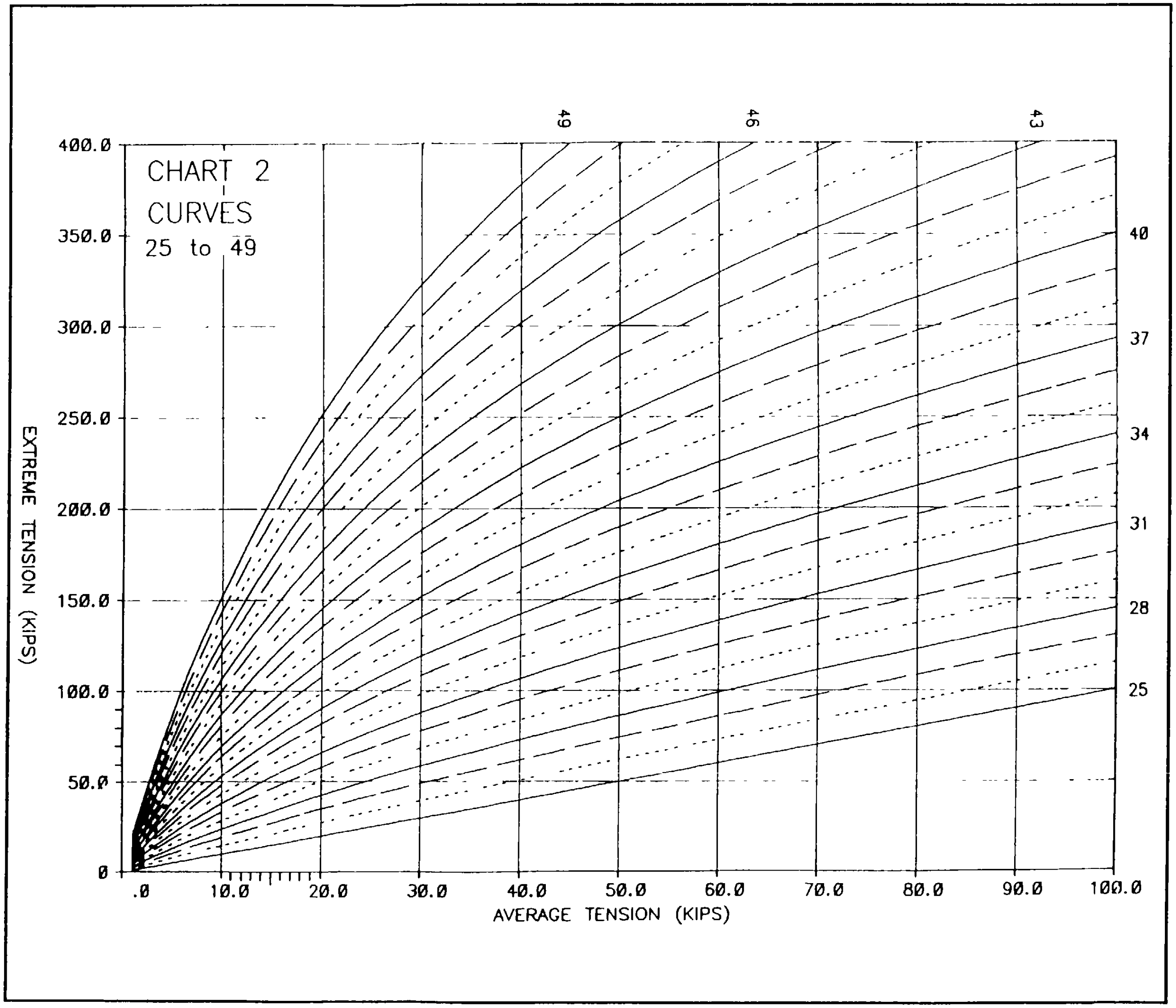


FIGURE L-3. Extreme Tension (Curves 25 to 49).

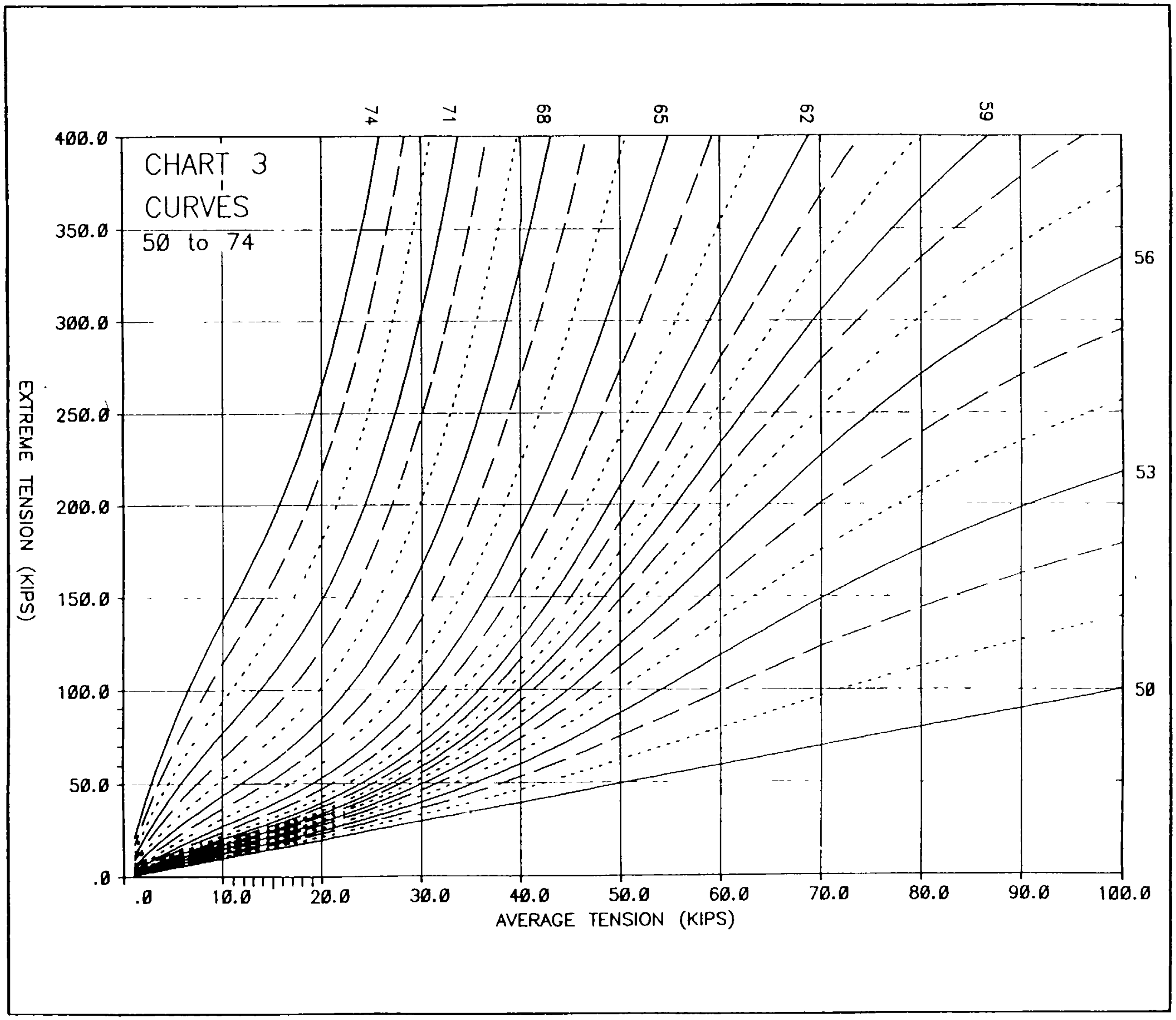


FIGURE L-4. Extreme Tension (Curves 50 to 74).

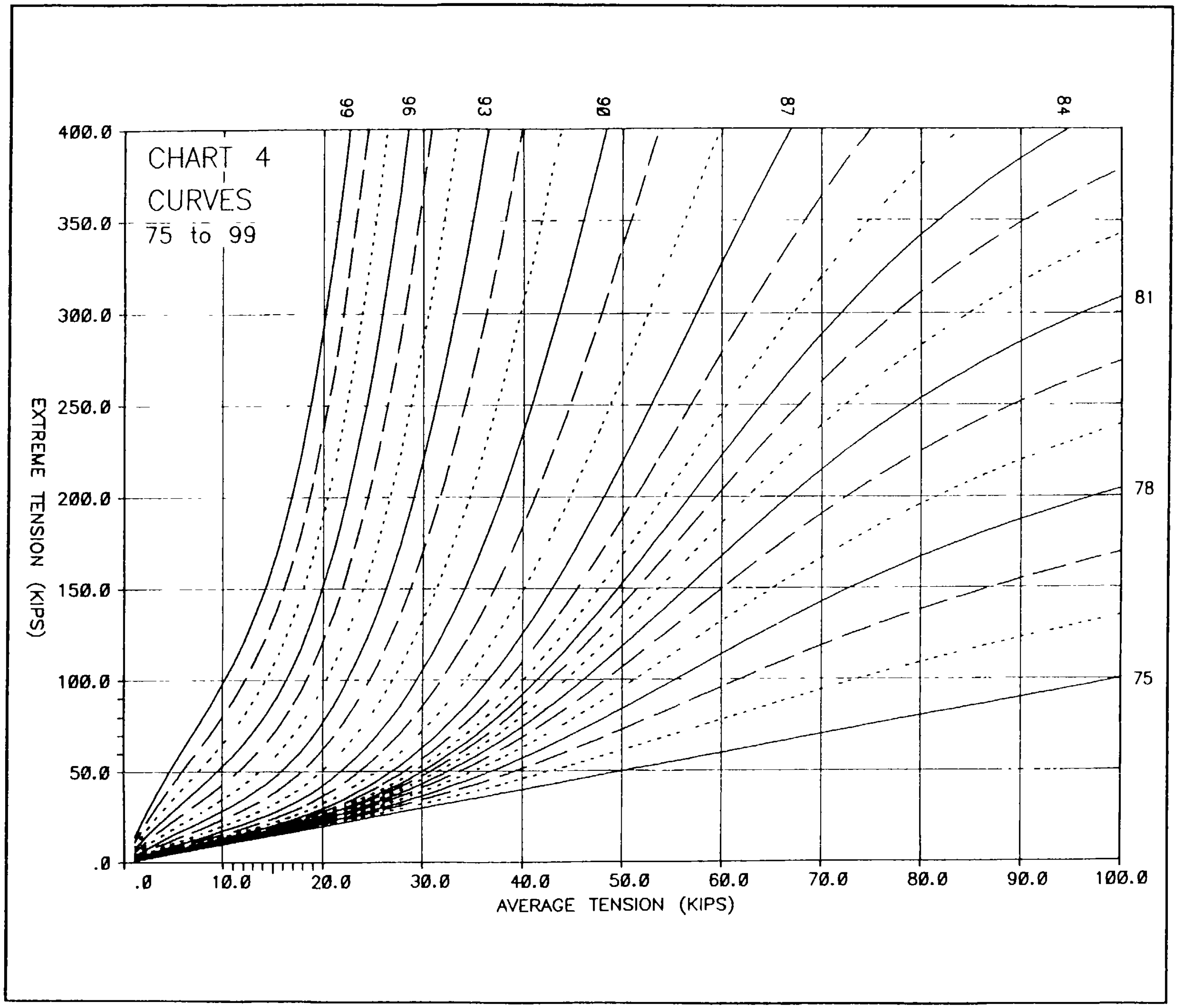


FIGURE L-5. Extreme Tension (Curves 75 to 99).

TABLE L-1. T-ATF Towing YRBM Barge Displacing 650 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-79 1200-51 1500- 1 1800-26 2100-26	1000-51 1200- 1 1500-26 1800-26 2100-26	1000- 1 1200-26 1500-26 1800-26 2100-26
60	1000-79 1200- 2 1500- 1 1800-26 2100-26	1000-77 1200-51 1500-26 1800-26 2100-26	1000-51 1200- 1 1500-26 1800-26 2100-26
120	1000-81 1200-79 1500- 2 1800-51 2100-76	1000-86 1200-81 1500-52 1800- 2 2100-51	1000-60 1200-82 1500-53 1800-52 2100-77
180	1000-89 1200-86 1500-53 1800-77 2100-76	1000-64 1200-87 1500-86 1800-80 2100-77	1000-37 1200-35 1500-34 1800-82 2100-81
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000-90 1200-89 1500-84 1800-79 2100-77	1000-63 1200-85 1500-79 1800-52 2100-51	1000-81 1200-79 1500-52 1800-28 2100-27
60	1000-89 1200-63 1500-86 1800-79 2100-77	1000-63 1200-85 1500-79 1800-52 2100-28	1000-82 1200-54 1500-52 1800- 2 2100-51
120	1000-89 1200-89 1500-87 1800-82 2100-79	1000-67 1200-64 1500-86 1800-81 2100-54	1000-67 1200-64 1500-62 1800-82 2100-55
180	1000-69 1200-90 1500-89 1800-63 2100-84	1000-95 1200-68 1500-90 1800-89 2100-87	1000-46 1200-43 1500-17 1800-65 2100-88
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000-94 1200-68 1500-90 1800-89 2100-87	1000-69 1200-90 1500-88 1800-60 2100-56	1000-16 1200-62 1500-83 1800-55 2100- 4
60	1000-68 1200-90 1500-66 1800-88 2100-86	1000-67 1200-89 1500-87 1800-84 2100-80	1000-15 1200-61 1500-83 1800-80 2100-53
120	1000-70 1200-91 1500-90 1800-89 2100-88	1000-70 1200-91 1500-65 1800-88 2100-62	1000-71 1200-69 1500-66 1800-63 2100-61
180	1000-97 1200-94 1500-68 1800-67 2100-90	1000-99 1200-96 1500-93 1800-68 2100-90	1000-24 1200-97 1500-71 1800-69 2100-68
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000-74 1200-96 1500-69 1800-91 2100-90	1000-73 1200-71 1500-91 1800-66 2100-64	1000-71 1200-69 1500-65 1800-62 2100-84
60	1000-96 1200-70 1500-91 1800-90 2100-89	1000-72 1200-69 1500-66 1800-88 2100-62	1000-71 1200-17 1500-62 1800-60 2100-82
120	1000-97 1200-95 1500-68 1800-90 2100-66	1000-98 1200-95 1500-68 1800-66 2100-89	1000-99 1200-95 1500-68 1800-66 2100-64
180	1000-24 1200-74 1500-71 1800-69 2100-68	1000-24 1200-99 1500-95 1800-69 2100-69	1000-24 1200-24 1500-74 1800-72 2100-69

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-2. T-ATF Towing FFG 1 Frigate Displacing 3,200 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800-26	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0
60	1000- 1	1200-26	1500-26	1800-26	2100-26	1000-27	1200-26	1500-26	1800-26	2100-26	1000-26	1200-26	1500-26	1800-26	2100-26
120	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500-26	1800-26	2100-26	1000-71	1200-51	1500-76	1800-26	2100-26
180	1000-76	1200-76	1500-26	1800-26	2100-26	1000-77	1200-51	1500-76	1800-76	2100-26	1000-83	1200-53	1500-77	1800-51	2100-76
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 3	1200- 2	1500-28	1800-51	2100- 1	1000-29	1200-28	1500-27	1800-27	2100-26	1000-29	1200-28	1500-27	1800-27	2100-26
60	1000-30	1200-29	1500-28	1800-28	2100-27	1000-30	1200-29	1500-28	1800-28	2100-27	1000-29	1200-29	1500-28	1800-27	2100-27
120	1000- 4	1200- 3	1500- 2	1800-28	2100-51	1000-80	1200-78	1500-52	1800-28	2100-28	1000-56	1200-79	1500-78	1800- 2	2100- 2
180	1000-83	1200-54	1500-78	1800-77	2100- 2	1000-65	1200-83	1500-80	1800-53	2100- 3	1000-68	1200-66	1500-60	1800-81	2100-54
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-13	1200- 7	1500-79	1800- 3	2100-30	1000- 8	1200- 5	1500-32	1800-30	2100-29	1000-36	1200-33	1500-31	1800-30	2100-29
60	1000-61	1200-83	1500-31	1800-30	2100-29	1000-57	1200-33	1500-30	1800-30	2100-29	1000- 7	1200-32	1500-30	1800-30	2100-29
120	1000-64	1200-83	1500-54	1800-31	2100-52	1000-66	1200-63	1500-55	1800- 4	2100- 3	1000-66	1200-63	1500-82	1800-54	2100-53
180	1000-68	1200-90	1500-11	1800-81	2100-54	1000-70	1200-68	1500-64	1800-10	2100-56	1000-73	1200-70	1500-67	1800-64	2100-61
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-18	1200-66	1500-13	1800- 8	2100- 5	1000-17	1200-15	1500- 9	1800- 6	2100-33	1000-16	1200-14	1500- 7	1800-34	2100-32
60	1000-67	1200-67	1500-61	1800-34	2100-32	1000-67	1200-65	1500-58	1800-33	2100-31	1000-66	1200-63	1500-36	1800-32	2100-31
120	1000-68	1200-67	1500-63	1800-56	2100- 5	1000-69	1200-67	1500-65	1800-60	2100-80	1000-71	1200-68	1500-66	1800-61	2100-56
180	1000-73	1200-70	1500-67	1800-65	2100-11	1000-99	1200-72	1500-69	1800-67	2100-15	1000-24	1200-98	1500-71	1800-69	2100-67

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions.

TABLE L-3. T-ATF Towing DDG 963 Destroyer Displacing 6,707 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0
60	1000-26	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100- 0
120	1000- 1	1200-26	1500-26	1800-26	2100-26	1000-76	1200- 1	1500-26	1800-26	2100-26	1000-51	1200-51	1500- 1	1800-26	2100-26
180	1000-76	1200-76	1500-26	1800-26	2100-26	1000-77	1200-51	1500-76	1800-26	2100-26	1000-53	1200-52	1500-51	1800-51	2100-76
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-30	1200- 2	1500-28	1800-27	2100- 1	1000- 2	1200-28	1500-27	1800-27	2100- 1	1000-28	1200-28	1500-27	1800-26	2100-26
60	1000-30	1200-29	1500-28	1800-27	2100-27	1000-30	1200-28	1500-28	1800-27	2100-27	1000-29	1200-28	1500-28	1800-27	2100-27
120	1000- 3	1200-29	1500-28	1800-28	2100-27	1000- 4	1200- 3	1500- 2	1800-28	2100-51	1000- 5	1200-53	1500-52	1800- 2	2100-28
180	1000- 5	1200-53	1500-52	1800- 2	2100-28	1000- 8	1200- 6	1500- 4	1800- 3	2100-77	1000-16	1200-61	1500-38	1800-54	2100-53
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 7	1200- 5	1500- 4	1800- 3	2100-30	1000-35	1200-33	1500-31	1800-30	2100-29	1000-34	1200-32	1500-30	1800-29	2100-29
60	1000-35	1200-32	1500-31	1800-29	2100-29	1000-34	1200-32	1500-31	1800-29	2100-29	1000-34	1200-32	1500-31	1800-29	2100-29
120	1000- 8	1200-51	1500- 3	1800-30	2100-29	1000-12	1200- 6	1500- 4	1800-31	2100-30	1000-62	1200- 8	1500- 5	1800- 4	2100- 3
180	1000-15	1200-12	1500- 7	1800- 5	2100- 4	1000-68	1200-16	1500-11	1800- 7	2100-80	1000-21	1200-69	1500-15	1800-13	2100- 8
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-17	1200-14	1500- 8	1800- 6	2100-34	1000-16	1200-11	1500-37	1800-34	2100-33	1000-14	1200-39	1500-36	1800-33	2100-32
60	1000-16	1200-10	1500-35	1800-32	2100-32	1000-15	1200-39	1500-34	1800-32	2100-32	1000-15	1200-37	1500-34	1800-32	2100-31
120	1000-67	1200-64	1500- 7	1800-34	2100-32	1000-68	1200-65	1500- 8	1800- 6	2100- 4	1000-18	1200-66	1500-12	1800- 7	2100- 5
180	1000-20	1200-68	1500-15	1800-12	2100- 8	1000-22	1200-71	1500-67	1800-15	2100-12	1000-24	1200-74	1500-70	1800-68	2100-16

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-4. T-ATF Towing AE 26 Displacing 20,000 Tons

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-26 1200-26 1500-26 1800- 0 2100- 0	1000-26 1200-26 1500- 0 1800- 0 2100- 0	1000-26 1200-26 1500- 0 1800- 0 2100- 0
60	1000-26 1200-26 1500-26 1800- 0 2100-26	1000-26 1200-26 1500-26 1800- 0 2100-26	1000-26 1200-26 1500-26 1800- 0 2100- 0
120	1000- 1 1200-26 1500-26 1800-26 2100-26	1000-76 1200- 1 1500-26 1800-26 2100-26	1000-51 1200-51 1500- 1 1800-26 2100-26
180	1000-76 1200-76 1500-26 1800-26 2100-26	1000-77 1200-51 1500-76 1800-26 2100-26	1000-53 1200-52 1500-51 1800-51 2100-76

Rel Wave Dir	20 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-30 1200- 2 1500-28 1800-27 2100- 1	1000- 2 1200-28 1500-27 1800-27 2100- 1	1000-28 1200-28 1500-27 1800-26 2100-26
60	1000-30 1200-29 1500-28 1800-27 2100-27	1000-30 1200-28 1500-28 1800-27 2100-27	1000-29 1200-28 1500-28 1800-27 2100-27
120	1000- 3 1200-29 1500-28 1800-28 2100-27	1000- 4 1200- 3 1500- 2 1800-28 2100-51	1000- 5 1200-53 1500-52 1800- 2 2100-28
180	1000- 5 1200-53 1500-52 1800- 2 2100-28	1000- 8 1200- 6 1500- 4 1800- 3 2100-77	1000-16 1200-61 1500-38 1800-54 2100-53

Rel Wave Dir	25 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000- 7 1200- 5 1500- 4 1800- 3 2100-30	1000-35 1200-33 1500-31 1800-30 2100-29	1000-34 1200-32 1500-30 1800-29 2100-29
60	1000-35 1200-32 1500-31 1800-29 2100-29	1000-34 1200-32 1500-31 1800-29 2100-29	1000-34 1200-32 1500-31 1800-29 2100-29
120	1000- 8 1200-51 1500- 3 1800-30 2100-29	1000-12 1200- 6 1500- 4 1800-31 2100-30	1000-62 1200- 8 1500- 5 1800- 4 2100- 3
180	1000-15 1200-12 1500- 7 1800- 5 2100- 4	1000-68 1200-16 1500-11 1800- 7 2100-80	1000-21 1200-69 1500-15 1800-13 2100- 8

Rel Wave Dir	30 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-17 1200-14 1500- 8 1800- 6 2100-34	1000-16 1200-11 1500-37 1800-34 2100-33	1000-14 1200-39 1500-36 1800-33 2100-32
60	1000-16 1200-10 1500-35 1800-32 2100-32	1000-15 1200-39 1500-34 1800-32 2100-32	1000-15 1200-37 1500-34 1800-32 2100-31
120	1000-67 1200-64 1500- 7 1800-34 2100-32	1000-68 1200-65 1500- 8 1800- 6 2100- 4	1000-18 1200-66 1500-12 1800- 7 2100- 5
180	1000-20 1200-68 1500-15 1800-12 2100- 8	1000-22 1200-71 1500-67 1800-15 2100-12	1000-24 1200-74 1500-70 1800-68 2100-16

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-5. T-ATF Towing LHA 1 Displacing 40,000 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-26 1200-26 1500-26 1800- 0 2100- 0	1000-26 1200-26 1500- 0 1800- 0 2100- 0	1000-26 1200- 0 1500- 0 1800- 0 2100- 0
60	1000-26 1200-26 1500-26 1800- 0 2100-26	1000-26 1200-26 1500- 0 1800- 0 2100- 0	1000-26 1200-26 1500- 0 1800- 0 2100- 0
120	1000- 1 1200-26 1500-26 1800-26 2100-26	1000-51 1200- 1 1500-26 1800-26 2100-26	1000-51 1200-76 1500- 1 1800-26 2100-26
180	1000-76 1200-26 1500-26 1800-26 2100-76	1000-77 1200-51 1500-76 1800-26 2100-26	1000-78 1200-77 1500-51 1800-76 2100-76
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000-52 1200- 2 1500-28 1800-51 2100- 1	1000- 2 1200-51 1500- 1 1800- 1 2100-26	1000-28 1200-51 1500- 1 1800-26 2100-26
60	1000-29 1200-28 1500-27 1800-27 2100- 1	1000-29 1200-28 1500-27 1800-27 2100-27	1000-28 1200-28 1500-27 1800-27 2100-27
120	1000- 3 1200- 2 1500-28 1800-27 2100-27	1000- 4 1200-52 1500- 2 1800-28 2100-51	1000- 4 1200- 3 1500-52 1800- 2 2100-28
180	1000- 5 1200-53 1500-52 1800- 2 2100-28	1000- 8 1200- 6 1500- 4 1800- 3 2100-52	1000-15 1200-11 1500-81 1800-54 2100-53
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000- 7 1200- 5 1500- 4 1800- 3 2100-52	1000- 5 1200- 4 1500- 3 1800-52 2100- 2	1000- 4 1200-31 1500-52 1800- 2 2100-28
60	1000-34 1200-32 1500-30 1800-29 2100-29	1000-33 1200-31 1500-30 1800-29 2100-29	1000-34 1200-32 1500-30 1800-29 2100-29
120	1000- 7 1200- 5 1500-31 1800-30 2100-29	1000- 9 1200- 6 1500- 4 1800- 3 2100-52	1000-12 1200- 7 1500- 5 1800- 4 2100- 3
180	1000-15 1200-10 1500- 6 1800- 5 2100- 4	1000-18 1200-15 1500-10 1800- 7 2100-80	1000-20 1200-68 1500-15 1800-12 2100- 8
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000-17 1200-13 1500- 8 1800- 6 2100- 4	1000-14 1200- 9 1500- 6 1800- 5 2100- 4	1000-12 1200-38 1500-35 1800-33 2100-32
60	1000-15 1200- 8 1500-34 1800-32 2100-31	1000-15 1200-37 1500-33 1800-32 2100-31	1000-13 1200-38 1500-35 1800-33 2100-32
120	1000-66 1200-63 1500- 6 1800- 4 2100-32	1000-68 1200-64 1500- 7 1800- 5 2100- 4	1000-18 1200-15 1500- 9 1800- 6 2100- 5
180	1000-20 1200-18 1500-15 1800-10 2100- 7	1000-22 1200-20 1500-17 1800-15 2100-11	1000-24 1200-22 1500-70 1800-18 2100-15

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-6. ARS 50 or ATS 1 Towing YRBM Barge Displacing 650 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-83	1200-80	1500-51	1800- 1	2100-26	1000-79	1200-77	1500- 1	1800-26	2100-26	1000-77	1200- 1	1500-26	1800-26	2100-26
60	1000-83	1200-78	1500-77	1800- 1	2100-26	1000-80	1200-53	1500- 1	1800-26	2100-26	1000-53	1200-51	1500- 1	1800-26	2100-26
120	1000-88	1200-86	1500-78	1800-51	2100-51	1000-88	1200-89	1500-83	1800-52	2100-77	1000-89	1200-88	1500-84	1800-54	2100-78
180	1000-89	1200-89	1500-82	1800-53	2100-51	1000-41	1200-90	1500-89	1800-86	2100-54	1000-36	1200-35	1500-34	1800- 7	2100-60
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-91	1200-90	1500-87	1800-82	2100-78	1000-90	1200-90	1500-85	1800-79	2100-77	1000-89	1200-63	1500-82	1800-52	2100-28
60	1000-90	1200-88	1500-90	1800-83	2100-53	1000-89	1200-90	1500-86	1800-55	2100-52	1000-89	1200-63	1500-60	1800-53	2100- 2
120	1000-68	1200-90	1500-88	1800-84	2100-55	1000-93	1200-91	1500-89	1800-88	2100-83	1000-94	1200-91	1500-89	1800-89	2100-63
180	1000-94	1200-68	1500-90	1800-90	2100-63	1000-96	1200-93	1500-91	1800-90	2100-90	1000-44	1200-42	1500-93	1800-16	2100-89
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-95	1200-92	1500-67	1800-89	2100-89	1000-94	1200-68	1500-90	1800-89	2100-63	1000-92	1200-91	1500-90	1800-88	2100-59
60	1000-93	1200-91	1500-67	1800-89	2100-88	1000-92	1200-91	1500-66	1800-89	2100-63	1000-68	1200-90	1500-89	1800-88	2100-86
120	1000-95	1200-92	1500-90	1800-65	2100-88	1000-96	1200-92	1500-91	1800-90	2100-88	1000-97	1200-94	1500-91	1800-90	2100-90
180	1000-98	1200-95	1500-68	1800-91	2100-90	1000-22	1200-96	1500-93	1800-68	2100-91	1000-24	1200-98	1500-71	1800-93	2100-67
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-98	1200-96	1500-69	1800-91	2100-67	1000-97	1200-95	1500-92	1800-91	2100-90	1000-96	1200-94	1500-68	1800-67	2100-66
60	1000-97	1200-94	1500-68	1800-90	2100-90	1000-96	1200-94	1500-91	1800-90	2100-90	1000-97	1200-93	1500-67	1800-90	2100-89
120	1000-98	1200-96	1500-92	1800-90	2100-90	1000-98	1200-96	1500-93	1800-91	2100-90	1000-99	1200-97	1500-93	1800-91	2100-67
180	1000-24	1200-98	1500-95	1800-92	2100-68	1000-24	1200-22	1500-72	1800-70	2100-68	1000-24	1200-24	1500-96	1800-96	2100-70

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-7. ARS 50 or ATS 1 Towing FFG 1 Frigate Displacing 3,200 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800-26	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0
60	1000-27	1200-27	1500-26	1800-26	2100-26	1000-27	1200-27	1500-26	1800-26	2100-26	1000-27	1200-27	1500-26	1800-26	2100-26
120	1000-76	1200- 1	1500-26	1800-26	2100-26	1000-51	1200-76	1500-26	1800-26	2100-26	1000-77	1200-51	1500-76	1800-26	2100-26
180	1000-76	1200-76	1500-26	1800-26	2100-26	1000-77	1200-51	1500-76	1800- 1	2100-26	1000-87	1200-79	1500-77	1800-51	2100-76
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000- 4	1200-52	1500- 2	1800-51	2100- 1	1000-30	1200- 2	1500-28	1800-27	2100- 1	1000-29	1200-29	1500-28	1800-27	2100-27
60	1000-32	1200-30	1500-28	1800-28	2100-28	1000-31	1200-30	1500-28	1800-28	2100-28	1000-31	1200-30	1500-28	1800-28	2100-28
120	1000-80	1200-78	1500-77	1800-28	2100-51	1000-82	1200-79	1500- 3	1800- 2	2100- 2	1000-60	1200-55	1500-53	1800-77	2100-77
180	1000-61	1200-55	1500-53	1800-52	2100-77	1000-89	1200-61	1500-55	1800-79	2100-78	1000-92	1200-91	1500-61	1800-82	2100-80
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-65	1200-62	1500-80	1800- 4	2100- 3	1000-13	1200- 7	1500- 4	1800-31	2100-30	1000- 8	1200-35	1500-32	1800-30	2100-29
60	1000-65	1200- 8	1500- 4	1800-31	2100-30	1000-63	1200-60	1500-32	1800-31	2100-30	1000-12	1200-35	1500-32	1800-30	2100-30
120	1000-66	1200-63	1500-55	1800- 4	2100- 3	1000-67	1200-64	1500-59	1800-54	2100-53	1000-91	1200-65	1500-85	1800-55	2100-79
180	1000-69	1200-67	1500-64	1800-82	2100-80	1000-71	1200-92	1500-66	1800-61	2100-82	1000-97	1200-94	1500-68	1800-89	2100-62
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-70	1200-68	1500-64	1800-10	2100-81	1000-19	1200-66	1500-13	1800- 7	2100- 5	1000-18	1200-15	1500- 9	1800-36	2100-34
60	1000-19	1200-67	1500-62	1800- 6	2100-33	1000-18	1200-67	1500-63	1800-35	2100-33	1000-18	1200-66	1500-61	1800-34	2100-32
120	1000-71	1200-68	1500-65	1800-60	2100-55	1000-71	1200-68	1500-67	1800-63	2100-56	1000-72	1200-69	1500-90	1800-63	2100-83
180	1000-73	1200-71	1500-68	1800-90	2100-61	1000-99	1200-96	1500-93	1800-91	2100-65	1000-24	1200-98	1500-95	1800-93	2100-91

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-8. ARS 50 or ATS Towing DDG 963 Destroyer Displacing 6,707 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-26 1200-26 1500-26 1800- 0 2100- 0	1000-26 1200-26 1500-26 1800- 0 2100- 0	1000-26 1200-26 1500- 0 1800- 0 2100- 0
60	1000-26 1200-26 1500-26 1800-26 2100-26	1000-26 1200-26 1500-26 1800-26 2100-26	1000-26 1200-26 1500-26 1800-26 2100-26
120	1000-76 1200- 1 1500-26 1800-26 2100-26	1000-51 1200-76 1500-76 1800-26 2100-26	1000- 2 1200-51 1500-76 1800-26 2100-26
180	1000-76 1200-26 1500-26 1800-26 2100-26	1000-77 1200-51 1500-76 1800-26 2100-26	1000-80 1200-78 1500-77 1800-51 2100- 1
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-56 1200-79 1500-28 1800-51 2100- 1	1000-52 1200- 2 1500-51 1800- 1 2100- 1	1000- 2 1200-28 1500-27 1800-26 2100-26
60	1000- 4 1200- 3 1500-28 1800-27 2100-27	1000-30 1200-29 1500-28 1800-27 2100-27	1000-30 1200-29 1500-28 1800-27 2100-27
120	1000-30 1200-29 1500-77 1800-51 2100-51	1000-80 1200-53 1500-52 1800- 2 2100-28	1000-56 1200-54 1500-53 1800-77 2100- 2
180	1000- 3 1200-77 1500-78 1800-77 2100- 2	1000-65 1200-82 1500-54 1800-78 2100-52	1000-68 1200-64 1500-83 1800-80 2100-53
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-13 1200-56 1500-54 1800-53 2100-52	1000- 8 1200- 5 1500- 4 1800- 3 2100-29	1000- 6 1200- 4 1500- 3 1800-29 2100-29
60	1000-10 1200- 5 1500-32 1800-30 2100-30	1000-60 1200-33 1500-31 1800-30 2100-29	1000-36 1200-33 1500-31 1800-30 2100-29
120	1000-64 1200-83 1500-54 1800-53 2100- 3	1000-90 1200-61 1500-55 1800-79 2100-78	1000-67 1200-63 1500-82 1800-54 2100- 4
180	1000-68 1200-65 1500-58 1800-81 2100-54	1000-71 1200-68 1500-63 1800-84 2100-81	1000-73 1200-70 1500-67 1800-63 2100-59
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-69 1200-66 1500-13 1800-83 2100- 6	1000-18 1200-15 1500- 9 1800- 6 2100- 5	1000-17 1200-13 1500- 7 1800- 5 2100-32
60	1000-68 1200-65 1500- 8 1800-34 2100-33	1000-18 1200-64 1500- 7 1800-33 2100-32	1000-17 1200-64 1500-65 1800-33 2100-32
120	1000-69 1200-67 1500-63 1800-81 2100- 5	1000-70 1200-91 1500-64 1800-82 2100-55	1000-71 1200-68 1500-36 1800-59 2100-56
180	1000-73 1200-70 1500-67 1800-63 2100-11	1000-98 1200-72 1500-69 1800-66 2100-14	1000-24 1200-98 1500-71 1800-69 2100-66

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions.

TABLE L-9. ARS 50 or ATS 1 Towing AE 26 Displacing 20,000 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0
60	1000- 1	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100-26
120	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500-26	1800-26	2100-26	1000-77	1200-51	1500-76	1800-26	2100-26
180	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-51	1500-76	1800-26	2100-26	1000-53	1200-52	1500-51	1800-76	2100-26
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 3	1200- 2	1500-28	1800-51	2100- 1	1000-29	1200- 2	1500-51	1800- 1	2100- 1	1000- 2	1200-28	1500-27	1800-26	2100-26
60	1000-31	1200-29	1500-29	1800-27	2100-28	1000-31	1200-29	1500-29	1800-27	2100-28	1000-30	1200-29	1500-29	1800-27	2100-27
120	1000-32	1200- 3	1500-28	1800-28	2100-51	1000- 4	1200- 3	1500-77	1800-28	2100-28	1000-55	1200-79	1500-52	1800- 2	2100- 2
180	1000-80	1200-79	1500-52	1800-77	2100-51	1000-10	1200-81	1500-79	1800-78	2100-77	1000-66	1200-61	1500-82	1800-54	2100-53
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 9	1200- 6	1500- 4	1800- 3	2100-30	1000-37	1200-34	1500-32	1800-30	2100-30	1000-36	1200-33	1500-31	1800-30	2100-29
60	1000-37	1200-34	1500-33	1800-30	2100-30	1000-36	1200-33	1500-32	1800-30	2100-30	1000-36	1200-33	1500-32	1800-30	2100-30
120	1000- 9	1200- 6	1500- 4	1800-31	2100-30	1000-63	1200- 7	1500- 5	1800- 4	2100- 3	1000-15	1200-10	1500-81	1800-79	2100-53
180	1000-17	1200-13	1500-82	1800-80	2100-79	1000-70	1200-17	1500-13	1800-82	2100-55	1000-96	1200-70	1500-65	1800-62	2100-83
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-19	1200-16	1500-11	1800- 7	2100- 5	1000-18	1200-14	1500- 8	1800-35	2100-34	1000-16	1200-12	1500-38	1800-35	2100-33
60	1000-18	1200-13	1500-37	1800-34	2100-33	1000-17	1200-11	1500-36	1800-33	2100-33	1000-17	1200-40	1500-36	1800-33	2100-32
120	1000-18	1200-67	1500- 8	1800- 6	2100- 4	1000-69	1200-66	1500-10	1800- 7	2100- 5	1000-70	1200-67	1500-13	1800- 8	2100- 6
180	1000-72	1200-70	1500-16	1800-13	2100-83	1000-98	1200-72	1500-68	1800-16	2100-13	1000-24	1200-98	1500-71	1800-68	2100-16

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-10. ARS 50 or ATS 1 Towing LHA 1 Displacing 40,000 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED	6 KNOTS APPROXIMATE TOW SPEED	9 KNOTS APPROXIMATE TOW SPEED
0	1000-26 1200-26 1500-26 1800- 0 2100- 0	1000-26 1200-26 1500- 0 1800- 0 2100- 0	1000-26 1200- 0 1500- 0 1800- 0 2100- 0
60	1000-26 1200-26 1500-26 1800- 0 2100-26	1000-26 1200-26 1500-26 1800- 0 2100- 0	1000-26 1200-26 1500-26 1800- 0 2100- 0
120	1000-76 1200-26 1500-26 1800-26 2100-26	1000-51 1200-76 1500-26 1800-26 2100-26	1000-77 1200-76 1500- 1 1800-26 2100-26
180	1000-76 1200-26 1500-26 1800-26 2100-26	1000-51 1200-76 1500-76 1800-26 2100-26	1000-78 1200-77 1500-51 1800-76 2100- 1
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000- 3 1200- 2 1500-28 1800-51 2100- 1	1000- 2 1200-28 1500-51 1800- 1 2100- 1	1000-28 1200-51 1500- 1 1800- 1 2100-26
60	1000-30 1200- 2 1500-28 1800-27 2100-27	1000-29 1200- 2 1500-28 1800-27 2100-27	1000-29 1200-29 1500-28 1800-27 2100-27
120	1000- 3 1200-52 1500- 2 1800-51 2100- 1	1000- 4 1200- 3 1500-77 1800- 2 2100-51	1000- 5 1200-53 1500-52 1800-77 2100-28
180	1000-80 1200-53 1500- 3 1800-77 2100-51	1000-83 1200-55 1500-79 1800-78 2100-52	1000-65 1200-60 1500-81 1800-54 2100-53
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000- 8 1200- 6 1500- 4 1800-78 2100-52	1000- 6 1200- 5 1500-78 1800-52 2100- 2	1000- 5 1200- 4 1500- 3 1800- 2 2100- 2
60	1000-36 1200-33 1500-31 1800-30 2100-29	1000-35 1200-33 1500-31 1800-30 2100-29	1000-36 1200-33 1500-31 1800-30 2100-30
120	1000- 8 1200- 6 1500- 4 1800- 3 2100-29	1000-12 1200- 7 1500- 5 1800-53 2100- 3	1000-14 1200- 8 1500- 6 1800- 4 2100- 3
180	1000-16 1200-13 1500-82 1800-80 2100-79	1000-69 1200-16 1500-12 1800-82 2100-55	1000-99 1200-69 1500-16 1800-13 2100-83
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED	**6 KNOTS APPROXIMATE TOW SPEED**	**9 KNOTS APPROXIMATE TOW SPEED**
0	1000-68 1200-15 1500- 9 1800- 7 2100- 3	1000-16 1200-13 1500- 7 1800- 5 2100- 4	1000-15 1200-10 1500- 7 1800- 5 2100-32
60	1000-17 1200-10 1500-36 1800-33 2100-32	1000-16 1200-39 1500-35 1800-33 2100-32	1000-45 1200-41 1500-36 1800-34 2100-33
120	1000-18 1200-14 1500- 7 1800- 5 2100- 4	1000-19 1200-66 1500- 9 1800-66 2100- 5	1000-20 1200-17 1500-12 1800- 7 2100- 5
180	1000-72 1200-69 1500-16 1800-13 2100- 8	1000-74 1200-71 1500-68 1800-15 2100-13	1000-24 1200-73 1500-70 1800-68 2100-15

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions.

TABLE L-11. ARS 38 Towing YRBM Barge Displacing 650 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-51	1200-26	1500-26	1800-26	2100-26	1000- 1	1200-26	1500-26	1800-26	2100- 0	1000-26	1200-26	1500-26	1800-26	2100- 0
60	1000-51	1200- 1	1500-26	1800-26	2100-26	1000- 1	1200-26	1500-26	1800-26	2100-26	1000- 1	1200-26	1500-26	1800-26	2100-26
120	1000-53	1200-77	1500- 1	1800- 1	2100-26	1000-82	1200-53	1500-51	1800-51	2100- 1	1000-83	1200-54	1500-77	1800-28	2100-51
180	1000-86	1200-79	1500-28	1800-51	2100-26	1000-89	1200-87	1500-80	1800-78	2100-51	1000-37	1200-37	1500-14	1800-64	2100-33

Rel Wave Dir	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-61	1200-82	1500-53	1800-52	2100-28	1000-82	1200-53	1500- 2	1800-28	2100-27	1000-80	1200-78	1500-28	1800-27	2100-27
60	1000-87	1200-82	1500- 3	1800- 2	2100-28	1000-80	1200-53	1500- 2	1800-28	2100-51	1000-79	1200-52	1500-28	1800-27	2100-27
120	1000-89	1200-89	1500-82	1800-53	2100-52	1000-90	1200-89	1500-87	1800-56	2100-78	1000-67	1200-64	1500-63	1800-82	2100-79
180	1000-92	1200-89	1500-88	1800-59	2100-54	1000-71	1200-91	1500-67	1800-64	2100-61	1000-22	1200-95	1500-69	1800-68	2100-90

Rel Wave Dir	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-69	1200-66	1500-64	1800-61	2100- 6	1000-91	1200-65	1500-61	1800-56	2100- 4	1000-66	1200-89	1500-60	1800-54	2100-30
60	1000-68	1200-64	1500-61	1800-83	2100-79	1000-15	1200-60	1500-56	1800-54	2100- 3	1000-11	1200-82	1500- 5	1800- 4	2100-30
120	1000-94	1200-67	1500-89	1800-88	2100-58	1000-94	1200-91	1500-90	1800-89	2100-88	1000-95	1200-68	1500-67	1800-89	2100-63
180	1000-97	1200-70	1500-68	1800-67	2100-90	1000-99	1200-72	1500-70	1800-69	2100-67	1000-24	1200-22	1500-71	1800-69	2100-68

Rel Wave Dir	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-98	1200-97	1500-68	1800-67	2100-65	1000-72	1200-69	1500-68	1800-66	2100-64	1000-71	1200-68	1500-67	1800-64	2100-61
60	1000-96	1200-69	1500-66	1800-64	2100-61	1000-95	1200-93	1500-14	1800-61	2100- 7	1000-71	1200-16	1500-11	1800- 8	2100- 6
120	1000-21	1200-70	1500-68	1800-90	2100-65	1000-21	1200-71	1500-69	1800 67	2100-90	1000-99	1200-71	1500-69	1800-91	2100-67
180	1000-23	1200-22	1500-71	1800-69	2100-18	1000-24	1200-23	1500-72	1800-19	2100-70	1000-24	1200-24	1500-23	1800-19	2100-99

Note. Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions.

TABLE L-12. ARS 38 Towing FFG 1 Frigate Displacing 3,200 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0
60	1000-26	1200-26	1500-26	1800-26	2100-26	1000-26	1200-26	1500-26	1800-26	2100-26	1000-26	1200-26	1500-26	1800-26	2100-26
120	1000-26	1200-26	1500-26	1800-26	2100-26	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500-26	1800-26	2100-26
180	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-51	1500-76	1800-26	2100-26	1000-79	1200-52	1500-51	1800-51	2100-76

Rel Wave Dir	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 2	1200-28	1500-27	1800-27	2100-26	1000-28	1200-51	1500-27	1800-27	2100-26	1000-28	1200-27	1500-27	1800-27	2100-26
60	1000-29	1200-28	1500-27	1800-27	2100-27	1000-28	1200-28	1500-27	1800-27	2100-27	1000-28	1200-28	1500-27	1800-27	2100-27
120	1000-52	1200- 2	1500-28	1800-27	2100-27	1000-78	1200-52	1500-28	1800-28	2100-27	1000-79	1200- 3	1500-29	1800-28	2100-28
180	1000- 5	1200-78	1500-30	1800- 2	2100-28	1000- 9	1200-55	1500- 4	1800- 3	2100-28	1000-67	1200-13	1500- 7	1800- 5	2100- 4

Rel Wave Dir	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 7	1200- 5	1500-31	1800-30	2100-29	1000- 5	1200- 4	1500-30	1800-29	2100-28	1000-32	1200-31	1500-29	1800-29	2100-28
60	1000-58	1200-31	1500-30	1800-29	2100-28	1000-32	1200-30	1500-29	1800-29	2100-28	1000-31	1200-30	1500-29	1800-29	2100-28
120	1000-58	1200- 5	1500-31	1800-30	2100-29	1000-63	1200-82	1500- 4	1800-31	2100-30	1000-64	1200-57	1500- 5	1800-32	2100-31
180	1000-16	1200-12	1500-36	1800- 5	2100-32	1000-19	1200-16	1500-12	1800- 8	2100-35	1000-22	1200-19	1500-17	1800-14	2100- 9

Rel Wave Dir	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-17	1200-14	1500-38	1800-35	2100-33	1000-15	1200-10	1500-36	1800-33	2100-32	1000-14	1200-37	1500-34	1800-32	2100-31
60	1000-67	1200-61	1500-34	1800-32	2100-31	1000-65	1200-60	1500-33	1800-31	2100-30	1000-14	1200- 9	1500-32	1800-31	2100-30
120	1000-17	1200-65	1500- 8	1800-34	2100-32	1000-18	1200-67	1500-62	1800- 6	2100-33	1000-19	1200-67	1500-13	1800- 7	2100-34
180	1000-21	1200-19	1500-16	1800-13	2100-37	1000-99	1200-21	1500-69	1800-17	2100-13	1000-24	1200-23	1500-72	1800-70	2100-18

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-13. ARS 38 Towing DDG 963 Destroyer Displacing 6,707 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200- 0	1500- 0	1800- 0	2100- 0	1000-26	1200- 0	1500- 0	1800- 0	2100- 0
60	1000-26	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100-26
120	1000-27	1200-26	1500-26	1800-26	2100-26	1000- 1	1200- 1	1500-26	1800-26	2100-26	1000-51	1200-76	1500- 1	1800-26	2100-26
180	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500- 1	1800-26	2100-26	1000-53	1200-77	1500-51	1800-27	2100- 1

Rel Wave Dir	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 2	1200-28	1500-27	1800-27	2100-26	1000-28	1200-51	1500-27	1800-26	2100-26	1000-51	1200- 1	1500-26	1800-26	2100-26
60	1000-28	1200-28	1500-27	1800-27	2100-27	1000-28	1200-27	1500-27	1800-26	2100-27	1000-28	1200-27	1500-27	1800-26	2100-27
120	1000-52	1200- 2	1500-28	1800-27	2100-27	1000- 3	1200-77	1500-28	1800-27	2100-27	1000- 4	1200- 3	1500-29	1800-28	2100-28
180	1000- 4	1200- 3	1500-29	1800- 2	2100-28	1000- 7	1200- 5	1500-31	1800-30	2100-29	1000-16	1200-10	1500- 6	1800-54	2100- 3

Rel Wave Dir	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 6	1200- 4	1500-31	1800-30	2100-29	1000- 4	1200- 3	1500-30	1800-29	2100-28	1000- 4	1200-30	1500-29	1800-28	2100-28
60	1000- 4	1200-30	1500-29	1800-28	2100-28	1000-31	1200-30	1500-29	1800-28	2100-28	1000-31	1200-29	1500-29	1800-28	2100-28
120	1000- 6	1200- 4	1500-31	1800-29	2100-29	1000- 8	1200- 5	1500-32	1800-30	2100-29	1000-12	1200- 6	1500-33	1800-31	2100-30
180	1000-14	1200- 8	1500-35	1800-33	2100-31	1000-18	1200-15	1500-39	1800-36	2100-34	1000-22	1200-19	1500-16	1800-12	2100-37

Rel Wave Dir	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-16	1200-12	1500-37	1800-34	2100-32	1000-14	1200- 8	1500-35	1800-33	2100-31	1000- 9	1200- 6	1500-33	1800-32	2100-30
60	1000-14	1200- 8	1500-33	1800-31	2100-30	1000-13	1200-35	1500-32	1800-31	2100-30	1000-13	1200-34	1500-32	1800-30	2100-30
120	1000-67	1200-62	1500-35	1800-33	2100-31	1000-17	1200-64	1500- 7	1800- 5	2100-32	1000-18	1200-71	1500- 9	1800- 6	2100-33
180	1000-21	1200-18	1500-15	1800-39	2100-37	1000-99	1200-21	1500-18	1800-15	2100-40	1000-24	1200-22	1500-72	1800-69	2100-45

Note. Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-14. ARS38 Towing AE 26 Displacing 20,000 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200- 0	1500- 0	1800- 0	2100- 0	1000-26	1200- 0	1500- 0	1800- 0	2100- 0
60	1000-26	1200-26	1500-26	1800- 0	2100-26	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200-26	1500-26	1800- 0	2100- 0
120	1000-26	1200-26	1500-26	1800-26	2100-26	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500-26	1800-26	2100-26
180	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500-76	1800-26	2100-26	1000-78	1200-77	1500-51	1800-76	2100- 1
	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000- 2	1200-28	1500-27	1800-27	2100-27	1000-28	1200-51	1500-27	1800-26	2100-26	1000-51	1200- 1	1500-27	1800-26	2100-26
60	1000-29	1200-28	1500-28	1800-27	2100-27	1000-28	1200-27	1500-27	1800-27	2100-27	1000-28	1200-27	1500-27	1800-27	2100-27
120	1000-29	1200-28	1500-27	1800-27	2100-27	1000- 3	1200- 2	1500-28	1800-28	2100-27	1000-53	1200- 3	1500- 2	1800-27	2100-28
180	1000- 2	1200- 3	1500-29	1800-28	2100-28	1000- 6	1200-79	1500-78	1800-30	2100-29	1000-14	1200- 8	1500- 5	1800- 4	2100- 3
	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-34	1200- 4	1500-31	1800-30	2100-29	1000-33	1200-31	1500-30	1800-29	2100-28	1000-32	1200-30	1500-29	1800-28	2100-28
60	1000-32	1200-30	1500-30	1800-29	2100-29	1000-32	1200-30	1500-30	1800-28	2100-28	1000-31	1200-30	1500-29	1800-28	2100-28
120	1000- 5	1200- 4	1500-30	1800-29	2100-28	1000- 6	1200- 4	1500-31	1800-30	2100-29	1000- 8	1200- 5	1500-32	1800-31	2100-30
180	1000-12	1200- 7	1500-34	1800-33	2100-31	1000-17	1200-13	1500-38	1800-35	2100-33	1000-21	1200-18	1500-14	1800-10	2100-36
	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					**6 KNOTS APPROXIMATE TOW SPEED**					**9 KNOTS APPROXIMATE TOW SPEED**				
0	1000-15	1200-39	1500-36	1800-34	2100-32	1000-41	1200-37	1500-34	1800-33	2100-31	1000-38	1200-36	1500-33	1800-32	2100-31
60	1000-13	1200-35	1500-33	1800-31	2100-31	1000-39	1200-34	1500-32	1800-31	2100-30	1000-38	1200-34	1500-32	1800-31	2100-30
120	1000-15	1200- 8	1500-34	1800-32	2100-31	1000-16	1200-12	1500-35	1800-33	2100-32	1000-17	1200-14	1500-37	1800-34	2100-33
180	1000-20	1200-17	1500-13	1800-38	2100-36	1000-22	1200-20	1500-14	1800-14	2100-39	1000-24	1200-22	1500-71	1800-18	2100-44

Note Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

TABLE L-15. ARS 50 or ATS 1 Towing LHA 1 Displacing 40,000 Tons.

CURVE NUMBERS FOR VARIOUS TOWLINE LENGTHS (LENGTH-CURVE #)

Rel Wave Dir	15 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-26	1200-26	1500-26	1800- 0	2100- 0	1000-26	1200- 0	1500- 0	1800- 0	2100- 0	1000-26	1200- 0	1500- 0	1800- 0	2100- 0
60	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0	1000-26	1200-26	1500- 0	1800- 0	2100- 0
120	1000-26	1200-26	1500-26	1800-26	2100-26	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500-26	1800-26	2100-26
180	1000-76	1200-26	1500-26	1800-26	2100-26	1000-51	1200-76	1500- 1	1800-26	2100-26	1000-52	1200-77	1500-51	1800-76	2100- 1

Rel Wave Dir	20 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 2	1200-28	1500-27	1800-27	2100-26	1000-28	1200-51	1500- 1	1800- 1	2100-26	1000- 1	1200- 1	1500-26	1800-26	2100-26
60	1000-28	1200-51	1500-27	1800-27	2100-27	1000-28	1200-27	1500-27	1800-26	2100-26	1000-27	1200-27	1500-27	1800-26	2100-26
120	1000- 2	1200-28	1500-27	1800-27	2100-27	1000- 3	1200- 2	1500-28	1800-27	2100-27	1000-78	1200-52	1500-29	1800-28	2100-27
180	1000- 4	1200- 3	1500-29	1800-28	2100-28	1000- 6	1200- 4	1500-31	1800-30	2100-29	1000-13	1200- 8	1500- 5	1800- 4	2100- 3

Rel Wave Dir	25 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000- 5	1200- 4	1500-31	1800-30	2100-29	1000- 4	1200- 3	1500-29	1800-29	2100-28	1000-21	1200-30	1500-29	1800-28	2100-28
60	1000-31	1200-30	1500-29	1800-28	2100-28	1000-31	1200-30	1500-29	1800-28	2100-28	1000- 7	1200-30	1500-29	1800-29	2100-28
120	1000- 5	1200- 3	1500-30	1800-29	2100-28	1000- 6	1200- 4	1500-31	1800-30	2100-29	1000-31	1200- 5	1500-32	1800-31	2100-29
180	1000-11	1200- 7	1500-34	1800-32	2100-31	1000-17	1200-13	1500-38	1800-35	2100-33	1000- 3	1200-18	1500-14	1800- 9	2100-36

Rel Wave Dir	30 KNOT WIND—3 KNOTS APPROX TOW SPEED					6 KNOTS APPROXIMATE TOW SPEED					9 KNOTS APPROXIMATE TOW SPEED				
0	1000-14	1200- 9	1500-35	1800-34	2100-32	1000-39	1200- 7	1500-34	1800-32	2100-31	1000-37	1200-35	1500-33	1800-31	2100-30
60	1000-39	1200-34	1500-32	1800-31	2100-30	1000-37	1200-34	1500-32	1800-30	2100-30	1000-38	1200-35	1500-32	1800-31	2100-30
120	1000-14	1200- 7	1500-33	1800-32	2100-31	1000-15	1200- 9	1500-35	1800-33	2100-31	1000-16	1200-10	1500-36	1800-34	2100-32
180	1000-20	1200-17	1500-41	1800-38	2100-35	1000-22	1200-20	1500-17	1800-13	2100-39	1000-23	1200-74	1500-19	1800-18	2100-43

Note. Numbers listed with each hawser length are curves found in Figures L-2 through L-5 Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0 1 percent of occurring in 24 hours of towing under the stated conditions

APPENDIX M

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APPENDIX N

GLOSSARY

Aerodynamic resistance
The force created by the movement of air against a solid body

Alongside "Chinese"
Denotes that two ships are alongside each other such a manner that the stern of one is facing the same direction as the bow of the other

Anchor hawk
A device used to recover lost chains, wire rope, etc.

Anchor windlass
The machine used to hoist and lower anchors.

Ancillary equipment
Equipment that supports the operation of a system's principal components or assemblies.

Appendage drag
The hydrodynamic force created by the resistance of underwater appurtenances such as rudders, skegs, struts, propellers, etc.

Assembly
Compatible parts fitted together for a common usage.

Athwart
Lying at right angles to the fore-and-aft axis of a ship, sometimes pronounced "thwart- ships"

Automatic
Self-moving, operating by itself, regulating itself, done with automatic equipment

Automatic tension towing machine
Winch-like machine which relieves tension on the towline by automatically paying out and then reclaiming wire when the tension is reduced.

Auxiliary towline
A spare or secondary hawser used for multiple emergency tows.

Auxiliary vessel
A vessel that maintains, supplies or supports combatants.

Bail
The part of a pelican hook or chain stopper that holds the hook closed

Barrel
The rotating drum of a capstan or winch

Batten
A strip of wood or steel used to keep tarpaulins in place over a hatch

Beach gear
A generic term for specialized ground tackle, purchases and ancillary equipment used to extract a grounded ship.

Beam
A ship's breadth at its widest point; any of the heavy, horizontal crosspieces of a ship.

Beam ends
Term describing the situation where a vessel is hove over or listed until her deck beams approach vertical

Beam sea
A sea that runs athwart the vessel's course

Beam wind
A wind that blows athwart the vessel's course.

Bear down
To approach the target.

Beaufort No. or scale
A numerical scale (from 0 to 12) used for rating wind velocity, m ascending strength.

Bird-caging
The phenomenon of wires flaring out around the full diameter of wire rope, with resulting kinks in the wires. This can occur when there is a sudden release of a heavy load on a wire rope.

Bitt
A pair of metal posts to which mooring or towing lines are made fast

Bitter end
The last part of a rope or chain, in contrast to the middle part or bight

Bollard
Single cast-steel posts secured to a wharf or pier and used for mooring vessels by means of lines extending from the vessel.

Bollard pull
The maximum pulling power of a ship at a given power rating, with no way on.

Bow thruster
A propeller used to control lateral movement of the bow.

Breaking strength
The actual or ultimate rated load required to pull a wire, strand or rope to destruction. As an aggregate value, the sum of individual breaking loads of all wires in a strand or rope.

Breast line
A mooring line from ship to pier, or ship to ship, running perpendicular to the ship's fore-and-aft axis

Bridle
A tow-legged towing rig of wire or chain attached to towing pads or sets of bitts on the tow At the apex is a flounder plate or ring, dependent upon whether a chain bridle is being used. The two legs and the imaginary line between the points of attachment should form an equilateral triangle

Birdie rig
The rigging of a tow with two legs from the tow's bow to a flounder plate.

Bull rope
Colloquial term referring to a towing hawser

Bullnose
A closed chock at the bow of a vessel

Bulwark
Section of a ship's side continued above the main deck that serves as a protection against heavy weather.

BUSHIPS
Bureau of Ships, now Naval Sea Systems Command.

Cable
A heavy rope, chain or wire of great strength. Applications include attachment to anchors and towing Also a unit of length, equivalent to 120 fathoms or 720 feet.

Cable grip
A termination which is wrapped about the end of a wire rope using interlocking helical strands, designed so that tensile loads are resisted by induced radial pressures.

Cable-laid
Three ropes flaid up like strands from right- to left-handed. The ropes which serve as strands are laid up from left to right (i.e., non-rotating wire).

Calculated risk
Accepting an operation or decision based on less than satisfactory conditions. As applied to towing, accepting a tow when the tow's material condition, seaworthiness, weather, etc., makes the tow less than satisfactory. This should be rarely used as a basis of acceptance of the tow.

Calm water resistance
The hydrodynamic resistance created by a tow without the influence of waves created by the weather, tug, tow, or other outside influences; approximates steady tension.

Caprail
Rail on the stern of a towing vessel, over which the sweep of the tow wire rides.

Capstan
A revolving device with a vertical axis, used for heaving in mooring lines

Carpenter stopper
A mechanical device consisting of a pair of gates that enclose a sliding jar that can be opened by knocking away a latch that holds them closed. Used for holding a wire

Catenary
The downward curve for sag of a rope suspended between two points

Center of Gravity (CG)
The point in a ship where the sum of all moments of weight is zero.

Chafing pendant
A length of chain used to reduce chafing or wearing.

Chain bridle
A chain sused in a bridle rig or a single pendant rig.

Chain connecting link
See "Detachable link."

Chain pendant
A piece of chain used as a strap, chain rigged between the tow and tow haswer; chain used to create a catenary.

Chain stopper
A device used to secure chain, thereby relieving the strain on the windlass; also used to secure the anchor in the housed position in the hawsepipe.

Chamfer
To bevel, to form a smooth round surface

Check
To keep a strain on a line without parting it.

Chock
A heavy smooth-surfaced fitting usually located near the edge of the weather deck through which wire ropes or fiber hawsers may be led

Chute
An inclined or vertical trough or passage down which something may be slid or passed.

Closed socket
A wire rope termination similar to a padeye or ring.

COLROEG
U S. Coast Guard Rules of the Road.

Control, lateral
The power to direct or regulate sideways movement.

Core (line)
The axial member of a wire rope, about which the strands are laid It may consist of wire strand, wire rope, synthetic or natural fiber or solid plastic

Crabbing
Moving sideways through the water

Cross-flow drag
(See Paragraph 0-3.3.2)

Cutwater
The stem of a ship, the forwardmost portion of the bow, which cuts the water as the ship moves.

Deshackling kit
A tool set used to assemble and dissemble detachable links. Tools included in these sets fare hammers, punches, lead pellets, spare taper pins and hairpins

Detachable link
A joining link or chain link used to connect chain to mooring, towing or beach gear equipment

Die lock chain
Chain formed by forging.

Dipped shackle, padeye
The placement of a shackle through a padeye or connection, as opposed to passing the mortise over the padeye. The padeye is shaped to accept a shackle as described.

Dog
A pawl; a device applied to the winch drum to prevent rotation. See "On the dog"

Drag
Forces opposing direction of motion due to friction, profile and other components

Drogue
A device used to slow rate of movement.

Dynamic load
Relating to energy or physical force in motion, as opposed to static load, a force producing motion or change

Extremal statistics
Determination of the probability of a remote, yet possible, occurrence taking place. Used in ship motion dynamics.

Eye splice
A loop formed in the end of a rope by tucking the strand ends over and under the strands of the standing part of the

rope A thimble is often used in the loop

Fairlead
Metal fittings which lead lines m the direction desired.

Fairlead chock
A chock with a roller(s) installed to lead a line to a bitt or cleat

Fake (faked down)
To lay out a line lengthwise in long, flat bights, so that when needed, it will pay out freely.

Falling off
Drifting away from a desired position, direction or course.

Fatigue
The tendency for materials or devices to break under repeated (cyclic) loading

Fetch
The distance a wind blows over the sea surface without a significant change of direction. A factor in the buildup of waves

"Fish hooks"
Outer wires of wire rope that break and cause short ends to project from the rope; a sign of wire rope deterioration.

Flounder plate
A triangular steel plate to which chain bridle legs are connected, sometimes called "fish plate."

Freeboard
The distance from the weather deck to the water's edge

Free-running speed
Unencumbered speed of a tug.

Free-spooling
To pay out scope by releasing the brake and allowing the towing drum to rotate as a result of the drag of the tow, with the tow motor disengaged.

Freshening the nip
Paying out or hauling in the hawser to move the contact point m order to distribute wear on the hawser, stern roller, towing bows, H- bitts, winch drum, etc.

Frictional resistance
The force created by an object as it moves through a fluid such as water or air

Fuse pendant
A pendant of wire rope or chain specifically designed to fail at a known tension May be used to protect the rest of the rigging arrangement. Also called a "weak link."

GM
See "Metacentric height."

Grapnel
A small, 4-armed anchor used mainly to recover objects in the water.

Gun tackle
Tackle using two single-sheave blocks

Gunwale
The upper edge of a boat's side, pronounced "gunnel."

Gypsy head
The horizontal drum of a winch, around which a rope is wound for heaving in

H-bitt
A large structure mounted on the deck or in a bulkhead that is used to lead or stop off a tow hawser A hard point used for towing.

Hawk anchor
See "Anchor hawk'"

Hawsepipe
Heavy castings through which the anchor chain runs from the deck down and forward through the ship's bow plating.

Hawser
A heavy line or wire rope; any line over 5 inches in circumference.

Heave
Vertical displacement of a ship m a seaway, as distinct from pitching, which is essentially a rotation about an athwartships axis. Heave generally refers to an upward movement, bodily, of the entire ship.

Heave around
To haul in

Heave in
To haul in

Heave taut
To haul in until the line has a strain on it.

Heave to
To stop; to bring the ship to a halt, dead in the water

Heeling over
Listing.

Helix
The twist or curvature of the individual strands of a wire rope.

Hockle
Kinking of one or more strands of twisted fiber or wires on a wire rope.

Hog (hogging)
Deviation of the keel from a straight line, in which the keel is concave downward.

Hogging strap
A restraining line exerting force on the hawser to hold it close against the caprail and/or closer to the fantail.

Horsepower, brake
The power delivered at the engine's shaft.

Horsepower, indicated
Power measured in diesel engine cylinders by means of an instrument (the "indicator") which continuously records the steam or gas pressure throughout the length of the piston travel

Horsepower, shaft
Power transmitted through the shaft to the propeller. It is usually measured aboard the ship as close to the propeller as possible by means of a torsionmeter. The power actually delivered to the propeller is somewhat less than that measured by the torsionmeter

Hydrodynamic resistance
The force exerted by the motion of fluids upon a body immersed in the fluid As applied to towing the resis-

tance created by water as a body moves through it.

IMO
International Maritime Organization.

"In irons"
An expression used by shiphandlers to indicate limited control m maneuvering the ship.

"In step"
An expression used to indicate that the towing ship and its tow are riding the crests and troughs of waves simultaneously

IPS wire
Improved Plow Steel wire

IWRC
Independent Wire Rope Core. The internal strand of a multiple-strand wire rope, made up of wire strands twisted together

Keckling
Chafing gear on a cable, consisting of old rope.

Kenter detachable link
A type of connection normally used to join two pieces of stud link or cast chain. See "Detachable link:'

Kjellam grips
A lightweight stopper useful for passing a wire rope where there is only low tension likely to be exerted on the rope.

Kort nozzle
A nozzle used to enclose the propeller of a ship as a means of boosting power.

Lateral control wire
An auxiliary wire used to move the tow hawser athwartships.

Lay
The direction of the twist or strands of a rope.

Lay length
The distance measured parallel to the axis of the rope (or strand) in which a strand (or wire) makes one complete helical convolution about the core (or center).

Layer
A single thickness, coat, fold, wrap, or stratum.

"Lazy Jacks"
Small lines used to tend and recover the towline when rigging a recovery for a Liver- pool bridle

Level wind
A device used to wind the wire of a drum evenly on a towing machine

Lighter
A boat or barge used to service large ships in harbors

Line
A term frequently applied to a fiber or synthetic line, especially if it moves or is used to transmit a force

Liverpool bridle
A method of rigging a tow used to maintain ship control when the yawing of the tow can overcome directional stability of the towing vessel; most commonly used in refloating a stranded ship.

Load cell

An instrument for measuring tension or torque

Locking pin

Keeper or device used to hold or maintain a chain stopper, shackle, or other similar devices in a designated position.

Map

The method of hawser identification for wear, chafing, etc.

Messenger

A light line used for hauling over a heavier rope or hawser.

Metacentric height (GM)

Distance between the metacenter and the center of gravity of a ship, a measure of stability.

Mortise

The opening of a shackle or detachable link. The inside dimension, measured across the opening of a shackle or detachable link.

MPI

Magnetic Particle Inspection A non- destructive test, using a magnetic field and steel filings or particles to locate and define flaws in steel structures.

NAVSEA OOC

Naval Sea Systems Command, Director of Ocean Engineering/Supervisor of Salvage and Diving, Washington, D.C.

Nip

A sharp bend in a line or wire.

Norman pin

A steel rod or post that can be raised or lowered, and which usually is mounted to- ward the stern of a vessel to limit the sweep of a hawser across the rear deck and provide safe areas for the crew.

OCIMF

Oil Companies International Marine Forum

Offset

A term used for the coordinates of a ship's form, deck heights, etc.

Offset shackle

A device used to connect towing components of different sizes.

On the brake

Towing with the tow hawser restrained by the brake system of the towing machine or winch.

"On the dog"

Description of the winch status when a pawl is engaged in the ratchet teeth of the towing machine's drum.

Open socket

A wire rope termination that is shaped similarly to a shackle, mates with a closed socket.

OTSR

Optimum Track Ship Routing

Padeye (horizontal, vertical)

A metal structure with a hole for a shackle or pin to pass a ring. On a vertical padeye, the axis of the hole is parallel to the deck On a horizontal padeye, the axis is perpendicular to the deck

Vertical padeyes are often referred to as "free- standing" padeyes.

Parceling
Wrapping a line or wire with strips of canvas

Pay out
To slack off on a line, or let it run out.

Pear-shaped link
A shackle or detachable link used to connect a small fitting or chain to a larger fitting or chain

Pelican hook
A hook which can be opened while under a strain by knocking away a locking ring which holds it closed; used to provide an instantaneous release

Pendant (pendant rig)
A single wire or chain that leads from the apex of a towing bridle to the towline; a length of wire used as an underrider wire in a "Christmas Tree" rig

Pitch
The vertical motion of a ship's bow or stern in a seaway about the athwartships axis. See also "sway" and "yaw."

Plate shackle
A connecting device made up of two metal plates and bolts, used to connect the towing pendant and the towline, or to serve as a connecting unit in other parts of a towing rig

Port
The left-hand side of a ship when looking forward, the opposite of "starboard."

Poured socket
A wire rope termination installed by pouring molten zinc over splayed wire, often referred to as "spelter socket"

Power block (transport block)
A portable, hydraulic motor-driven line sheave, providing back tension to the traction winch.

Preventer
Any line, wire, or chain whose general purpose is to act as a safeguard in case some- thing else carries away.

Preventer hawser
A hawser secured to the chain as preventer.

Prow
The part of the bow above the waterline.

"Pudding"
Fendering fabricated from fiber ropes

Purchase
A general term for any mechanical arrangement of blocks and tackle for multiplying force.

Quarter rollers
Rollers mounted m the forward and stern waists of a tug for mooring, beach gear, and similar evolutions.

Range up
To reduce the range between tow and tug, accompanied by the tendency for the tow to overtake the tug by sheering out to the side.

Reclaiming device
The mechanism on a towing machine which automatically recovers slack previously paid out.

Reeving
The threading of a line or wire through a block, sheave, or other parts of a wire rope system

Reserve buoyancy
A measure of the capability of a ship to be flooded or ballasted without sinking.

Resistance
A force that retards, hinders, or opposes motion.

Riding chocks
The chocks on deck through which the anchor chain or towing gear passes in-board.

Rockwell C
A measure of hardness on a caprail, Norman pin, etc.

Roll
Side-to-side motion of a ship about its longitudinal axis See also "pitch;' "sway" and "yaw:'

Roller chock
A chock fitted with a roller

Rope
A flexible, heavy cord of twisted hemp or other fiber.

Run out
To send out, as to run out a towing hawser

Safe Working Load
The load for which a rope, fitting or working gear is designed.

Safety factor
A multiple representing extra strength over maximum intended stress

Safety shackle
A connecting device similar to the common shackle except that the mortise is held closed by a nut and bolt.

Sag (sagging)
Deviation of the keel from a straight line when the keel is concave upward. Also, the concave curve of a towline said to have catenary.

"Sally ship"
A term referring to the practice of imparting a rolling motion to a ship by the crew's repeatedly moving from one side of the ship to the other.

Salvage towing
Towing a disabled ship

Scope
The amount of towline streamed

Scow
A large, open, usually flat-bottomed boat for transporting sand, gravel or mud.

Screw-pin shackle
A type of shackle in which the pin passes through one side of the shackle and threads into the other side of it to form a closure.

Screw stopper
A chain stopper fitted with a turnbuckle.

Sea anchor
A device, usually made of wood and/or can- vas, streamed by a vessel or boat in heavy weather in order to hold the bow or stern into the sea.

Seaway
The motion of the sea when clear of shoal water.

Seize
To bind with small stuff, as one rope to another or a rope to a spar.

Serving
To wrap small stuff tightly around a rope that has been previously wormed and parceled.

Shackle (anchor, chain)
U-shaped metal fittings closed at the open end with a pin. Used to connect wire, chain, padeyes, etc. The anchor type has an exaggerated bow, the chain type has parallel sides.

Sheave
A pulley with a rim, used to support or guide a rope in operation.

Sheer
In towing, the tow's meandering from the towing vessel's track. The tow may sheer out to a constant position on one side of the tug's track, or it may swing from one side to the other with a fairly long period of several minutes or more. See also "yaw" TB 55-1900-232-10

Shot
A standard length of chain, 15 fathoms (90 feet)

SHP
Shaft horsepower. See "Horsepower. shaft."

Side-slipping
Moving sideways through the water.

SITREP
Situation Report A special report generally in a prescribed format, required to keep higher authority advised. Required under certain predictable circumstances, but also may be required at any time.

Skegs
A continuation of the keel structure aft under the propeller, for supporting the rudder post

Slip stopper
A chain stopper hooked or shackled to the deck and fitted with a slip-hook for holding the .towline. A strap is passed through the end eye of a working line or wire, one end of which is secured to a pad with the end having a soft eye held by a chain stopper. The slip stopper is released by tripping the chain stopper allowing the soft eye of the strap to render fully through the holding part.

Small stuff
Any small-circumference line used for general purposes.

Smit Towing Bracket
A specially-designed deck-mounted device used to connect a tow pendant quickly to the tow.

Snapback
The sudden recoil occurring when a line parts.

Snatch block
A type of fairlead which can be broken easily to insert a bight of line.

Socket
A wire rope termination attached by zinc or resin. Sockets poured with resin are not approved for towing. See "Poured socket."

Spanish windlass
A device to exert force in bringing together two parts of a rope for any purpose, shortening a pair of parallel lines by twisting them with a lever inserted between them at a right angle to their axis.

Spelter socket
See "Poured socket."

Splay
To unlay and broom the bitter end of a wire rope, usually done preparatory to attaching a socket.

Spliced eye
See "Eye splice."

Spooling
Winding a rope on a reel or drum.

Spring
A mooring or docking line leading ashore from a vessel at an angle of less than 45 degrees to the vessel's fore-and- aft lines. Used to turn a vessel or prevent it from moving ahead or astern.

Spring lay rope
A rope combining fiber and wire.

Spring line
See "Spring."

Spring, stretcher
A pendant or grommet used to dampen towline surges.

Starboard
The right-hand side of a ship when looking forward. Opposite of "port."

Static load
The force applied by deadweight, often referred to as the "average" or "mean" load.

Steady tension
The average or mean tension experienced by the tow hawser, approximated by calm water resistance.

Stem
The forward extremity of a ship's hull.

Stern
The aftermost section of a ship.

Stern line
A mooring line leading from the stern of a vessel.

Stern rollers
The horizontal and vertical rollers at the stern of a tug used to lead, capture and control the tow hawser.

Stopper hitch
Two rolling hitches backed up with half- hitches to secure lines or wire.

Stud-link
A chain link with a bar fitted across the middle to prevent the chain from kinking

Strap
A short working wire with a spliced eye at each end.

Strain
To draw or stretch tight, to injure or weaken by force, pressure, etc., to stretch or force beyond the normal, customary limits; to change the form or size of, by applying external force.

Stream
To extend, or increase, the scope of the tow hawser.

Surge
To hold a line taut on a winch drum without hauling in, to slack off a line or let it slip around a fitting Surging synthetic lines require great care.

Swage
To connect, splice or terminate wire rope by use of steel fittings installed under extremely high pressure

Sway
Motion of a ship in which it is displaced laterally, as distinct from rolling See also "pitch;' "roll" and "yaw."

Swivel
A removable anchor chain link fitted to revolve freely and thus keep turns out of a chain.

SWL (Safe Working Load)
The load for which a rope, fitting or working gear is designed

Synthetic towline
A line or pendant used for towing, made from any of a group of continuous or synthetic fibers.

Tackle
An arrangement of ropes and blocks to give a mechanical advantage, a purchase.

Thimble
A grooved metal buffer fitted snugly into an eye splice

Tiller (tiller arm)
Casting or forging attached to the rudder stock.

Tow pad
A padeye designated or dedicated as the connection to the tow hawser or bridle. See "Padeye"

Tow resistance
The total force resisting the movement of the tow

Towing bracket
See "Smit Towing Bracket" or "Tow pad."

Towing chock
Chock designed or dedicated to use during a towing operation.

Towing hawser
The towing member which connects the tug with the tow

Towing Machine
A towing winch with automatic features.

Towing pad
Large padeye to which a towline may be attached.

Towing point
A device for attaching a towline to a ship.

Towing winch
A basic winch used in towing which stores, pays out and heaves m the towing hawser to compensate for variations in towline tension.

Towline pull
See '"Towline tension."

Towline strength
The nominal breaking strength of the tow hawser.

Towline tension
The stress imparted to a towline during a towing operation

Traction winch
A multi-sheaved device that generates line tension. Tension is generated by friction between the line and traction heads.

Tripping lines
A line used for capsizing and hauling in a sea anchor

Turnbuckle
A metal appliance consisting of a threaded link bolt and a pair of opposite-threaded screws, capable of being set up or slacked off and used for setting up standing rigging or stoppers.

Two-blocked
Term describing when the two blocks of a block-and-tackle have been drawn together or tightened so that they touch.

Underrider
The wire rope, chain or combination used as a pendant heavy enough to pass under a leading tow to a trailing tow, at a sufficient depth not to foul on the leading tow.

Veer
To pay out chain.

Wallis brake
A wire brake used for keeping a steady load on a wire rope as it is installed on a drum

Winch
An electric, hydraulic or steam machine aboard ship used for hauling in lines, wire or chain.

Wire rope
Rope constructed of wire strands twisted together, as distinct from the more common, and weaker, fiber rope.

Wire rope pendant
A length of wire with a termination fitting at each end.

Worming
Filling the lays of line or wire before parceling.

XIPS wire
Extra Improved Plow Steel wire.

Yard tug
A term used to describe harbor tugs or tugs used in berthing operations-e-g., YTL, YTM and YTB Classes of tugs.

Yaw

Failure of a vessel to hold a steady course because of forces of wind, sea, damage to vessel, etc. In towing, yaw angle is the difference between the tow's heading and the tug's heading Yawing can be manifested by an oscillation of the tow's heading by a small angle to either side of the base course, with the tow remaining on the same track as the tug. See also "sheer;' "sway," "pitch" and "roll"

APPENDIX O
ALPHABETICAL INDEX OF CONTENTS

By Order of the Secretary of the Army:

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General, United States Army
Chief of Staff

Official:

PATRICIA P. HICKERSON
Brigadier General, United States Army
The Adjutant General

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The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 decagram = 10 grams = .35 ounce
1 hectogram = 10 decagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters =10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	***To***	***Multiply by***	***To change***	***To***	***Multiply by***
inches	centimeters	2.540	ounce-inches	Newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	Newton-meters	1.356	metric tons	short tons	1.102
pound-inches	Newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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