U.S. Department of Homeland Security
United States Coast Guard

Auxiliary Specialty Course
SEARCH AND RESCUE
(AUXSAR)

STUDENT STUDY GUIDE

PUBLISHED FOR EDUCATIONAL PURPOSES ONLY

COMDTPUB P16794.35B

U.S. Department
of Transportation

**United States
Coast Guard**

Commandant
United States Coast Guard

2100 Second St. S.W.
Washington, DC 20593-0001
Staff Symbol: G-OCX-1
Phone: 202-267-1001

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Subj: AUXILIARY SPECIALTY COURSE (AUXSAR) STUDENT STUDY GUIDE

1. <u>PURPOSE</u>. This publication is intended for use as the student study guide for the Auxiliary Specialty Course Search and Rescue (AUXSAR). It is published for instructional purposes only and is not policy material.

2. <u>ACTION</u>. Area and district commanders, commanders of maintenance and logistics commands, commanding officers of Headquarters units, Commandant (G-A, G-H, G-L, G-M, G-O, G-S, and G-W) and special staff offices at Headquarters shall ensure compliance with the provisions of this directive.

3. <u>PUBLICATION AFFECTED</u>. The Auxiliary Specialty Course Search and Rescue (AUXSAR), Student Text, Commandant Publication P16794.35A is cancelled.

4. <u>DISCUSSION</u>. The Auxiliary Specialty Course (AUXSAR) student study guide is a substantial revision of earlier text materials. This revision is designed to accomplish three things: include tow-planning worksheets for 20 and 25 foot Auxiliary Facilities, rewrite Chapter 3 to make it easier for home-study students to follow, and lastly to make the text compatible with the most recent revision to the Coast Guard Addendum to the National SAR Manual.

T.L. TERRIBERRY
Chief, Operations
Capability Directorate

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PREFACE

This issue of the AUXSAR Specialty Course Text and Student Study Guide, COMDTPUB P16794.B, is a substantial revision of the A issue, COMDTPUB P16794.35A, although much of the material is similar. This "B" Revision is designed to accomplish three things: include tow-planning Worksheets for 20 and 25ft Auxiliary Facilities, rewrite Chapter 3 to make it easier for home-study students to follow, and make the text compatible with the most recent revision to the Coast Guard Addendum to the National SAR Manual. Minor changes have been made in the Review Questions to make them compatible with the revisions in the Text. The Instructor Guide has been updated to COMPUB P16794.36B; the Examination Packet for this revision is 497-9-51.

The AUXSAR Specialty Course is designed to present the student with a thorough understanding of the policy, organization, and procedures involved in the search and rescue process as generally practiced by the U.S. Coast Guard. We expect that students completing this course will gain a broad understanding of the subject matter beyond the skills and limited operational procedures learned in training for qualification in Boat Crew training. Neither Boat Crew training or AUXSAR are prerequisites one for the other, but AUXSAR takes the student to a higher level of knowledge of the search and rescue process. Attaining this higher level of understanding will enable better understanding of why and how tasks and skills taught in Boat Crew training activity are required and employed to accomplish search and rescue functions. Further, the student will better understand and appreciate the roles of other organizations and units involved in search and rescue beyond the 'horizon' of his or her facility and the controlling Coast Guard group or station. AUXSAR may be completed prior to Boat Crew training thus providing the student with a "leg up" on the subject or after Boat Crew training to expand the student's knowledge in this important field.

The course will be of most interest to members of the Auxiliary whose operational activity is off-shore, either Ocean or the Great Lakes. Relatively little of the Text is devoted to the operational activity that takes place on navigable river waters, and none is devoted to Auxiliary activity on inland lakes, other than the Great Lakes.

SUGGESTIONS TO THE STUDENT

This AUXSAR course is designed to be taught by a qualified Instructor in a classroom atmosphere in six two-hour sessions. The AUXSAR Instructor Guide includes instruction aids–which can be made into overhead transparencies–that illustrate the text material. Although the course may be self-taught most students benefit from interacting with other students and with the instructor.

The material in Chapter 1 is entirely descriptive, and can be taught in the first session even if the student's copies of the Text are handed out at that session. After that, however, the student should read the assigned homework chapter and answer as many as possible of the REVIEW QUESTIONS at the end of the assigned chapter. It is unreasonable to expect the instructor to "teach" a student who has not read the material; the role of the instructor is to "explain", especially the parts the students have difficulty with. Remember the scientist's mantra: Chance favors the prepared mind.

In studying the text there are places where several pages of explanation refer to a single Figure, and the Figure cannot be put on a facing page. The text is designed to be inserted into a loose-leaf notebook. If it is, remove the referenced Figure and lay it where it can be referred to as the explanation is studied. (Don't forget to replace the Figure page!)

There are places in the REVIEW QUESTIONS where a Form is needed. Appendix A contains photo-reproducible copies of every Form required, and it is a good idea to make a few copies of each Form and file them in the back of the book. Copies of the Forms are **required** for the Examination, and are **not** included in the Examination Packet; they are the responsibility of the Student.

Appendix A has Tow Planning Worksheets that can be specialized for a particular Facility. If the Student has an Auxiliary Vessel Facility, select the appropriate Worksheet and make a master Tow Planning Worksheet. It represents a little work but is well worthwhile and makes an excellent Saturday project for several students to get together and each create a unique Tow Planning Worksheet specialized for the facility usually used in operations. These same comments apply to the Leeway Correction Table in Chapter 4.

Appendix A also has a Practical Demonstration Worklist. This Worklist must be completed satisfactorily before the Student is allowed to take the Final Examination. There is no National requirement that the completed Worklist be submitted to the DIRAUX office, but some Districts may require it, so the Worklist is set up to record the Instructor's Signature.

FINALLY, use a highlighter as you study; pencil in the answers to the REVIEW QUESTIONS on the blank lines; and when you check the answers note the page number where you found the answer. Highlighting reinforces learning-by-reading, and when you check your answers in class (the Instructor Guide has the answers) you can see where you went off–if you did.

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Abbreviations and Acronyms

ACTSUS	Active Search Suspended Pending Further Developments
AOR	Area of Responsibility
ASW	Average Surface Wind
B/P	Blood Pressure
C	Coverage Factor
C	Course (True)
C	Creeping Line Pattern
CAMSLANT	Communications Area Master Station, Atlantic
CAMSPAC	Communications Area Master Station, Pacific
CASP	Computer Assisted Search Planning
C/C	Cabin Cruiser
CGADDNSM	Coast Guard Addendum to National SAR Manual
CGAS	Coast Guard Air Station
CGAUX	Coast Guard Auxiliary
COG	Course Over the Ground
COMMCEN	Communications Center
CSP	Commence Search Point
CUR	Current
DMB	Data Marker Buoy
DOC	Department of Commerce
DOD	Department of Defense
DOT	Department of Transportation
DR	Deduced Reckoning
DTG	Date\Time\Group
ELT	Emergency Locator Transmitter
EPIRB	Emergency Position Indicator Radio Beacon
EXCOM	Extended Communication Search
FCC	Federal Communication Commission
F/V	Fishing Vessel
GDOC	Geographic Display Operations Computer
GPS	Global Positioning System
HF	High Frequency
ICAO	International Civil Aviation Organization
ICSAR	Interagency Committee on Search and Rescue
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite/Satellite Telephone
KT	Knot, (Nautical Mile per Hour)
LE	Law Enforcement
LKP	Last Known Position
LORAN	Long Range Aid to Navigation
LPOC	Last Port of Call
LUT	(SARSAT) Local Users Terminal
LW	Leeway
MARB	Marine Assistance Request Broadcast
MCC	(SARSAT) Master Control Center
MEP	Marine Environmental Protection
M\V	Merchant Vessel
MLB	Motor Life Boat
NASA	National Aeronautic and Space Administration
NM	Nautical Mile

NOAA	National Oceanic and Atmospheric Administration
NPOC	Next Port of Call
NSM	National Search and Rescue Manual
OPCEN	Operations Center
OPCON	Operational Control
OSC	On Scene Commander
P\C	Pleasure Craft
PIW	Person In the Water
PLB	(SARSAT) Personal Locator Beacon
POA	Probable Search Area
POD	Probability of Detection
POS	Probability of Success
PRECOM	Preliminary Communication Search
RADAR	Radio Direction and Ranging
RCC	Rescue Coordination Center
RSC	Rescue Coordination Sub Center
RU	Rescue Unit
S	Track Spacing
S	Square Pattern
SAR	Search and Rescue
SARSAT	Search and Rescue Satellite System
SC	Search and Rescue Coordinator
SC	Sea Current
SITREP	Situation Report
SMC	Search and Rescue Mission Coordinator
SOA	Speed of Advance
SOG	Speed Over the Ground
SOP	Standing Operating Procedure
SP	Surface Position
SRB	Surf Rescue Boat
SRR	Search and Rescue Region
SRU	Search/Rescue Unit
S/V	Sail Vessel
TC	Tidal Current
TD	Loran Time Delay
TWC	Total Water Current
U	Wind Speed
UMIB	Urgent Marine Information Broadcast
UTB	Utility Boat
VDSD	Visual Distress Signaling Device
VHF	Very High Frequency
W	Sweep Width
WC	Wind Driven Current
WHEC	High Endurance Cutter
WMEC	Medium Endurance Cutter

Note: The terms Operations Center, Command Center and Rescue Coordination Center are synonymous. In the International SAR Community the Command Center is addressed as "RCC (Dist Hdqrs)", eg, "RCC Long Beach".

CHAPTER 1. SAR SYSTEM, ORGANIZATION, & RESOURCES.

A. Introduction.

1. Definition. Search and Rescue (SAR) is the use of available resources to help persons and property in potential or actual distress. It is the explicit policy of the United States, as expressed in Federal Statutes, to provide assistance to persons and property in distress.

2. National Policy.

a. The National Search and Rescue **Plan** formalizes the policy of the United States Government SAR activities; it states the responsibilities of participating agencies as defined by statutes, executive orders and international agreements. The National Search and Rescue **Plan** is a four-page document signed by heads of the Departments of Transportation, Defense, Commerce, Interior, Federal Communications Commission, National Aeronautics and Space Administration, and Federal Emergency Management Agency. The Interagency Committee on Search and Rescue (ICSAR), is responsible for coordinating the activities specified in the Plan.

b. The National Search and Rescue **Plan** identifies the departmental responsibilities for domestic SAR. It interprets the provisions of several conventions of the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). These conventions require establishment of a national civil system with internationally recognized aeronautical and marine SAR coordination responsibilities. No single U.S. organization has sufficient SAR resources to provide complete SAR services. Therefore the National Search and Rescue **Plan** specifies that Rescue Coordination Centers (RCCs) may use "all available" resources to respond to cases.

3. SAR Manual. ICSAR publishes the National Search and Rescue **Manual** (NSM) in two volumes: VOLUME I-NATIONAL SEARCH AND RESCUE SYSTEM, and VOLUME II-PLANNING HANDBOOK. The **Manual** incorporates the results of accumulated experience, research and development, and advances in search theory. The two volumes serve both as a training and operational tool for civil SAR operations, and as a reference library of technical data related to planning search operations.

4. Coast Guard Addendum.

a. The National Search and Rescue **Manual** covers the complete spectrum of potential SAR activities, yet does not cover the detailed structure of SAR activity for each responsible agency. Each Agency prepares its own **Addendum** to the National Search and Rescue **Manual**. The Coast Guard **Addendum**, COMDTINST M16130.2B, (also called by the acronym CGADDNSM) establishes policy, guidelines and general information for Coast Guard use in search and rescue operations. The Coast Guard uses the **Manual** with the **Addendum** to organize, plan and execute SAR operations.

b. The Coast Guard **Addendum** has seven Chapters:

Chapter 1 - SAR Coordination and Case Documentation
Chapter 2 - Search Planning
Chapter 3 - Maritime Assistance Policy, General Salvage Policy, and Firefighting activities Policy
Chapter 4 - Descriptions and Operating Guidelines of Coast Guard Search Rescue Units (SRUs)
Chapter 5 - Coast Guard SRU Operations
Chapter 6 - Procedures for Underwater Incidents
Chapter 7 - Emergency Medical Service

There are 14 Appendices that cover selected subjects in detail. Among them are "SAR Checksheets (proposed)" that are comparable to the "Worksheets" contained in this text. The Worksheets are copies of SAR School forms; although they differ in layout, the information content is the same as the proposed Checksheets in Appendix G of the CGADDNSM.

5. District SAR **Plan**. Each District Commander issues a **District** SAR **Plan** that interprets the National **Manual** and the Coast Guard **Addendum** as they apply in the District. The District SAR **Plan** serves as the basis for the way the Auxiliary works with the Coast Guard in SAR activities.

6. Purpose. What is the purpose of the hierarchy of documents described above? It is National Policy to help persons and property in potential or actual distress; each agency **Addendum** specifies the resources that the agency can use. The documents also standardize SAR organization and terminology so that different agencies speak the same language. Voluntary agencies–such as state and county agencies–then understand how they may fit into the big

picture. Although all of the documents are required reference material, it is the Coast Guard Addendum that establishes the one Coast Guard policy.

B. SAR Stages. SAR activity divides into five stages. It is well for the student to keep these five **stages** in mind while studying the rest of this text. Everything in the text relates to one or more of these **stages**.

1. AWARENESS: the knowledge by any person or agency that an emergency may exist.

2. INITIAL ACTION: the preliminary action taken to gather amplifying information. This stage may include evaluation and classification of the information, alerting of SAR facilities, Preliminary Communication checks (PRECOM), and Extended Communication checks (EXCOM). In urgent cases, the system skips this stage and takes immediate action.

3. PLANNING: the development of operational plans, ie, plans for search, rescue, and final delivery.

4. OPERATIONS: (a) the dispatch of Search/Rescue Units (SRUs), (b) conducting searches, (c) rescuing survivors, (d) assisting distressed craft, (e) providing emergency care for survivors, and (f) delivering casualties to medical facilities.

5. MISSION CONCLUSION: the return of SRUs to a location where they are finally debriefed, refueled, replenished, remanned, and prepared for other missions; and the completion of documentation of the SAR mission by all SAR facilities.

C. Coast Guard SAR Organization.

1. National Organization. The National **Plan** assigns responsibility for the Maritime Area to the Coast Guard which divides the Maritime area into two sub-areas viz., Atlantic and Pacific. The Commander of each Area is the SAR Coordinator (SC) for that Area. Using the Area Command Center (CC), the Area Commander functions as SC for SAR cases within the U.S. maritime area for cases that go over two or more District boundaries, or where the nature of the incident or resources require the Area to be SMC. Also, the Area Commander can "take it" as a senior command prerogative.

2. Area Organization. The Area Commands in turn, designate each District Commander as SAR Coordinator for the region defined by the District land boundaries and the

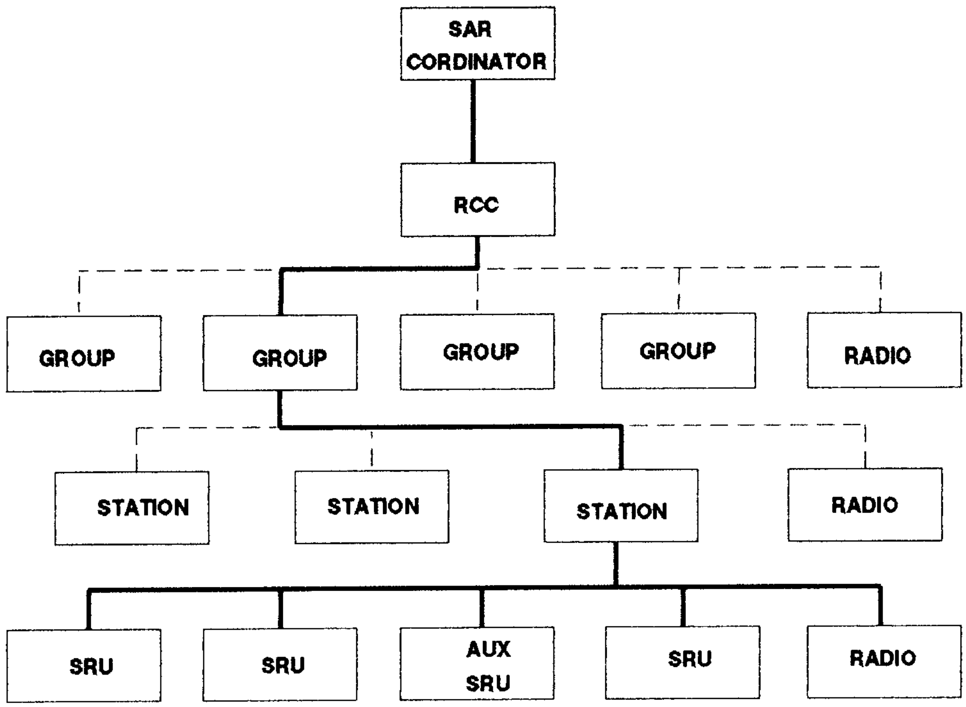

Figure 1-1 Typical District Organization

adjacent maritime areas. The Region SC–the District Commander–prepares a SAR **Plan** as part of the Standing Operating Procedure (SOP) for the District. The term "SAR Coordinator" describes the duties of the Commander, District xxxx, U.S. Coast Guard.

Throughout the rest of this Text the term "SC" means only the Commander, District xxxx, who is the Region SC.

3. SAR Coordinator Responsibility:

a. Identify all Search/Rescue Units (SRU) and other SAR resources within the region; establish close liaison and agreements with other Services, agencies, and organizations having SAR potential; cooperate and coordinate with SAR authorities of other nations.

b. Prepare and distribute a current comprehensive District SAR **Plan**.

c. Establish a Rescue Coordination Center (RCC) to coordinate SAR resources within the area-of-responsibility (AOR) and ensure that operations conform with the National SAR **Manual**, Coast Guard **Addendum**, and the District SAR **Plan**.

d. Conduct SAR, designate the SAR Mission Coordinator (SMC) and dispatch SRUs until assistance is no longer necessary, or rescue has been completed. Report results to the Coast Guard as specified in the Coast Guard **Addendum** to the NSM.

e. Suspend SAR cases when there is no longer a reasonable chance of success.

f. Train and indoctrinate RCC personnel in correct and current SAR procedures and techniques.

D. District SAR Resources and Facilities.

1. Resources available for SAR response include all resources that are permanently part of the Coast Guard, and resources from other Agencies that may be useful during a SAR mission. SAR Coordinators organize the resources to provide the most effective response. SMCs normally select resources from those listed in the District SAR plan, but may request other resources during a SAR mission. A SRU is any craft, vehicle, or team that can operate independently. The use of any SRU depends on SMC judgment. Is the unit able to reach the distress scene? Does it have the necessary SAR capabilities, eg, endurance, training, and experience?

2. Aircraft. Aircraft SRUs can search large areas, and are very effective in locating distressed vessels. The pilot of the SRU is the final judge of SRU capability during a mission.

a. Helicopters, because of their slow speed and hovering ability, are effective aircraft SRUs. SAR helicopters have a hoisting device for rescue and delivery operations. The helicopters presently used by the Coast Guard include the HH-60 and the HH-65.

b. Land-based fixed-wing aircraft are excellent search platforms, and can direct surface craft to the scene once the target is found. Coast Guard fixed-wing aircraft include the HC-130 and the HU-25. The HC-130 is a four-engine turboprop long-range plane with space and facilities for performing as On Scene Commander (OSC); the HU-25 is a twin-engine executive-size jet. Both aircraft can drop rescue equipment and supplies to targets.

c. Most aircraft SRUs are prohibited from flying in thunderstorms, severe turbulence, and severe icing.

3. Vessels. Coast Guard vessels are "boats" when they are less than 65′ in length. Boats are usually most effective when combined with aircraft SRUs for coordinated air/surface search. The long endurance of vessels allows assignment when responding to nearby incidents where search is not a major factor. Marine SRUs are also used to escort or tow disabled surface craft, and to deliver supplies, equipment, and personnel to the distress scene. The SRU commander is the final judge of SRU capability, and has the final authority to accept or reject instructions from the SMC.

a. The 30-ft Surf Rescue Boats (SRB), the 41-ft Utility Boats (UTB) and the 44- and 52-ft motor lifeboats (MLB) are designed for short-range SAR operations. SAR boats 30 to 65 feet in length operate in sheltered waters, or for a limited distance offshore in moderate sea and weather conditions.

b. Prototypes of the new 47-ft MLB are now in the field. This boat is fast and very seaworthy in heavy seas.

c. Multi-mission Patrol boats (WPB), 82 to 110 feet in length operate offshore, conduct visual and electronic searches, and have an endurance of up to 10 days.

d. Medium-endurance cutters (WMEC) have helicopter flight decks and support facilities; their sustained operational capability, especially when paired with a helicopter, makes these cutters ideal SRUs.

e. High-endurance cutters (WHEC) are 378 feet long and can sustain search operations at sea for up to 30 days. All have flight facilities to support helicopters at sea.

f. The Coast Guard Auxiliary—according to the National SAR **Manual**—is "a volunteer civilian organization formed to assist the Coast Guard in preventive and direct SAR activities. Its members are small-boat, yacht, aircraft, or amateur radio station owners, or persons with special qualifications in the field of boating safety or SAR". The Auxiliary provides several thousand privately-owned SRUs throughout the country. In some locations Auxiliary Boats are the only SAR facilities available. CGAUX personnel also supplement Coast Guard Group Offices and Air Stations during heavy SAR operations. The Auxiliary Communications Net supplements the established coastal radio net.

g. Marine craft are usually reliable platforms for towing or delivering resources such as dewatering pumps, fire-fighting equipment, damage control supplies and medical personnel. SAR Boats are ideal for recovery of persons in sheltered and semi-sheltered waters. 41-ft boats can operate up to 30 miles offshore; 44- and 47-ft boats can operate up to 50 miles offshore. Boat rescue equipment is usually limited to heaving lines, life rings, life jackets, litters, boat hooks, boarding ladders, dewatering pumps, and fire-fighting apparatus.

4. Surface Facilities. The Coast Guard maintains a wide variety of SAR resources throughout the United States and its territories. Coast Guard facilities include an extensive communications network of coastal radio stations, specialized land-line circuits, and communications centers, all guided by RCCs.

a. Stations are along the coastlines of the United States, on the shores of the Great Lakes, and on some major river systems. Usually they have boats, a radio, four-wheel-drive vehicles, land line communications with the operational commander, ie. the Group Office, and when appropriate, amphibious vehicles. When stations obtain early information of life and property in danger they take immediate action. The District SAR Plan is quite specific about the conditions that must exist for a Station to assume the role of SMC. The object of the rules is to have each incident handled at the lowest command level that can prosecute the case successfully.

b. Group commands are an operational level, designed to coordinate between the District Rescue Coordination Center (RCC) and Stations. They have Stations and Patrol Boats (WPBs) under their command.

c. Rescue Coordination Center. The RCC Reports directly to the senior Staff Officer in charge of SAR, the Chief of Search and Rescue (osr). The Coast Guard District or Area office is the physical location of the SAR Coordinator for that location. RCC usually handles SAR cases that involve several Groups or cases that require resources from outside the District or borrowed from non-CG agencies. The RCC assumes SMC for these cases and normally retains SMC until the case is suspended or closed. The RCC may act as SMC for several SAR missions simultaneously. In addition, RCC oversees other ongoing cases throughout their AOR even when they are not SMC. Supplemental RCC personnel provide a continuous live watch, and relieve the SMC(s) of time-consuming tasks. (See § F this Chapter for detailed information on the RCC.)

d. The Coast Guard employs Computer-Aided Search Planning (CASP) at District RCCs. CASP is a computer program used by search planners to identify probable search areas and plan resource allocation. Currently (1994), CASP is available only at the District level; in the future it will be available to Groups and Stations.

E. District SAR Plan.

1. Contents. The District SAR **Plan** is the primary document that SAR personnel use for training and operations. It identifies the specific parts of the National Search and Rescue **Manual** and Coast Guard **Addendum** required in District SAR operations. The **Plan** identifies the command authority, specifies the district's Area of Responsibility (AOR), authorizes the RCC to "function for the Commander," specifies the duties of the SAR units, specifies how requests for SAR units not under the SMC's Operational Command (OPCON) are handled, specifies SAR units eligible to be OSC, and specifies the authorization procedure for dispatching units from cooperating agencies. This list is not complete but is adequate to illustrate the detail embodied in the **Plan**.

2. Resource Status sections of the Plan define Alfa, Bravo and Charlie status, specify resource status requirements at Stations and Groups, and specify reporting requirements.

3. Fatigue is a critical factor in executing SAR operations safely. The **Plan** includes Operating Standards for all types of SRUs and identifies the normal fatigue limits for different sea conditions. This makes the SMC responsible for following these standards and not allowing an aggressive skipper jeopardize the vessel or crew.

4. Heavy Weather is defined; in District 11 it is any condition when the numerical sum of the Wind Speed + Wave Height exceeds the number 30. Boats—except specific self-bailing and self-righting surf boats—are ***not used*** under these conditions. (Note that in Chapter 5 the top wind speed in the towing tables is 25kts. At

this wind speed the wave height is over 5ft, so this is a reasonable upper limit for conditions under which an Auxiliary vessel should operate).

F. Rescue Coordination Center.

1. Organization. RCCs-there are 14[†] Coast Guard RCCs-are at the Command Center of the District or Area Offices, and the Duty Officer on watch acts for the District/Area Commander. When the SMC is at Station or Group level, RCC monitors the incident and receives routine Situation Reports (SITREPs). The Command Center Duty Officer has the responsibility of prioritising use of resources between conflicting requirements, eg, Law Enforcement (LE), SAR, and Marine Environmental Protection (MEP).

2. Operations Center (OPCEN) at the Group level is an internal Coast Guard designation. Group OPCENs-there are 44 of them-perform many of the SAR duties, but are not designated as RCCs. The OPCEN is responsible for its AOR which is within the search and rescue region (SRR) of the RCC. The OPCEN has primary search planning and coordination responsibilities for the search and rescue units (SRUs) located within the Group.

3. Communication capability is a prime requirement for effective SAR. The primary comms of the RCC are via phone (including INMARSAT) or hard copy message. RCC does not have the capability of talking on the radio to SAR units, but can use a phone patch through the Group radio if direct comms are needed. RCC can control\assume SMC of a SAR case at any time, but that doesn't mean RCC would usually be in direct comms with anyone. Communications are normally handled at the Group level via one of the Communications Area Master Stations, or via telex/INMARSAT with the distressed vessel. Communication facilities also include telephone lines (emergency numbers listed in the front of telephone books go directly to the RCC or the local SAR Station) and multichannel recorders with timing channels. Each District has its own High Frequency (HF) channels for Command and Control. All Districts use the public distress and Coast Guard VHF-FM Channels to receive calls and to control operations.

[†]Coast Guard RCCs are at the following commands: LANTAREA, CCGD1, CCGD2, CCGD5, CCGD7, CCGD8, CCGD9, CCGD11, CCGD13, and CCGD17. PACAREA has no assigned SRR and therefore no RCC.

4. Plotting Equipment is extensive and is designed to use overlays on back-illuminated tables so that a complete record of a SAR operation can be maintained. RCCs are now equipped with GDOC (Geographic Display Operations Computer) which can display computer-generated charts overlaid with search patterns. This reduces the work of planning extensive searches, and the computer "logs" all of the planning steps.

5. Files and Records are an important part of a RCC. The SMC has access to historical files on current patterns, wrecks, stolen craft, etc.

6. SARSAT.

   a. Search And Rescue Satellite-Aided Tracking is an international system for alerting the SAR System of a Distress. The devices on vessels (or aircraft) are Emergency Locating Transmitters (ELT) or Emergency Position Indicating Radio Beacons (EPIRB). The most modern version of EPIRB is one that operates on 406MHz and in a way that almost eliminates useless searches. The National Oceanographic and Atmospheric Administration (NOAA) operates the ground stations of SARSAT and maintains files of make, model, serial number, and owner's name and address. The RCC can usually correct for an accidental triggering by a telephone call. (See Appendix B for a complete description of the 406 MHz system).

7. Suspend Search, or ACTUS, authority is not delegated to the RCC duty officer but must be authorized by the SAR Coordinator or the District Branch Chief of Search and Rescue(osr).

G. Documentation.

1. Case Record. Each incident is documented for subsequent review and evaluation. The Record contains copies of all of the communication exchanges, action taken, SITREPS, briefings, contacts with family of persons involved, etc.

2. Minor SAR. The Case Record is simplified for cases that qualify as Minor SAR. In some Districts the Minor SAR cases are summarized in one paragraph in a daily Group message report. To qualify as Minor SAR (after the fact) the case must meet all of the following requirements:

a. Actual Severity evaluated as 0 or 1. Actual Severity is an on-scene evaluation of the degree of danger that existed. The degrees of severity are:

0 - **None**: no foreseeable threat to life and/or property.

1 - **Slight**: no threat to life and/or property upon arrival on scene. However, without action the situation may have resulted in a threat to life or property.

2 - **Moderate**: a threat to life and/or property existed. It is reasonable to assume that personnel and/or property will be seriously injured, damaged, or lost if action is not taken.

3 - **Severe**: personnel and/or property was physically rescued/recovered from imminent danger, or was lost.

b. Time on case less than 4 hours.

c. Case involved only 1 resource.

d. Case involved unit smaller than 82′ WPB.

REVIEW QUESTIONS

1. Define SAR.

2. What is the policy of the United States with regard to SAR?

3. In what document is the national policy on SAR expressed?

4. Name some of the Agencies involved in SAR.

5. What is the lead agency for the National Search and Rescue Manual?

6. What are the purposes of the Coast Guard Addendum to the National SAR Manual?

7. If the Coast Guard 2is the lead agency for the publication of the National SAR Manual why does there have to be a Coast Guard Addendum?

8. What does a District SAR Plan accomplish?

9. Name the SAR stages.

10. What is the lowest level in the Coast Guard that prepares a SAR Plan?

11. What office holds the title "SAR Coordinator" as used in the text?

12. What are the principal responsibilities of the SC?

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13. What Resources other than Coast Guard resources are available to the SC?

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14. What document defines the conditions that must exist for a Coast Guard Station to assume the role of SMC?

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15. Name some of the things in the District SAR Plan that are not in the National SAR Manual or Coast Guard Addendum.

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16. How does the District SAR Plan address crew fatigue?

____

17. Define Heavy Weather.

____

18. What boats are restricted when Heavy Weather exists?

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19. Where is the Rescue Coordination Center located?

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20. Who is in charge of the RCC?

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21. Describe the principal facilities at the RCC.

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22. What type of SAR incident does <u>not</u> require a separate Case Record?

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23. How does a SAR incident qualify as Minor SAR?

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24. Describe the four degrees of severity of a case.

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25. Describe the SARSAT system.

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26. Who has the authority to suspend a search?

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CHAPTER 2. AWARENESS AND INITIAL ACTION

A. Awareness Stage. The first receipt of information by the SAR system of an actual or potential SAR incident initiates the Awareness Stage. Persons or craft in distress may report a problem, nearby persons may observe an incident, or an uncertainty may exist due to failure to communicate or to arrive at a destination. The receiving and recording of information do not delay other SAR response. The SAR System maintains communication with the person or craft reporting an emergency, and they are kept advised of action being taken.

1. Type of Incident. When the Coast Guard is first made aware of an incident it immediately collects all crucial information about the incident. All levels of the Coast Guard use an Incident Sheet as a check list of required data. There is an Incident Sheet for each possible type of incident; so the first step is to determine what type of incident has occurred. The Incident Sheets, which are district specific, are color coded for ease in identifying the nature of the distress.

   a. Surface Vessel

   b. Aircraft

   c. Overdue Vessel

   d. Medico/Medevac

   e. Miscellaneous

   f. Dive Accident

   g. EPIRB/ELT

   h. Earthquake/Natural Disaster

   i. Inland Medevac

   The Type of incident when the Auxiliary is possibly the first contact with the distressed vessel is Surface Vessel. Although the Auxiliary prosecutes other types of incidents, it is very unlikely to be the first Coast Guard resource to be notified.

2. Surface Vessel Incident Sheet. Figure 2-1 is an Incident Sheet used in the 11th District; similar forms are used in other Districts. Each Auxiliary unit should be aware of the information detail that the Coast Guard expects in incident data. Most of the abbreviations on the Surface

Vessel Incident Sheet are self explanatory, but some need special mention as they differ from older forms. The first line records the Informant's telephone number (or radio channel) if the Informant is other than the person in distress. Line 5 records the location and type of the cabin to help a search unit recognize the target. The form is also a convenient place to record the results of an Urgent Marine Information Broadcast (UMIB), or a Marine Assistance Radio Broadcast (MARB) if either is issued.

B. SAR Mission Coordinator (SMC) assignment is, initially, automatic in the Coast Guard. The Coast Guard element receiving information that there may be a distress becomes (effectively) the SMC, but the assignment may change quickly depending on the type and location of the incident.

1. The <u>RCC</u> can assume the SMC role at any time, but the SMC is usually at Group level and operates out of the Group OPCEN. SMC is at Group or higher whenever formal Planning is required. Groups routinely are SMC when local, state and other federal agencies supply resources; usually there are agreements in place for resource supply.

2. The SMC must be at a <u>Shore-based Facility</u>. Normally cutters act as OSC, but the SC <u>could</u> designate a cutter SMC of a case. Usually the SMC is at the Group level.

3. In many areas of the country, particularly inland, where the only Coast Guard presence is the <u>Auxiliary</u>, the SMC is at Group and command/control is district specific. In these cases, especially non-emergency assists, the Auxiliary SRU is pretty much on its own and receives little direction from the SMC. A shore-based Auxiliary Radio may act as a relay to the SMC, or contact may be by cellular telephone.

C. Initial Action Stage is the period in which the SAR system begins response, and follows immediately after an element of the system is made aware of the emergency. Unless the incident is clearly a hoax or false alarm, or occurs outside its jurisdiction, the very first step is to determine the degree of severity of the incident, and classify it's *phase* as Uncertainty, Alert, or Distress.

1. <u>Non-Distress</u>, also called Non-Emergency, cases are ones in which the craft or person is experiencing some difficulty but is not in imminent danger or in need of immediate response. Non-Distress is not, strictly speaking, a phase. However, it is substantially like a phase in that it is handled in a unique way. The principle concern is

SURFACE VESSEL INCIDENT SHEET

DATE TIME NOTIFIED | INFORMANT | PHONE NUMBER/FREQ

REPORTED POSITION

NATURE OF DISTRESS | IMMEDIATE DANGER YES NO

NAME OF DISTRESSED VESSEL | REG/DOC NUMBER | CALL SIGN/FREQ AVAIL

LENGTH | TYPE | S/S-CABIN (CIRCLE ONE) FWD MID AFT | COLOR HULL/TRIM | TOTAL PCS

HOME PORT | FLAG

MISC INFO

ON SCENE WEATHER

POB NAME AGE ADDRESS AND PHONE NUMBER

OWNER: ____________________ ON BD? YES NO

OP: ____________________

UMIB NUMBER ________ DATE ISSUED: ____________ DATE CANCELED ________

POSITION LOCATED ____________ BOARDED YES NO N/A

VIOLATIONS ________ VALUE: $________ NATURE OF DISTRESS ____________

SAR UNITS ____________ DATE CLOSED ____________

DISTRICT FILE NUMBER ____________

RCC UNIT CASE NR ____________

DISTRICT MUCNR ____________

PACAREA MUCNR ____________

Figure 2-1 Surface Vessel Incident Sheet

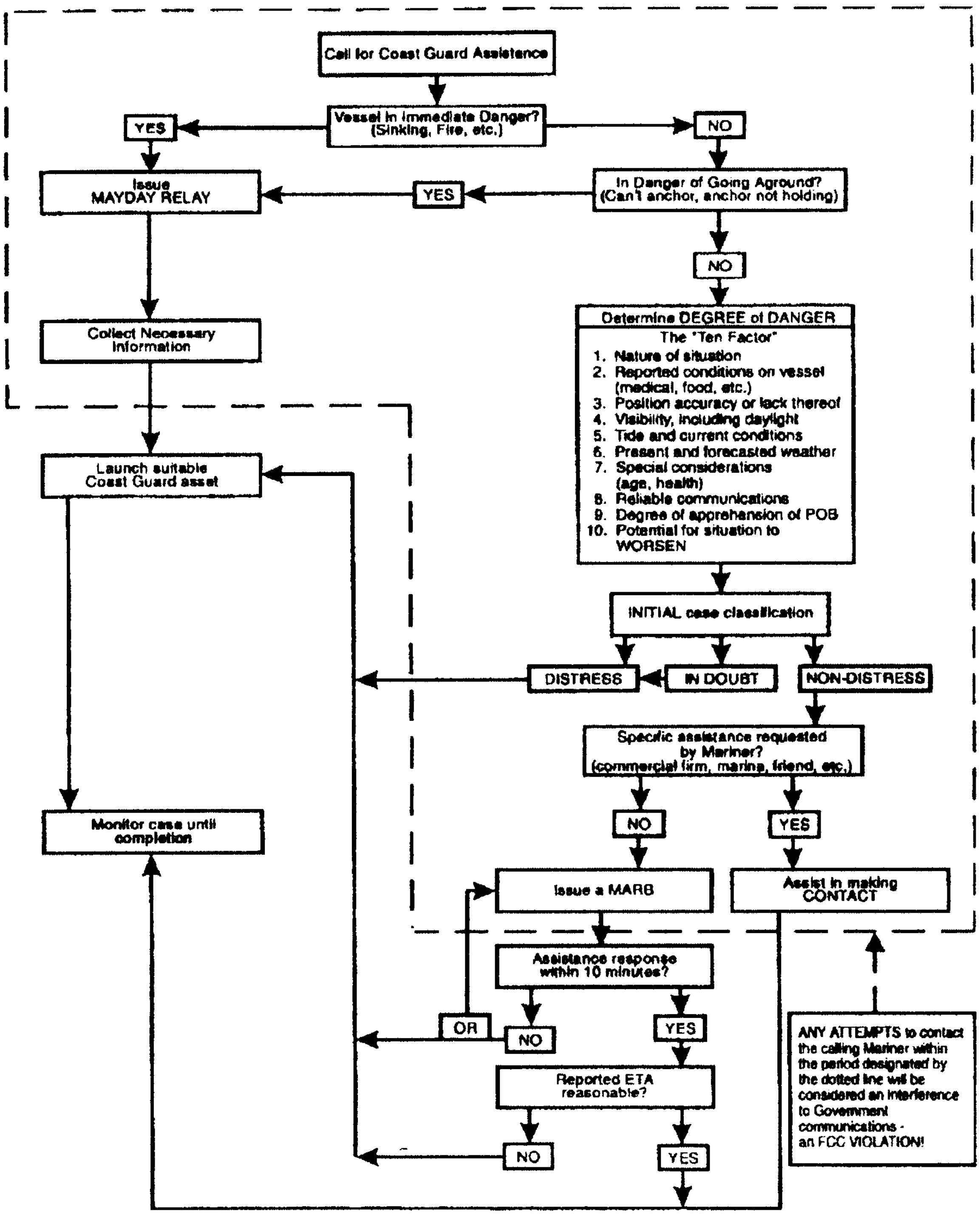

Figure 2-2 Assistance Policy Decision Matrix

to not use Coast Guard resources if other adequate non-CG resources are available, but to monitor the progress of assistance, and to take charge if the incident appears likely to degenerate into a Distress. If there is any doubt that the situation can be handled safely as a non-emergency, the Coast Guard assumes the worst and moves the incident out of the Non-Distress category. Non-Distress is usually reported by the vessel requesting assistance, ie, is not an overdue or unreported.

Figure 2-2 (on the facing page) is the Decision Matrix that is followed when the Coast Guard is called for assistance. The diagram is fairly complicated but is especially useful in understanding the Coast Guard's policy on non-emergency assists. Cases discovered by the Auxiliary are particularly sensitive sections of the Coast Guard Assistance policy. It intends that the Auxiliarists, not the SMC, will make the judgement as to whether he/she can safely assist. The specific policy-as stated in CGADDNSM is:

> *When an Auxiliary vessel on routine safety patrol or otherwise on orders discovers a vessel requesting assistance, but not in radio contact with the Coast Guard, it should relay the request for assistance to the Coast Guard operational commander and may undertake to provide assistance, if capable. If a tow is undertaken, the Auxiliary vessel is required to notify the operational commander of the identity of the vessel, the location of the vessel, and the destination to which the vessel is being towed. No Auxiliary vessel may undertake the tow of another vessel unless the Auxiliarist is reasonably assured of the safety of both vessels and the persons on board. If the Auxiliary vessel cannot safely tow a disabled vessel which is standing into danger, it may endeavor to remove the persons from the threatened vessel and stand by until a more capable resource arrives on scene.*

A standard MARB broadcast text is illustrated in Table 2-1. The call is initiated on Channel 16 with an "ALL STATIONS" call to "SWITCH AND LISTEN ON CHANNEL 22 ALPHA FOR A MARINE ASSISTANCE REQUEST BROADCAST". After an appropriate preamble, the text outlined in the Table is broadcast.

2. Uncertainty Phase exists when there is knowledge of a situation that may need to be monitored, or to have more information gathered, but that does not require moving resources. When there is *doubt* about the safety of a

THIS IS COAST GUARD GROUP XXXX RELAYING A MARINE ASSISTANCE REQUEST BROADCAST FOR PLEASURE CRAFT (Name) (Radio Call Sign). PLEASURE CRAFT (Name) IS A (description) DISABLED DUE TO (problem) IN THE VICINITY OF (location). ANY VESSEL DESIRING TO ASSIST THE (Name) IS INVITED TO PROCEED TO THAT LOCATION OR CONTACT HIM BY RADIO. PLEASURE CRAFT (Name) IS STANDING BY CHANNEL (Channel number). IF YOU ARE OFFERING TO ASSIST THE (Name), PLEASE RESPOND AND PROVIDE AN ESTIMATED TIME OF ARRIVAL.

Table 2-1 MARB Text

craft or person, or they are overdue, the situation is investigated and information gathered; a preliminary communications search (PRECOM) begins in this phase. Vessels that are overdue or unreported are generally placed in this phase when the Coast Guard is initially notified. As part of the PRECOM, the SMC issues simple radio callouts to encourage local boaters who may have knowledge of the craft or person to pass the information to the Coast Guard.

3. Alert Phase exists when a craft or person has difficulty and may need assistance, but is not in imminent danger or need immediate assistance. *Apprehension* is usually associated with the Alert Phase. For over-dues, Alert occurs when there is continued lack of information concerning progress or position. The SMC begins an extended communications search (EXCOM), may dispatch SRUs to investigate high-probability locations or to overfly the craft's intended route, and issues a standard Urgent Marine Information Broadcast (UMIB).

4. Distress Phase exists when a craft or person is threatened by *grave or imminent danger* requiring immediate response to the distress scene. For overdues, distress exists when communications searches and other forms of investigation have not succeeded, and search planning and execution are needed.

D. Incident Phase Determination. Historical statistics, collected by the Coast Guard and incorporated into the NSM, are the basis of guidelines for incident evaluation. Many of the possible types are of no applicable interest to Auxiliarists and are noted only briefly and without the qualifying conditions used to determine the degree of urgency.

1. A Marine-Vessel Incident is considered probable or actual when:

a. a condition such as fire, sinking, or collision is reported; the incident is immediately put into the *Distress* phase.

b. an electronic distress signal is transmitted, or a visual or audio distress signal is used; the incident is put into the *Distress* phase.

c. a vessel is overdue, is unreported, or misses a position report; the incident is placed in the *Uncertainty* phase. The incident is upgraded to *Alert*, and SRUs are dispatched, only after a careful evaluation is made of the estimated length of the voyage, fuel and food endurance, type of craft, operator experience and habits, and weather and sea conditions.

2. An Aircraft Incident is considered probable or actual when:

a. an aircraft requests assistance or transmits a distress signal.

b. aircraft ditching, crash, or forced landing is actual or imminent. (If the site is in near-shore waters the Auxiliary may be called to help rescue efforts or to patrol the scene for spectator control).

c. the crew is about to abandon, or has abandoned the aircraft.

d. unlawful aircraft interference is known or believed.

e. the aircraft is overdue. (The amount by which the aircraft is overdue to be declared an emergency depends on the particular circumstances the details of which are not germane to this Text).

3. If Communications have been established with a distressed craft, it is always assumed they may be quickly lost. Next to degree of urgency, position is the most important element in the data required to prosecute the incident. After all of the information outlined on the Incident Sheet is obtained, and if the communication link continues to be effective, the most important data is confirmed, particularly position information.

a. Many pleasure craft that travel near-shore carry LORAN receivers with built-in coordinate converters. Such craft almost always report their position as the Lat/Long shown on their LORAN receivers. But if the craft is near shore, within about one mile, the Lat/Long information is likely to be in serious error. Near shore, TD information should be used instead of Lat/Long. The TD lines on charts are corrected for the land/sea interface distortion that occurs to LORAN signals. Receiver coordinate converters do not correct for this distortion.

b. Positions given in relation to uncharted or locally-named landmarks are suspect. Not only are landmarks with names such as "Bird Rock" common to many areas, the same name may be used for different objects in the same area.

c. When bearings and ranges are reported the position should be confirmed by asking for other known information about the area.

d. Soundings may be used to cross check between reported and charted position reports.

e. On-scene weather may help resolve position information conflicts if the weather conditions in the area are highly localized.

4. Flare Incidents. Now that Federal law requires flares on all vessels, flare sightings are routinely responded to. Red and orange flares and pyrotechnics are recognized as marine and aviation emergency signals and they are treated as a distress unless available information indicates otherwise. Unresolved (insufficient information to either close or suspend) red or orange flares require first-light searches. Continued searches and follow-up searches of other than red or orange flares depend on the specifics of the case.

5. EPIRB Incidents. Distress beacons are one of the most important tools available to SAR authorities. But their reliability is substantially less than 100%. Table 2-2 shows the response policy to different types of beacon alerts. The designation "GEO" means geostationary earth orbit; the designation "LEO" means low earth orbit. The GEO alert does not give position information but the LEO alert does. See Appendix B for a complete description of the COSPAS-SARSAT system.

E. Urgency of Response. The nature of the incident and the rate the situation may deteriorate determine the urgency of response. The chances of survival diminish with time and the seriousness of the incident, so these two aspects are evaluated as quickly as possible. Signaling equipment available to survivors greatly influences the degree of urgency and type

BEACON ALERT	EMERGENCY PHASE
• 121.5/243 MHz Second Composite alert • 406.025 MHz GEO registered alert • 406.025 MHz LEO "A" solution alert • 406.025 MHz LEO registered, unlocated alert	Initially evaluate as Distress
• 121.5/243 MHz First report of audible alert • 121.5/243 MHz First Composite alert • *406.025 MHz LEO "B" solution alert with probabilities >20%	Initially evaluate as Alert. Investigate, reevaluate and respond as facts and circumstances warrant.
• 121.5/243 MHz first alert • *406.025 MHz LEO "B" solution alert with probabilities <20%	Initially evaluate as Uncertainty. Investigate, reevaluate and respond as facts and circumstances warrant.
* All "B" solutions should be coordinated with the "A" solution cognizant RCC in evaluating and/or responding to alert/distress candidate "B" solutions. Always check vessel type/description and homeport/registration POC data against alert position. This practice can help flag correct "B" solutions.	

Table 2-2 Beacon Responses

of SAR response most suitable to the circumstances, viz., there is no point in searching at night unless the survivors are known to have night signalling equipment.

1. It is assumed that all Survivors are incapacitated, are capable of surviving only a short time, are under great stress, are experiencing shock, and require medical care. Normally able-bodied, logical-thinking persons may be unable to accomplish simple tasks or to assist in their own rescue. Some may be calm and rational, some hysterical, and others temporarily stunned and bewildered. This last group will be passive and easily led during the first 24 hours after the incident. As shock wears off, most regain active attitudes. Those who remain passive die unless quickly rescued. This behavior, commonly known as "disaster syndrome" is characterized by an attitude of "I am not here and this is not happening to me".

2. The probability of the Target Remaining within the Search Area decreases with time. For survivors adrift, the search area expands dramatically with time.

3. Environmental Factors-including daylight hours remaining-may severely limit available rescue time. Exposure to the cold air, wind, or water, results in hypothermia, the abnormal lowering of internal body temperature. Hypo-

thermia is a problem in any incident in ocean waters; Figure 2-3 shows life expectancy for a person immersed without an exposure suit. (An exposure suit extends survival).

4. Weather influences the probability of detection and the ability of the SRUs to operate safely. Predicted change in the weather is a major factor in accelerating or delaying SAR response to an incident.

F. Communications Searches. Particularly for overdues and unreported, facts are needed to help determine if there really is a problem. Communication searches include efforts to contact the craft, to determine whether the craft is overdue or simply unreported, to define the search area, and to obtain more information for determining subsequent SAR action. Any case that requires a Communications Search is handled by a SMC at RCC. The two types of communication searches are the Preliminary Communication search (PRECOM) and the Extended Communication search (EXCOM). The PRECOM is conducted during the Uncertainty phase of the case, and this search usually locates a vessel that is simply Unreported. The EXCOM is conducted during the Alert phase of the case and consists of contacting all possible sources of information on the vessel. It may include actually conducting Harbor Checks based on specific information. PRECOM search contacts major facilities

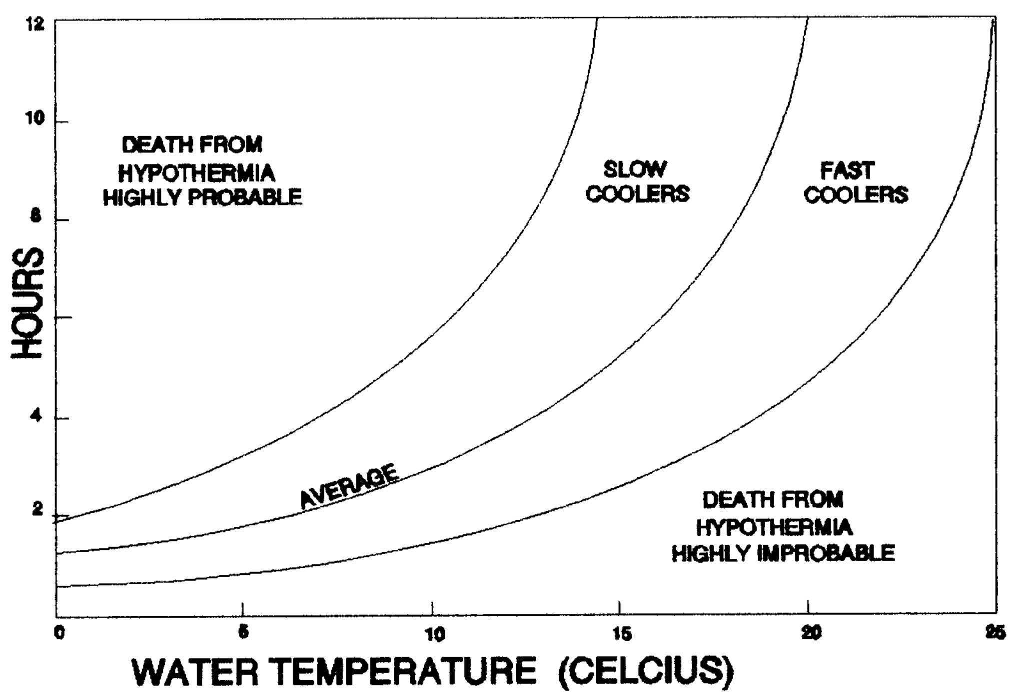

Figure 2-3 Water Chill Response

where the craft might be or might have been. The contacts include:

1. All dedicated SAR facilities in the area.

2. Bridge and lock tenders.

3. Local harbor patrols, harbor masters and dockmasters.

4. Marinas, yacht clubs, supply facilities, fuel docks, repair yards.

5. Commercial towing concerns.

6. Local police, pilot boats, customs and immigration authorities.

7. Relatives, friends, boating buddies, baby sitters, and anyone who might have knowledge about the habits of the persons involved in the incident.

8. If the missing craft is known to have a radio aboard, marine operators are asked to check their logs for information and are asked to attempt a contact.

9. EXCOM search, normally conducted after the PRECOM, contacts all possible sources of information on the missing craft. It includes asking organizations or persons to physically check harbors, marinas, or ramps. EXCOM continues until either the target is located or the search is suspended.

G. Medico/Medevac situations present unusual Initial Action problems. (Medico is defined as medical advice given to a vessel in distress; Medevac is defined as evacuation of person(s) in distress.) In many cases a vessel with an ill or injured crewman will request that the crewman be evacuated by the Coast Guard. Often the vessel is in a position to proceed to a nearby port in approximately the same time it would take to complete an evacuation by Coast Guard vessel or aircraft. Unless the particular Coast Guard unit is transporting competent medical personnel to the vessel, nothing is gained by dispatching a Coast Guard unit. In order to assure that each case is handled properly, several precautions are taken:

1. RCC will normally be SMC for all Medico/Medevac cases.

2. Medical authorities are consulted for a recommendation; the primary sources are Coast Guard or DOD Flight Surgeons, Coast Guard or DOD general medical officers, and Civilian physicians.

3. In all cases, when the SMC has directed a Medevac, the Aircraft Commander makes the final decision to conduct or abandon a hoist, based on flight safety.

4. Heart Attack patients have additional factors to be considered. A majority of deaths due to heart attacks occur during the first few minutes. Therefore, only a small number of cases are improved by immediate evacuation. In some cases the condition may be aggravated during the hoist or transfer to a boat. The medical officer working the case is selected as someone who is aware of the hazards present to the patient and SRU crew involved in an evacuation.

5. Carbon Monoxide Poisoning is a common occurrence on boats with gasoline engines. The symptoms are very much like a heart attack and, especially for older persons, are often mistaken as a heart attack. It usually occurs when the boat is travelling down-wind at about the wind speed, but can occur any time the wind is light and the boat is travelling slowly. The obvious corrective action is to change heading and open everything up.

REVIEW QUESTIONS

1. What initiates the Awareness stage?

---

2. What is the very first action taken when the SAR system is made aware of a distress?

---

3. In what type of incident is the Auxiliary most likely to become involved?

---

4. What does the acronym UMIB stand for?

---

5. What does the acronym MARB stand for?

---

6. What is the purpose of a UMIB, and when is one issued?

---

7. What is the purpose of a MARB, and when is one issued?

---

8. How is the SMC assignment made?

---

9. Who has the authority to change a SMC assignment?

---

10. When can a cutter be the base for a SMC?

---

11. After the SAR system has determined the kind of incident what is the next determination that must be made?

---

12. How many "official" Phases are there, and what are they?

____

13. What circumstance is very much like a Phase but is not considered one?

____

14. What <u>words</u> best describe the Uncertainty, Alert and Distress phases?

____

15. An Overdue or Unreported is usually placed into which phase?

____

16. What is the most important job of the SMC when a case is in the Uncertainty phase?

____

17. Would a SMC order a MARB on a case in the Uncertainty phase, and why?

____

____

18. Would a SMC order a UMIB on a case classified as Non-Distress, and why?

____

____

19. Name some of the situations that put a marine incident immediately into the Distress phase.

____

____

20. If communications exists with the Distress what information is verified after the Incident Sheet is completed, and why?

____

____

21. What are some of the factors that determine the Urgency of Response?

____

____

22. In what phase would a PRECOM usually be conducted?

____

23. In what phase would a EXCOM usually be conducted?

____

24. What are the primary purposes of PRECOM and EXCOM activity?

____

____

25. Define Medico.

____

26. Define Medevac.

____

27. Name the most important elements of the Incident Data and their order of importance.

____

____

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CHAPTER 3. SEARCH AREA PLANNING

A. Introduction. When an incident has progressed to the point where it is classified as a *DISTRESS*, and the exact location of the Distress is either not known, or a significant amount of time has passed since the search object's exact position was last know, Search Planning is necessary. The first step is to define the Search Area, the area that has a high probability of containing the Search Object. Search Planning involves a number of factors each of which influences the final plan.

1. Distressed Vessel. The physical characteristics of the Distressed Vessel affect the way the vessel responds to the environment, and how easily it can be seen by a SRU. This information is determined during the Awareness and Initial Action phases of the case, and is transcribed as Incident Information to each of the planning forms used. If there is substantial uncertainty about the physical characteristics, for example does the life raft have a canopy, or, has the vessel capsized, it may be necessary to assume "best" and "worst" physical characteristics and plan for both.

2. Search Parameters. The Coast Guard has established a "decision tree" to aid the SMC determine the Search Area. Figure 3-1 shows how the planning is done as a function of the case parameters. The final result is a Search Area where the Distressed Vessel is most likely to be.

3. Asset Allocation. After the SMC has determined the Search Area, SRU(s) are assigned to perform the search operation. What SRU(s) are available, their search capabilities, and the amount of time available for searching all have an effect on the Search Plan.

4. Search Effectiveness. The task of the SMC is to plan the search so that the Probability of Success (POS) is maximized. The POS is the product of the *probability of detection* (POD) multiplied by the *probability that the search object is in the search area* (POA). Search-planning documents in this text do not calculate the POS but do calculate POD. Historically, POD has been used as a measure of search effectiveness because there is no reasonable way to calculate POA manually. The 1995 revision to the Coast Guard **Addendum** incorporates techniques for calculating POS, based on new CASP programs which are able to calculate POA hours-or days-after an incident.

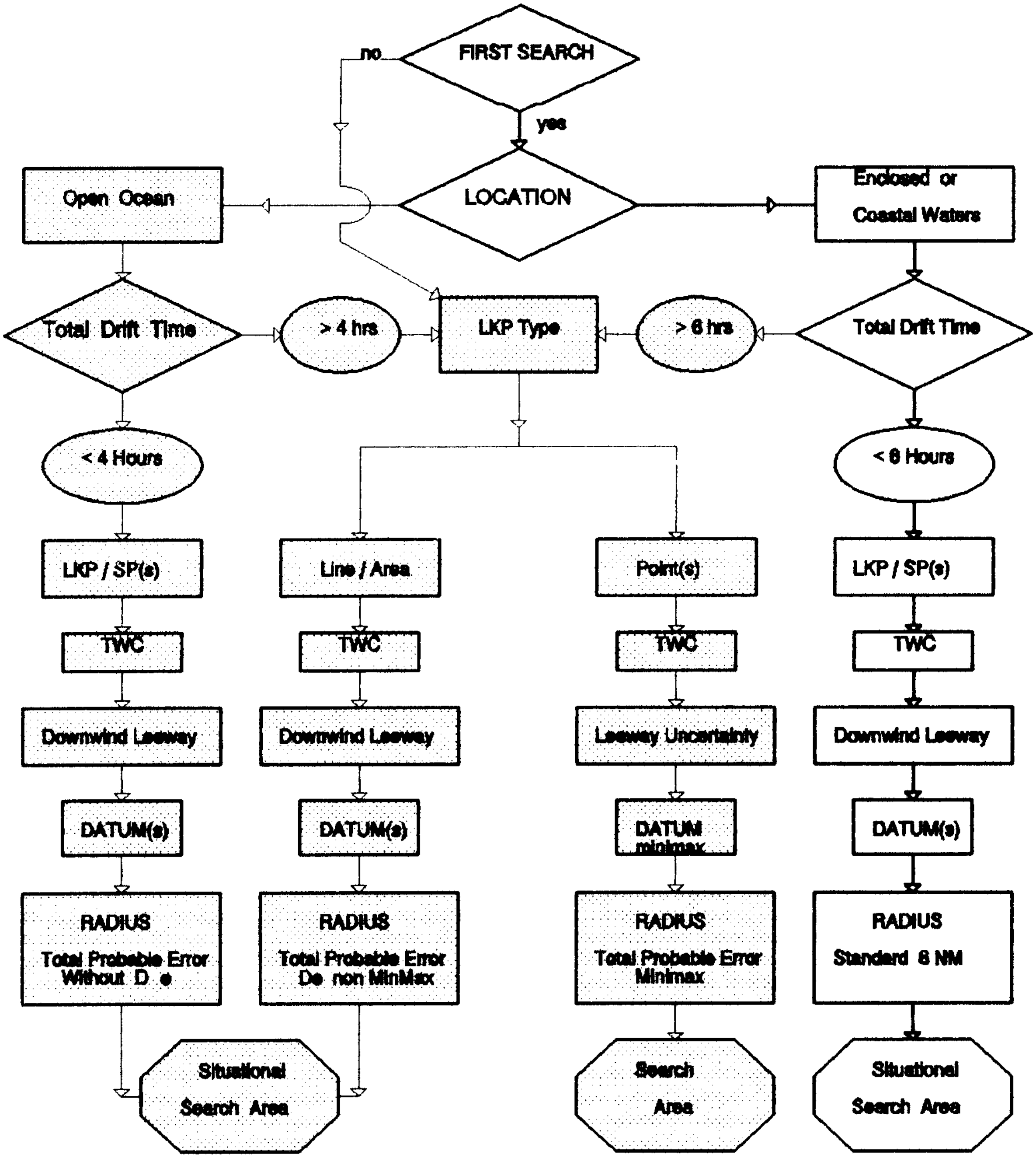

Figure 3-1 Search Area Decision Tree

5. Auxiliary Operations. This Chapter gives special emphasis to cases involving Enclosed or Coastal Waters with a drift time <6 hours. These are the circumstances for essentially all of Auxiliary involvement in searches. The historical success rate for searches with these parametric limitations is very high and it is rare that the first search is unsuccessful and a second more complicated search plan becomes necessary. In addition, since the search area is near shore, assets can reach the scene quickly and allocation is not generally a problem.

B. Definitions. The following are the terms that are used in Search Planning; many may be cryptic but they will be made more understandable in the examples.

1. Course. The intended direction of travel of a craft, expressed in degrees True.

2. Datum. The most probable location of the search object, corrected for movement over time.

3. Open Ocean. Ocean waters where the depth is >300 feet and the distance offshore is >25NM.

4. Last Known Position (LKP). The last witnessed, reported, or computed DR position of the search object.

5. Surface Position (SP). The position where marine drift begins; this term is used when aerospace (parachute) drift is also a consideration.

6. Vector. The representation of a quantity that has a direction, for example speed and direction, or distance and direction.

7. Total Water Current (TWC). The vector sum of the currents in the vicinity of the distress.

8. Situational Search Area. This term is used when something exists that modifies the area determined simply by the Radius, for example a land mass. This happens very often in Enclosed or Coastal a Waters.

9. Tidal Current (TC). The component of TWC represented by Tides. This component appears only near-shore in tidal basins.

10. River Current. The current in a river or the component of TWC represented by the discharge from a river.

11. Wind Current (WC). The component of TWC represented by the surface current that results from the wind; it is calculated only in Open Ocean cases.

12. Sea Current (SC). The component of TWC stemming from the large-scale flow of ocean waters.

13. Leeway (LW). Movement of the search object under the influence of local wind. Downwind Leeway is assumed to be directly downwind; Leeway Uncertainty assumes the search object's leeway diverges from downwind; the amount of divergence depends on the physical characteristics of the search object and ranges from $\pm 15^\circ$ to $\pm 60^\circ$.

14. Drift. The movement of a search object caused by external forces; the movement may be a rate (knots), or a displacement (nautical miles). Drift is the vector sum of TWC and LW.

15. Radius. The radius of a circle that has an optimum probability of containing the search object.

C. Search Area Decision Tree. The decision tree, Figure 3-1, shows the way the Search Area is determined. By the time Search Area planning is required, the SMC has all of the information that determines the "path" to be followed down the decision tree. The only path of special interest to Auxiliarists is the one on the far right side of the diagram, the path through the unshaded boxes. It is the one that is covered in detail in the remainder of this Chapter.

1. First Search, Enclosed or Coastal Waters, Total Drift Time $\leq$6 hours. This "path" indicates that under these circumstances the LKP is known, then Total Water Current computed, Leeway is computed as Downwind, Datum determined (by vector addition of TWC and Leeway), and a 6NM radius drawn around Datum to establish the Search Area.

2. Other Paths should be understood, but are rarely of interest to Auxiliarists. For example, if the case qualifies as Enclosed or Coastal Waters but is not the First Search, the "path" leads directly to the middle two paths, one for a point LKP and one for a Line/Area LKP. If a First Search is not successful, a much more elaborate algorithm must be used to determine the Search Area.

3. First Search, Open Ocean will usually follow one of the middle two "paths" since it is unlikely that the Total Drift Time will be < 4 hours.

D. Coastal and Oceanic SAR Models. The major differences between the First Search Coastal path and other paths are how Leeway (LW) is applied and how the Search Radius is determined.

1. In the First Search Coastal Model, LW is assumed to be in the downwind direction. By design, no divergence is assumed. LW may be figured with two different rates if there are two different possible descriptions for the search object-for example a raft with or without a drogue-but for both assumptions the leeway is considered directly downwind. In point of fact leeway almost always diverges from directly downwind; if the drift time is <6 hours the divergence is not likely to be as big as other inaccuracies in estimating Datum, and is ignored.

2. In the Open Ocean Model with drift time >4 hours, LW for a point (or points) LKP is calculated using divergence, ie, downwind ± a divergence angle determined by the type of target. When divergence is used there are always at least two Datums. Note: the Open Ocean Model is being substantially modified by the use of the CASP program that calculates POA.

3. The Coastal Model Search Radius is a standard six miles centered on Datum. It is independent of inaccuracies of calculated drift and navigation, but the six mile radius was selected based on typical drift and navigation errors.

4. The Oceanic Model Search Radius has a complicated dependence on several drift variables, navigation accuracy, and distances between possible Datums. This text does not attempt to explain the calculations; the whole process is being switched to CASP and manual calculation is no longer relevant, besides which the Auxiliary never encounters the circumstances where the Oceanic Model Search Radius has to be determined.

E. Vectors. As noted in §B, a Vector is a representation of something that has an amount and a direction. Many parameters used in search planning are vectors, for example, wind speed and direction, drift distance and direction, course speed and direction, distance travelled and direction. The parameters dealt with that are not vectors (in mathematics called scalar quantities) are those that have no implied direction, eg, Mass, Time, Position. Very often it is necessary to determine the net effect of two forces both of which are vectors, and that determination requires vector arithmetic. Two, or more, vectors can be added, or subtracted, either analytically or graphically. The manual solution used in the search planning illustrations in this text use the graphical method of handling vectors. It is imperative that the student understand the vector examples in this Chapter, and be able to do the vector problems at the end of this Chapter. It is impossible to do the search planning problems without a thorough understanding of vector addition and subtraction. Appendix C is a tutorial on Vector Arithmetic. This text does not explain the analytical method of performing vector arithmetic, however such a method may be used if the student understands it on his own initiative. The analytical method is more accurate than the manual method but the accuracy of the quantities being manipulated is only rarely sufficient to warrant using the analytical method.

F. Search Area. All of the paths in the Search Area Decision Tree get to a Datum (or Datums) about which the Search Area is defined. In all of the paths there are two general types of forces that cause a search object-that is not anchored or aground-to move from the LKP: **water currents** and **wind** acting on the exposed surface of the search object. There are several different-and usually independent-types of water current that are estimated or calculated and combined into a single vector called Total Water Current (TWC). TWC, expressed as a rate, viz., knots, multiplied by the Time Interval between the LKP and the Datum, is a displacement vector expressed as Nautical Miles and Direction. This vector quantity is independent of the characteristics of the search object. Thus the TWC is the same whether the search object is a Person-in-the-Water (PIW), a raft, or a disabled vessel. The second type of force is **wind** acting on the exposed surface of the search object; this force causes Leeway (LW). It is independent of the Current and is totally dependent on the amount of wind and the characteristics of the search object.

G. Currents. There are a number of possible types of water current; they are not of equal importance to Auxiliarists.

1. Lake. The volume of water entering and exiting a lake is the major determinant of lake current. In the Great Lakes this information is published monthly by the Army Corps of Engineers.

2. Alongshore. The transport of water from swells striking the coast generate alongshore currents. In many parts of the coast these currents are persistent, and are documented in local references. They are rarely significant more than a mile offshore.

3. Tidal. In the tidal influence area, mostly within three miles of the shore line and within bays and sounds (where 80% of search cases occur), Tidal Current is the biggest contributor to TWC. Where tidal currents are restricted by land masses the currents are usually reversing; further offshore the currents are usually rotary. Reversing

Tidal Current (TC) is studied in detail later in this chapter.

4. Sea. Established Sea Currents such as the Gulf Stream and Japan current are sizeable and very important in the Oceanic Model.

5. River. Often tidal basins are fed by rivers with the result that the ebb tidal current is greater than the flood. Historic data is incorporated into the Tide Current Tables but this has to be adjusted by local knowledge of the volume of water the river is discharging. In the inland area-where a significant portion of Auxiliary SAR activity takes place-River Current may be the dominant factor in drift.

6. Surf. Breaking surf generates a current alongshore and, where it reverses, a rip tide. Although hazardous to swimmers it is not generally considered in search planning.

7. Wind Driven. Wind generates waves and breaking waves cause a transport of water, ie, a surface current. The amount of the current depends on the wind speed and fetch, and how long the wind has blown. The direction of the current is determined by the direction of the wind and by the offset from the Coriolis force. The algorithms are applicable only in deep water, greater than 100 fathoms, and are therefore almost never used in coastal search planning.

   Note: There are a few places in coastal waters where there is observational data on wind-driven currents. These are listed in the **Tidal Current Tables**, and include the ratio of wind speed to wind-driven current speed, and the average deviation of current to the right or left of wind direction for different wind directions. Where such data exists it can be used in near-shore cases.

H. Reversing Tidal Current (TC). The calculation of this component of Total Water Current (TWC) is simplified by using a specialized planning form, Reversing Tides and Other Currents Worksheet (see page A-3,4 in Appendix A). In order to understand the calculation a fictitious problem is worked out below, step-by-step. The finished product is shown in Figure 3-2,3 on pages 3-9,10, but the student is advised to take a blank Reversing Tides and Other Current Worksheet and fill in the data as the example is followed step-by-step. Copies of all the required tables are included in this text, however this text does not instruct on the general use of tide and tidal current tables. (See AUXNAV Specialty Course). The applicable pages from the **TIDAL CURRENT TABLES** of North

America & AsiaNorth are reproduced here as pages 3-11, 3-12 and as Figure 3-6 on page 3-15.

The object of the calculation is to arrive at a Total Reversing Current Vector, expressed as Nautical Miles and True Direction, which can be plotted on a chart. This requires a knowledge of the current direction and speed during the interval between the Incident and Datum Time. **TIDAL CURRENT TABLES** allow the determination of tidal current for every 20^m of the tide cycle. The Worksheet uses this feature of the tables to determine the current speed in 20^m time slices, and then average the 20^m values over the drift interval. The Worksheet, if followed step-by-step, makes the calculation relatively straightforward.

1. The Incident Summary in §A of the Worksheet is filled in from the data given in the SCENARIO. In the illustration, there is no uncertainty about LKP so either the Maximum

TIDAL CURRENT ILLUSTRATION SCENARIO

LKP	37° 47'.0 N	122° 43'.0 W
Incident	301110ZJUL92	
Datum	301540ZJUL92	

Note: Since Tidal Current (TC) is independent of characteristics of search object, no search object is specified.

or Minimum column is used. (It is customary to use the Maximum column when there is only one LKP). The Drift Interval on line 5 is the time difference between the Date-Time-Group (DTG) of the LKP and the DTG of Datum, expressed as hours and decimal fraction.

2. The **TIDAL CURRENT TABLES** and associated data are all in Local Zone Time and the LKP and Datum DTGs are converted to Zone Time and recorded in §B Time Conversions. In this illustration the Local time would probably be Daylight Saving, ie, T(ango) Zone, but Current publications are <u>always</u> in Standard Time; in this illustration the Standard Zone is U(niform).

3. All of the data from the **TIDAL CURRENT TABLES** that is applicable to the problem being analyzed is transcribed to §C of the Worksheet. First, the Substation that is nearest to the Lat/Long of the LKP is located. Substa-

Reversing Tides & Other Currents
(rev. 5/31/91) (WORKSHEET

Case Title: M/V AURORA Planner's Name: J. SMALL Date: 30 Jul 92

A. Incident Summary

	MINIMUM	MAXIMUM
1. Latitude	____ N/S	37 47.05 N/~~S~~
2. Longitude	____ W/E	122 43.0 W/~~E~~
3. Surface Position DTG	____ Z ____	3011 10 Z Jul 92
4. Datum DTG	3015 40 Z Jul 92	
5. Drift Interval	____ HRS	4.5 HRS

B. Time Conversions: GMT + Zone Description (Rev) = Zone Time

1. Surface Position DTG *(Zone Time)* ____ 300310 U Jul 92
2. Datum DTG *(Zone Time)* 300740 U Jul 92

C. Reversing Tidal Currents - (Minimum) (Maximum) (First Search) *(Circle One)*

1. REFERENCE STATION: SF Golden Gate PAGE: 9 DATE: 30 Jul
   SUBSTATION: Pt. Lobos 8.7 NM WSW REFERENCE NUMBER: 141

2. TIME DIFFERENCES

Minimum Before Flood 0 HRS -30 MIN	Minimum Before Ebb 0 HRS -30 MIN
Max Flood 0 HRS -30 MIN	Max Ebb 0 HRS -30 MIN

3. VELOCITY INFORMATION

FLOOD: SPEED RATIO 0.1 AVERAGE DIRECTION 135 °T EBB: SPEED RATIO 0.1 AVERAGE DIRECTION 315 °T

4. a) REFERENCE STATION / b) SUBSTATION

a) TIME	SPEED	TIME	SPEED(E/F?)	b) TIME	SPEED	TIME	SPEED(E/F?)
0045	SLACK	0359	5.8 E	0015	SLACK	0329	.58 E
0749	SLACK	1051	4.7 F	0719	SLACK	1021	.47 F
1407	SLACK	1635	3.6 E	1337	SLACK	1605	.36 E
1949	SLACK	2243	3.8 F	1919	SLACK	2213	.38 F
	SLACK				SLACK		

5. TIDAL CURRENT CHART

INCIDENT TIME: 0310 DATUM TIME: 0740

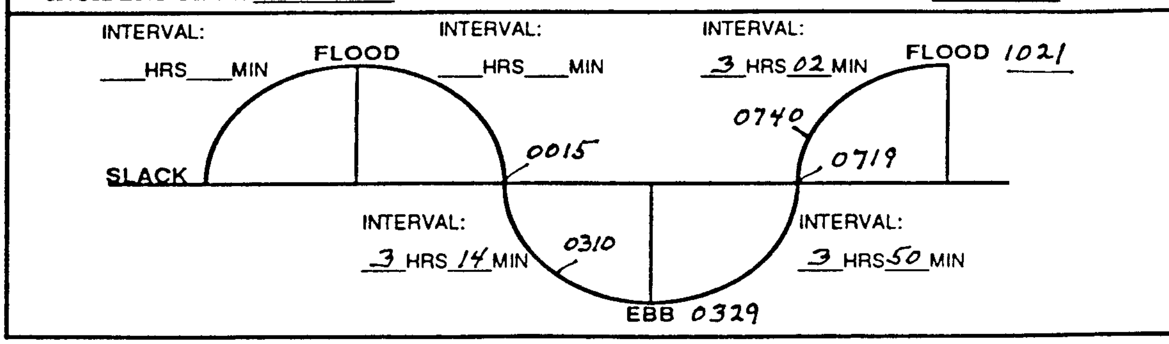

Figure 3-2 Reversing Tidal Current Illustration p-1

6. **COMPUTING AVERAGE FACTOR OF CYCLE:**
   a) Time interval from slack water to incident: 2 HRS 55 MIN (Same Half-Cycle)
   Time interval from slack water to DATUM: 0 HRS 21 MIN (Same Half-Cycle)

b) FACTORS FOR THE ~~FLOOD~~/EBB CYCLE (1)	b) FACTORS FOR THE FLOOD/~~EBB~~ CYCLE (2)
1.0 1.0 0.7 0.1	0.2
1.0 1.0 0.6	
0.9 0.5	
0.9 0.4	
0.8 0.3	
c) TOTAL VALUE OF FACTORS IN THIS CYCLE: 9.2	c) TOTAL VALUE OF FACTORS IN THIS CYCLE: 0.2
Divided by: Total Number of Factors in Cycle: 13	Divided by: Total Number of Factors in Cycle: 1
Equals: Average Factor for Cycle: 0.71	Equals: Average Factor for Cycle: 0.2

7. **COMPUTING THE AVERAGE CURRENT SPEED FOR THE CYCLE:**

Maximum Current Speed for the Cycle: 0.58 KTS	Maximum Current Speed for the Cycle: 0.47 KTS
Multiplied by the Average Factor EQUALS the Average Speed for the Cycle 0.41 KTS	Multiplied by the Average Factor EQUALS the Average Speed for the Cycle 0.1 KTS

8. **COMPUTING TIDAL CURRENT VECTOR FOR THE CYCLE:** (1) ~~F~~/E (2) F/~~E~~

	(1) ~~F~~/E	(2) F/~~E~~
Time Duration of Drift through the Flood/Ebb Cycle:	4.15 HRS	.35 HRS
Multiplied by the Average Current Speed:	0.41 KTS	0.1 KTS
EQUALS: Magnitude of Current Vector for the Cycle:	1.7 NM	0.04 NM

9. **CALCULATING THE TOTAL TIDAL CURRENT VECTOR:**
   1st Current Vector: 315 °T 1.7 NM + 2nd Current Vector: 135 °T 0.04 NM

EQUALS: Total Reversing Tidal Current Vector 315 °T 1.7 NM

Other Currents Worksheet

1. There are many other currents that may effect a search object. Some of these are: Lake, Longshore, River, Surf, Rotary, etc. The form is self-explanatory.
2. Type of Current ____________
3. Source of Information ____________

		MINIMUM	MAXIMUM
4.	SET	______ °T	______ °T
5.	Drift	______ KTS	______ KTS
6.	Vector	______ °T	______ °T
	Direction from above and Drift X Drift Interval	______ NM	______ NM

Figure 3-3 Reversing Tidal Current Illustration p-2

San Francisco Bay Entrance (Golden Gate), Calif., 1992

F–Flood, Dir. 065° True E–Ebb, Dir. 245° True

July

Day	Slack (h m)	Maximum (h m)	knots
1 W	0051	0416	6.0E
	0810	1112	4.6F
	1439	1655	2.9E
	1959	2252	3.3F
2 Th	0141	0503	5.8E
	0854	1155	4.6F
	1521	1741	3.1E
	2053	2347	3.3F
3 F	0235	0552	5.4E
	0938	1240	4.4F
	1603	1832	3.3E
	2152		
4 Sa		0039	3.1F
	0333	0641	4.8E
	1024	1327	4.0F
	1646	1921	3.5E
	2257		
5 Su		0140	2.9F
	0437	0734	4.0E
	1112	1415	3.6F
	1731	2016	3.6E
6 M ◐	0007	0249	2.6F
	0550	0831	3.1E
	1203	1507	3.1F
	1819	2113	3.7E
7 Tu	0119	0406	2.5F
	0709	0933	2.3E
	1301	1604	2.7F
	1910	2216	3.8E
8 W	0230	0531	2.6F
	0830	1044	1.8E
	1406	1705	2.5F
	2003	2322	4.0E
9 Th	0335	0646	2.9F
	0946	1205	1.5E
	1512	1812	2.3F
	2058		
10 F		0028	4.2E
	0433	0748	3.2F
	1052	1332	1.5E
	1614	1913	2.4F
	2151		
11 Sa		0126	4.4E
	0525	0839	3.5F
	1146	1436	1.7E
	1708	2004	2.5F
	2242		
12 Su		0213	4.6E
	0611	0924	3.7F
	1232	1511	1.8E
	1755	2047	2.6F
	2328		
13 M		0256	4.7E
	0652	1005	3.8F
	1312	1540	2.0E
	1838	2126	2.6F
14 Tu ○	0010	0332	4.8E
	0730	1040	3.8F
	1348	1609	2.1E
	1917	2204	2.7F
15 W	0051	0407	4.7E
	0805	1109	3.7F
	1422	1637	2.3E
	1954	2241	2.7F
16 Th	0129	0442	4.6E
	0838	1138	3.6F
	1455	1712	2.5E
	2032	2319	2.6F
17 F	0207	0518	4.4E
	0909	1207	3.4F
	1526	1747	2.7E
	2111	2354	2.5F
18 Sa	0246	0554	4.1E
	0938	1237	3.2F
	1557	1829	2.8E
	2154		
19 Su		0039	2.3F
	0329	0635	3.6E
	1007	1312	3.0F
	1628	1909	3.0E
	2242		
20 M		0124	2.1F
	0417	0719	3.1E
	1036	1347	2.7F
	1701	1954	3.1E
	2338		
21 Tu		0219	1.9F
	0515	0806	2.5E
	1109	1429	2.4F
	1737	2043	3.2E
22 W ◑	0042	0319	1.8F
	0626	0901	2.0E
	1151	1520	2.1F
	1820	2137	3.3E
23 Th	0150	0428	1.8F
	0748	0958	1.6E
	1245	1611	2.0F
	1911	2234	3.5E
24 F	0255	0545	2.1F
	0907	1104	1.4E
	1357	1714	1.9F
	2008	2333	3.9E
25 Sa	0354	0656	2.6F
	1016	1209	1.4E
	1513	1818	2.1F
	2106		
26 Su		0034	4.4E
	0448	0755	3.2F
	1113	1313	1.7E
	1618	1917	2.5F
	2204		
27 M		0130	4.9E
	0536	0840	3.7F
	1203	1411	2.1E
	1715	2012	2.9F
	2259		
28 Tu		0224	5.4E
	0622	0927	4.2F
	1247	1501	2.6E
	1807	2101	3.3F
	2352		
29 W ●		0313	5.7E
	0706	1008	4.5F
	1327	1549	3.1E
	1858	2152	3.6F
30 Th	0045	0359	5.8E
	0749	1051	4.7F
	1407	1635	3.6E
	1949	2243	3.8F
31 F	0139	0447	5.6E
	0832	1131	4.6F
	1445	1720	3.9E
	2041	2335	3.8F

August

Day	Slack (h m)	Maximum (h m)	knots
1 Sa	0233	0534	5.1E
	0914	1213	4.3F
	1524	1807	4.2E
	2137		
2 Su		0029	3.7F
	0331	0623	4.4E
	0956	1255	3.9F
	1605	1856	4.3E
	2236		
3 M		0124	3.4F
	0433	0714	3.6E
	1041	1343	3.4F
	1648	1944	4.2E
	2341		
4 Tu		0231	3.0F
	0541	0807	2.7E
	1131	1432	2.9F
	1735	2041	4.0E
5 W ◐	0050	0345	2.7F
	0655	0906	2.0E
	1230	1529	2.4F
	1829	2142	3.8E
6 Th	0202	0510	2.6F
	0813	1017	1.4E
	1340	1637	2.1F
	1929	2248	3.7E
7 F	0311	0626	2.7F
	0928	1150	1.2E
	1453	1748	2.0F
	2031		
8 Sa		0006	3.8E
	0412	0729	3.0F
	1033	1336	1.4E
	1558	1854	2.1F
	2131		
9 Su		0113	3.9E
	0505	0820	3.3F
	1124	1423	1.6E
	1653	1950	2.3F
	2225		
10 M		0202	4.1E
	0551	0908	3.5F
	1206	1500	1.9E
	1740	2037	2.5F
	2313		
11 Tu		0239	4.3E
	0630	0943	3.6F
	1241	1521	2.2E
	1821	2115	2.7F
	2357		
12 W		0313	4.3E
	0706	1012	3.6F
	1314	1542	2.5E
	1900	2150	2.8F
13 Th ○	0038	0345	4.3E
	0739	1037	3.5F
	1344	1612	2.8E
	1936	2224	2.9F
14 F	0118	0418	4.3E
	0808	1104	3.4F
	1413	1643	3.1E
	2011	2300	2.9F
15 Sa	0157	0453	4.0E
	0836	1131	3.3F
	1440	1718	3.3E
	2048	2335	2.8F
16 Su	0236	0530	3.7E
	0902	1157	3.1F
	1507	1755	3.5E
	2126		
17 M		0016	2.7F
	0318	0609	3.3E
	0928	1230	2.9F
	1535	1836	3.6E
	2208		
18 Tu		0059	2.5F
	0404	0650	2.9E
	0955	1305	2.6F
	1605	1918	3.6E
	2257		
19 W		0147	2.3F
	0459	0737	2.4E
	1027	1346	2.3F
	1641	2003	3.6E
	2356		
20 Th		0248	2.2F
	0606	0830	1.9E
	1109	1435	2.0F
	1726	2100	3.6E
21 F ◑	0104	0351	2.1F
	0724	0930	1.5E
	1206	1538	1.8F
	1823	2201	3.7E
22 Sa	0215	0508	2.3F
	0841	1037	1.4E
	1327	1640	1.8F
	1930	2303	3.9E
23 Su	0320	0622	2.7F
	0947	1142	1.5E
	1453	1751	2.1F
	2040		
24 M		0006	4.3E
	0418	0726	3.2F
	1043	1251	1.9E
	1603	1857	2.5F
	2146		
25 Tu		0107	4.7E
	0509	0814	3.7F
	1129	1347	2.5E
	1701	1954	3.0F
	2247		
26 W		0201	5.1E
	0556	0858	4.1F
	1211	1439	3.1E
	1754	2050	3.6F
	2345		
27 Th ●		0254	5.3E
	0641	0940	4.4F
	1250	1524	3.8E
	1845	2140	4.0F
28 F	0041	0343	5.2E
	0723	1019	4.4F
	1327	1610	4.3E
	1936	2232	4.2F
29 Sa	0136	0428	4.9E
	0805	1059	4.3F
	1405	1653	4.7E
	2026	2322	4.3F
30 Su	0231	0517	4.4E
	0847	1141	4.0F
	1443	1739	4.9E
	2119		
31 M		0014	4.1F
	0327	0603	3.8E
	0929	1223	3.6F
	1523	1826	4.8E
	2214		

September

Day	Slack (h m)	Maximum (h m)	knots
1 Tu		0111	3.7F
	0426	0653	3.0E
	1015	1308	3.0F
	1607	1915	4.5E
	2315		
2 W		0210	3.2F
	0530	0746	2.3E
	1106	1359	2.5F
	1656	2009	4.1E
3 Th ◐	0020	0322	2.8F
	0639	0842	1.7E
	1208	1457	2.1F
	1753	2108	3.7E
4 F	0130	0442	2.6F
	0750	0951	1.3E
	1322	1606	1.8F
	1857	2214	3.5E
5 Sa	0239	0555	2.6F
	0859	1134	1.2E
	1436	1724	1.7F
	2004	2333	3.4E
6 Su	0341	0657	2.8F
	0958	1307	1.5E
	1540	1838	1.9F
	2108		
7 M		0041	3.5E
	0434	0748	3.0F
	1045	1352	1.8E
	1634	1929	2.2F
	2204		
8 Tu		0130	3.6E
	0519	0829	3.2F
	1124	1424	2.2E
	1720	2020	2.5F
	2255		
9 W		0211	3.7E
	0558	0906	3.3F
	1158	1442	2.5E
	1801	2055	2.8F
	2341		
10 Th		0247	3.8E
	0633	0933	3.3F
	1229	1509	2.9E
	1836	2130	3.0F
11 F ○	0025	0320	3.8E
	0704	0958	3.2F
	1258	1538	3.3E
	1914	2205	3.1F
12 Sa	0106	0352	3.7E
	0734	1024	3.1F
	1326	1613	3.6E
	1949	2240	3.2F
13 Su	0147	0428	3.5E
	0801	1053	3.0F
	1352	1646	3.9E
	2025	2315	3.2F
14 M	0228	0507	3.2E
	0827	1122	2.9F
	1419	1725	4.1E
	2101	2356	3.1F
15 Tu	0312	0548	2.9E
	0854	1157	2.7F
	1447	1803	4.1E
	2142		
16 W		0039	2.9F
	0359	0629	2.6E
	0924	1234	2.4F
	1520	1849	4.1E
	2229		
17 Th		0128	2.8F
	0454	0717	2.2E
	1001	1317	2.1F
	1559	1936	4.0E
	2326		
18 F		0223	2.6F
	0558	0810	1.8E
	1050	1409	1.9F
	1648	2031	3.9E
19 Sa ◑	0031	0331	2.5F
	0707	0911	1.6E
	1158	1512	1.8F
	1752	2131	3.9E
20 Su	0140	0440	2.6F
	0815	1018	1.6E
	1326	1623	1.8F
	1907	2236	4.0E
21 M	0245	0550	2.9F
	0914	1122	1.9E
	1446	1737	2.1F
	2023	2339	4.1E
22 Tu	0344	0647	3.3F
	1004	1225	2.4E
	1553	1841	2.6F
	2134		
23 W		0044	4.4E
	0436	0739	3.7F
	1048	1321	3.1E
	1650	1943	3.2F
	2239		
24 Th		0139	4.5E
	0525	0824	3.9F
	1129	1410	3.9E
	1742	2037	3.8F
	2339		
25 F		0233	4.5E
	0610	0906	4.0F
	1207	1459	4.5E
	1832	2131	4.2F
26 Sa ●	0036	0324	4.3E
	0654	0947	4.0F
	1245	1543	5.0E
	1921	2220	4.4F
27 Su	0132	0411	4.0E
	0736	1028	3.8F
	1324	1627	5.2E
	2010	2309	4.4F
28 M	0227	0457	3.6E
	0819	1109	3.5F
	1403	1712	5.2E
	2101		
29 Tu		0003	4.2F
	0321	0544	3.1E
	0903	1152	3.1F
	1445	1757	5.0E
	2153		
30 W		0053	3.8F
	0418	0633	2.5E
	0951	1239	2.6F
	1530	1848	4.6E
	2250		

Time meridian 120° W. 0000 is midnight. 1200 is noon.

Figure 3-4 Current Tables

TABLE 2. - CURRENT DIFFERENCES AND OTHER CONSTANTS

NO.	PLACE	METER DEPTH	POSITION Lat.	Long.	TIME DIFFERENCES Min. before Flood	Flood	Min. before Ebb	Ebb	SPEED RATIOS Flood	Ebb	AVERAGE SPEEDS AND DIRECTIONS Minimum before Flood		Maximum Flood		Minimum before Ebb		Maximum Ebb	
		ft	° ' N	° ' W	h. m.	h. m.	h. m.	h. m.			knots	deg.	knots	deg.	knots	deg.	knots	deg.
	CALIFORNIA COAST Time meridian, 120°W				on SAN FRANCISCO BAY ENT., p.8													
97	San Pedro Channel <2>..................		33 36	118 16	- - -	- - -	- - -	- - -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
101	Los Angeles and Long Beach Harbors <3>..		- - -	- - -	- - -	- - -	- - -	- - -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
105	El Segundo, Santa Monica Bay <4>........		33 54	118 26	- - -	- - -	- - -	- - -	- -	- -	0.0	- -	0.6	330	0.0	- -	- -	- -
109	Point Arguello.........................		34 34	120 40	-2 21	-2 21	-2 21	-2 21	0.2	0.2	0.0	- -	0.5	005	0.0	- -	0.5	185
113	Point San Luis.........................		35 09	120 46	-2 01	-2 01	-2 01	-2 01	0.2	0.2	0.0	- -	0.5	305	0.0	- -	0.5	125
117	Point Piedras Blancas..................		35 40	121 18	-1 29	-1 29	-1 29	-1 29	0.2	0.2	0.0	- -	0.5	315	0.0	- -	0.5	135
121	Point Sur..............................		36 18	121 55	-1 11	-1 11	-1 11	-1 11	0.2	0.2	0.0	- -	0.5	325	0.0	- -	0.5	145
	MONTEREY BAY																	
125	Point Pinos............................		36 38	121 57	-1 01	-1 01	-1 01	-1 01	0.2	0.2	- -	- -	0.5	035	- -	- -	0.5	215
129	Point Santa Cruz, 2 miles south of......		36 55	122 01	Current weak and variable													
	California Coast-continued																	
133	Ano Nuevo Island, 2 miles SW of.........		37 05	122 22	Current weak and variable													
137	Point Montara, 2 miles west of..........		37 32	122 34	Current weak and variable													
	GOLDEN GATE and APPROACHES <5>																	
141	Point Lobos, 8.7 miles WSW of <6>.......		37 45	122 42	-0 30	-0 30	-0 30	-0 30	0.1	0.1	- -	- -	0.4	135	- -	- -	0.4	315
145	Point Bonita Lt., 5.27 nmi. WSW of......	39d	37 48.27	122 38.33	-1 52	-1 41	-1 41	-1 19	0.2	0.2	- -	- -	0.4	095	0.1	196	0.5	266
149	Point Lobos, 5 miles west of <7>........		37 47	122 37	- - -	-0 10	- - -	-0 32	0.2	0.2	- -	- -	0.6	020	- -	- -	0.8	236
153	Point Lobos, 3.73 nmi. W of.............	46d	37 47.25	122 35.32	-2 14	-1 09	-1 10	-0 49	0.3	0.2	- -	- -	0.8	092	- -	- -	0.5	241
157	Point Lobos, 2.5 miles west of <7>......		37 46	122 34	- - -	+0 26	- - -	-1 26	0.3	0.5	- -	- -	0.9	080	- -	- -	1.7	269
161	Point Lobos, 1.3 nmi. SW of.............	46d	37 46.30	122 32.13	-1 24	-0 57	-0 23	-0 24	0.4	0.3	- -	- -	1.0	008	- -	- -	1.1	182
165	South Channel...........................		37 45	122 32	-1 29	-1 27	-1 04	-1 10	0.4	0.4	- -	- -	1.2	023	- -	- -	1.4	180
169	Point Lobos, 5.47 nmi. SW of............	39d	37 43.23	122 35.87	-1 59	-2 08	-1 41	-1 28	0.2	0.2	0.2	110	0.6	048	- -	- -	0.8	211
173	Bonita Channel approach <7>.............		37 50	122 37	- - -	-0 16	- - -	-1 14	0.2	0.2	- -	- -	0.5	061	- -	- -	0.6	290
177	Bonita Channel, off Tennessee Cove <7>..		37 50	122 34	- - -	-0 40	- - -	-1 14	0.4	0.2	- -	- -	1.1	112	- -	- -	0.8	325
181	Bonita Channel, off Point Bonita........		37 49	122 32	- - -	-0 28	- - -	-2 14	0.4	0.1	- -	- -	1.3	115	- -	- -	0.3	355
185	Point Bonita, 0.8 nmi. NE of............	22d	37 49.25	122 30.97	-4 49	-3 54	-5 11	-4 19	0.3	0.3	0.2	323	0.8	064	0.1	326	0.9	267
	...do...................................	41d	37 49.25	122 30.97	-5 10	-4 29	-5 35	-4 19	0.2	0.2	0.1	171	0.6	111	0.2	174	0.7	247
189	Point Bonita Lt., 0.4 nmi. SSE of.......	43d	37 48.72	122 31.27	-0 46	-1 06	-3 10	-1 13	0.1	0.4	- -	- -	0.3	104	0.1	162	1.4	229
	...do...................................	95d	37 48.72	122 31.27	-0 45	-1 05	-2 32	-1 28	0.2	0.4	0.2	100	0.6	086	0.3	174	1.5	222
	...do...................................	14d	37 48.72	122 31.27	-1 06	-1 10	-2 18	-1 43	0.2	0.4	0.2	120	0.6	060	0.1	141	1.4	220
193	Point Bonita, 0.95 nmi. SSE of..........	22d	37 48.07	122 31.13	-0 28	-0 38	-0 28	-0 51	0.7	0.8	0.1	146	2.1	072	0.5	142	2.6	239
	...do...................................	42d	37 48.07	122 31.13	-0 32	-0 38	-0 17	-0 46	0.7	0.6	0.2	144	2.1	072	0.3	159	2.2	243
	...do...................................	85d	37 48.07	122 31.13	-1 09	-0 28	-0 20	-0 05	0.6	0.4	0.2	161	1.8	069	0.2	009	1.4	232
197	Mile Rock Lt., 0.2 nmi. NW of...........	15d	37 47.72	122 30.68	-0 33	-0 31	-0 32	-0 51	0.8	0.8	0.4	143	2.5	063	- -	- -	2.6	230
	...do...................................	35d	37 47.72	122 30.68	-0 46	-0 34	-0 27	-0 52	0.9	0.7	0.5	135	2.5	054	0.1	340	2.3	231
	...do...................................	29d	37 47.72	122 30.68	-1 19	-0 11	-0 04	-1 01	0.5	0.4	0.1	308	1.5	035	- -	- -	1.5	247
201	Point Diablo, 0.2 mile SE of............		37 49	122 30	-0 07	-0 59	-1 37	-0 10	0.6	0.9	- -	- -	1.8	082	- -	- -	3.0	263
205	Baker Beach (South Bay), 0.3 nmi. NW of.	31d	37 47.87	122 29.31	-5 04	-4 21	-2 49	-3 10	0.4	0.3	0.2	113	1.2	038	0.2	161	0.9	208
	...do...................................	50d	37 47.87	122 29.31	-5 09	-4 20	-2 23	-3 12	0.3	0.2	0.1	120	1.0	043	0.2	162	0.7	215
209	Fort Point, 0.3 nmi. west of............	75d	37 48.55	122 28.97	-2 08	-0 47	+0 12	+0 02	0.5	0.2	0.6	342	1.4	044	0.2	101	0.7	335
213	SAN FRANCISCO BAY ENT.(S. of Pt. Diablo)		37 48.63	122 30.13	Daily Predictions						0.0	- -	2.9	065	0.0	- -	3.4	245

Figure 3-5 TABLE 2 Current Differences

tions are listed in TABLE 2, Current Differences & Other Constants of the **TIDAL CURRENT TABLES**; the appropriate page is reproduced as Figure 3-5 on page 3-12. Station No 141 has the nearest Lat/Long and is therefore the Substation chosen, its name and reference number are transcribed to the second line of §C.1 of the Worksheet.

4. Substations are grouped geographically and the ones in Figure 3-5 are "on" San Francisco Bay Ent. The Reference Station name, and the page number with the appropriate date, is transcribed to line C.1.

5. The principal information in TABLE 2 is the time difference of Slack, Flood, Slack, Ebb at the Substation compared to the Reference Station. These Time Differences are transcribed to §C.2. The Flood and Ebb Speed Ratios are given in the SPEED RATIOS column of TABLE 2 and Average Directions are given in the right hand column of TABLE 2. The appropriate numbers are transcribed to §C.3 Velocity Information.

6. The time of occurrence of the Slack, Ebb, Slack, Flood, Slack, Ebb, Slack, Flood-the cardinal points of the tide cycle at the Reference Station-is transcribed to §C.4.a).

7. Data for the Substation comparable to that for the Reference Station is developed in §C.4.b) by adding the appropriate Time Differences to the Reference Station times, and multiplying the SPEED (E/F) at the Reference Station by the SPEED RATIO in §C.3. In this particular illustration all of the time differences are -30^m, so 30^m is subtracted from each of the Time values in the Reference Station data to create the Substation Data. Ordinarily the time differences are not the same so care must be exercised in associating a time difference with the appropriate phase of the current.

8. Most of the Substation data that has been transcribed is transferred to the Tidal Current Chart which is an easier way to visualize what is going on. The Incident Time and the Datum Time are copied from §B. The Incident occurred at 0310 so the cardinal point in the current cycle that occurred immediately before LKP Time was the Slack at 0015. The next cardinal point is the Ebb at 0329, then the Slack at 0719, then the Flood at 1021. There is no interest in any of the other cardinal points because they occur either before the Incident or after Datum Time. There are three important Intervals, the one between the first Slack and Ebb-the Interval that contains the Incident-the one between the Ebb and next Slack, and the one between the second Slack and Flood-the one that contains the Datum. These Intervals are simply the difference

between the cardinal-point times, ie, the difference between 0329 and 0015 is 3^h 14^m, etc. The Chart is completed by adding tick marks to indicate time of the Incident and the time of Datum.

9. The only complication in marking up the Chart is knowing where to start. The Chart obviously does not cover the complete period of time covered in the Substation data. But it does cover at least 6 hours, and that is as long as the Incident is considered as Coastal/First Search. And 6 hours will never involve more than three quarter-cycles of the current. The job is to pick the appropriate quarter-cycle when the Incident Time and Datum Time occur.

10. On the back side of the Worksheet the time between the first *SLACK* and the *Incident*, and the time between the last *SLACK* and the *DATUM* are calculated and recorded. The Worksheet notes that these intervals are for the "Same Half-Cycle"; this is to assure that Ebb and Flood factor values are not mixed.

11. The sections labeled "FACTORS FOR THE FLOOD/EBB CYCLE (1)" and "FACTORS FOR THE FLOOD/EBB CYCLE (2)" are completed using TABLE A, Figure 3-6, Speed of Current at any Time. One section is used for *FLOOD* data and one section for *EBB* data. TABLE A shows the current as a fraction of the maximum current every 20^m between *SLACK* and the *DESIRED TIME* for several different values of *INTERVALS* between *SLACK* and *MAXIMUM CURRENT*.

12. The first quarter-cycle to deal with is the one that contains the Incident ie, the 3^h 14^m Interval between the 0015 *SLACK* and the 0329 *EBB*. The <u>column</u> in TABLE A nearest to that time interval is labeled 3^h 20^m; the <u>row</u> labeled 3^h 00^m is the row nearest to the amount of time between the 0015 *SLACK* and the *INCIDENT*. At the column selected, the numbers are read <u>down</u> from the row selected, and the numbers transcribed in the *EBB* Factors section. Note that in §C.6.b) the first column contains 1.0 and 1.0.

13. The second quarter cycle is fully experienced, and is still an *EBB* current. The total Interval is 3^h 50^m so the <u>column</u> headed 4^h 00^m is selected. All of the factors in this column are copied from the bottom up <u>except</u> the first one at 4^h 00^m; the first factor is not used because it is for the value at maximum *EBB* and that has already been entered in Step 12.

14. The third quarter-cycle is only partially experienced. The Interval is 3^h 2^m so the 3^h 00^m <u>column</u> is selected. The 20^m <u>row</u> is selected since the time between the 0719 *SLACK* and the *DATUM* is only 21^m, and only one factor is entered into the *FLOOD* Factors section ie, 0.2.

15. Each set of factor values is summed and divided by the number of factors to get the average factor value for each half-cycle. These two average factor values are multiplied by the maximum current speed, one for *EBB* and one for *FLOOD*, taking the speeds from the Substation information on the first page of the Worksheet.

16. The numbers generated in Step 15 are *Average EBB Speed* and *Average FLOOD Speed*. These numbers are multiplied by the amount of time the object is in the *EBB* and *FLOOD* currents and the results recorded in §C.8 of the Worksheet. In §C.9 the two vector expressions are completed by adding the Direction information copied from the Substation data recorded on the first page of the Worksheet.

TABLE A

Interval between slack and desired time	*Interval between slack and maximum current*													
	h.m. 1 20	*h.m.* 1 40	*h.m.* 2 00	*h.m.* 2 20	*h.m.* 2 40	*h.m.* 3 00	*h.m.* 3 20	*h.m.* 3 40	*h.m.* 4 00	*h.m.* 4 20	*h.m.* 4 40	*h.m.* 5 00	*h.m.* 5 20	*h.m.* 5 40
h. m.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.
0 20	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0 40	0.7	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
1 00	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3
1 20	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
1 40	—	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4
2 00	—	—	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5
2 20	—	—	—	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6
2 40	—	—	—	—	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7
3 00	—	—	—	—	—	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7
3 20	—	—	—	—	—	—	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8
3 40	—	—	—	—	—	—	—	1.0	1.0	1.0	0.9	0.9	0.9	0.9
4 00	—	—	—	—	—	—	—	—	1.0	1.0	1.0	1.0	0.9	0.9
4 20	—	—	—	—	—	—	—	—	—	1.0	1.0	1.0	1.0	0.9
4 40	—	—	—	—	—	—	—	—	—	—	1.0	1.0	1.0	1.0
5 00	—	—	—	—	—	—	—	—	—	—	—	1.0	1.0	1.0
5 20	—	—	—	—	—	—	—	—	—	—	—	—	1.0	1.0
5 40	—	—	—	—	—	—	—	—	—	—	—	—	—	1.0

Figure 3-6 Speed of Current at any Time

17. The two vectors must be added as vectors; that is simple in this example as the directions are exactly 180° apart. The smaller number can be subtracted from the larger, to determine the quantity of the resulting vector, and the direction of the larger taken for the resulting vector. This is recorded on the last line of §C.9 and then used for TWC on the Datum Worksheet.

18. There is one important check that can be made to determine if the correct number of factors has been considered. Each factor is for a 20^m interval, so there should be as many factors as there are 20^m intervals between the Incident and Datum. In this example there are 13 *EBB* factors and 1 *FLOOD* factor, for a total of 14. The total drift time is 4^h 30^m, or 270^m; this divided by 20^m is 13.5, which agrees with the number of factors considered.

Tutorial on use of Table A. Many students (and Instructors) have a problem understanding the use of Table A (Figure 3-6) to calculate the amount of displacement caused by the reversing tidal current. This tutorial is designed to help understand what is going on.

Tides have two characteristics that have to be considered to figure out what effect they have: the Period, and the Magnitude. An examination of Figure 3-4 shows that the Period varies all over the map, as does the Magnitude. Table A (Figure 3-6) is designed to accommodate every possible value of Period and Magnitude. The columns are for different Periods, ranging from 1^h20^m to 5^h40^m. The rows indicate the fraction of the maximum current, at Flood or Ebb, that occurs the indicated amount of time after the last Slack. The table assumes the current varies smoothly, and more or less sinusoidally, between Slack and Maximum, and between Maximum and Slack (but perhaps with a different Period). Both the rows and the columns are in twenty minute steps.

Figure 3-2a on the facing page is a redraw of the EBB CYCLE portion of the Tidal Current Chart of Figure 3-2 with the horizontal (x-axis) line representing Time in uniform intervals. Each 20^m is marked. Each dot on the curve represents the amount of current in that 20^m interval. The value of each dot is the Ebb speed (0.58 kt) multiplied by the appropriate factor. For instance the value of the dot for the interval between 0020 and 0040 is 0.2 x 0.58, or 0.11kt. Each of the dots is calculated this way. Note that the curve does not follow the dots exactly; this is not significant, and stems from the fact that the factors are tabulated only to the nearest 0.1kt.

Note that the curve between 0329 and 0719 is not the mirror image of the curve between 0015 and 0310; this shows the difference in

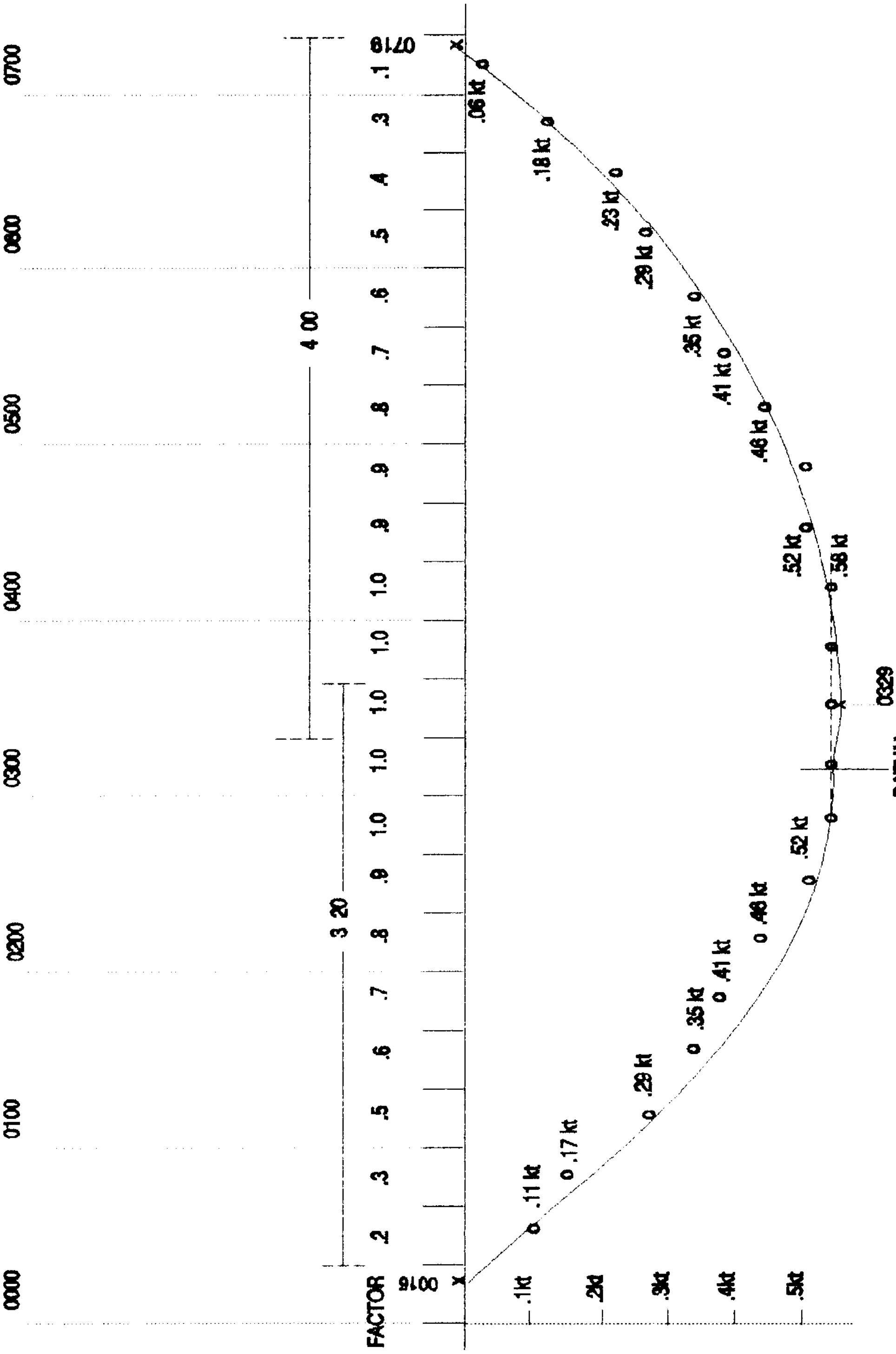

Figure 3-2a Reversing Tidal Example

the Period of the current in the different quarter cycles. Also note the overlap of the 20^m period exactly at the Ebb cardinal point. This explains why the first value of the quarter cycle following the Ebb cardinal point is not counted. The smoothed curve shows the value of the current (y-axis, kts) at any time between 0015 and 0719.

From this curve we can determine the displacement caused by the current during each 20^m interval. For each interval between Incident and the next Slack multiply the value of the current (shown in numbers printed horizontally) by the amount of time, ie, 20 minutes. All of these little displacements are added together to get the net effect of the (Ebb or Flood) tide. If this calculation is carried out, the total Ebb displacement is 1.78NM. The Ebb displacement calculated by the method on the Worksheet is 1.7NM; the agreement is well within the accuracy of either way of calculating the displacement.

Comments. This example doesn't generate a very large drift-so why bother? The example is designed to demonstrate the technique of calculating Reversing Tidal Current (TC); often the drift is larger. Even so, the example is not entirely unreasonable. If the incident is a PIW, this calculation would be vital. The incident occurs at night in a location with a 50% chance of dense fog, and it is very likely that the search would have to wait for daylight. With a PIW the principal component of drift would be TC.

Caveats. Although the calculations are detailed, the planner must interpret the results with caution.

1. The **CURRENT TABLES** are for average climate conditions. They accurately account for variations in the moon's declination (whereas the Tidal Current Charts do not), but they cannot predict the actual fresh water discharge. If there has been an unseasonable amount of rain in the Delta, the *EBB/FLOOD* ratios will be different than those in the **CURRENT TABLES**.

2. The Incident is rarely exactly at a Subordinate Station. The planner may have to modify the data in the **CURRENT TABLES** based on local knowledge.

3. The mechanics of doing the calculations make them prone to mistakes. That is one reason why a Worksheet is used; the mechanics can be checked by a second person.

4. The biggest source of error is in the handling of the Factors from TABLE A. The diagram at the bottom of the first page of the Worksheet is a time line; the Factors are read in the direction that time is passing. Another

hint: read down when going from Slack to Maximum, and read up when going from Maximum to Slack.

5. All of the *EBB* Factors are put together, and all of the *FLOOD* Factors put together; the two are not mixed.

6. In most cases the direction of *EBB* and *FLOOD* are not exact reciprocals, and the two vectors must be added using vector arithmetic.

7. Tidal currents in restricted areas, where tidal currents are the largest, are extremely sensitive to exact location. So if the Object experiences a tidal current for any appreciable amount of time it moves out of the area where the data applies. This complicates the problem greatly.

8. Some lines of data in the Current Differences and Other Constants have an "end note" marked <x>, where the "x" is the number of a special end note which modifies some aspect of the information. In the example given, end note #6 indicates that the tidal current is principally rotary, so the calculations are very suspect.

9. Many of the Substations indicate the depth of the current measurement, so many are of no use for an Object like a raft or a PIW. It is these kinds of uncertainties that are accommodated by using a 6NM Radius for the search area.

I. Leeway (LW). Leeway is the movement of the Search Object caused by the Wind acting on its exposed surface. Usually, Leeway is the largest drift component if the object is anything but a PIW. Because of its importance, the Coast Guard uses a specialized planning form: Leeway Worksheet (see page A-5,6 in Appendix A). As was done with TC, a fictitious problem is analyzed and the student should use a blank copy of the Leeway Worksheet and following the text step-by-step fill in the data. The completed page 1 of the Leeway Worksheet is shown in Figure 3-7.

As is true of all planning forms, the top line of the Leeway Worksheet has the Case Title, Planner's Name, and Date; this information simplifies the assembly of all completed planning forms in the case file. The Incident Summary-common to most of the planning forms-is transcribed to §A. The characteristics of the Search Object that are important for LW calculation are recorded in §B. In §C the synoptic wind history is recorded and the average calculated for the interval between Incident time and Datum time. The purpose of this section is to calculate a single value for Average Surface Wind (ASW) that can be used in further calculations instead of the multiple values of wind speed and direction that have actually existed. In §D the Leeway is computed using the Formulas in Table 3-1 or the Graphs in Figure 3-9.

The back side of the Leeway Worksheet, page A-6, has workspace for three situations that do not qualify for simple downwind leeway calculation: when there is Drift Rate Uncertainty, eg, is there a drogue?; Time Uncertainty, eg, when did the Incident actually occur?; or when Leeway Divergence must be used. In all three of these situations there are two LW calculations, hence the MINIMUM and MAXIMUM columns.

Note that the ILLUSTRATION SCENARIO covers a time period of over 15 hours, and hence does not qualify as Near Coastal with Drift Time ≤6 hours. But the purpose of the ILLUSTRATION is to demonstrate the technique, and multiple synoptic wind periods help to do that. In a real life incident, no more than two wind periods could ever be required because each is for a period of 6 hours.

1. §A of the Worksheet is completed using the data given in the SCENARIO. Local time is converted to Z(ulu) so that all Case information uses a common time reference; for Leeway much of the reported data may be in Local Time.

2. The Search Object Description in §B is in as much detail as the Search Target Type descriptions in Table 3-1.

3. The wind history from the SCENARIO is transferred to columns (B) and (C) of §C. The "day number" is added to the Reported Wind DTG column.

4. Synoptic winds are reported every six hours. Obviously the actual wind doesn't suddenly shift, but for analysis

LEEWAY ILLUSTRATION SCENARIO

LKP	37° 38'.4 N	122° 46'.1 W	
Incident	0320 Pac Daylight Saving Time Aug 20, 1992		
Datum	1845 Pac Daylight Saving Time Aug 20, 1992		
Search Object	32' cabin cruiser without drogue		
Wind History	200000 Z	220°	8.0 kt
	0600	250°	12.0
	1200	270°	10.0
	1800	240°	9.0
	210000	220°	11.0
	0600	240°	14.0

LEEWAY WORKSHEET

(rev. 5/31/91)

Case Title: C/C BLAZE Planner's Name: J. STRAKER Date: 20 Aug 92

A. Incident Summary

		MINIMUM		MAXIMUM	
1.	Latitude		N/S	37 38.4	N/~~S~~
2.	Longitude		W/E	122 46.1	W/~~E~~
3.	Surface Position DTG	Z		201020 Z Aug 92	
4.	Datum DTG	210145 Z Aug 92			
5.	Drift Interval		HRS	15.42	HRS

B. Search Object(s) 32' C/C w/o drogue

C. Average Surface Winds (ASW)

Reported Wind DTG	Wind Valid Period	Number of Hours (A)	Wind Direction (B)	Wind Speed (C)	Wind Contribution (B)/(AxC)
200000Z	2100 - 0300	0	220	8.0	/
0600Z	0300 - 0900	0	250	12.0	/
1200Z	1020 ~~0900~~ - 1500	4.67	270	10.0	270 / 46.7
1800Z	1500 - 2100	6.0	240	9.0	240 / 54.0
21 0000Z	2100 - ~~0300~~ 0145	4.75	220	11.0	220 / 52.3
0600Z	0300 - 0900	0	240	14.0	/
1200Z	0900 - 1500				/
1800Z	1500 - 2100				/
0000Z	2100 - 0300				/
0600Z	0300 - 0900				/
1200Z	0900 - 1500				/
1800Z	1500 - 2100				/
0000Z	2100 - 0300				/
	Total Hours	15.42		Total Wind Vector	242 / 143

Divide Total Wind Vector by total hours to get: ASW 242 °T 9.28 KTS

D. Downwind LEEWAY

1.	Average Surface Winds (ASW)		242 °T
			9.28 KTS
2.	Set (ASW Direction ±180°)		062 °T
3.	Formula (if used)		.07V+0.04
4.	Drift (LEEWAY SPEED GRAPH OR EXPONENTIAL FORMULA)		0.69 KTS
5.	Drift Interval		15.42 HRS
6.	Leeway (LW) Vectors	062 °T	10.6 NM

Figure 3-7 Leeway Illustration Worksheet p-1

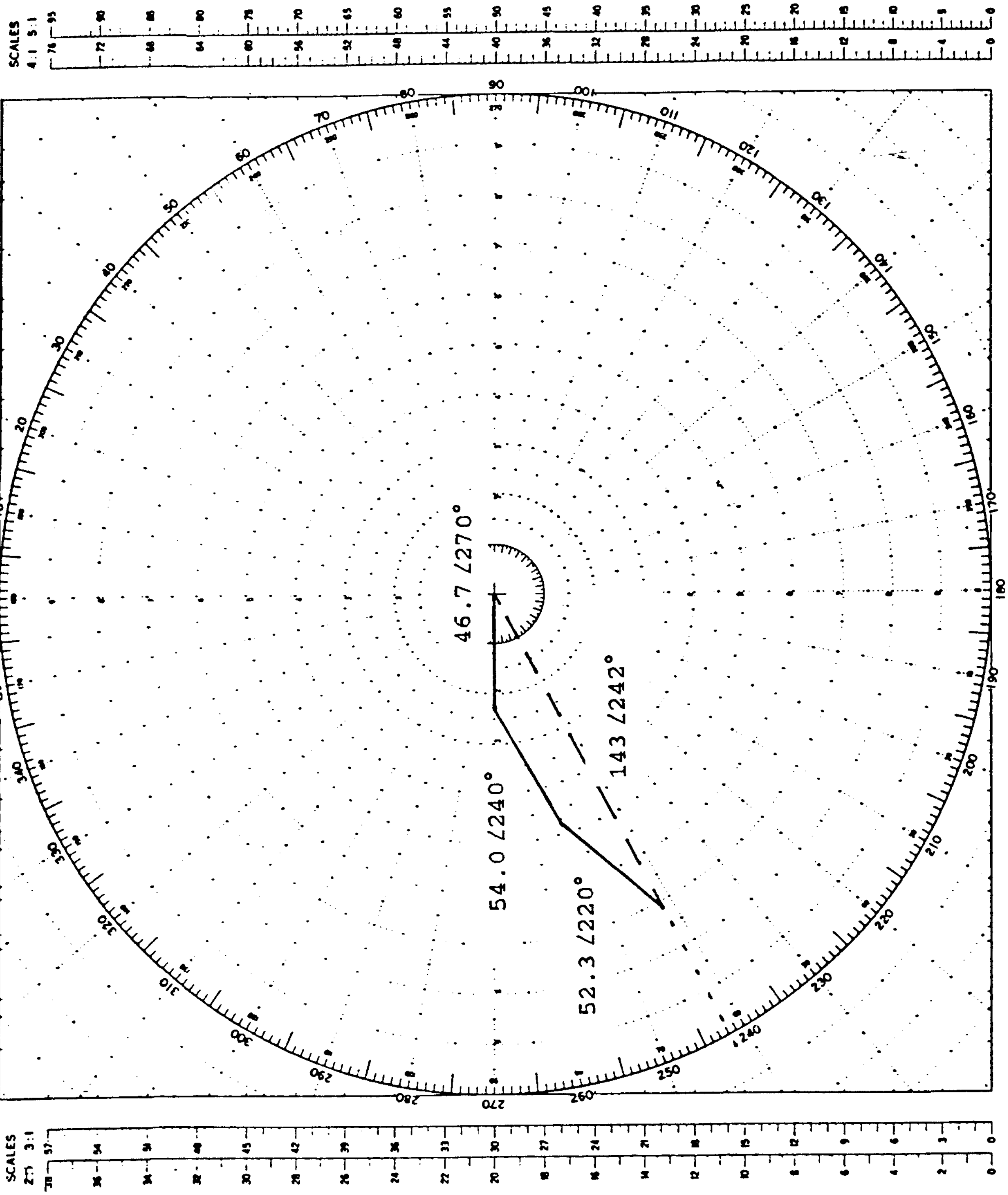

Figure 3-8 Leeway Illustration Wind Vectors

purposes the reported wind is assumed to be steady in amount and direction for the six-hour period that begins three hours before the report time, and extends to three hours after the report time. For instance, if the report is time-stamped 0600 it is assumed that the report is correct for the period between 0300 and 0900, etc.

5. The Wind Valid Period column includes all possible times and the Incident Time is marked by finding the Period during which the Incident occurred and replacing the beginning time for that period with the Incident Time. (The wind that occurred before Incident Time obviously has no effect on the Search Object's drift after the Incident.) In like fashion the Datum Time is recorded by striking out the time in the second half of the Wind Valid Period that is immediately after Datum Time.

6. The Number of Hours (A) column records the amount of the Wind Period that contributes to the Drift; the number in each row is the difference between the two sets of numbers in the Wind Valid Period that occur between the time of the Incident and Datum. This is the way the different periods of wind are weighted for their effect on the Search Object. In the ILLUSTRATION, the incident occurs at 1020, thus the amount of the 0900-1500 period that can cause Leeway is the difference between 1500 and 1020, ie, $4^h\ 40^m$, or 4.67^h.

7. All of the Period between 1500 and 2100 is at work on the Search Object so 6.0 is entered into column (A). Only a portion of the next Wind Valid Period is applicable, the period between 2100 and Datum Time 0145 (next day). Thus the Number of Hours (A) is 2545-2100 or $4^h\ 45^m$, or 4.75^h.

8. The Total Hours at the foot of column (A) must be the same as the Drift Interval in §A.5 at the top of the Worksheet.

9. The Wind Contribution column is a column of vectors, the first part is the direction, and the second part is the amount. The direction is copied from Column (B); the quantity part is the *hours* in column (A) multiplied by the *knots* in column (C). These numbers are Wind Contribution displacement vectors (they are displacement vectors because Time has been multiplied by Speed), and must be summed by vector arithmetic in order to get a Total Wind Vector. Figure 3-8 shows the graphical method of adding these three vectors; the sum is a vector 143 units long, in the direction of 242°. This is the Total Wind Vector. Note that a scale of 20:1 is selected so that the plot stays on the chart yet still uses most of it.

10. Since the Total Wind Vector is a displacement vector, the quantity part is divided by the Total Hours to get an Average Surface Wind <u>speed</u> vector; the direction component of the vector is unchanged. In the ILLUSTRATION, the ASW is 9.28 kts from 242°. This is the value and direction of a wind that would have the same effect on the Search Object as the actual winds it experienced during the 15.42^h of drift.

11. In §D Downwind Leeway is calculated. Line 1 is simply a repeat of ASW; Line 2 is the SET, 180° different than the

SEARCH TARGET TYPE	LEEWAY SPEED FORMULA U = WIND SPEED	LEEWAY DIVERGENCE ± degrees
1- *Light displacement cabin cruisers, outboards, rubber rafts**, etc. (without drogues)	0.07U +0.04	35
2- *Light displacement cabin cruisers, outboards, rubber rafts**, etc. (with drogues)	0.05U - 0.12	35
3- Large cabin cruisers	0.05U	60
4- Medium displacement sailboats, fishing vessels, eg, trawlers, tuna boats, etc.	0.04U	60
5.- Heavy displacement deep draft sailing vessels	0.03U	45
6- Surfboards	0.02U	35

NOTES

* Do not use these formulas for values of U below 5 knots.

** These formulas and the leeway speed chart apply to rafts without canopies or ballast system. Some rafts may be modified with either canopies or ballast systems or both. Use the following guidelines:

a. Rafts with canopies and ballast pockets: Leeway speed is approximately the same as rafts without.

b. Rafts with canopies (no ballast pockets) have leeway speeds approximately 20% faster than rafts without.

c. Rafts with ballast pockets (no canopies) have leeway speeds approximately 20% slower than rafts without.

d. Rafts with canopies and a deep ballast system have uncertain leeway speeds. Speeds approximate that for rafts with drogues. The minimum leeway speed is 0 for winds of 0-5 kts, and 0.1 kt for winds greater than 5kts. For deep ballast rafts where the canopy does not deploy, the leeway speed falls between 0-3% of wind speed.

e. Circular Rafts and Circular Rafts with Deep Ballast Systems are considered a special category with divergence of 15°. If there is doubt as to the raft type, OR if the ballast pocket(s) are asymetrical to the center axis of a circular raft, this category should not be used.

Table 3-1 Leeway Speed Formulas

direction of the ASW. On line 3, the formula from Table 3-1 for the Target Type that corresponds to the Search Object is copied, and in line 4, the Drift rate is calculated by applying the ASW amount to the formula. Line 5 is a copy of the Drift Interval from §A.5. Line D.6 is the resulting LW vector; the amount is the product of the Drift Rate (0.69 kts) multiplied by the Drift Interval (15.42^h) with a Direction of the Set.

12. If the planner is diffident about arithmetic he can use the Graphs in Figure 3-9 instead of the formulas; he selects the proper curve and reads the Leeway speed for the calculated ASW wind speed. The curves are numbered to correspond to the Target Type descriptions in Table 3-1. In general it is better to use the formula rather than a curve as it is much easier to check the work.

13. With this long drift time the planner would ordinarily use divergence instead of downwind Leeway, but this fictitious ILLUSTRATION specified downwind Leeway only. In almost all cases that would involve the Auxiliary the drift time would be $\leq 6^h$, so divergence would not be used in planning the Drift.

14. As a fun exercise, complete the third situation on the back side of the Leeway Worksheet using the 35° divergence for a Type 1 Target, and calculate how far apart the two LW vectors are. (Answer-slightly over 12NM)

<u>Caveats</u>. The Leeway Worksheet is less susceptible to errors than the Reversing Tidal Current Worksheet, but some precautions must be observed.

1. The Date/Time/Group used are all Z(ulu) time zone, and conversion from local time, especially Daylight Saving Time-as might be reported on the Incident Sheet-must be done accurately.

2. If the Search Object is a type whose Leeway Speed is modified by a drogue, and the planner does not know whether the Search Object has a drogue or not, it is necessary to use the reverse side of the Leeway Worksheet and calculate <u>two</u> Leeway vectors, one for the Object with a drogue and one for the Object without a drogue.

3. The Total Wind Vector is always the <u>vector</u> sum of the Wind Contribution vectors; it is <u>not</u> the arithmetic sum of the quantity parts and the average of the direction parts of the Wind Contribution vectors.

4. The wind is <u>always</u> reported <u>from</u> (whereas current and drift are reported <u>to</u>). The same value of ASW is used

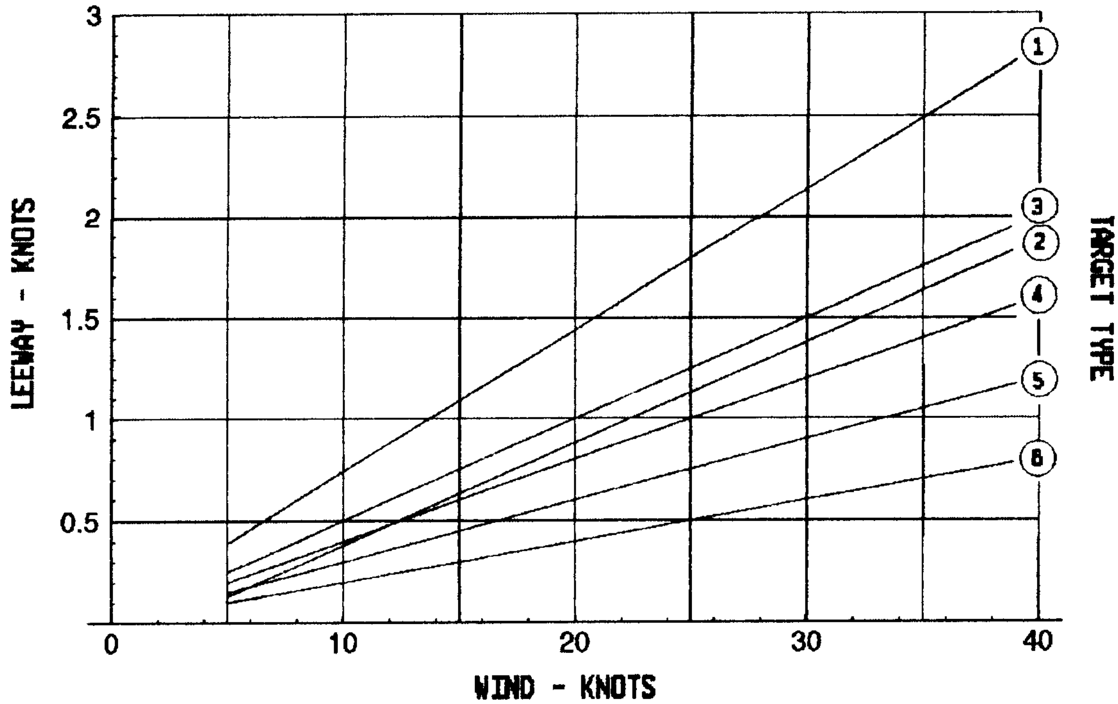

Figure 3-9 Leeway Speed Graphs

when divergence has to be considered; one Leeway vector has a direction of the reciprocal of the ASW *plus* the divergence angle, and the other Leeway vector has a direction of the reciprocal of the ASW *minus* the divergence angle.

5. A curious student may ask "Displacement of What?" when the Wind Contribution Vectors are called "displacement" vectors. Since the Hours in column (A) are multiplied by the Knots in column (C) the product must be Nautical Miles. What this represents is the distance a balloon would travel if released exactly at the Incident Time and if it experienced the three values of wind amount and direction represented by the three vectors. So the displacement is "of" a chunk of air that experiences the actual wind.

J. Datum. Having determined the values of all of the vector forces that move the Search Object, these displacements are combined to determine Datum. It is customary to combine all of the currents into one Total Water Current vector and then add the Leeway vector. The reason for this "custom" is because in all cases where drift time is >6 hours (>4 hours for Open Ocean) there are at least two Leeway vectors. In such cases the TWC is the same, but is added to two different LW vectors. When there is only one LW vector it is not necessary to compute a TWC; the various Current vectors can be added to the LW vector at one time. The vector addition can be done on a maneuvering board (or Vector Worksheet) or the vectors can be plotted directly on a chart.

The planning form, Datum Worksheet (see pages A-7,8 in Appendix A), is designed to record most of the information that is worked up to determine Datum. In order to demonstrate its use a fictitious DATUM ILLUSTRATION SCENARIO is used; the process should be followed step-by-step by the student working with a blank Datum Worksheet.

1. The heading information at the top of the Datum Worksheet is slightly more elaborate than on the other Worksheets. The planner plots the LKP to determine the "Surface Position Desc(ription)". Since the Incident is obviously a Distress, he can then assign assistants to alert the nearest Station to prepare for a SAR mission.

2. If the first search does not find the Search Object and a second search becomes necessary a new Datum must be calculated since the Datum Time for a second search will be much later. Therefore the heading includes the information on which Datum number and which Search Plan is being worked out on this particular Worksheet. In the DATUM ILLUSTRATION SCENARIO this is the Worksheet for Datum #1 and Search Plan A.

3. §A is not applicable to this Incident since this is a vessel Incident. §B contains the Incident information (from the SCENARIO). Note that the TARGET is identified

DATUM ILLUSTRATION SCENARIO

LKP	37° 42'.1 N 122° 44'.5 W
Incident	0042 Pac Daylight Saving Time Aug 10, 1992
Datum	0600 Pac Daylight Saving Time Aug 10, 1992
Search Obj	4-man Raft 2 POB
Weather	Vessel experienced winds >25 kts from 275° before foundering.
Report	Radio call from F/V Duncan Ross, foundering, crew escaping in 4-man raft, no VDSD, LORAN position.

as a "Raft w/o canopy" but the SCENARIO does not state if the raft has a canopy or not. This is the Planner's first guess!

4. §C contains the Planner's second guess, ie, what Datum Time should he use for the search plan? Taking into account the size of the Search Object, the sea state (winds >25 kts), and the lack of night visual aids he concludes that the search should commence at first light, 6AM PDST. This decision determines the Drift Interval recorded in §C.2.

5. §D has provision for five different currents. For the SCENARIO assume a TC vector of 2.1NM at 240° (§D.2) and a SC vector of 0.6 kts at 331° (§D.3), (Worksheets are not included). The displacement SC vector is calculated (Drift, §D.3.c multiplied by Drift Interval, §C.2) and entered in §D.3.d.

6. The TWC can now be computed as shown in Figure 3-12. The Datum Worksheet does not have a blank line for TWC; in the ILLUSTRATION §D.5 is used to record TWC.

7. The ILLUSTRATION SCENARIO assumes a LW vector of 9.7NM at 095°, (Worksheet not included).

8. The Total Surface Drift, §F, is computed as illustrated in Figure 3-12. However, §G requires that the data be plotted on a chart so the Lat/Long of the Datum can be determined.

Caveats. There is really no point in doing the work shown in Figure 3-12; it might just as well be done on the chart in the first place. Whenever a vector is a displacement vector applicable to the Search Object, the vector can be plotted on the chart; only speed vectors cannot be charted but must be worked out on a maneuvering board or Vector Worksheet.

1. The Datum Worksheet has places to record the source of the information the planner is using. §D.1 is a place for Observed Total Water Current; the source of the information is important to determine its reliability and accuracy. For example, a D(ata) M(arker) B(ouy) is a much more reliable source than a report from a local fisherman.

2. The information source for §D.3 is the Coast Pilot and L(ocal) K(nowledge). The area where the incident occurs has a great deal of traffic that can report on actual local conditions. The Planner would undoubtedly issue a UMIB, and also request information on sea conditions from anyone transiting the area.

DATUM WORKSHEET
(rev. 5/31/91)

Case Title: F/V Duncan Ross Planner's Name: W. Morris Date: 10 Aug 92

Surface Position Desc: 53NM SW GG Datum #: 1 Search Plan: (A) B C ___ CIRCLE ONE

A. Aerospace Drift (d_a)

1. Bailout Position — Latitude ______ N/S; Longitude ______ W/E
2. Bailout Position DTG ______ Z ______
3. Total Vector from Aerospace Worksheets ______ °T; ______ NM

B. Position Where Surface Drift Will Start

	MINIMUM	MAXIMUM
1. Surface Position from Aerospace Worksheets, Last Known Position/Incident Position, Previous Datum (non-minimax), Previous D_{min} and D_{max} Positions. TARGET(S)	______	Raft w/o canopy
2. Time	______ Z ______	100742 Z Aug 92
3. Latitude	______ N/S	37 42.1 N/~~S~~
4. Longitude	______ W/E	122 44.5 W/~~E~~

C. Datum Time

1. (Commence Search Time/Mid-Search Time) 101300 Z Aug 92
2. Drift Interval ______ HRS 5.3 HRS

D. Total Water Current

1. Observed Total Water Current (TWC)

		MINIMUM	MAXIMUM
a.	Source (DMB, debris, oil)	______	
b.	Set	______ °T	______ °T
	Drift	______ KTS	______ KTS
c.	TWC Vector	______ °T	______ °T
	Direction from above and Drift x Drift Interval	______ NM	______ NM

	MINIMUM	MAXIMUM
2. Tidal Current Vector	______ °T	240 °T
Use Substations of Both positions If drifting from D_{min} and D_{max} (Attach Tidal Current Worksheet)	______ NM	2.1 NM

Figure 3-10 Datum Illustration Worksheet p-1

	MINIMUM		MAXIMUM	
3. Sea Current (SC)				
a. Information Source			Coast Pilot ≠ LK	
b. Set		°T	331	°T
c. Drift		KTS	0.6	KTS
Use lat/long of both positions if drifting from D_{min} and D_{max}				
d. Sea Current (SC) Vector		°T	331	°T
Direction from above and **Drift x Drift Interval**		NM	3.18	NM
4. Wind Current (WC)				
Wind Current (WC) Vector		°T		°T
Use Latitude of both positions if drifting from D_{min} and D_{max}		NM		NM
(Attach Wind Current Worksheet)				
5. ~~Other~~ Total Water Current				
Use information for both positions		°T	297	°T
if drifting from D_{min} and D_{max} (Attach Other Water Current Worksheet)		NM	3.75	NM
E. Leeway (LW)				
1. Leeway (LW) Vector		°T	095	°T
(Attach Leeway Worksheet)		NM	9.7	NM
F. Total Surface Drift (d_{min} and d_{max})				
From Chart, UPS, or calculator				
1. Direction		°T	082	°T
2. Distance		NM	6.4	NM
G. Datum (D_{min} and D_{max})				
1. Latitude		N/S	37 43.1	N/~~S~~
2. Longitude		W/E	122 36.4	W/~~E~~
H. Distance between D_{min} and D_{max}				NM
I. $Datum_{minimax}$				
1. Latitude				N/S
2. Longitude				W/E
3. $Datum_{minimax}$ DTG			Z	
4. Direction from SP to $Datum_{minimax}$				°T

Figure 3-11 Datum Illustration Worksheet p-2

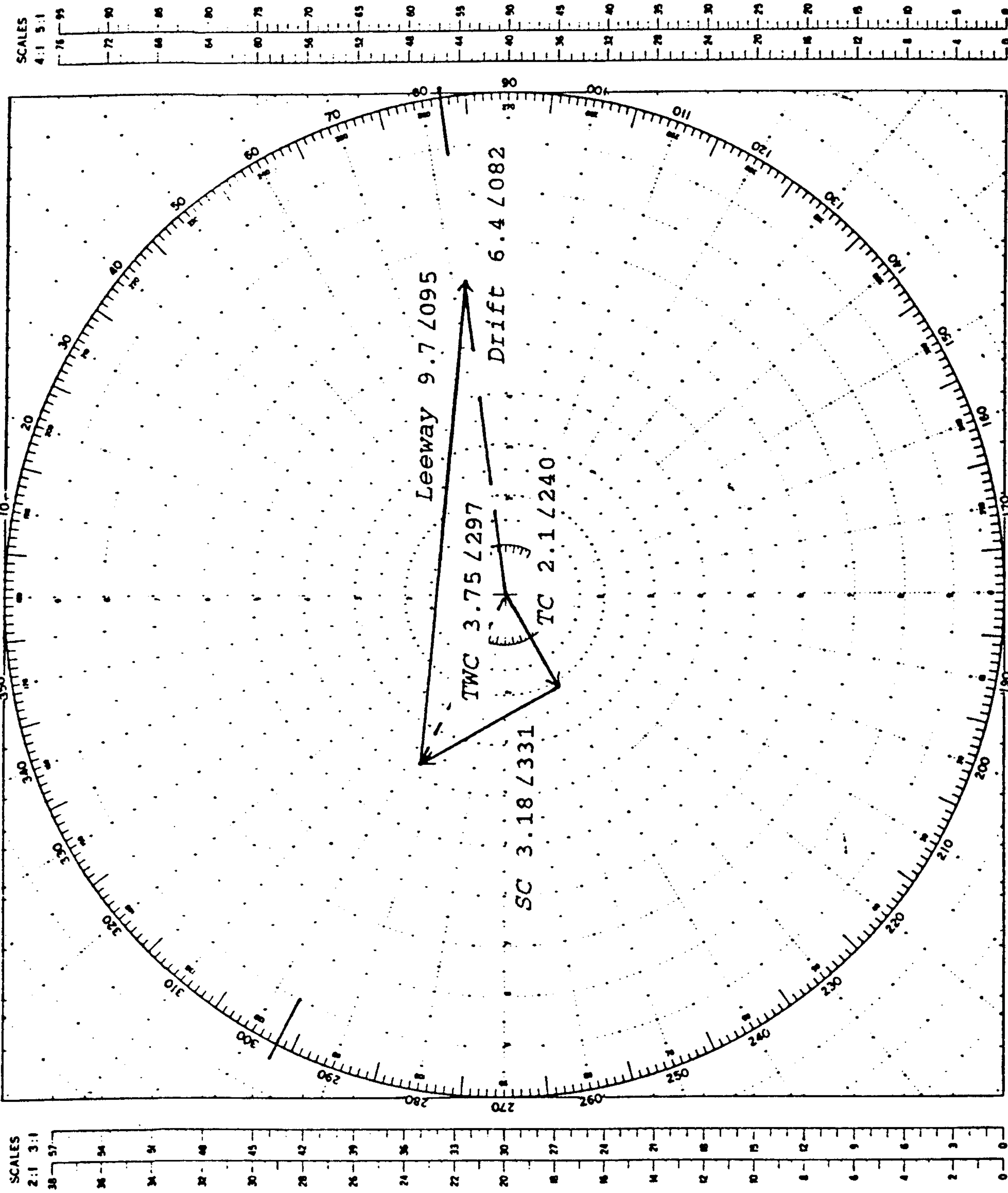

Figure 3-12 Datum Illustration Vectors

K. Search Area. There is a dedicated Search Area Worksheet (pages A-9,10 in Appendix A) but it is not very applicable to Near-Shore First Search ≤6 Hours. In this case the Search Area is defined as an area having a Radius of 6NM centered at the computed Datum. Since Search Rescue Units cannot search circular areas very systematically, the circular search area is "squared off" with two sides parallel to the Drift direction. Thus the standard Search Area is 144 NM^2.

The SEARCH AREA ILLUSTRATION SCENARIO is the same as that used for Datum. Figuring out the Search Area is done using a large-scale chart of the local area.

1. The ILLUSTRATION is plotted on the chart shown in Figure 3-13. The printing process makes it difficult to show the chart properly, but the LKP, the TWC vector, and the Datum position are clearly marked. (The "notation", ie, the charting symbols used, are the standard used by SMCs). In the example, the Search Area is about 12NM^2 less than 144 because the Search Area overlaps the land. This is not at all unusual, and is one of the reasons why the Search Area is always plotted on a large-scale chart.

2. In the case of Open Ocean, or Near Coast with more than 6^h elapsed time, the Search Area determination is much more complicated. Even more complicated is Asset Allocation, ie, what Resources to use, and what fraction of the total Search Area will be assigned to each. Since these examples have dealt only with Near Coast it is usually not necessary to complete a formal Asset Allocation Worksheet, and the Search Area description is included in the Remarks section of the Search Area Worksheet. The corners (that are offshore) are noted, and possibly the route that is assigned to the SRU that is dispatched.

4. Asset Allocation does not receive much attention in this text because it is rarely a problem in Near Coast cases. In this ILLUSTRATION the SMC would probably dispatch a 82-ft Patrol Boat to arrive at Datum at first light, and a helo to arrive at LKP at first light. Coast Guard experience has shown that the SRU should go first to LKP, then to Datum, and then proceed with its assigned search pattern. A helo is much the best search platform but a boat is necessary for rescue. In addition, it is a safety measure to have a boat in the vicinity of a helo operation in case the helo experiences difficulty.

L. D_{MIN} and D_{MAX}. The Datum example illustrates how the incident information can result in two datums. The call to the Coast Guard was fairly complete, but it didn't indicate if the raft had a drogue or not. Note that the Datum Worksheet has room

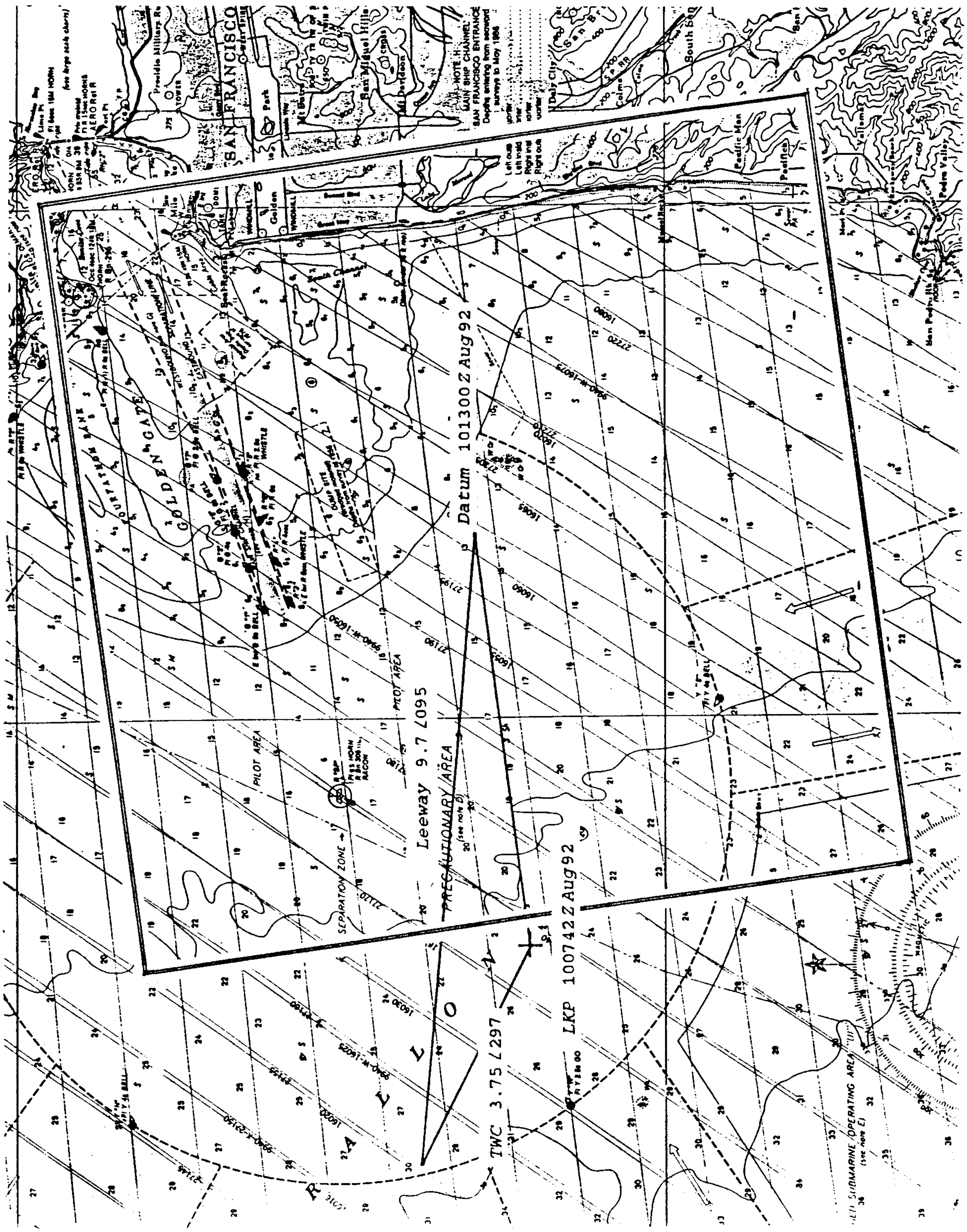

Figure 3-13 Datum & Search Area Illustration

for two sets of calculations, one labeled MINIMUM and one labeled MAXIMUM. For example, the SMC can plan for two different Leeways; he does this by using the Drift Rate Uncertainty (page A-6) instead of §D on the first page of the Leeway Worksheet. He calculates the Minimum Leeway by assuming the raft has a drogue, and calculates the Maximum Leeway by assuming the raft does not have a drogue. In the Datum example this results in two Drift vectors and thus two Datums. The Drift vector in the DATUM ILLUSTRATION SCENARIO is 6.4NM in the direction of 082°. If the raft has a drogue its LW is only 6.14NM and the Drift becomes 3.1NM in the direction of 068°. Thus there are two Datums, and the 6NM radius is drawn around each and the combined circles squared off as shown in Figure 3-14. Note that the search area is now larger (187NM^2), and the orientation of the axis slightly different.

In the Coastal cases with multiple Datums the Search Area is determined by a 6NM radius around each Datum and the circles squared off. In Open Ocean cases there may be several possible Datums; the one that is farthest from the LKP is defined as D_{MAX} and the one that is nearest the LKP is defined as D_{MIN}; the position half way between the two is defined as $D_{MIN-MAX}$. The Search Area is specified from that reference Datum.

M. Computer Assisted Search Planning (CASP). It is obvious that a considerable amount of Search Planning is tedious number crunching that could be done on a computer rather than by hand. In addition the latest phase of CASP program development includes the capability of calculating POA, a process that is essentially impossible manually. CASP is a system with remote terminals at each RCC; although in existence for a few years, CASP, historically, has not been much used. In 1991 a major effort was undertaken to make CASP more effective, and to assure its use (and subsequent evaluation and improvement) the Coast Guard now <u>requires</u> that CASP be used whenever:

1. The incident is outside the 30 fathom line, <u>or</u>

2. The duration of the incident has or could have exceeded 24 hours, <u>or</u>

3. There is uncertainty concerning the incident time, incident location, type of search object(s) involved, etc.

CASP is used by search planners to identify probable search areas and plan resource allocation. It is supplied with the search object's characteristics and the uncertainties of the case; CASP uses this information together with on-line environmental databases to simulate drift. After drift simulation, CASP calculates probabilities for different search

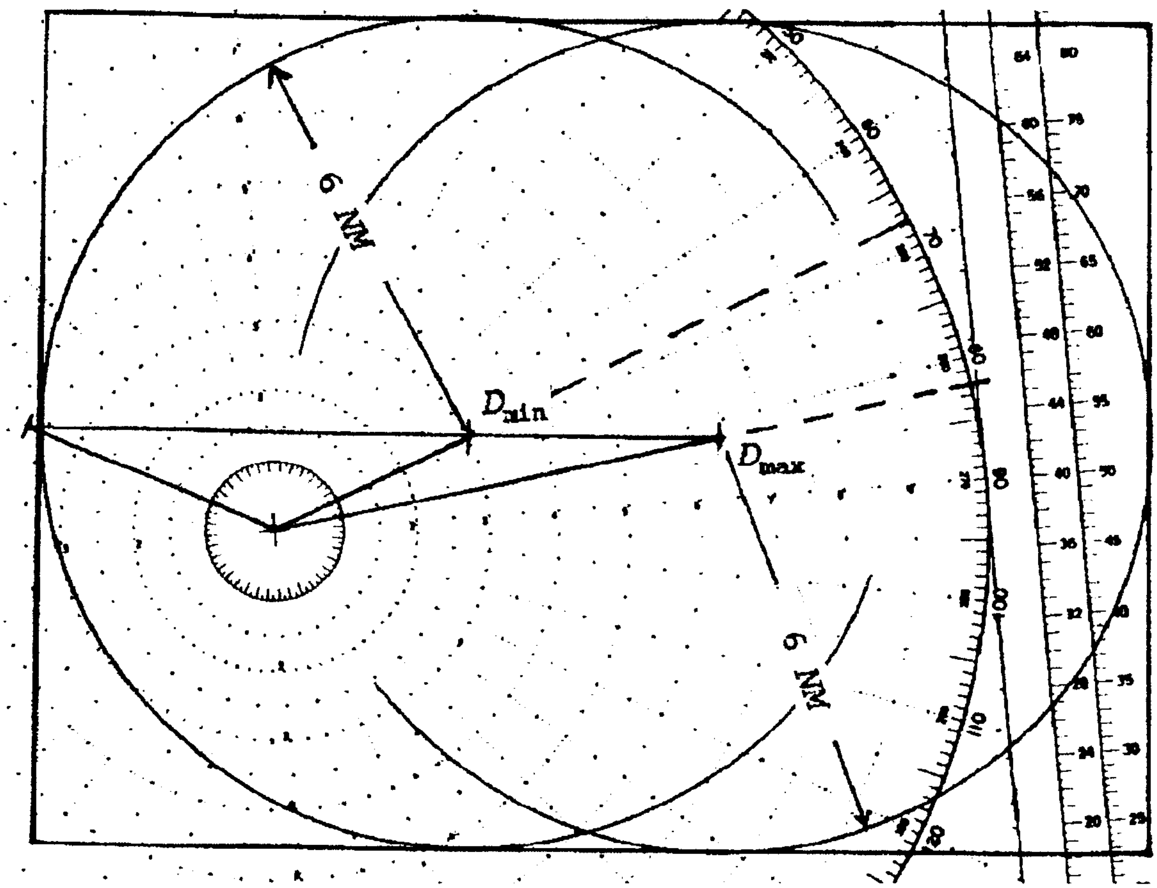

Figure 3-14 D_{MIN} and D_{MAX} Example

areas, platforms and patterns. The goal of all search planning is to maximize POS, rather than POD.

The Coast Guard policy that <u>requires</u> that CASP be used really means that data must be entered into CASP when the incident meets the criteria. As with any other information that bears on a distress incident, it is the SAR planners responsibility to decide what information to use.

N. Open Ocean. Searches in the open ocean are of no practical interest to Auxiliarists; however, having mastered coastal waters search planning the Auxiliarist might think it not to difficult to master the open ocean case. In point of fact it requires a degree of sophistication beyond the scope of this course.

Note: The Chart from which Figure 3-13 was prepared reprinted by permission of International Sailing Supply.

REVIEW QUESTIONS

1. When is Search Planning necessary?

2. What is the purpose of Search Area Planning?

3. Referring to Figure 3-1 which column is used for First Search, Coastal Waters, Drift time > 6 hours?

4. Referring to Figure 3-1 which column is used for Second Search, Coastal Waters, Line/Area LKP?

5. Referring to Figure 3-1 which column is used for First Search, Enclosed Waters, Drift Time ≤ 6 hours?

6. When is Drift Rate Uncertainty used in Leeway calculation?

7. What is the Search Area Radius for a First Search, Coastal Waters, Drift Time ≤ 6 hours?

8. Define LKP.

9. Define Open Ocean.

10. Define TWC.

11. Define TC.

12. Define LW.

---

13. Define Vector.

---

14. Use a Tidal Current Worksheet and work out the Total Reversing Tidal Current Vector. Use the Tidal Current Tables in the Text.

LKP 37° 45'.0 N   122° 32'.0 W
Incident Time   261420 Z Aug 92
Datum Time   262100 Z Aug 92

---

15. Use a Tidal Current Worksheet and work out the Total Reversing Tidal Current Vector. Use the Tidal Current Tables in the Text.

LKP 37° 49'.0 N   122° 30'.0 W
Incident Time   262105 Z Sep 92
Datum Time   270400 Z Sep 92

---

16. Is the Tidal Current calculation not very accurate, moderately accurate, or very accurate?

---

17. Use a Leeway Worksheet and work out the Leeway Vector.

Object: Medium Displacement Fishing Vessel "PROBLEM 17"
LKP 37° 40'.0 N   122° 45'.0 W
Incident Time   131340 Z Aug 92
Datum Time   132300 Z Aug 92
Synoptic Winds:

130000 Z	265°	18.0kt
130600 Z	270°	15.0
131200 Z	295°	10.0
131800 Z	180°	5.0
140000 Z	260°	11.0

---

18. Use a Leeway Worksheet and work out Leeway Vectors.

Object: Raft (with drogue) & Raft (without drogue).
LKP 37° 41'.0 N 122° 46'.0 W
Incident Time 092106 Z Jul 92
Datum Time 100518 Z Jul 92
Synoptic Winds:

090000 Z	260°	10.0kt
090600 Z	220°	7.0
091200 Z	180°	5.0
091800 Z	240°	10.0
100000 Z	270°	15.0
100600 Z	290°	11.0

---

19. Use a Datum Worksheet and Maneuvering Board and work out the TWC and Total Surface Drift.

Object: Raft (with drogue) & Raft (without drogue)
LKP 37° 42'.0 N 122° 44'. 0 W

Data previously worked out:

Tidal Current Vector	2.3NM ∠220°
Sea Current	0.4kt ∠320°
Average Surface Wind	24kt ∠280°

Incident Time 202200 Z Sep 92
Datum Time 210330 Z Sep 92

---

20. Use a Datum Worksheet and Maneuvering Board and work out TWC and Total Surface Drift.

Object: Raft (with drogue) and Raft (without drogue)
Drift Time 5 hours
TWC 1.1kt ∠042°
Leeway w/drogue 1.2kt ∠163°
Leeway wo/drogue 1.8kt ∠163°

---

21. What is the normal Search Area for a Coastal Model First Search?

---

22. Under what circumstances might the Search Area for a Coastal Model First Search be <u>less</u> than 144NM^2?

---

23. What does CASP stand for?

---

24. When is CASP used?

---

25. Why is the TWC, LW and Datum plotted on a large scale chart?

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CHAPTER 4 SEARCH OPERATIONS PLANNING

A. Introduction. The goal of search operations planning is to maximize the probability of success. As indicated earlier in this text the *PROBABILITY OF SUCCESS (POS)* is the product of the *PROBABILITY THAT THE TARGET IS IN THE SEARCH AREA (POA)* multiplied by the *PROBABILITY OF DETECTING THE TARGET (POD)*. Chapter 3 has reviewed the various algorithms used to determine the Search Area; this Chapter will review the statistics of detecting the target. In the final analysis the SMC has to balance the constraints imposed by the system-how many SRUs he has available and the characteristics of the incident-to maximize the *POS*. For most incidents confronting Auxiliarists the balance is not very complicated because of the near-coast parameters of nearly all of the incidents in which the Auxiliary is involved. However, in order to present a complete picture of the planning process the comments in this Chapter are not limited to the near-coast environment.

B. Probability of Detection *(POD)*. The probability that the target will be detected, if it is in the search area, depends on several factors. One that is assumed is an accurate target description; this influences both the search area plan and the probability of detection. For example, if the target is a boat, has it capsized? A capsized boat is an entirely different target than one that is still upright-its drift is different, and it looks different. The accuracy of target description depends on the detective work and imagination of the SMC, and not on any algorithm or formula.

The parameters that can be handled by "planning" are those that are formal, ie, those that assume the parameters that depend on intuition and judgement are correct. There are two such formal parameters that influence probability of detection.

1. Track Spacing *(S)*. It is obvious that the closer two successive search courses are, the greater the chance that the target will be seen. It is equally obvious that the closer together the courses are, the longer it takes to cover the search area. In order to calculate the effect of track spacing, it has to be defined and quantified. Figure 4-1 shows the definition of Track Spacing; Track Spacing *(S)* is the distance between two adjacent parallel legs. It directly influences target detection.

   The method of selecting *S* depends on the decision path followed in Figure 3-1. For Near-Coastal First Search where a "standard" radius is used, a "standard" Track Spacing is also used. In every other scenario, the SMC selects *S* to achieve his desired final result. Table 4-1 shows the "standard" track spacing used for the Near-Coastal First-Search model.

Search Object	Good Conditions wind < 15 kts or seas < 3 ft	Poor Conditions wind ≥ 15 kts or seas ≥ 3 ft
PIW	0.1*	0.1*
< 15 ft & rafts	0.5	0.2
≥ 15 ft	1.0	0.5

* > 0.1 up to SRUs minimum ability to navigate

Table 4-1 Coastal First-Search Track Spacing (NM)

2. Area Coverage. Although not strictly a parameter, the Time it takes to cover the search area is an important number used in search planning. It requires a decision on the Speed of the SRU, and hence a selection of a SRU type. This is often not a difficult decision, as in a real Distress case the SRU is almost always an aircraft; it is a helo near coast and a fixed-wing off shore. The area covered is expressed by the equation

$$A = V \cdot S \cdot T$$

where A is the area searched in NM^2, V is the speed of the SRU in knots, S is the Track Spacing in NM, and T is the Search Time in hours. This aspect of Search Operations Planning shows the transcendental nature of search planning; the SMC must estimate T before he can determine Drift since he will usually use mid-search time as Datum Time. For near-coastal searches the Area is known-$144NM^2$ and either T or S is

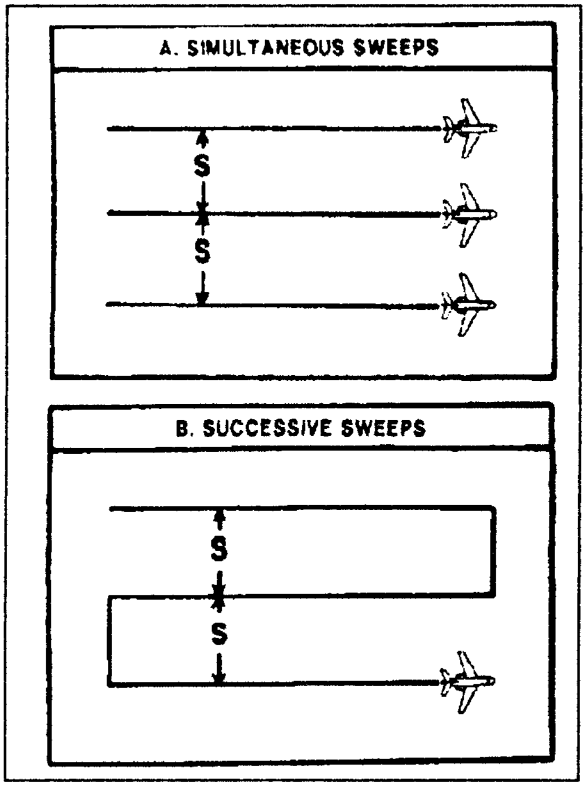

Figure 4-1 Track Spacing

the unknown. If *T* is the limiting factor, eg, the hours of daylight remaining, solve for *S*, otherwise select *S*, from Table 4-1, and solve for *T*.

3. Sweep Width is defined as *"the distance on both sides of the SRU where the probability of detecting a target at a greater distance is just equal to the probability of missing a target at a lesser distance"*. The term "Sweep Width" is, in many ways, an unfortunate choice of name; it might better be called "Detection Width". Whatever called, it is the most important parameter used in search operations planning. Figure 4-2 illustrates graphically the definition of Sweep Width. Most of the variables that determine Sweep Width have been measured by experiment, and tables generated for SMCs to use. These tables-explained later in this Chapter-tabulate an "Uncorrected Sweep Width"; this number is "corrected" by general condition factors to generate a "Corrected Sweep Width". It is the Corrected Sweep Width that is used in Search Operations Planning.

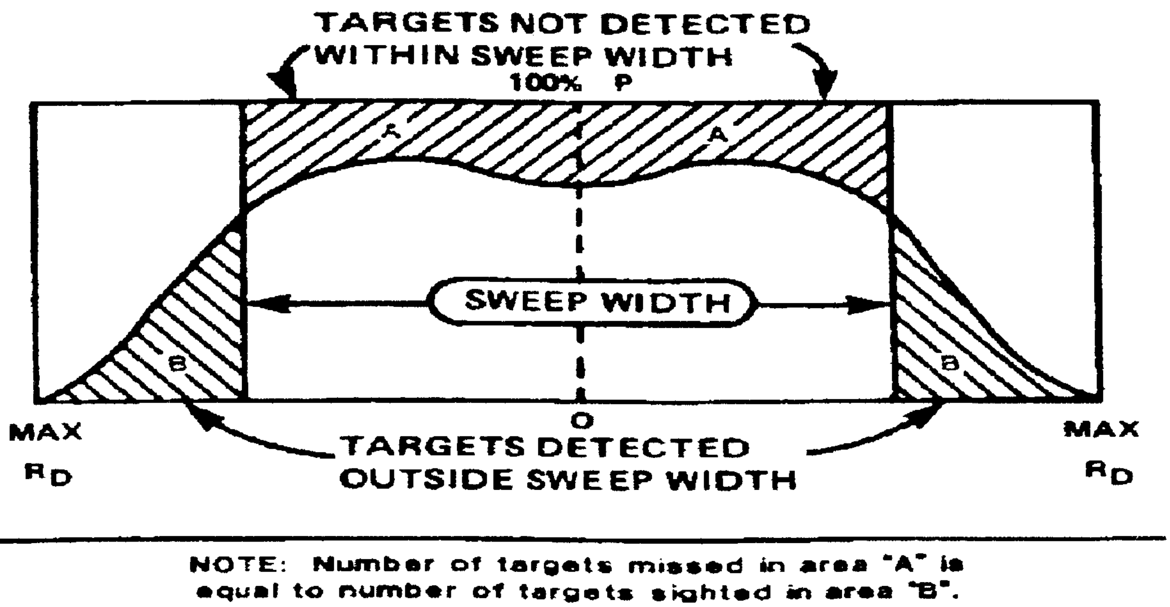

Figure 4-2 Sweep Width

4. Uncorrected Sweep Width. Table 4-2 is a table of Uncorrected Visual Sweep Widths for a small-boat SRU, and for an aircraft SRU flying at 1000 feet. The SMC has many such tables, for larger SRUs, for aircraft flying at different altitudes, different speeds, etc. This single Table is adequate for Auxiliary purposes however, because Auxiliary vessels are all "small boats", and Auxiliary

Small Boat SRU Visibility (NM)						Searching For	Altitude 1000 (ft) Visibility (NM)						
1	3	5	10	15	20		1	3	5	10	15	20	30
0.2	0.2	0.3	0.3	0.3	0.3	Person in Water	0.0	0.1	0.1	0.1	0.1	0.1	0.1
0.7	1.3	1.7	2.3	2.6	2.7	Raft 1 person	0.3	0.7	0.9	1.2	1.4	1.4	1.4
0.7	1.7	2.2	3.1	3.5	3.9	Raft 4 person	0.3	1.0	1.3	1.8	2.1	2.3	2.3
0.8	1.9	2.6	3.6	4.3	4.7	Raft 6 person	0.4	1.1	1.6	2.2	2.6	2.8	2.8
0.8	2.0	2.7	3.8	4.4	4.9	Raft 8 person	0.4	1.2	1.7	2.4	2.8	3.0	3.0
0.8	2.0	2.8	4.0	4.8	5.3	Raft 10 person	0.4	1.3	1.8	2.6	3.0	3.3	3.3
0.9	2.2	3.0	4.3	5.1	5.7	Raft 15 person	0.4	1.4	2.0	2.8	3.4	3.7	4.2
0.9	2.3	3.3	4.9	5.8	6.5	Raft 20 person	0.4	1.5	2.2	3.2	3.9	4.3	4.9
0.9	2.4	3.5	5.2	6.3	7.0	Raft 25 person	0.4	1.6	2.3	3.5	4.2	4.7	5.4
0.4	0.8	1.1	1.5	1.6	1.8	Power Boat < 15 ft	0.4	1.0	1.3	1.7	1.8	2.0	2.0
0.6	1.5	2.2	3.3	4.0	4.5	Power Boat 15–25 ft	0.5	1.7	2.5	3.7	4.4	5.0	5.0
0.8	1.9	2.9	4.7	5.9	6.8	Power Boat 25–40 ft	0.5	2.2	3.4	5.4	6.8	7.8	9.3
0.9	2.4	3.9	7.0	9.3	11.1	Power Boat 40–65 ft	0.6	2.7	4.5	8.2	10.9	13.1	16.6
0.9	2.5	4.3	8.3	11.4	14.0	Power Boat 65–90 ft	0.6	2.8	5.1	9.8	13.6	16.7	21.7
0.8	1.5	2.1	3.0	3.6	4.0	Sail Boat 15 ft	0.5	1.6	2.3	3.3	4.0	4.4	4.4
0.8	1.7	2.5	3.7	4.6	5.1	Sail Boat 20 ft	0.5	1.8	2.7	4.2	5.1	5.7	5.7
0.9	1.9	2.8	4.4	5.4	6.3	Sail Boat 25 ft	0.5	2.1	3.2	5.0	6.2	7.1	7.1
0.9	2.1	3.2	5.3	6.6	7.7	Sail Boat 30 ft	0.6	2.3	3.6	6.0	7.6	8.9	10.7
0.9	2.3	3.8	6.6	8.6	10.3	Sail Boat 40 ft	0.6	2.6	4.3	7.6	10.9	12.0	14.9
0.9	2.4	4.0	7.3	9.7	11.6	Sail Boat 50 ft	0.6	2.7	4.6	8.5	11.4	13.7	17.4
0.9	2.5	4.2	7.9	10.7	13.1	Sail Boat 65–75 ft	0.6	2.8	4.9	9.3	12.8	15.6	20.1
0.9	2.5	4.4	8.3	11.6	14.2	Sail Boat 75–90 ft	0.6	2.8	5.1	9.9	13.8	17.0	22.2
1.4	2.5	4.6	9.3	13.2	16.6	Ship 90–150 ft	0.6	2.9	5.4	11.1	15.9	20.1	27.0
1.4	2.6	4.9	10.3	15.5	20.2	Ship 150–300 ft	0.6	3.0	5.7	12.5	18.9	24.7	34.9
1.4	2.6	4.9	10.9	16.8	22.5	Ship >300 ft	0.6	3.0	5.8	13.2	20.6	27.9	41.4

Table 4-2 Uncorrected Visual Sweep Width (NM)

aircraft usually fly at 1000 feet. The table is entered with the SRU type, the Visibility, and the Target type. The number at the intersection of these variables is the Uncorrected Visual Sweep Width in nautical miles.

5. Radar Sweep Width. Auxiliary vessels with RADAR might be dispatched on a search when the visibility is very low and the search must be done using RADAR for detection. The NSM includes RADAR Sweep Width numbers for the AN/-SPS-64 and AN-SPS-66 systems. Civilian small-boat RADAR is not exactly comparable with either of these sets, but the numbers for the AN/SPS-66 can probably be used in most cases; these are given in Table 4-3. When visibility is less than 1NM, RADAR is definitely superior, and should be used. Douglas Sea State defines "1" as having 0-1 foot waves, "2" having 1-3 foot waves, and "3" having 3-5 foot waves. Larger sea states generally cause such severe sea return that RADAR is useless.

Target Type \ Douglas Sea State	*0-1*	*2-3*	*0-2*
Small boats without reflective material	*0.8*	*0.0*	
Small boats with reflective material	*2.0*	*0.4*	
Large boats with significant reflective material			*9.5*

Table 4-3 RADAR Sweep Width (NM)

6. Corrections. The Uncorrected Visual Sweep Width is adjusted for Weather, SRU Crew Fatigue and SRU Speed by the formula

$$W = W_a \cdot f_w \cdot f_r \cdot f_v$$

where W_a is the Uncorrected Sweep Width, f_w is the Weather correction factor, f_r is the Crew Fatigue correction factor, and f_v is the SRU Speed correction factor.

a. Weather Correction Factor. Table 4-4 gives the correction factor to be used for differing weather conditions. This factor is used only with Visual Sweep Widths; RADAR Sweep Widths are already corrected for sea state.

Target Type	**Winds** **Seas**	*<15 Kts* *<2 ft*	*≥15 Kts* *2-3 ft*	*≥25 Kts* *>4 ft*
PIW, rafts, or anything <30 ft long		*1.0*	*0.5*	*0.25*
Other Targets		*1.0*	*0.9*	*0.9*

Table 4-4 Weather Correction Factor

b. Fatigue Correction Factor. If a crew is fatigued its efficiency is reduced 10%, ie, the Fatigue Factor is 0.9 for a tired crew (and 1.0 for a fresh crew).

c. Speed Correction Factor. Speed Correction is applicable only to Coast Guard and military aircraft; for Auxiliary aircraft and vessels a f_v of 1.0 is used.

7. Coverage Factor. Probability of Detection is a statistical concept that permits the SMC to compare different search scenarios; it is a "quality" number that relates Track Spacing (*S*) and Corrected Sweep Width (*W*) with the statistical probability of the target being detected. The relationship is expressed in terms of the ratio of *W* to *S*; this ratio is called Coverage Factor (*C*). From the equation one can see that increasing *S* reduces Coverage, and increasing *W*-for example by using a helicopter instead of a boat-increases Coverage.

$$C = \frac{W}{S}$$

8. Probability of Detection. This is the final number generated by the SMC; once he knows *C*, he can read *POD* from Figure 4-3. If more than one search is required the criterion for using 6NM as the search radius is void; the Search Area Planning has to be done all over again using a different path down the logic tree in Figure 3-1.

   The graph shows that if *C*=1, ie, the Track Spacing is selected equal to the Corrected Sweep Width, the *POD* is 78%. It is interesting to look at the slope of the graph; in the neighborhood of *C*=1 the slope is such that a small change in *C* produces only half as much change in *POD*. The larger *C* becomes, the less effective-percentagewise at least-is the increase in *POD*.

9. Probability of Success. For a *C* of "1" the *POA* must be 64% for the product of the two probabilities to be 50%. In near-coastal incidents the numbers are better than that because the 6NM radius is too pessimistic. The 6NM radius is not just pulled out of thin air; it comes from the assumption that the error in reported LKP is ≈5NM. This is not an unreasonable assumption if the LKP is deduced from bearings, but is certainly too large if the LKP is reported from LORAN readings, even from coordinate converter LORAN readings. The 50% *POS* is more reasonable for Ocean Searches where the Search Radius is much larger and is derived by an elaborate statistical model using probable errors in the accuracy of navigation, LKP, Drift, etc.

   Example. Assume a typical case assigned to the Auxiliary. The Visibility is 5.0NM, Wind is 12kt, the Target is a disabled power boat 20ft long, and the Auxiliary crew is fresh. What is the *POD*?

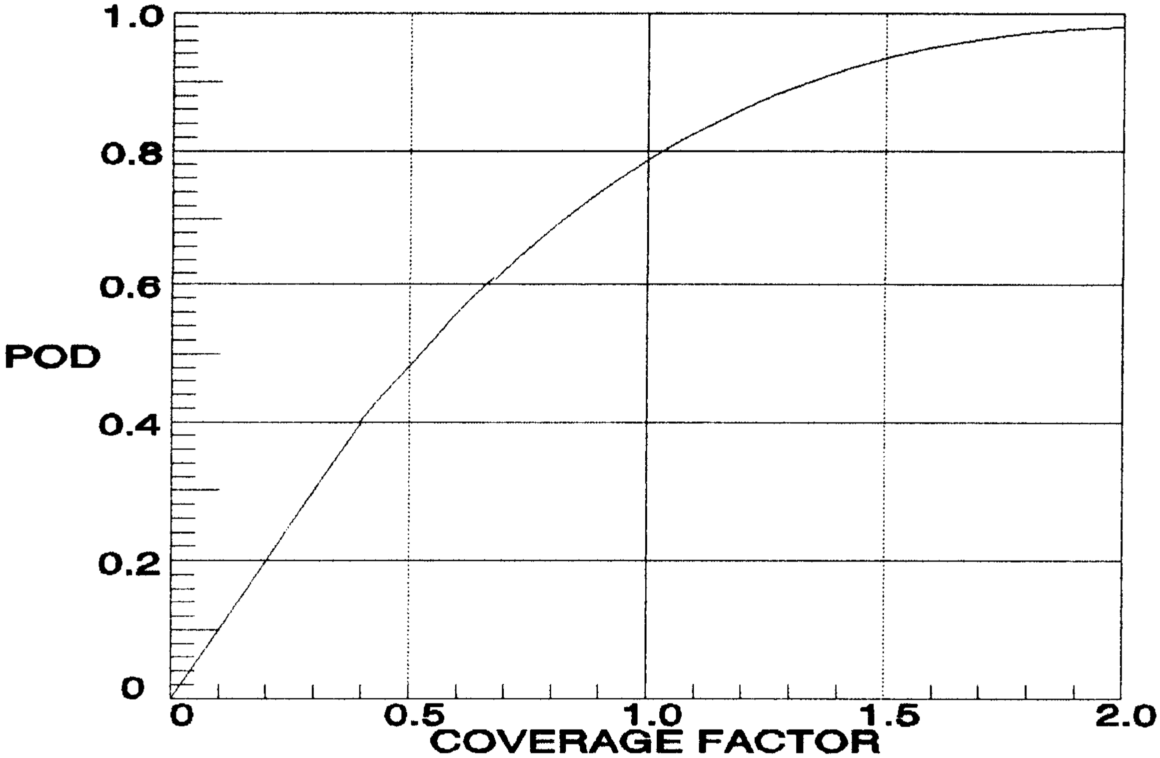

Figure 4-3 Probability of Detection

From Table 4-2 the Uncorrected Visual Sweep Width is 2.2NM. The Weather Correction Factor f_w is "1" because the winds are only 12kt; the Fatigue Correction Factor is also "1" because the crew is fresh; the Speed Correction Factor is "1" because the SRU is a boat. So the Corrected Visual Sweep Width is 2.2NM. Table 4-1 calls for a Standard Track Spacing of 1NM, hence the Coverage Factor is 2.2/1 or 2.2. From Figure 4-3 the *POD* is >98%!

This example demonstrates why the Coast Guard achieves a *POS* for a Coastal First Search of 95%. This success rate stems from the conservative standards used for Search Area and Track Spacing for near-coastal distress incidents.

C. SRU Assignment. Depending on the path (from Figure 3-1) used to calculate the Search Area, SRU assignment is either a major problem, or a relatively minor one. This text reviews just two of the possible paths, ie, **Near-Coast First Search** and **Ocean Search (Drift Time > 4^h)**; the other two possible paths are modifications of these extreme paths.

1. Near-Coast First Search. Most maritime SAR cases occur within 25NM of the coast and are usually handled at the group or station level, the level receiving the distress call. Once the call is verified as an actual Distress, a SRU is dispatched immediately to the LKP. The selection of SRU usually depends on the distance between the LKP and the SRU base. If a boat SRU can reach the LKP within about 2 hours it is used (since it is also a Rescue unit); if the transit time is longer, a helo is used because it can reach the scene much more quickly.

a. SRU Action. When the SRU arrives on scene and the target is not seen or located, the SRU 1) immediately notifies the SMC who begins search planning, 2) assumes a 6NM radius for search area, 3) begins a search pattern appropriate to the geography of the LKP-usually an Expanded Square or Sector, and 4) uses the numbers in Table 4-1 for Track Spacing. Thus the SRU Action is semi-automatic. This is exactly the action that is expected of an Auxiliary Facility that is dispatched on a case.

b. SMC Action. If the initial SMC is at a facility lower than Group, the SMC function is transferred to Group, or RCC. Only at Group, or RCC, are there facilities and qualified personnel for Search Area Planning.

2. Multi-unit Search. If the Track Spacing is very small, more than one SRU may be required to cover the search area in a reasonable time. For example, the SMC can divide the nominal $144NM^2$ area into four squares each $36NM^2$. Under these circumstances the SMC appoints an On Scene Commander (OSC) who is in charge of the other three SRUs and who handles all of the communication with the SMC. This is a common occurrence with Auxiliary SRUs who assist a Coast Guard Unit in a search, and the Coast Guard Unit is the OSC.

3. Open Ocean—Drift Time $>4^h$. SRU assignment for the Open Ocean case is much more complicated. Unless the Distressed vessel has used a newer type EPIRB to signal its distress, the search area becomes very large before the SMC can get resources to the scene. His problem is to balance the number of resources, the search area, and the track spacing to maximize the *POS*. The version of CASP called Phase II (now under development) makes his problem manageable by making more accurate calculations of *POA*, and by resolving potential conflicts between SRUs that have overlapping search areas.

D. Search Patterns. A SAR text for the Auxiliary would not be complete if it didn't cover the various Search Patterns that might be assigned to an Auxiliary vessel. But the student should bear in mind that the ones he must become proficient at executing-and the ones most difficult to do well-are Expanded Square and Sector patterns, as they are the ones most often assigned to Auxiliary vessels. Most of the patterns are square or rectangular, although the Search Area analysis generally results in a circular area. Except for Sector patterns all the other patterns are square or rectangular, the only practical shapes for actual operational searches. Circular Search Areas are converted to "squared off" patterns by running boundary lines tangent to the Search Area circle with one set of lines parallel to the Total Drift vector, and with other lines at right angles. If there is only one Datum the Search Area is square; if there are two Datums the Search Area is rectangular.

1. Pattern Designation. A coded system of letters is used to designate search patterns. The major pattern characteristic is identified by the first letter, the second letter denotes SRU number ("S" is a single-unit search; "M" is a multi-unit search), and the third letter designates specialized SRU patterns or instructions ("R" is for a return pattern; "N" is a non-return pattern). For example pattern "SS" is Expanded Square Single unit, "SM" is Expanded Square Multi-unit, "VS" (Victor Sierra-not Vector Sierra) is Sector Single unit, and "VM" is Sector Multi-unit. The pattern designations apply whether the SRU is an aircraft or a vessel.

2. Pattern Element Definition. There are several definitions that are unique to search patterns. They are used so the details of the pattern assigned are clear to both the SMC and the skipper of the SRU.

a. Commence Search Point (CSP) is the location in the search pattern where the SRU begins searching. (Before arriving at the CSP, the SRU is "en route"). Specifying the CSP allows the SRU to plan the course en-route, ensure that the SRU(s) are separated and begin searching at the desired position and time.

b. Search Leg is the long leg along the track of any pattern. (Not applicable to Sector or Square patterns.

c. Crossleg is the connection between two Search Legs in a rectangular pattern.

d. Creep is the general direction a SRU moves through a rectangular pattern.

3. <u>Search Area Specification</u>. SRUs plot their courses to the assigned search area on the basis of information received from the SMC. Several standard methods have been devised to describe search areas.

a. Boundary: Any square or rectangular area oriented E-W and N-S is described by two Latitudes and two Longitudes.

b. Corner Points: Any area (except circular areas) is described by the Lat and Long, or geographical features, of each corner; the corners need not be square.

c. Center Point: This method uses Lat and Long of the center point and the search Radius (if circular), or the direction of the major axis and applicable dimensions, if rectangular.

d. Track Line: Search areas are defined by stating the track and the width of the coverage.

4. <u>Typical Search Patterns</u>

a. Expanded Square. This is one of the most common pattern used by Auxiliarists; it is illustrated in Figure 4-4. The Figure is oriented to imply that the heading of the first leg is 000° ; in fact the first leg should be oriented in the direction of drift, ie, downwind. If the SMC has not relayed his calculation of drift, the SRU simply uses downwind as the direction, as the principal drift component is usually Leeway. Appendix A contains an EXPANDED SQUARE WORKSHEET (page A-11) that is useful in executing an Expanded Square pattern. It includes

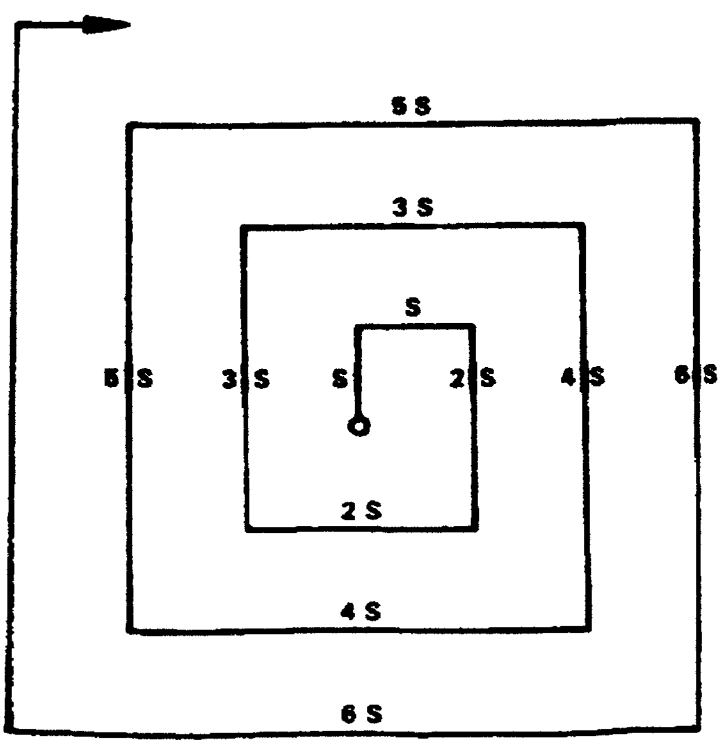

Figure 4-4 Expanded Square

the Track Spacing values given in Table 4-1 and shows what speeds can be used so that the leg times are all integral minutes. Most Auxiliary vessels will not go slower than about 5kt at idle throttle, so the only speed that is useful for a 0.1NM Track Spacing is 6kt. At a Track Spacing of 0.1NM it takes a <u>long</u> time to search 144NM^2; ten legs cover only a quarter of a square mile, and take almost a half hour.

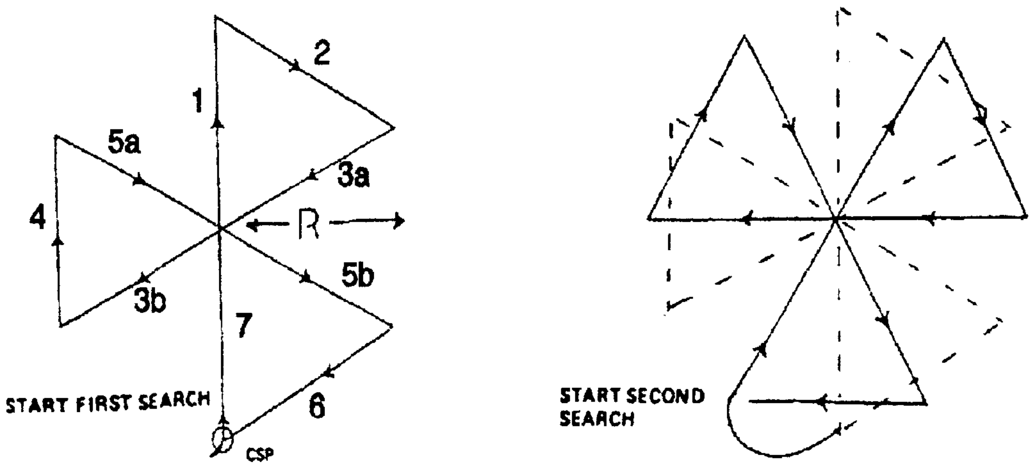

Figure 4-5 Sector Pattern

b. Sector Search Pattern. This pattern is used when datum is established within close limits, when the area to be searched is not extensive, and the drift time is short. Figure 4-5 illustrates the pattern, and page A-12 is a SECTOR WORKSHEET that is often useful. By definition, Track Spacing is not applicable since the legs are not parallel; but when S is required in a calculation it is taken as ½R. Since several legs pass through datum, a Datum Marker Buoy (DMB) of some sort should be used; this allows each leg that crosses datum to be adjusted for SRU leeway. The lower limit for the radius is 0.5NM which gives an equivalent Track Spacing of about 0.25NM. The SECTOR WORKSHEET assumes the Commence Search Point (CSP) is at Datum, but the patterns in Figure 4-5 assume a CSP that will cause the SRU to cross Datum after one leg. This is obviously more efficient but is not a general enough practice, by the Auxiliary, for a worksheet to be specialized. Figure 4-5 also shows the path of a second search; the legs are rotated 30° to the right of the legs in the first search.

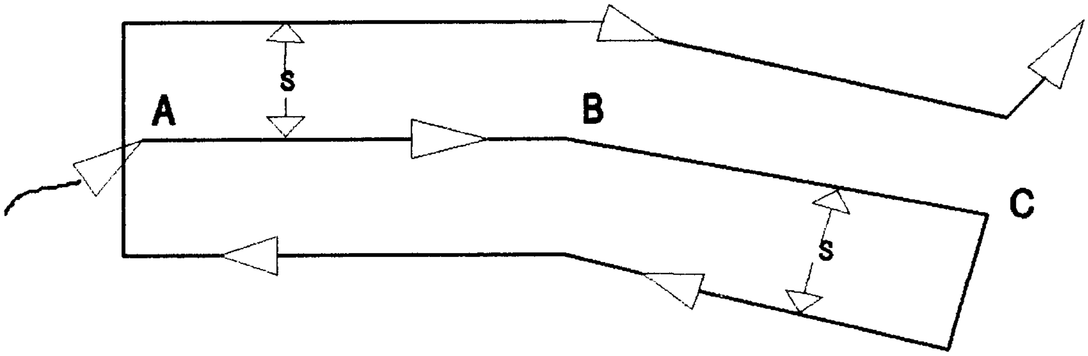

Figure 4-6 TSN Pattern

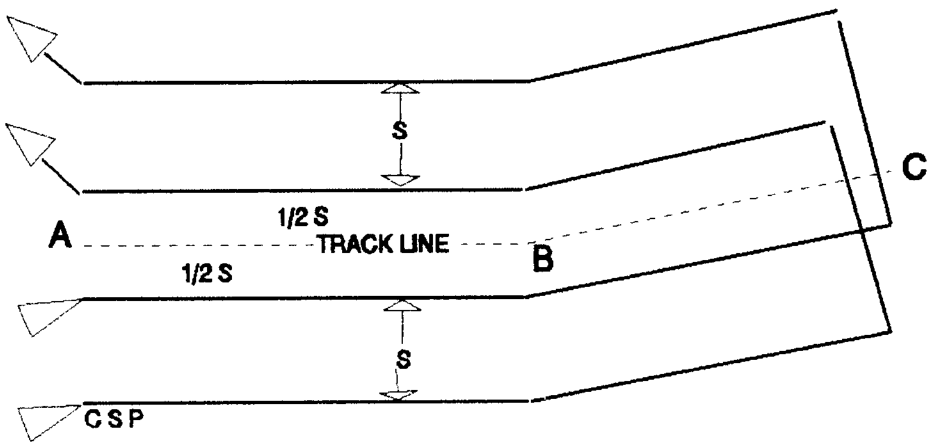

Figure 4-7 TMR Pattern

c. Trackline patterns (first letter designation "T") are used when the intended route of the target is known. A route search is usually the first search action in an overdue incident since it is assumed that the target is near the track. The Trackline pattern is used for a rapid and reasonably thorough search of the missing craft's proposed track and the area immediately adjacent to it. The four versions shown in Figures 4-6, 7, 8 and 9 differ only in the number of SRUs and whether the pattern is non-return or return, ie, third letter N or R.

d. Parallel patterns (first letter designation "P") are used to search rectangular areas and have "legs" aligned parallel to the major axis. These patterns are used when only approximate initial position is known, and when uniform coverage is desired. Since these patterns have

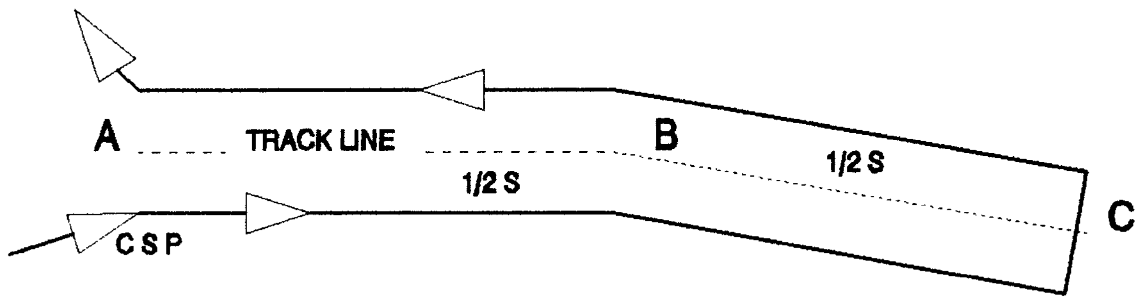

Figure 4-8 TSR Pattern

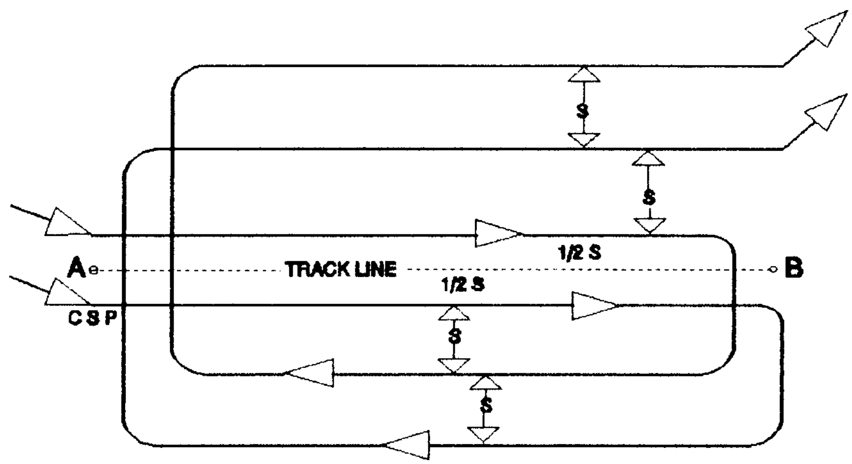

Figure 4-9 TMN Pattern

the longest legs and the fewest turns they are used extensively when the SRU is a fixed wing aircraft and the search area is in the open ocean. Two versions of the parallel pattern are shown in Figures 4-10 and 4-11.

The multi-unit version is often appropriate for near-shore searches for an object such as a PIW. Several boats can search line-abreast with close spacing; this reduces the navigation error in the coverage since the spacing-visually maintained-can be less than the navigation accuracy of the individual SRUs. Another use of a multi-unit pattern is a circumstance like the following. Suppose that because of time constraints the SMC divides the Search Area into two equal-sized sub-areas with a SRU assigned to each. If one SRU loses its navigation capability the SMC can order the SRUs to combine their assigned search areas and search in a multi-unit mode. This results in the same coverage factor, and the same Time-for-Search, and saves having to find and dispatch a replacement SRU for the one that develops navigation difficulty.

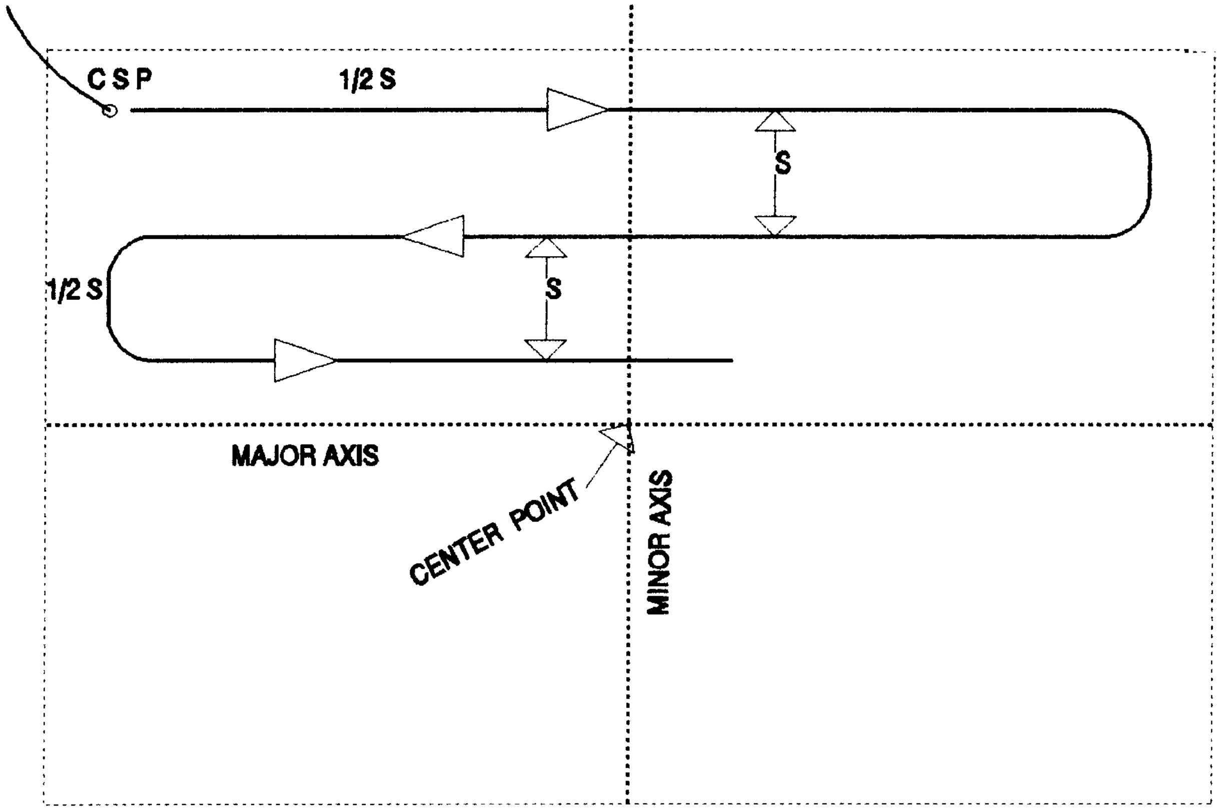

Figure 4-10 PS Pattern

e. Creeping Line patterns (first letter designation "C") are rectangular patterns with the direction of creep along the major axis, as illustrated in Figure 4-12. They are used when the SMC decides to cover one end of the area first, or to use an aircraft and vessel for a coordinated search. A "coordinated" search-designated CSC-is a pattern run so that the advance of the aircraft on each of its Creeping Line legs causes the aircraft to pass directly over the vessel, which steams along in the direction of creep in the middle of the search area. The result is a more accurate pattern, and enables quick rescue once the object is sighted. Appendix D elaborates on the CSC pattern and gives tables of vessel/aircraft speeds that assist coordination.

5. <u>Drift during Search</u>. If the Search Object and the SRU are both in motion it may be necessary to consider their relative motion, especially in high-current areas. Failure to account for target motion may result in the target drifting out of the search area before the search is completed. Even if the target remains in the search area, the pattern relative to the target may be so dis-

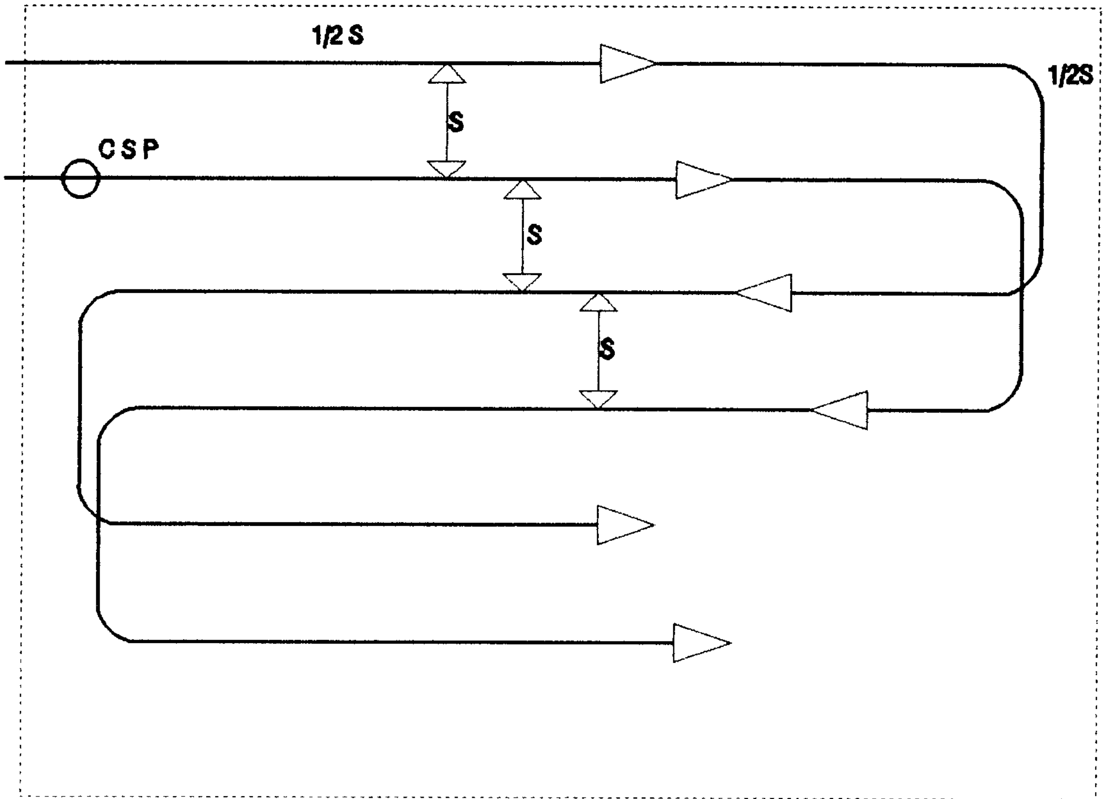

Figure 4-11 PM Pattern

torted that POD is greatly reduced. There are three different circumstances when drift is a consideration.

a. Barrier Search. If the incident occurs in a location with substantial current, eg, a river or a tidal channel, the best search pattern may be a barrier established downstream of the incident, with the SRU patrolling across the current. The SRU can use landmarks on either side of the channel to maintain a constant CMG and let the current bring the target to the SRU.

b. Distorted Pattern Search. The SMC may plan for the search pattern to become distorted due to current and/or leeway experienced by the SRU. In this case the SMC directs the SRU to perform the assigned pattern by DR, and the CMG is distorted by the effects of current and leeway. This is a reasonable procedure if the SMC thinks that the SRU will experience the same external forces as the target.

c. Ground Track Pattern. If directed to do so by the SMC, the SRU can run the assigned pattern in such a way that

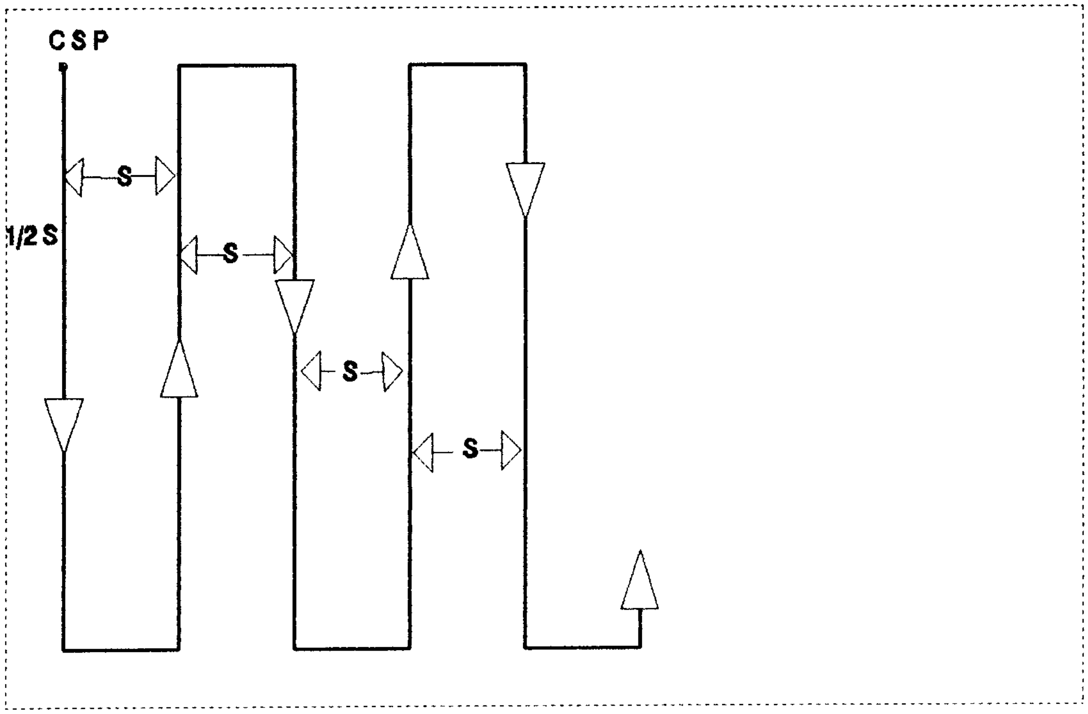

Figure 4-12 CS Pattern

the result is a ground track pattern. The SRU navigates by DR taking into account the anticipated current and compensating for leeway experienced on each leg. This method is not very accurate but the results are better than if the current and leeway are ignored. The best way to follow an assigned ground track is to use an electronic navigation aid such as LORAN, RADAR or GPS. Any of the patterns can be run as a ground track pattern by navigating using position sensors that are independent of local conditions.

6. SRU Leeway. Auxiliary vessels are designed primarily as pleasure craft, and have a much larger ratio of above-water to below-water area than do Coast Guard boats. As a consequence, the leeway experienced by Auxiliary facilities is much greater than the leeway experienced by Coast Guard boats. The effect of wind on a vessel is 1) to require a change in RPM to maintain planned speed, and 2) to require a course change to correct for leeway. The calculation of RPM demand as a function of relative wind depends on engine, propeller and hull characteristics that are unique to each type of Facility. It is not, however, difficult to calculate, in a general way that applies to all boats, the course angle change necessary to correct for leeway. Table 4-5 is a table of Heading

Changes (in degrees) for different relative wind headings and speed. To prepare a table for a particular boat multiply all of the heading-change numbers in Table 4-5 by the specializing formula:

$$F = \frac{6}{V_b}\sqrt{\frac{A_a}{A_w}}$$

In this equation, V_b is the search speed (in knots) for which the table is being made, A_a is the side view area (in ft^2) above the waterline, and A_w is the side view area (in ft^2) below the waterline. The numbers in the Table aren't very substantial, but when multiplied by the specializing factor, and rounded to the nearest degree, can become very important. Each number in Table 4-5 is multiplied by *F*, ie, *F* has to be calculated only once.

The Flag Angle is the "tell-tail" angle relative to the keel; astern is 0°. The heading change is made into the relative wind; wind speed is measured by a hand-held or mast-mounted anemometer.

Leeway can be quite large. For instance a relatively heavy displacement boat such as a Grand Banks 42, experiences 9° of leeway in a 20kt beam wind. Light boats experience <u>more</u> leeway. So for local winds greater than about 10kt, failure to correct for leeway modifies the search pattern substantially.

HEADING CHANGE INTO WIND - DEGREES

FLAG ANGLE

Wind	0	15	30	45	60	90	120	135	150	165	180
0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1.0	.0	.1	.2	.2	.3	.3	.3	.2	.2	.1	.0
2.0	.0	.2	.3	.5	.6	.7	.6	.5	.3	.2	.0
3.0	.0	.3	.5	.7	.9	1.0	.9	.7	.5	.3	.0
4.0	.0	.3	.7	1.0	1.2	1.4	1.2	1.0	.7	.3	.0
5.0	.0	.4	.8	1.2	1.5	1.7	1.5	1.2	.8	.4	.0
7.0	.0	.6	1.2	1.7	2.0	2.4	2.0	1.7	1.2	.6	.0
9.0	.0	.8	1.5	2.1	2.6	3.0	2.6	2.1	1.5	.8	.0
11.0	.0	1.0	1.9	2.6	3.2	3.7	3.2	2.6	1.9	1.0	.0
13.0	.0	1.1	2.2	3.1	3.8	4.4	3.8	3.1	2.2	1.1	.0
15.0	.0	1.3	2.5	3.6	4.4	5.1	4.4	3.6	2.5	1.3	.0
17.0	.0	1.5	2.9	4.1	5.0	5.7	5.0	4.1	2.9	1.5	.0
19.0	.0	1.7	3.2	4.5	5.6	6.4	5.6	4.5	3.2	1.7	.0
21.0	.0	1.8	3.5	5.0	6.1	7.1	6.1	5.0	3.5	1.8	.0

Table 4-5 SRU Leeway Correction

REVIEW QUESTIONS

1. What is the goal of Search Operations Planning?

2. Define Track Spacing.

3. What is the "standard" Track Spacing for a Coastal First Search under Good Conditions for an Object >15ft long?

4. What is the "standard" Track Spacing for a Coastal First Search for an Object >15ft if the Wind is 12kt and the seas are >3ft?

5. What is the "standard" Track Spacing for a PIW?

6. What is the "standard" Track Spacing for a Coastal First Search for an Object >15ft if the Wind is 18kt and the seas are <3ft?

7. What is the formula that relates Velocity of the SRU, S, and Time on Search, to Area Covered?

8. If S is halved what happens to A?

9. If A and S stay the same but V is increased 20 times what happens to T?

10. How much area can a boat SRU cover in remaining daylight of 4 hours at a speed of 9kt using a track spacing of 1NM?

11. How long will it take a SRU searching at 8.5kt using a S of 1NM to cover 120NM^2?

---

12. Define Sweep Width?

---

13. What is the difference between Uncorrected Visual Sweep Width and Corrected Sweep Width?

---

14. What are the Factors used to "correct" Uncorrected Visual Sweep Width?

---

15. Why are these Factors not used to correct Radar Sweep Width?

---

16. What is the difference between the Probability of Detection and Sweep Width?

---

17. What is the equation that relates Coverage Factor to Track Spacing and Sweep Width?

---

18. For a Coastal First Search, Aux Vessel SRU, Fresh Crew, what is the Track Spacing, Probability of Detection, and Time to search an area of 120NM^2 at a search speed of 10kt for the following:

    a. Target 14' outboard.
       Winds 12kt.
       Seas 2ft.
       Visibility 5NM.

---

b. Target 14′ outboard.
Winds 16kt.
Seas 3ft.
Visibility 5NM.

---

19. If a SRU is dispatched on a Coastal First Search and gets to the LKP (8 miles offshore) and is unable to see the Target, and has had no specific instructions from the SMC what should the Coxswain do?

---

20. In what direction should the first leg of an Expanded Square pattern be run?

---

21. What does CSP stand for, and how is it used?

---

22. Define Search Leg, Cross Leg, and Creep.

---

23. Describe four methods of specifying Search Area.

---

24. Describe the TSR pattern and when might it be the most appropriate pattern.

---

25. Searching for a PIW several SRUs travel line abreast 200 yds apart with one SRU doing all of the navigation. What is this pattern called?

---

26. Which patterns can be run with a LORAN reference?

---

27. Why is leeway of the SRU important?

---

28. What is the Heading Change to compensate for leeway for a boat with $A_a = 220ft^2$, an $A_w = 90ft^2$, at a searching speed of 8kt in a relative wind of 15kt with a flag angle of 45°?

---

29. What is the Heading Change to compensate for leeway for a boat with $A_a = 240ft^2$, an $A_w = 95ft^2$, at a searching speed of 7kt in a relative wind of 13kt with a flag angle of 120°?

---

30. When there are several SRUs on scene to whom do they report?

---

31. What happens to the SMC assignment if a SRU, reporting to a Station, gets to the LKP and does not find the Object?

---

32. If the Search Area is $144NM^2$, the Track Spacing is 0.5NM, and the SRU Speed is 10kt, how many SRUs does the SMC need if he needs to complete the search in 6 hours?

---

33. If an Auxiliary SRU completes his assigned search area, which is part of a larger search area, to whom does he report?

---

34. Is an Auxiliary Facility ever likely to be assigned OSC? Why?

---

35. What is the Corrected Sweep Width for a 32'CC, in 20kt Wind, with Visibility 10NM, for a Tired SRU Crew?

---

36. What is the Corrected Sweep Width for a 10-person Raft, in 18kt Wind, with Visibility 5NM, for a fresh SRU Crew?

---

37. Use the Expanding Square Worksheet. If S=1NM, Speed is 10kt, and Start is at 1430, at what clock time does the 5th leg commence? the 8th leg commence?

---

38. Use the Sector Worksheet. If R=2NM, Speed is 12kt, and Start at Datum is 1150, at what clock time does the 4th leg commence? at what clock time does the SRU pass through Datum after the 5th leg?

---

39. For a rectangular Search Area when is a CS pattern used instead of a PS pattern?

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CHAPTER 5. TOWING

A. Introduction. Every year the Coast Guard Auxiliary tows thousands of vessels, and by far the majority of cases are "non-emergency". Often, however, it is not known in advance that the case is non-emergency, and in some situations the case can become an emergency unless towing assistance is given. Being able to tow is, therefore, an important skill of an Auxiliarist doing SAR duty. Among Auxiliarists who enjoy Operations, a successful tow is the "raison d'etre" for all the training, practice, qualifying, expense, work and boredom associated with Safety Patrols.

All towing, by Auxiliary vessels under orders, is undertaken only on approval of the cognizant Coast Guard Command. An Auxiliary vessel under orders is not, repeat NOT, a good samaritan; the Facility is a United States Government vessel operating within the bounds of an organized command structure. In an assist, the only initiative left to the discretion of the Auxiliary Coxswain is SAFETY — SAFETY for the Auxiliary vessel and its crew, and SAFETY for the crew, passengers, and vessel being assisted. All other decisions are made by the command organization, the very tail end of which is the Auxiliary Coxswain. (There is a partial exception to this statement; see CG Policy statement on page 2-5 regarding "targets of opportunity" discovered by the Auxiliary).

Almost everything done during a tow is potentially hazardous; a successful tow is one during which no damage is done to the engine(s) of the towing vessel, and nothing breaks. Both of these aspects are addressed in this Chapter. Tow forces are so sensitive to boat waterline length (L_w) and displacement that it is necessary to divide this chapter into two parts: paragraphs through §J deal mostly with Auxiliary facilities with L_w at least 30ft; §K covers the modifications necessary to account for Auxiliary facilities with $L_w<30$ft.

There are three distinctively different forces operating in every towing evolution: ***Acceleration Forces***, ***Steady Forces***, and ***Shock Forces***.

1. Acceleration Forces are those involved in getting the towed vessel started from a dead-in-the-water position; they depend almost entirely on the skill of the Coxswain, and are not easily quantified. The main caution is "start very slowly", have the towing vessel out of gear at the instant the towline becomes taut, and engage gears just as the towline slackens and the towed boat begins to move. These forces are not discussed further in this text

as there is no reason they should become the limiting factor in a towing situation.

2. Steady Forces are those that are necessary to pull the towed vessel through smooth water at a constant speed. They depend entirely on the characteristics of the towed vessel, and are independent of the characteristics of the towing vessel, tow hawser, and sea state. This Chapter addresses the problem of estimating the *Steady Force* by eyeballing the vessel to be towed, and controlling the engine(s) of the towing boat so no damage is done to them.

3. Shock Forces are those caused by the sea state, ie, wave action. They depend on the characteristics of the towed vessel, the towing vessel, the tow hawser, and the sea state. All of these parameters are addressed in this Chapter.

4. Tow Planning. The analysis that follows culminates in a set of Tow Planning Forms which the Auxiliary Coxswain can use to determine-approximately-the risk of a tow when the combination of Steady Force and Shock Force-induced by an adverse sea state-approach a hazardous limit. Examine the typical Tow Planning Worksheet on the facing page and note that there are four elements to it: the *Size* (as measured by waterline length) of the Auxiliary Vessel; the *Maximum RPM* the vessel can use without overstressing the engines; the *Steady Force* that results from the towed vessel characteristics; and the *Shock Force* that results from the sea state. The final calculation on the Tow Planning Form is labeled *MAXIMUM PEAK FORCE* (an INSTANTANEOUS Force), and it is this number that is important to the Coxswain. Its precise value is not particularly significant; as a first cut the Coxswain wants to know that this number is less than 1500 pounds, for a vessel whose waterline length is ≥30ft, or less than 850 pounds for a small vessel whose waterline length is <30ft. Where these limits come from is discussed later in this chapter; in addition they are reasonable limits to assign to a typical vessel being assisted. If the first cut produces a *MAXIMUM PEAK FORCE* that is significantly less than the *LIMIT* the tow is probably safe. It is only when the *MAXIMUM PEAK FORCE* is near (over or under) the *LIMIT* that the Coxswain should refine the analysis and consider some techniques that will reduce the *MAXIMUM PEAK FORCE*.

B. Towing Vessel Performance. Few Auxiliary vessels are designed for towing; they are propped to handle only their own weight, and they do not have a tow post midships and forward of the propeller(s) and rudder(s). Each of these deficiencies puts a

TOW PLANNING WORKSHEET

35 FOOT (10.3 tons) AUXILIARY FACILITY

AUX Facility ____________________ Actual Disp. ________ tons

Max Cont Cruise __________ RPM Speed ____ knots Slip _____ %

Towline Type ____________________ Towline Length _________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type ____________ Waterline Length ____ feet TOW Speed _______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] ____________ pounds

---

SUMMARY

Standard Shock Force [2] _________ pounds

Double Braid 1.6 x [2] = [3] ________ " (use only if applicable)

Heading ___ x [3] = [4] ________ "

Adjusted Shock Force [4] _______________ pounds

Steady Force [1] _______________ pounds

Maximum Peak Force [1] + [4] _______________ pounds

LIMIT 1500 pounds

propeller(s) and rudder(s). Each of these deficiencies puts a limitation on the performance of the towing vessel. It is especially important not to overlook the limitations placed on the towing vessel because of the extra load put on its engines. Overloading an engine does serious damage and requires a major overhaul to restore performance.

1. Engine Load. For inboard gasoline or diesel engines (non-supercharged), there are two limitations for optimum life in use: the maximum continuous RPM, and the maximum continuous torque. For gasoline engines the continuous duty rating is 75% of the redline RPM, or 75% of the rated maximum torque, whichever occurs first. If the vessel is towing, the 75% of maximum torque limit is reached well before the 75% of maximum RPM limit. If, while towing, a vessel engine is run up to 75% of maximum RPM, the engine is seriously overloaded!

   Most boat manufacturers select the propeller pitch to give maximum speed at redline RPM-when the boat is new. But when it is loaded with fuel, gear and crew, the maximum attainable RPM is likely to be less than redline. Within this text, redline RPM means maximum RPM that can be achieved under the existing load conditions (but before the tow is connected).

   Torque is more difficult to measure. An intake manifold vacuum gauge on a gasoline engine gives a reading that is related to the engine torque. When the engine is not running the gauge reads 0; when the engine is idling under no load, the gauge reads between 18 and 21 inches (mercury equivalent) vacuum; as the engine is engaged and the throttle opened, the gauge reading becomes less. A reading of 7 inches corresponds to 75% maximum torque for most engines. There is no comparable measure of torque for diesel engines; exhaust pyrometers can be calibrated for torque but are installation peculiar and a general statement is not possible. For diesel engines with a "yacht rating", manufacturers state that the engines may be run continuously at 90% of the maximum RPM that can be obtained under the existing conditions.

2. Load Limits. There are several methods of determining an RPM that does not overload the engine(s) of the towing vessel.

   a. For gasoline engines with vacuum gauges, never run with less than 7 inches of vacuum, or with an RPM greater than 75% of redline RPM. For diesel engines with calibrated exhaust pyrometers, do not run at an RPM that causes a higher pyrometer reading than that represented by the continuous torque rating.

b. If the towing vessel is a twin, and has a knotmeter, find the maximum speed with the tow while towing on one engine for a short period of time. Maintain no greater than that speed with both engines, and keep them in sync.

c. Measure the Slip at maximum continuous cruise speed (without a tow), using the formula below. Use Table 5-1 to determine the maximum RPM (as a fraction of cruising RPM) as a function of Cruising Slip, and the Ratio of Towing Speed, V_t, to Cruising Speed V_c. Use of Table 5-1 is an elegant method of assuring that the towing vessel gasoline engines are not overloaded, as it compensates for any unusual stress experienced during the tow. For

$$Slip = 1 - \frac{1215 \times V_c \times ReductionGearRatio}{RPM \times Pitch(inches)}$$

example, a vessel with a slip of 30% at cruise speed, can tow any size vessel at 55% of continuous cruise RPM. At that RPM the towing vessel is using 75% of the maximum torque even if the towed vessel is not moving at all, ie, the towing vessel is tied to a piling! As the towed vessel begins to move, the towing vessel can increase its RPM to a larger fraction of cruising RPM depending on the ratio of the towing speed to cruising speed.

	Slip at Maximum Continuous Cruise						
V_t / V_c	.15	.20	.25	.30	.35	.40	.45
.0	.39	.45	.50	.55	.59	.63	.67
.1	.43	.49	.54	.58	.63	.66	.70
.2	.48	.53	.58	.62	.66	.70	.73
.3	.54	.58	.63	.66	.70	.73	.76
.4	.59	.63	.67	.71	.74	.76	.79
.5	.65	.69	.72	.75	.78	.80	.82
.6	.72	.75	.77	.80	.82	.84	.86
.7	.79	.81	.83	.85	.86	.88	.89
.8	.86	.87	.88	.90	.91	.92	.93
.9	.93	.93	.94	.95	.95	.96	.96
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 5-1 Allowable Fraction of Max Cruise RPM - Towing

The maximum RPM that will not overload the towing vessel engine(s) **may** make the tow go too fast; the Coxswain can only use the maximum RPM if the result is a tow speed slower than for a Speed/Length ratio of 1.0 for the towed boat. (See Appendix E, page E-10 for a derivation of Table 5-1).

d. The problem of overstressed engines seems to be particularly prevalent with I/O and outboard drives, either single or twin. There is a simple solution for this class of boat; since the drive can be lifted, the props can be changed easily (before the patrol leaves the dock). A set of props with 1/2 the pitch of regular props permits using much more of the power of the engine and essentially eliminates the possibility of engine overstressing (although the boat goes slower at 75% red-line RPM enroute to the distress). (Two-stroke outboards do not have valves and can, apparently, be run full throttle regardless of the load as long as there is adequate intake cooling water).

3. Load Distribution. Auxiliary vessels generally have two cleats symmetrically separated at the stern instead of a tow post midships and forward of the rudder(s). Consequently it is often desirable, and sometimes essential, to reduce the torque that exists if the tow is from a single cleat, by dividing the load between the two cleats. Without a bridle the towing vessel may have difficulty in directional control. Single screw power vessels are often more sensitive to off-center pull than are twin screw vessels, although single screw vessels usually have much larger rudders. If the load of the towed vessel is such that a bridle is necessary it can be made in a variety of ways. One is illustrated in Figure 5-2. The distance from the cleat to the contact point on the sheave is 0.58 the distance between the stern cleats, and the sheave is large enough to accommodate the largest tow hawser. This configuration assures that the angles between the towline and the two legs of the bridle are each 120°. This form of bridle makes shortening the towline very simple as all

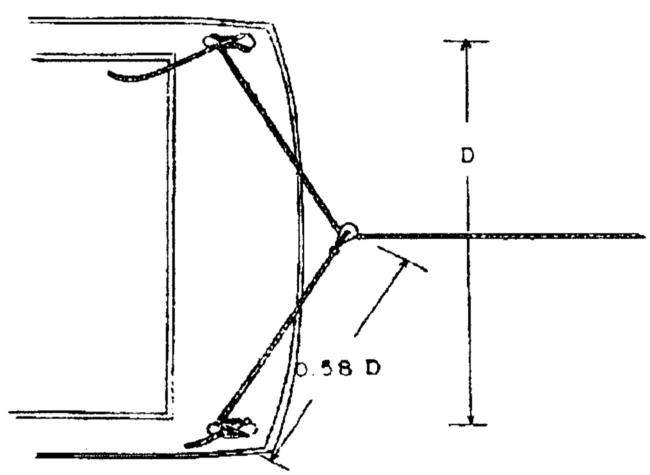


Figure 5-2 Bridle Device

of the length control is on one side. The Bridle Device is made of dacron, or dacron/Kevlar, to prevent stretch; all of the stretch occurs in the tow hawser. The sheave prevents any chafe at the contact point. This arrangement is satisfactory for loads-including shock loads-up to the limit determined by the pin diameter of the block fittings. For 1/4" stainless steel that limit is about 1500 lbs.

The Bridle Device does have one disadvantage; it puts a side load on the stern cleats of the towing vessel. When the load from the hawser is centered, the side load is one-half the load in the hawser, and cleats should be able to take that. However, if the side load must be reduced, a bridle can be made by connecting a dock line to the hawser with a rolling hitch and veering both lines until the legs have reached the desired length. When this arrangement is used, the length of the bridle is no more than 3 times the separation of the cleats.

If the towing vessel is a sailboat it may be able to use a single-leg towline rather than a bridle. If a bridle is necessary it has to go around the backstay, and that complicates the crew's tasks. Sailboats have a high ratio of lateral to longitudinal resistance (several times that of a power boat) and relatively little leeway is introduced by an asymmetrical load. A single leg towline is much easier to control, as it can be "fastened" to a sheet winch; shortening is simple, as is letting go in an emergency.

C. Smooth Water Towing. It would seem, intuitively, that the smoother the water the easier the towing. But that may not be true depending on the hull shape of the towed boat. Since there is no simple way to tell in advance by inspection of the hull, the Coxswain must be prepared to experience queer behavior by some boats being towed when they get to very smooth water.

1. <u>Stability.</u> For powered vessels, propulsion forces are normally introduced near the stern of the vessel. If the propulsion force is placed forward, a mode of instability, involving the hull and water, is introduced and is not easy to remove. Only if the propulsion force is placed sufficiently far behind the center of lateral resistance is the instability mode not present, and a simple rudder can control the direction of advance.

   For a towed vessel the applied propulsion force is at the bow. This fact alone introduces instability and the towed vessel does not track in calm water, even if the tow is started in a straight line. The mechanism is as follows:

the center of force opposing the tow is under the water, but the towline attachment is on the bow, well above waterline. The forefoot (the under-water part of the bow) becomes an effective rudder, the angle of which is determined by the roll of the vessel. As seen from the towed vessel, a roll to the right causes a sheer, or swerve, to the left; and a roll to the left causes a swerve to the right. Contrast this action to that of the vessel under power; a roll to the right causes a swerve to the right, and a roll to the left causes a swerve to the left. If there is no roll, the vessel under tow tracks; as soon as there is a small roll-from some movement on the vessel or wave action-the vessel swerves. If the roll is oscillatory, as it is if induced by chop, the direction oscillates and may not be noticed.

The towline contributes substantially to the effect by adding a component of force increasing the roll angle-and thus the swerve-since the towline is attached well above the below-waterline center of lateral resistance. *If the roll-righting moment of the towed vessel cannot overcome the opposite torque of the towline, the towed vessel continues to veer off.* If unchecked, the towed vessel comes abeam the towing vessel and is moving at a greater speed (since it traveled further to get there). This is potentially a dangerous situation ranging from merely the breaking of the towline, the tearing loose of cleats, to the capsizing of one or both the vessels. The instability force increases dramatically as the towed vessel veers off to one side.

> Note: this has happened to tugs that have a high tow post. When the towed vessel-usually a barge with no rudder-is abeam, it wants to move away from the tug; if the line is strong enough, and the towed vessel is large enough, the tug capsizes. This action has the name "girt"; tugboat captains describe it as being "in irons".

Thus it follows that for small vessels, the more stable condition overall is with some wind and chop. As the water becomes calm, as in a harbor, the conditions become ideal for the instability to develop and the tow to become a candidate for an accident. The behavior of the towed boat is counterintuitive; the tendency is to think that on entering a harbor the major dangers have been left on the ocean. Instead, towing might become more difficult and require a different technique.

2. Stability Bridle. In order to control smooth-water instability a tow arrangement illustrated in Figure 5-3 is

used. This type of bridle generates a restoring force very quickly and, being short, prevents the towed boat from going at high speed if it does swerve off line. The ideal ratio of boat separation to cleat separation has been determined experimentally to be 3; the two legs are cleated to the distressed vessel. This tow arrangement can also be used in the open seas when conditions permit; it gives better control of the towed vessel than a bridle and single leg towline.

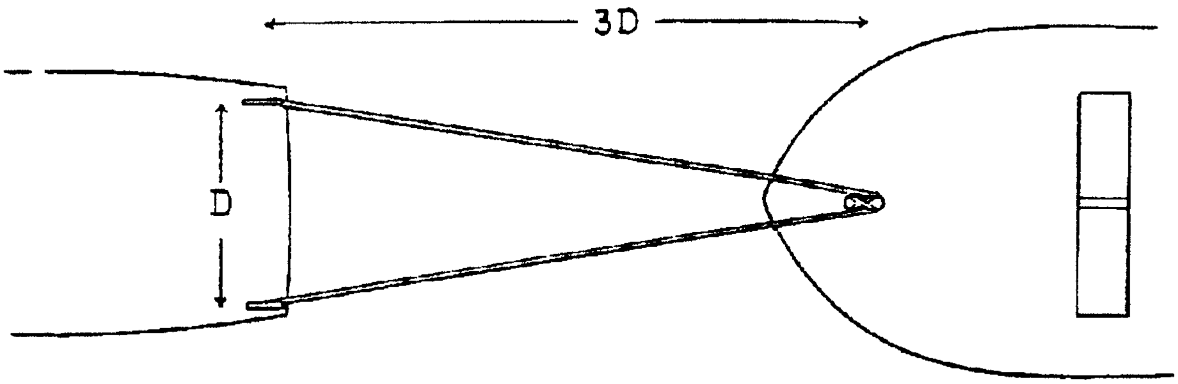


Figure 5-3 Stability Bridle

3. Drogue. Streaming a drogue or sea anchor from the stern of the towed boat greatly improves its stability. However, this usually involves putting crew and equipment aboard the towed boat, as very few pleasure craft carry a drogue, or the POB know how to stream one.

4. Along-Side is an alternative way to control the towed vessel in calm waters. However, if the configurations of the towing and towed vessels make an along-side tow awkward and limit maneuverability, the Stability Bridle is a preferred technique. Maneuverability is enhanced and, generally, docking the towed vessel is just as easy. In general, an along-side tow should not be hooked up until the towed vessel is in quiet water; a Stability Bridle can be rigged before the tow reaches still water.

5. Trailer Attachment. It is often desirable, and sometimes necessary, to tow trailerable boats by the stem pad eye; some manufacturers of trailerable boats specify that their boats are to be towed only by the stem pad, not the forward

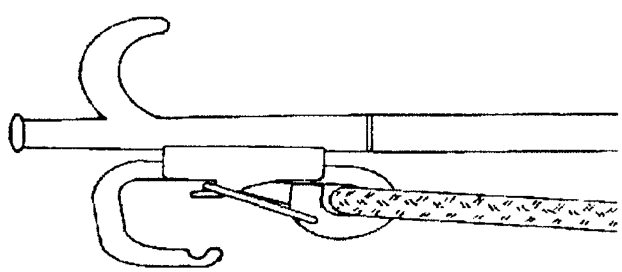


Figure 5-4 Skiff Hook

cleats. A convenient way is to use a short piece of line spliced to a "skiff" or "kicker" hook illustrated in Figure 5-4. The carbine hook is held open by a bracket mounted on a boat hook; as long as there is tension on the line, the notch in the bracket holds open the snap on the carbine hook. This method should not be attempted if the seas are anything but moderate, and extreme care must be taken when the Skiff Hook is detached. The carbine hook must be <u>forged</u> steel rated 2000 pounds at least. The last thing the Coxswain wants is for a tow force surge to straighten out the hook thus releasing it and sending it flying back toward the towing boat.

6. <u>Personal Watercraft (PWC)</u> can only be towed using the trailer eye-there is no other attachment point. The eye is often underwater so attachment of the snap shackle must be done by hand. Many PWCs don't tow very well unless the operator hangs off the back-in the water-and uses his legs as a rudder.

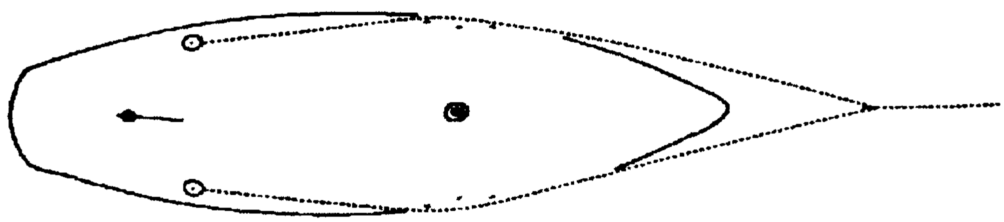


Figure 5-5 Sailboat Bridle

7. <u>Sailboats</u>. If the towed vessel is a sailboat it may present a problem of towline attachment. Sailboats over 25ft long usually have a forward cleat strong enough for anchoring, and strong enough for towing. Smaller sail-boats may not have a forward cleat and some other attach-ment point is required. All sailboats have some means of fastening jib sheets-usually winches-and these make ideal attachment points since they are designed with the strength to pull the boat through the water. Attaching to the winches requires a long bridle, each leg about 3/4 the length of the sailboat. The bridle goes "outside everything" (chafing gear is required if the bridle rubs against the shrouds) and is connected to the single leg towline a few feet ahead of the sailboat bow. Figure 5-5 illustrates the arrangement. If the towed sailboat is small-20 ft or less-it can be towed by using the Skiff Hook and fastening it to the forestay. A preventer line may be necessary but all sailboats have a means of at-taching the tack of the jib to the base of the forestay. Only a very small force is required to tow a small sail-boat at 3/4 hull speed.

D. Steady Forces. The Steady Force to tow is determined <u>only</u> by the characteristics of the towed vessel. The only characteristics that the Coxswain can estimate with any certainty is Waterline Length and Type. Appendix E is a tutorial on the characteristics of boats that explains how it is possible to eyeball a target and make a worse-case estimate of the steady force required to tow at a Speed/Length ratio of 1.0. **A Speed/Length ratio of 1.0 is a speed in knots equal numerically to the square root of the water-line length in feet.**

This is the maximum speed for which the tow forces-either Steady or Shock-can be estimated with any confidence.

1. <u>Eyeballing the Target</u>. The curves in Figure 5-6 enable the Coxswain to eyeball the distressed vessel and make a worst case estimate of the Steady Force required to tow at a Speed/Length ratio of 1.0. All that is required is to decide if the vessel is a sailboat or a power cruiser, and estimate the water-line length. Read the Steady Force (in pounds) from the appropriate boat-type curve. If the distressed vessel is very light the Steady Force **<u>might</u>** be less than indicated by the curves and it might be possible to tow the vessel at a Speed/Length ratio greater than 1.0, but there is no safe way to tell.

2. <u>Steady Force vs Speed</u>. The Steady Force varies almost linearly with speed, ie, the Steady Force of a towed boat travelling at a Speed-Length ratio of 0.5, is about 50% of that at a Speed-Length ratio of 1.0. This is very helpful in reducing the Total Peak Force if the combination of Steady Force and Shock Force exceeds 1500 pounds, (or 850 pounds for small facilities).

3. <u>Tow Planning Worksheet</u>. Examine the Worksheet illustrated on Page 5-3 and note the information required on the Towed Vessel, ie, Type, and Waterline Length. The Coxswain figures out the Tow Speed (the square root of the Waterline Length) and reads the Steady Force from the proper curve in Figure 5-6. This figure is replicated on the back of the Tow Planning Worksheets.

4. <u>Caveats</u>. Often, the vessel requiring towing assistance is disabled in a way that affects its towing characteristics, eg, it may be partially flooded. In such cases the estimate of steady force in Figure 5-6 is too low, and by an unpredictable amount. The Coxswain must use extreme caution when attempting to tow a boat that is partially flooded, or that is disabled for any other reason that changes its basic characteristics.

E. Towline, for facilities ≥30ft waterline length. The parameters that determine the shock forces in a rough-water tow

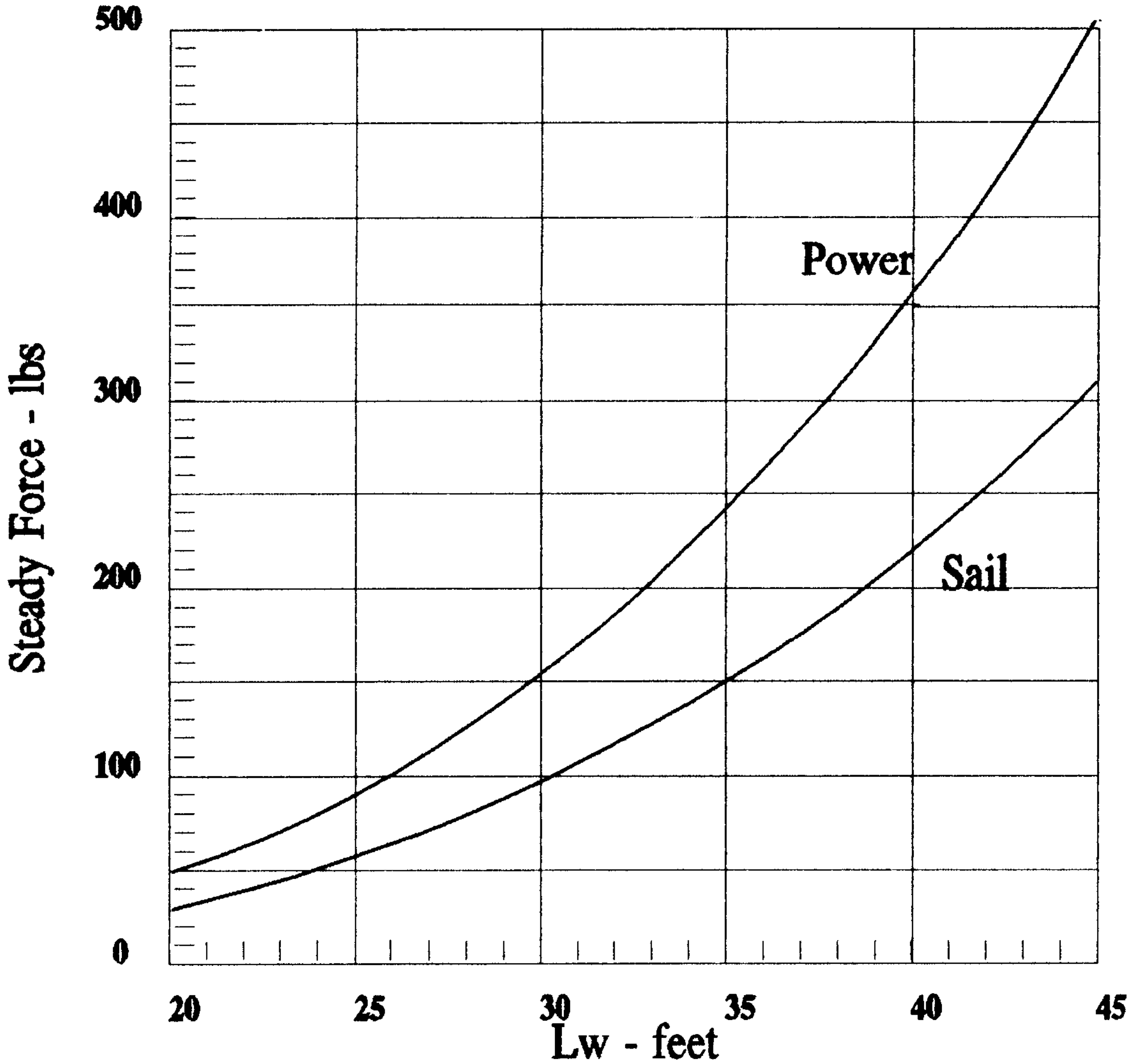


Figure 5-6 Steady Towing Force vs L_w

are: the displacement and length of the **towed boat**, the displacement and length of the **towing boat**, the **sea state**, and the elasticity of the **towline**. Of these, the most important is the towline.

1. Attributes.

a. Strength. The line must be strong enough, even after some ageing, to handle the maximum peak loads that are experienced, without either breaking or becoming permanently deformed. The Breaking Strength numbers given in

Table 5-2 are for new line. ASTM standards suggest that in line usage the maximum load should be no more than the Minimum Tensile Strength divided by a Safety Factor. For Nylon, the Minimum Tensile Strength is 80% of the Breaking Strength. Manufacturers recommend a Safety Factor of between 5 and 12, depending on the degree of life-critical service.

b. Elasticity. The line must stretch enough to accommodate instantaneous velocity differences-between the towing and towed boats-caused by the sea state. If the line does not stretch, velocity differences translate into enormous instantaneous shock forces.

c. Handling. The line must "feel good", be easy to splice and repair, and resist hockleing and kinking.

d. Friction determines how many turns around a cleat are necessary to absorb any given load; too little makes cleating very difficult, and too much makes the line very sensitive to chafe.

e. Durability. Line is expensive, so ideally it should last a long time and not deteriorate from weathering, ageing or use.

f. Cost. Initial cost is important, but the most expensive line is often not the best, as other physical attributes are more important.

2. <u>Characteristics</u>. Selection of a towline is always a compromise. For Auxiliary vessels the compromise usually takes the form of nylon for material, and double-braided or three-strand twisted for constr6ction. Small Auxiliary vessels used in inland lakes and rivers may select single-braided polypropylene or polyethylene, but these materials should not be used when peak loads greater than 500 pounds can be experienced. Some of the characteristics of 200ft lengths of four different types of line are tabulated in Table 5-2. The lines are compared at two different loads, 1500 and 4000 pounds; this is to demonstrate how the line should behave when worked at the planned *PEAK MAXIMUM FORCE* of 1500 pounds, and if worked to the point where the instantaneous tension is 4000 pounds and the line breaks.

a. Strength. The numbers given are for average <u>new</u> line; they are large enough that the line should not break at 4000 pounds, but the Safety Factor becomes uncomfortably small. And, a knot, eye splice, or turn around a cleat <u>will</u> break, or give way, at about one-half the breaking

	½" DB Nylon	½" Tw Nylon	⅝" Tw Nylon	¾" Braid Poly
Strength - lbs	8,500	7,500	11,700	10,575
Characteristics at 1500 lbs Working Load				
Stretch - ft	14	33	29	6.5
Stored Energy	7,800	14,600	13,900	4600
Gravity Drop - ft	26	16	27	51
Safety Factor	4.5	4.0	6.3	
Characteristics at 4000 lbs Load				
Stretch - ft	21	45	40	14
Stored Energy	28,100	44,100	41,400	26,300
Tip Velocity ft/sec	295	350	270	260
Gravity Drop - ft	7.1	5.1	9.0	9.5
Safety Factor	1.7	1.5	2.3	

Table 5-2 Characteristics of 200 Foot Towline
Large Auxiliary Vessels

strength of the line itself. So there is a likelihood that any one of the lines illustrated could break if instantaneously loaded to 4000 pounds.

b. Elasticity. The amount of stretch is a measure of elasticity, and it is apparent that Twisted Nylon line is the most elastic, and therefore able to absorb the largest shock load. **For all but the most unusual cases, ⅝" three-strand twisted is the ideal towline for large Auxiliary vessels, and ⅜" three-strand twisted is the ideal towline for smaller Auxiliary vessels**. All of the Shock Force calculations are based on the characteristics of three-strand twisted line. Figure 5-7 illustrates the effect of different elasticities for two lines. The two curves illustrate how the TENSION (force) varies with TIME as the towline absorbs the momentum transfer that occurs when the two vessels are at different speeds. The areas under the two curves are the same, indicating that the total amount of energy transferred is the same. But one line stretches much more than the other and takes longer to transfer the energy. The curves are to scale for lines of the same diameter and show that the Peak Force with Twisted line is only two-thirds as great as

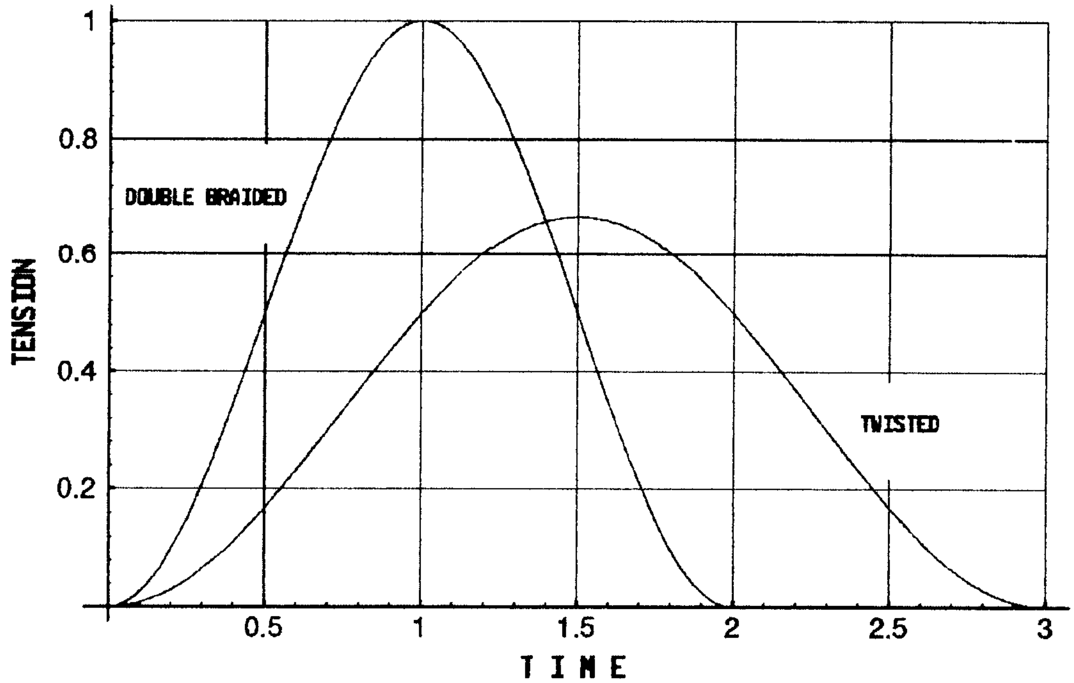


Figure 5-7 Effects of Elasticity

as the Peak Force with Double Braided line for the same energy transfer.

c. Handling. The "feel" of line is important for two reasons; after all, the line is handled, spliced, knotted and cleated, so it must be able to take this treatment. Nylons come in various degrees of hardness, but for the small lines used by the Auxiliary most nylon line is easy to splice and knot. For double-braided Nylon a correct (!) eye-splice achieves 90% of the line strength; a bowline 60%, and a sheet bend 55%. Numbers for 3-strand twisted are about the same; however, twisted, being more elastic, binds knots under load and makes releasing very difficult. When kinked, double braid does not hockle nearly as badly as 3-strand twisted. (Many of the boats that the Auxiliary assists are <25ft long and have cleats that will not accept line larger then 5/8" in diameter, and that presents a problem when a large facility tries to tow a small vessel). Metal thimbles should <u>never</u> be used with nylon; the stretch opens the throat at the thimble which can tumble and cut the line.

d. Friction. Modern synthetic fibre has a low coefficient of friction on polished metal or on itself. New nylon on polished stainless steel has a coefficient of about 0.15; ageing, especially from salt water exposure, probably doubles this figure. Therefore the tension required to hold a load is reduced by from 42% to 80% per turn depending on the age of the line. A tow hawser must <u>never</u> be connected on the towing vessel with a half hitch; that makes an emergency disconnect impossible except by cutting the line. For nylon, a turn around a cleat plus a turn around each horn reduces the load enough so that it can be held by hand. The poly line materials have a very low coefficient of friction-about .07-and cannot be cleated to handle large loads, but are very satisfactory for small Auxiliary vessels when the load is substantially less than the *LIMIT* of 850 pounds.

e. Durability. The synthetic fibers are very durable, resist exposure to sun and weather, and do not rot. However they are susceptible to chafe; friction-necessary to make cleating and knots hold-melts the strands and reduces the strength. Therefore chafing gear must be used wherever synthetic line contacts metal. An area often overlooked is the eye splice or bowline connected to the towed vessel. Chafing gear should be fastened to the line so that the chafing gear rubs on the metal, not the line. Duct tape, sail tape, canvas, or a piece of rubber tubing is satisfactory with most lines, but the most elegant treatment for a three-strand twisted eye-splice is worm, parcel and serve.

f. Cost. The real question is whether to use double braid or three-strand twisted. Double braid is about 50% more expensive than twisted, so twisted is substantially more cost effective.

g. Stored Energy and Gravity Drop. Table 5-2 shows the stored energy, in foot-pounds, for the various lines when loaded to 1500 and 4000 pounds. This number will not mean very much to most Auxiliary Coxswains; it is a measure of the damage the line can cause if it breaks. If the line breaks it will usually do so at one end where a connection is made. The important number is the Gravity Drop, ie, the amount the broken end of the line drops before it reaches the other end. Note that the gravity drop is substantial for 1500 pounds, and even for 4000 pounds is larger than the freeboard on most vessels (provided the line is 200ft long). The tow should always be arranged so that the gravity drop is sufficient for the line to fall harmlessly in the water and not cut some crew member in half.

h. Tip Velocity. The numbers indicate that in the event of a break there is no time to duck. To put the numbers in perspective, 60 miles-per-hour is only 88 feet-per-second!

F. Sea State. Estimating the shock force caused by the sea state is a very complicated subject. There is no easy way to define the sea state; just about the only evidence available to the Coxswain is the **Appearance** and the **Period** of the waves he experiences en route to an assist. There are two **classes** of sea state that can be distinguished by the **Appearance** of the waves: **Swells** caused by a distant storm, and **Wind Waves** driven by a local wind. While the Pacific is characterized by long swells, the Atlantic has shortened periodic waves and a steep chop. It is important therefore for the Coxswain to decide if he should treat the waves as a swell or as wind-driven. **Swells**-at least the important ones-will have an **Average Period** greater than 7 seconds; **Wind Waves** will have an **Average Period** less than 7 seconds.

1. Swells. In many areas where Auxiliarists operate, especially on the West Coast, distant storms cause large regular waves outside the area where they are created. When they get in shallow water (water depth ≈ swell wavelength) they lose their ideal sinusoidal shape and break, much to the delight of surfers. It is not at all unusual for these swells to have a wave length of several hundred feet and to travel at >25kt. (Swells traveling at speeds much less than 25kt dissipate quickly and do not travel far outside the area where they are generated.) Until they reach depths comparable to their wave lengths they are gentle and hardly noticeable to a boat. But when there is a tow the situation is quite different, as the two boats are seldom on the same phase of the swells. Going down-swell a boat gets a "push" at the top and a "pull" at the bottom. The amount, called the *Wave Effect*, is given by

$$C = 1.86\,\frac{W_h}{W_i}$$

where C is in knots, W_h is the swell height in feet, and W_i is the wave interval in seconds. For example, a 6ft swell travelling at 30kt has an instantaneous current of 1.1kt in the direction of the swell at the top, and a current of 1.1kt in the opposite direction at the bottom. Thus if the towing boat is on the top when the towed boat is on the bottom, they experience a velocity difference of 2.2kt. For this example the wave interval is 10 seconds and the wave length is 500 feet; a 200ft towline places the boats almost at the worst possible relative position, a half wavelength apart. It is obviously impossible to "keep the boats in step"; that would require a towline 500 feet long!

The situation is further complicated by the slope of the swell that makes the boat go uphill or downhill depending on where it is on the swell. The *Gravity Effect* can be as large as the *Wave Effect*, but since the two are 90° out of phase the *Gravity Effect* does not change the peak force.

The solution to towing in swells is to use a very short towline. If the two boats can stay closer than a fraction of the swell wavelength they will be on the same phase of the swell and will experience very little shock. The bridle arrangement shown in Figure 5-3 is ideal for this kind of situation.

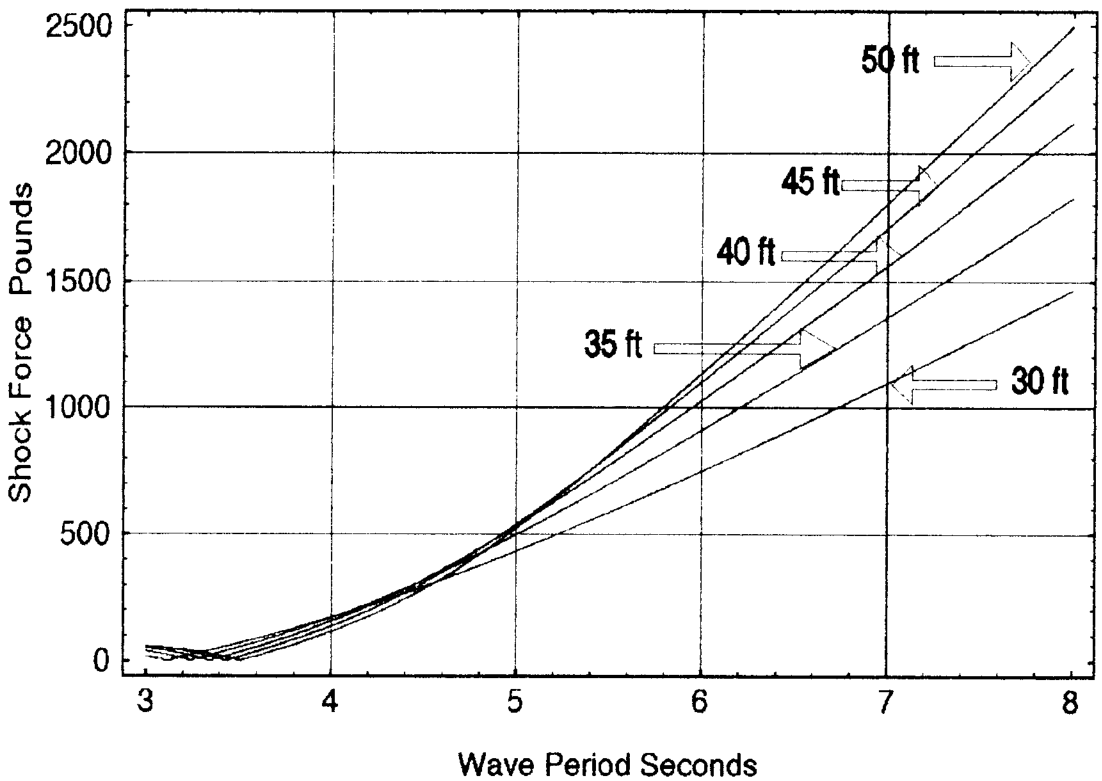


Figure 5-8 Peak Shock Force vs Average Period
35 foot Auxiliary Vessel

2. Wind Waves. Waves generated by a local wind have a trochoidal shape. Whereas the spectrum (the range of wave-

lengths and periods) of Swells is very narrow, the spectrum of Wind Waves is very broad. The large range of wavelengths and periods is the reason it is impossible to select a towline length that will keep the towing and towed boats "in step". No matter how the towline is adjusted there will be times when the two boats are on opposite phases of the wave system. Consequently Wind Waves must be analyzed statistically. Appendix E has a brief tutorial on the statistics of Wind Waves.

What the Coxswain needs is a way to estimate the Shock Force he might encounter using the data he can measure. About the only thing he can measure is the Average Period. Figure 5-8 is a graph that relates Shock Force to

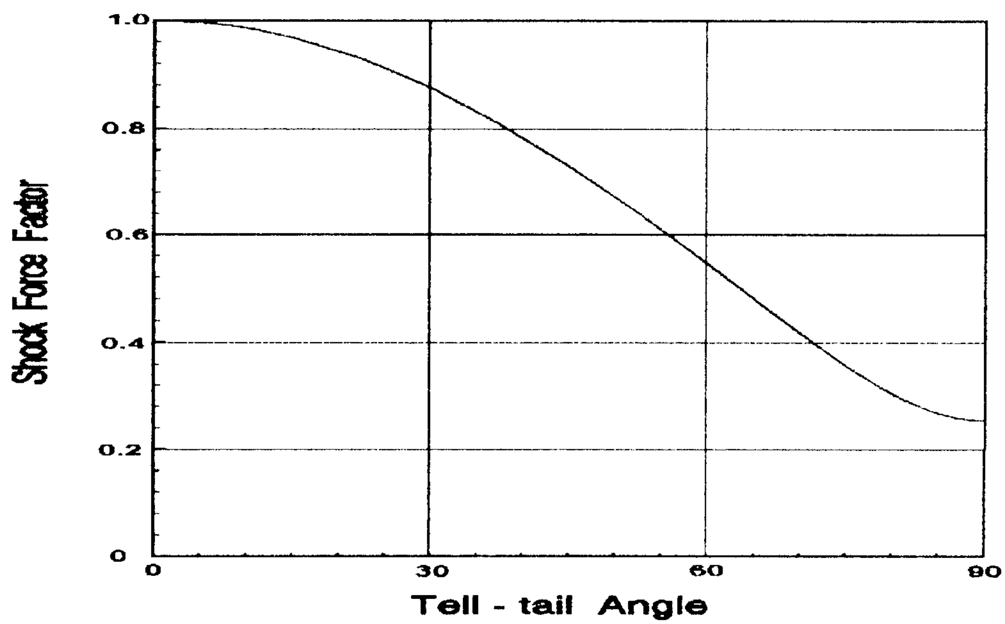


Figure 5-9 Relative Wind Direction Factor

the Average Period of the Wind Waves. Since the Shock Force is sensitive to both displacement and length, there must be six different sets of curves like those shown in Figure 5-8, one for each of six different length Facility. The five curves shown in Figure 5-8 are for five different length towed vessel, reading from the bottom up for a 30ft, 35ft, 40ft, 45ft and 50ft vessel. Appendix A has Tow Planning Worksheets specialized for a 20ft, 25ft, 30ft, 35ft, 40ft, and 45ft facility. The curves involve a complicated calculation of the towline characteristics and Wind Wave statistics. The Shock Force curves included on the back of the Tow Planning Worksheets are specialized for each length vessel, are based on the highest 10% of the wind waves that generate the Average Period shown, and assume a 200ft three-strand twisted towline for large Auxiliary vessels and a 100ft three-strand twisted towline for small Auxiliary vessels. (The difference between ½" and ⅝" three-strand twisted is less than the accuracy of the other calculations, so no distinction is made between the two diameters for large Auxiliary vessels).

3. Heading Correction. The Shock Force curves assume the tow is proceeding in the direction of the wind, either up-wind or down-wind. The Shock Force is probably greater up-wind than down-wind; the calculation ignores this because it is so highly dependent on the configuration of the towed and towing boats. However, the Shock Force is ameliorated if the tow tacks at least 45°. Smaller angles don't accomplish much because the wind waves spread about ±30° from the wind direction. Figure 5-9 shows the correction factor to be applied to the Shock Force as the tow diverges from parallel to the wind direction.

4. Wind Wave Summary. We now have all of the information required to estimate the Standard Shock Force for entry into the Tow Planning Worksheet. En route to the Distress, the Coxswain counts the wave crests that pass his boat for about 5 minutes. Ideally he should do this by station keeping at a fixed location; the 5 minutes lost is not of any consequence if the assist is non-emergency. But if he is skilled he can do a satisfactory job while continuing to the assist. When he gets to the other boat he estimates the Waterline Length and establishes the Type. From Figure 5-6 (all of the Figures he needs are on the back side of the Tow Planning Worksheet) he reads the data on Steady Force and enters this information on the Tow Planning Worksheet. From Figure 5-8 (or the equivalent for other length facilities) he reads the Standard Shock Force for the Average Period of waves he has experienced and for the L_w of the distressed vessel, and enters this information on the Tow Planning Worksheet. The Coxswain is now in a position to select the Tow Course relative to the wind if the Maximum Peak Force is near the Limit. He can make these last adjustments as the tow gets underway, slowly.

G. Tow Planning Worksheet. The Tow Planning Worksheets are designed to be specialized for a particular Auxiliary vessel, and then reproduced and carried aboard the vessel while on patrol. Follow the ILLUSTRATION step-by-step to generate the Tow Planning Worksheet for Auxiliary Vessel *SeaScape*.

1. The tow planning worksheet most appropriate for *SeaScape* is the 30ft form. Using the formula on page 5-5, the Slip is computed and found to be 0.35. The statistical data is filled in at the top of the Worksheet (see Figure 5-10).

FACILITY SPECIALIZATION ILLUSTRATION	
Name	*SeaScape*
Waterline Length	28 feet
Displacement	6.0 tons
Power	twin gasoline
Props	24" Diameter by 22" Pitch
Gear Reduction	2:1
Continuous Cruise	18 knots @ 3000 RPM
Towline	300 feet ½" 3-Strand Nylon

2. The TOW-Speed-Knots/Max-RPM-while-Towing table is computed. There are eleven sets of data with the intervals being 10% of the Maximum Continuous Cruise Speed, ie, 18 knots. The first column is for zero towing speed, eg, trying to tow an anchored boat; the last column is Continuous Cruising Speed, ie, 18 knots; and the columns in between are in 10% steps of Speed, ie, 1.8 knots, 3.6 knots, etc.

3. The second row of numbers are generated by multiplying 3000–the Continuous Cruise RPM–by the eleven numbers (one for each value of the allowable fraction of Cruising RPM) in the 0.35 slip column of Table 5-1. The second row is therefore the Maximum RPM that will cause no engine damage when towing at a speed of V_t shown in the corresponding column in the first row.

H. Worksheet Use Illustration. After the Worksheet is specialized for a particular facility, working copies can then be used for actual operations. To illustrate how, an artificial scenario is used.

1. The statistical information, ie, the fact that the TOWED VESSEL is a Cabin Cruiser and is 38 feet long, is entered in the appropriate spaces. The Tow Speed is simply the square root of 38, the waterline length in feet. (Taking the square root is not as complicated as it sounds. We only want to know the Tow Speed to the nearest knot, so remember 4^2 is 16; 5^2 is 25; 6^2 is 36; and 7^2 is 49, and pick the nearest number.) The Steady Force is 310 pounds

TOW PLANNING ILLUSTRATION SCENARIO	
Distressed Vessel	
Type	Cabin Cruiser
Waterline Length	38 feet
Sea State	
58 crests pass in exactly 5 minutes	
Safe Harbor	30° off downwind

for a 38ft Power Boat as read from the Steady Force vs L_w curves on the back side of the Worksheet.

2. The SCENARIO indicates that 58 crests pass in exactly 5 minutes, so the Average Period is 5.2 Seconds (5 x 60 ÷ 58 = 5.2). For a 40ft towed vessel the Shock Force is 500 pounds, as read from the Shock Force vs Average Period curves on the back side of the Worksheet. The Shock Force vs Average Period graphs are <u>different</u> for each length Auxiliary vessel; the other graphs are identical on all Worksheets. At an Average Period of 5.2 Seconds the curves bunch up and one can't be distinguish from another. Not to worry; since they bunch up any one will do. The sensitivity to towed boat length only shows up at the higher Average Periods, ie, in the worst seas.

3. The SUMMARY section can now be completed. Since it appears that the Maximum Peak Force is going to be comfortably below 1500 lbs, the Coxswain decides to use only 200ft of the towline and not all of the 300ft he has on board. The "tack" of 30° happens because that is the direction to the nearest safe harbor; it doesn't reduce the Shock Force very much, but probably does ease the ride. The Coxswain must refrain from running at greater than 2150 RPM; if he does he will cause permanent valve damage to his engines. Incidentally, the Vessel has twin engines and the engines <u>must</u> be kept in sync; a "beat" of only once per second is equivalent to 60 RPM and that makes one engine work much harder than the other.

   The Worksheet has "bullets" (numbers inside braces) to show what data goes into the Summary. The corrections are only those that apply to the Standard Shock Force and only require multiplying the appropriate Force value by the named Factor. The final Adjusted Shock Force is added to the Steady Force to arrive at the Maximum Peak Force. If this number is comfortably below 1500 pounds, then the tow can proceed with confidence. If the number is <u>near</u>

TOW PLANNING WORKSHEET

30 FOOT (6.5 tons) AUXILIARY FACILITY

AUX Facility *SeaScape* Actual Disp. *6* tons

Max Cont Cruise *3000* RPM Speed *18* knots Slip *35* %

Towline Type *5/8 " 3-strand nylon* Towline Length *300* feet

TOW Speed knots

0.0	1.8	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2	18.0
1770	1890	1980	2100	2220	2340	2460	2580	2730	2850	3000

Max RPM while towing

TOWED VESSEL

Type *Cabin Cruiser* Waterline Length *38* feet TOW Speed *6* knots

Steady Force [1] *310* pounds

SEA STATE

Average Period *5.2* seconds Standard Shock Force [2] *500* pounds

SUMMARY

Standard Shock Force [2] *500* pounds

Double Braid 1.6 x [2] = [3] *500* " (use only if applicable)

Heading *.84* x [3] = [4] *420* "

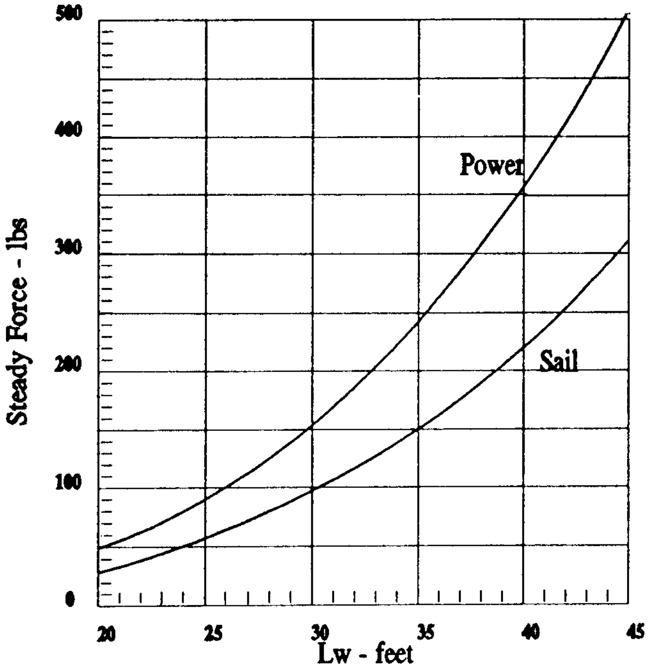
Adjusted Shock Force [4] *420* pounds

Steady Force [1] *310* pounds

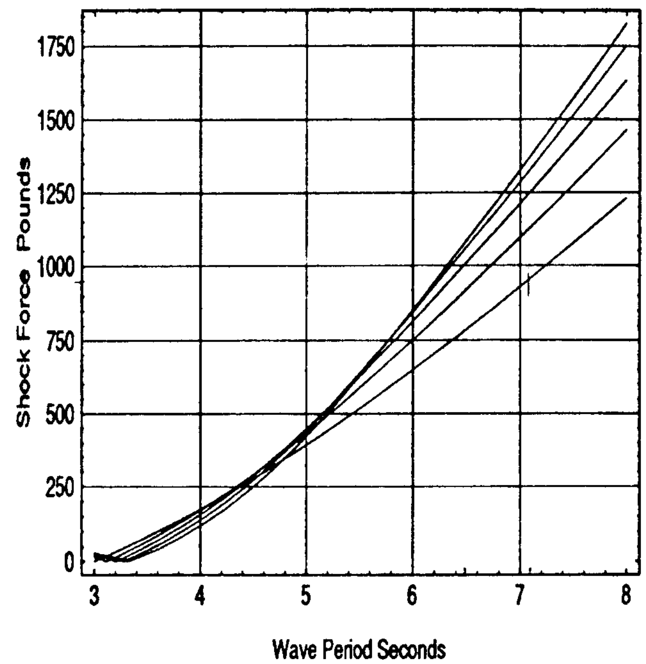
Maximum Peak Force [1] + [4] *730* pounds

Figure 5-10 Illustration Tow Planning Worksheet

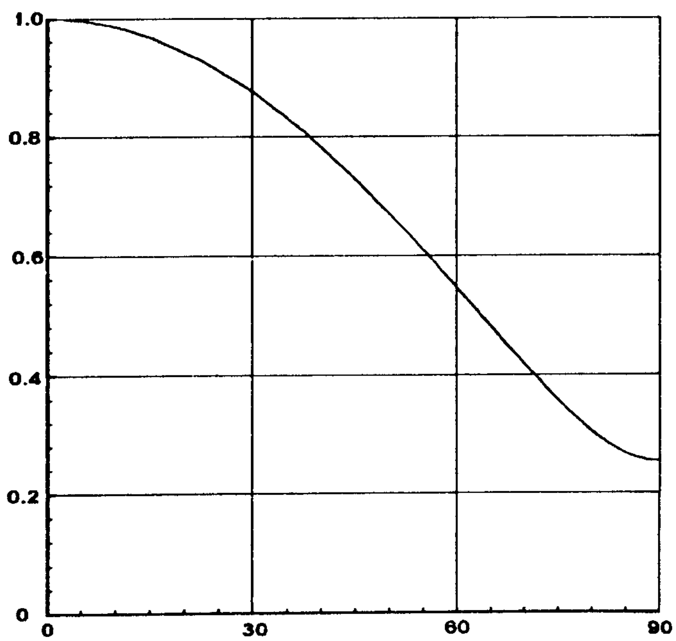
30 foot Facility



Steady Force vs L_w



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The five curves above are for - reading from the bottom up on the right hand side - 30, 35, 40, 45, and 50 foot waterline length boats to be towed.

NOTE: The Shock Force curves are for 3-Strand Twisted towline. If Double Braided line is used multiply the Shock Force by 1.6.

NOTE: The Shock Force curves are for 200 foot towline. A 100 foot line may more than double the Shock Force; for a 300 foot line use a factor of 0.6

Figure 5-11 SeaScape Illustration p-2

tow can proceed with confidence. If the number is near 1500 pounds the Coxswain should review the source for all the data, and check his arithmetic.

I. How often will the Maximum Peak Force be encountered? Since the Shock Force is calculated using the highest 10% of all waves it would appear that the Peak Force would be encountered every tenth wave on average. But the Peak Force calculation assumes that the towing boat and the towed boat are simultaneously on the worst possible phase of high waves, and this is very unlikely. It is unlikely that the facility will ever experience an Average Period greater than 7.5 seconds; that corresponds to a sea fully developed by a 26kt wind with 10% of the waves higher than 16ft. Even in this sea the average wavelength is less than 200ft, the length of the towline, so the two boats are on statistically independent waves. Hence the probability that both are simultaneously in the worst phase on a highest wave is essentially the product of the probabilities of each being on a highest wave. And 10% x 10% = about 1%. Assuming a middling worst Average Period of 6 seconds that means that a Maximum Peak Force should be expected about once every ten minutes.

J. Possible Adjustments. There are several things the Coxswain can do to reduce the Maximum Peak Force; these are not prioritized and any one or several can be used independently.

1. Towline Length. The towline length should be at least 200ft. A longer line will allow more stretch and will lower the probability that the Facility and the towed vessel are simultaneously on a 10% highest wave.

2. Tack. Figure 5-9 shows the dramatic effect of tacking.

3. Slow Down. Reducing speed reduces the Steady Force, not the Shock Force. However, when the speed is reduced the Coxswain can then measure the Average Period and check his determination of Standard Shock Force much more accurately than while en route to the assist scene.

4. Check the Numbers. Initially, the Worksheet is completed using numbers, such as L_w, on the side that will give large force values. These can be examined more carefully to see if the safe assumptions are too safe.

5. Should the Facility be there at all? The Coast Guard restricts small boats when the numerical sum of the Average Wave Height (in feet) + the Wind Speed (in knots) exceeds 30. The SMC may not know what the local conditions are and it is the responsibility of the Coxswain to question if he should be on scene at all if the "Weather" number is above 30.

K. Unusual Circumstances. There are occasionally situations when the "sea" is a combination of severe swells from distant storms and local wind-driven waves. Under these circumstances the towline cannot be short because the shock from the wind-driven waves would be severe; yet the towline cannot be long because that would permit severe shock from the long-period swells. What to do? There is no textbook answer, except to leave the towing to the Coast Guard. Their boats carry much longer towlines than do Auxiliary boats. If the Auxiliary does attempt the tow, the only thing the skipper can do is to try to adjust the towline length to minimize the shock force. The "dangerous" length is one-half the wavelength of the swells since in a mixed sea the swells are usually more of a problem than are the wind-driven waves.

L. Small Auxiliary Vessel Considerations. Most of this chapter does not discuss or analyze the Forces experienced by a vessel smaller than 30ft. This limitation comes from the fact that most Districts restrict off-shore SAR activity to vessels larger than 30ft. However, smaller vessels do engage in near-shore activity and thus might become involved in situations that could benefit from a towing force analysis. In addition, the majority of vessels that the Auxiliary assists are between 20 and 25 feet in length.

1. Towline. The small-vessel Worksheets (see page A-13,14 and A-15,16) have been specialized for a towline that is ⅜" in diameter, nylon, 3-strand twisted construction, and 100 feet long. Most 20 and 25ft boats have cleats that will not comfortably accept ½" or ⅝" line, and ⅜" line is more common. And many smaller Auxiliary vessels do not carry 200ft of towline, at least not in one piece. So the Worksheets assume a 100ft towline, although it is much safer to use a longer line. Table 5-3 also includes data on ⅜" poly line. Although nylon is safer, poly line is very appropriate for small Auxiliary vessels and the fact that it floats is a trade-off to cleating difficulty.

2. Load *LIMIT*. 1500 pounds is considered the upper limit of instantaneous towing forces for Auxiliary vessels with ≥30ft L_W. For the smaller line to have the same safety factor, the Working Load *LIMIT* is 850 lbs and the probable Breaking Load is 2100 lbs. So in using the TOW PLANNING WORKSHEETS for small Auxiliary vessels the value for Maximum Peak Force that should cause extreme caution is anything near 850 lbs.

3. It is also necessary to point out the dangerously small Gravity Drop. Even at the Working Load, the number is small and consequently snap-back is a serious worry; at 2100 lbs load, the line is a very serious hazard.

	3/8" Twisted Nylon	3/8" Braided Poly
Strength - pounds	4,200	3,000
Characteristics at 850 lbs. Working Load		
Stretch - feet	17	5
Stored Energy - foot pounds	4,144	1,850
Gravity Drop - feet	1.6	4.3
Safety Factor	4.0	3.5
Characteristics at 2100 lbs. Breaking Load		
Stretch - feet	22	9.2
Stored Energy - foot pounds	11,486	7,900
Tip Velocity - Feet per Second	532	390
Gravity Drop - feet	0.6	1.1
Safety Factor	1.6	1.4

Table 5-3 Characteristics of 100 Foot Towline
Small Auxiliary Vessels

4. Cleats and other fittings are disproportionately weaker on small boats, and it is very likely that the cleats on a 20ft boat would pull out at 2100 lbs load; there is simply no reason for the marine architect to design for such a large load. So there is ample reason to limit the instantaneous Maximum Peak Force to about 850 pounds.

5. Overload. There is another "problem" with small boats. The boat itself may have a low δ, ie, Length/Displacement ratio (see Appendix E), and thus appear to be easy to tow. However, if it is loaded with people its δ becomes much bigger and the boat becomes much harder to tow safely. Passengers have a greater effect on δ for small boats than for large boats, and small boats tend to be overloaded more often than large ones.

6. Adjustments. The possible adjustments outlined in the Text for large Auxiliary vessels are all applicable to smaller vessels as well. However, the emphasis might be changed some. On large vessels Gravity Drop is enough (compared to freeboard) that snap-back is not much of a hazard, and snap-back is not the reason for making ad-

justments. But for 5/8" line in a 100 foot length it <u>is</u> a hazard. Consequently, the adjustment should be selected that will do most to reduce that hazard ie, <u>increase</u> the length. Even tying two lines together helps reduce the snapback more than it reduces the overall strength.

REVIEW QUESTIONS

1- Why is the ability to tow safely an important skill?

2- What are the two situations when towing can be hazardous?

3- What are the principal decisions that a Coxswain can make while on an assist mission?

4- Why does smooth-water instability occur?

5- Why is a towed boat more stable when there is some chop?

6- When smooth-water instability occurs how may it be counteracted?

7- What are the three types of forces involved in every towing evolution?

8- In a marginal situation what is the purpose of tow planning?

9- The Maximum Peak Force contains what two components?

10- What is a reasonable upper limit on Maximum Peak tow force?

11- Why is stretch necessary in a towline?

12- Why is stretch undesirable in a towline?

13- What is gravity drop?

14- For the same diameter does 3-strand or double braid have the greatest strength?

15- For the same diameter does 3-strand or double braid have the greatest stretch?

16- For the same diameter does 3-strand or double braid have the greatest amount of stored energy?

17- For the same diameter does 3-strand or double braid have the largest gravity drop?

18- A properly made eye splice has about what percent of line strength?

19- A bowline has about what percent of line strength?

20- A sheet bend has about what percent of line strength?

21- Why are poly lines inappropriate for large towing loads?

22- What is the mechanism of chafe in synthetic line?

23- What chafe point is often neglected in a towline?

24- If a towline parts where is the break most likely to occur?

25- What is meant by "Speed-Length Ratio of One"?

____

26- What is the proper towing speed for boats with the following waterline lengths? 23ft, 38ft, 44ft.

____

27- For a Vessel with Maximum Cruise of 2000 RPM with a slip of 30% making 18 knots what is the Maximum RPM for the following Tow Speeds?

5 knots ____

6 knots ____

7 knots ____

8 knots ____

28- The Steady Force graph assumes what Speed/Length ratio?

____

29- What determines the amount of the Steady Force, provided the Speed/Length Ratio is "1"?

____

30- Estimate the Steady Towing Force for the following:

15′ L_w outboard ______________________

20′ L_w I/O c/c ______________________

35′ L_w diesel c/c ______________________

27′ L_w sailboat w outboard ______________________

31- What does the appearance of waves indicate to the Coxswain?

____

32- In long rolling swells what is the best technique to avoid large shock forces?

____

33- What is the shape of Wind Waves?

____

34- What does the Coxswain use to measure Sea State?

____

35- How is the average period of Wind Waves measured?

____

36- What is the "standard" towline length when there are significant wind waves?

____

37- What is the Steady Force to tow the following:

30′ L_w Cabin Cruiser ____________

32′ L_w Sailboat ____________

24′ L_w Sailboat ____________

44′ L_w Cabin Cruiser ____________

38- If the Standard Shock Force is 600 pounds what is the Adjusted Shock Force if the Auxiliary facility is using Double Braided towline?

____

39- If the Average Period is 7 seconds what is the Shock Force for:

40′ L_w Facility	; 35 L_w Distress		____________
35′ "	; 40′ "		____________
30′ "	; 45′ "		____________
45′ "	; 30′ "		____________

40- What is the Relative Wind Direction Factor if the tow is 45° off the wind?

____

41- What are the two characteristics of most Auxiliary boats that makes them less than totally satisfactory for towing?

____

42- For a gasoline-engine vessel with vacuum gauges what is the minimum reading that should be allowed during a tow?

43- How can a twin-engine vessel with a knotmeter be sure the engines are not overstressed during a tow?

44- What is the maximum continuous RPM for a gas engine?

45- What is the maximum continuous torque for a gas engine?

46- What is the maximum continuous RPM for a diesel engine with a yacht rating?

47- When is a bridle on the towing vessel desirable or necessary?

48- Using the ***SeaScape*** Tow Planning Worksheet what is the Maximum Peak Force for the following towed vessels with the corresponding sea conditions, using 200 foot towline?

vessel	wave period	towline	
15′ L_w outboard	5.0 sec	3-Strand	________
20′ L_w c/c	5.6 sec	Double Braid	________
35′ L_w diesel c/c	4.3 sec	Double Braid	________
27′ L_w sailboat	7.1 sec	3-Strand	________

49. When should the skipper do formal Tow Planning?

---

50. Why is an Auxiliary Vessel engine(s) certainly overloaded if the skipper tows at 75% of redline RPM?

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CHAPTER 6. RESCUE, CONCLUSION, DOCUMENTATION, & LEGAL

A. Rescue. Efficient and effective rescue planning and operations are critical to saving lives. Planning involves evaluating survivor location and condition, selecting an appropriate rescue method and facilities, devising a rescue plan, and selecting a delivery point and means of transport. The Rescue Units (RUs) are then briefed and carry out the rescue plan. Safety of the RU and the survivors is the primary concern. The term "Rescue Unit" and "RU" generally refers to units on rescue-only missions, or to facilities designed and equipped for rescue work. Auxiliary vessels are primarily search platforms. However, under some circumstances the Auxiliary vessel may perform the function of a Rescue Unit, eg, towing a disabled vessel to a safe harbor.

Rescue planning involves dispatching or diverting RUs for rescue of personnel and property in distress after the distressed vessel has been located. SRUs at the distress scene, if able, rescue without delay; if they are unable, rescue planning is necessary. Rescue planning follows a logical sequence:

1. Evaluating survivability.

2. Evaluating the environment.

3. Selecting the rescue method.

4. Selecting rescue facilities.

5. Developing an optimum rescue plan.

6. Developing an attainable rescue plan.

The first two steps in the sequence depend, to a large extent, on the observations of the SRU that locates the distressed vessel; selection of rescue facilities benefits from intelligent recommendations by the on-scene SRU. The attainable rescue plan may not be optimum because of logistic constraints.

B. Delivery Planning. The final step in the planning sequence involves the safe transport and delivery of survivors and their property. The SMC selects a safe delivery point, such as a hospital or safe mooring, and a means of transport. The delivery point is selected that is most suitable for receiving survivors or accepting delivery of a distressed craft. Generally, the SMC selects the closest safe delivery point.

Delivery points are preselected and plotted on the RCC response chart. Many major metropolitan areas have disaster plans, and have first aid stations, clinics, private hospitals, city/county hospitals, and emergency medical care centers.

For missions involving emergency services such as towing or escort of marine craft, the disabled craft is delivered to the nearest safe harbor where emergency repairs can be made, or to a commercial towing service. SAR system response to vessels ends when they are safely delivered to a harbor sufficiently deep to receive both the SAR vessel and the disabled craft, and protected from the elements so that, upon delivery, the SRU can depart without expecting a further emergency to develop. If the disabled craft declines delivery to a safe harbor, the SRU withdraws assistance and the disabled craft is advised of the reason for SAR service termination.

If the number of survivors is large, the RCC may establish a temporary delivery point for intermediate handling of survivors. In major aircraft or marine disasters a short distance offshore, survivors may be transported to a temporary emergency care center established nearby. A large number of survivors can be evacuated quickly from a hostile environment, and secondary SAR facilities, such as local police and ambulance services, can then transfer survivors to medical care centers.

C. Rescue Operations consist of briefing, dispatch of units, en-route travel, on-scene procedures, survivor transport and debriefing, return to base, and debriefing of SAR personnel. Rescue operations do not end until all located distressed persons or craft are rescued or accounted for. Search operations continue until all survivors of the distressed craft are located, or the search is suspended. No RU is directed to execute a maneuver hazardous to the craft or crew unless a thorough evaluation indicates that the risk is acceptable. The RU commander has ultimate authority and responsibility to determine if an operation can be executed safely.

1. Rescue by Helicopter is accomplished by landing or by hoisting (although the HH-65A helicopter cannot land on water). Hovering and hoisting is the preferred method for marine incidents. Prior to authorizing a helo evacuation from a distressed boat, the SMC contacts a flight surgeon to evaluate the circumstance and justify the risks; in the case of saving persons from the water the rule is "just do it".

An electrical shock hazard exists to individuals who contact an ungrounded helicopter hoist cable. The cable is first grounded by contact with the vessel or water.

The hoist line is never "tied off" to a vessel.

The noise from a helicopter makes radio communication at the vessel almost impossible. Prior to the helicopter getting on scene the pilot and crew of the vessel must agree on hand signals that the vessel will use during the hoist operation.

2. Rescue by Ship. Removal of survivors from the water, life rafts, lifeboats, or other vessels to the RU is often the most difficult phase of a maritime SAR mission. The condition of the survivors may be such that they are unable to help themselves; usually they will have to be assisted or actually hoisted aboard. For this reason all SAR vessels or boats are prepared to lift survivors from the water without expecting help from them.

   When survivors are located on lakes, sheltered waters, rivers, or coastal areas, rescue is often made by limited-range boats based close to the distress, or by private boats in the vicinity. Since boats may be too small to take all survivors on board at one time, a sufficient number of boats are dispatched; when this is not possible, each boat deploys rafts so that survivors who cannot be taken on board immediately, can either be towed ashore or kept afloat while waiting. Survivors left behind are made as safe as conditions permit.

3. Coordinated Helicopter/Boat Rescues. Occasionally both a helicopter and a boat are dispatched. When the helicopter arrives first and begins its rescue attempt, the boat takes station upwind in the 2 o'clock position at a safe distance and stands by as a backup. The boat does not cross over the helicopter hoisting cable, nor cross between the survivors and the helicopter, and stays within pilot vision.

   If the helicopter aborts the attempt, the pilot departs the immediate area of the survivors and signals for the boat to take charge of the rescue operation.

   If the boat arrives first and makes the rescue, survivors may be transferred to the helicopter for more rapid delivery to medical facilities.

D. Mission Conclusion is the final stage of the SAR incident. The mission is successful when the search objectives have been located and recovered; the mission is unsuccessful when the search objectives have not been located and the SAR mission has been suspended.

The decision to suspend is a difficult one. Each SAR case is considered on its own merits and the search is not suspended prematurely. Prior to suspension the complete case history is reviewed. The decision is based on the probability of the objective surviving the initial incident, the probability of survival after the incident, the probability that the victim was within the computed search area, the quality of the search effort, and the consensus of several search planners. Search decisions are examined to ensure that proper assumptions were made, and that planning scenarios were reasonable. The certainty of initial position and any drift factors used in determining search area are reconfirmed, and significant clues and leads are reevaluated. Datum computations are reviewed.

In the Coast Guard, every decision to suspend is made by the SC or his duly authorized representative, usually the Chief of Search and Rescue(osr). It is the responsibility of the SMC to notify the relatives of the distressed or missing persons that the mission has been suspended. Relatives normally are more willing to accept the decision to suspend if they have been allowed to follow the progress of the search. Notification of the decision to suspend is made at least one day prior to actual suspension of operations, allowing relatives one more day of hope, while giving them time to accept the decision that the search cannot continue indefinitely.

If significant new information or clues are developed, reopening of a suspended mission is considered. However, reopening without good reason wastes resources, risks injury to searchers, and limits ability to respond to other emergencies.

SRUs are limited in the number of hours they can operate safely and efficiently. A SAR mission is not ended until the last SRU has returned to its operational base and all participating agencies are dealerted.

E. Documentation consists of logs, forms, folders, charts, and reports. Any situation about which a unit opens a file, whether or not SRUs are dispatched, is documented. Documentation promotes operational efficiency and creates statistical data, information for SAR case studies, and official chronological records. Each SAR case is normally assigned a number and title as soon as the SAR system is notified of the case. Case titles identify the craft, individual or event and the nature of the emergency, and each RCC maintains a chronological narrative account of operational SAR activity. The narrative log is filed in the SAR case folder, as are the SAR operations log, SITREPS released and received, SRU movement orders, emergency phase classifications, communication checks, etc.

1. SRU Records. Each SRU maintains a log of SAR activity from the time of initial notification to the time of return to base. The log contains a record of all radio traffic relating to the SAR incident, a record of SRU movement during the search phase (including the chart on which the vessel movement was recorded), a record of any rescue effort including debriefing of survivors, a record of supplies expended, and any other pertinent data that may contribute to the understanding and/or analysis of the incident.

2. SRU Reports. Besides the SITREPs, the most important report prepared by the Auxiliary SRU is the SAR Incident Auxiliary Report, CG-4612 AUX. This standardized report is a "fill-in-the-blank" message form. It is used primarily for statistical analysis of SAR incidents in which the Auxiliary is involved.

3. Auxiliary SAR units also file a Mission Hour Report, USCG CG-4947, to record the hours spent by the crew during the SAR patrol, and the Owner (and Operator) of the Auxiliary SAR unit completes a copy of his Coast Guard Auxiliary Patrol Order, CG 5132 (Rev 5-94), to record the activity and request authorized reimbursement of expenses.

F. Legal Framework. Although obligated by international law, United States SAR is authorized primarily by several U.S. statutes.

1. 14 USC 88 authorizes the Coast Guard to rescue persons or property in distress, take charge of and protect property saved, provide food and clothing to persons in distress, and destroy or tow hazards-to-navigation. The authority is discretionary; duty to perform SAR is not mandatory. Once a mission is undertaken, however, it must be prosecuted in a responsible manner. The agency performing SAR may be subject to liability to a person in distress if physical harm results from a rescuer's failure to exercise reasonable care in a rescue, and if this negligence worsens the plight of the distressed person, or if harm is suffered because the person reasonably relied on the rescue effort foregoing other opportunities to obtain assistance.

Even in these situations, liability normally results only where injuries are caused by unreasonable actions on the part of the rescuer.

2. 14 USC 2 establishes maintenance and operation of rescue facilities as a primary mission of the Coast Guard.

3. 14 USC 821-832 provides for establishment and operation of the Coast Guard Auxiliary, defines Coast Guard Auxiliary vessels under orders as public vessels of the United States, and allows reimbursement of certain expenses incurred.

G. Private Property. Trespass is defined as unlawful entry upon real property belonging to another. As a general practice, personnel engaged in SAR must obtain permission from the property owner or occupant (skipper, if not the owner) prior to entry. If this is not possible, entry by SAR personnel is lawful if necessary; however, every effort must be made to minimize damage to the property.

Private property coming into possession of SAR personnel is safeguarded, inventoried, returned to its owner, and a receipt obtained. If the owner cannot be found immediately, SRUs take the property to the Coast Guard officer assigned for handling property. Recovered private personal property may, under direction of the SAR Coordinator, be delivered directly to local law-enforcement authorities.

H. Civil Action. Citizens, private attorneys, life insurance companies, and government agencies may seek information about a SAR case to assist in settling estates of persons missing after casualties, or to resolve other legal matters. All such information must be cleared by a Coast Guard legal office before release. Many civil actions involving SAR begin years after the event, therefore SAR controllers and personnel preserve complete and accurate records, including original RCC tapes if possible. Coast Guard attorneys provide guidance whenever SAR personnel are called upon as witnesses. Generally, SAR personnel provide factual information only, and do not make any statements that could, if taken out of context, be construed as an admission of error or a statement of opinion.

I. Bilateral International Agreements.

1. Treaty Regarding Reciprocal Rights for United States and Canada in the Matters of Conveyance of Prisoners and Wrecking and Salvage, was signed at Washington May 18, 1908 (35 Stat. 2035; TIAS 502). Article II of this treaty permits vessels and wrecking appliances, either

from the United States or from Canada, to salvage property wrecked and to render aid and assistance to any vessels wrecked, disabled, or in distress in areas specified as: that portion of the St. Lawrence River through which the international boundary line extends; Lake Ontario, Lake Erie, Lake St. Clair, Lake Huron, and Lake Superior; the Niagara, Detroit, St. Clair, and Ste. Marie Rivers, and Canals at Sault Ste. Marie; and the shores and in the waters of the other country along the Atlantic and Pacific coasts within a distance of 30 miles from the international boundary.

The reciprocal wrecking and salvage privileges include all necessary towing, and nothing in the Customs, Coasting, or other laws or regulations of either country restricts in any manner the salving operations of vessels or wrecking appliances. Vessels from either country employed in salving in the waters of the other are required, as soon as practicable afterwards, to make full report at the nearest custom house in the country in whose waters the salving takes place.

2. <u>Mexico, Treaty to Facilitate Assistance to and Salvage of Vessels in Territorial waters</u>, was signed at Mexico City June 13, 1935 (49 Stat. 3359; TIAS 905). Under this treaty vessels and rescue equipment of either country, may assist vessels and crews of their own nationality which may be disabled or in distress on the shores or within the territorial waters of the other country:

   a. Within a radius of 720 nautical miles of the intersection of the international boundary line and the coast of the Pacific Ocean; or

   b. Within a radius of 200 nautical miles of the intersection of the international boundary line and the coast of the Gulf of Mexico.

   The commanding officer, master, or owner of a vessel or rescue apparatus of either country entering or intending to enter the territory or territorial waters of the other to assist a distressed vessel is required, at the earliest possible moment, to send notice of such action to the authorities of that other country nearest the scene of distress. The vessel or apparatus may freely proceed to, and assist the distressed vessel unless the authorities advise that adequate assistance is available, or that, for any other reason, such assistance is not considered necessary. Notification is necessary when a vessel or apparatus of one country departs from the territory or waters of the other country entered to render assistance. Private vessels which have so entered, as well as private distressed vessels and the cargo, equipment, stores, crew, and passengers thereof, are subject to the laws in force in the country in whose territorial waters such assistance is rendered.

3. SRU Responsibility. When Auxiliary vessels or aircraft are involved in SAR activity involving these international agreements there is nothing particularly that the SRU must do to abide by the treaties and the concomitant reporting regulations, except to follow in detail the instructions issued by the RCC.

REVIEW QUESTIONS

1- How does the on-scene SRU contribute to Rescue Planning?

____

2- What is the responsibility of a SRU in a rescue involving towing?

____

3- If a disabled craft declines delivery to the nearest safe harbor what does the SRU do?

____

4- What is the primary consideration of the SRU during a rescue?

____

5- With whom does the SMC consult before ordering a helo medevac?

____

6- What precautions are necessary during a helo evacuation?

____

____

7- What help must a SRU be prepared to give to survivors in the water?

____

8- From what position does a SRU watch a helo rescue operation being carried out with a nearby distressed vessel?

____

9- On what factors is a decision to suspend based?

____

____

10- Who has the authority to suspend?

11- Who notifies relatives of the decision to suspend?

12- When might a closed SAR case be reopened?

13- What is the minimum documentation required of an Auxiliary SRU?

14- If an Auxiliary SRU does not know whether to keep records of a case what should be done?

15- What is the legal status of Auxiliary vessels operating under orders?

16- Is the Coast Guard required to assist persons and property in distress?

17- If the Coast Guard starts to assist a person in distress may it quit at any time?

18- Define trespass.

19- Do SAR personnel have the right to unauthorized entry?

20- Are Auxiliary personnel authorized to disclose information about a case?

21- Is it necessary to preserve SAR incident records?

22- With what countries does the United States have treaties governing SAR activity in border regions?

23- If an Auxiliarist is called as a witness in a SAR case what must he do?

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APPENDIX A FORMS & WORKSHEETS

A. Introduction. This Appendix contains reproducible copies of all of the forms used in the REVIEW QUESTIONS at the end of each Chapter. The student should remove these masters from his Text and have them reproduced. He will need copies not only for the REVIEW QUESTIONS but also for the written Examination and the Demonstration Practical. Copies of these Worksheets are NOT supplied with the Examination packets.

The Maneuvering Board sheet (page A-28 of this Appendix) is difficult to reproduce and students are encouraged to purchase pads of Maneuvering Boards from their local marine supply store. Not only are the printed forms more legible but they are less expensive than reproducing on a copying machine. Some Students may prefer using the Vector Worksheet (page A-27 of this Appendix) and using a ruler rather than dividers for measuring the length of the vectors. This allows complete flexibility in selecting the Scale. The Vector Worksheet reproduces much better than the Maneuvering Board.

B. Practical Demonstration. Page A-29 is a copy of the Practical Demonstration Worklist that must be completed satisfactorily before the Student is permitted to take the Final Examination. The Student will be reminded at the end of the lesson covering Chapter 5 that the Worklist should be completed at home and returned to the class at the next session. The Student may use any material in the Text and any notes taken during the lesson sessions, but must do the work alone.

C. Tools and References. The Student should equip himself with the necessary tools for working on Maneuvering Boards and doing the arithmetic required by many of the Worksheets. Only non-programmable calculators are allowed during the examinations. Whenever a problem requires reference to a Figure or Table in the Text the student should use that reference in completing the REVIEW QUESTIONS. A copy of each required Reference is included in the Examination Packet.

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National SAR School **Reversing Tides & Other Currents**
(rev. 5/31/91) (WORKSHEET

Case Title: ____________ Planner's Name: ____________ Date: ________

A. Incident Summary	MINIMUM	MAXIMUM
1. Latitude	________ N / S	________ N / S
2. Longitude	________ W /E	________ W / E
3. Surface Position DTG	______ Z ______	______ Z ______
4. Datum DTG	______ Z ______	
5. Drift Interval	________ HRS	________ HRS

B. Time Conversions: GMT + Zone Description (Rev) = Zone Time

1. Surface Position DTG ***(Zone Time)*** ____________ ____________
2. Datum DTG ***(Zone Time)*** ____________

C. Reversing Tidal Currents - (Minimum) (Maximum) (First Search) (*Circle One*)

1. **REFERENCE STATION:** ____________ PAGE: ____ DATE: ________
   SUBSTATION: ____________ REFERENCE NUMBER: ________
2. **TIME DIFFERENCES**

Minimum Before Flood ____ HRS ____ MIN	Minimum Before Ebb ____ HRS ____ MIN
Max Flood ____ HRS ____ MIN	Max Ebb ____ HRS ____ MIN

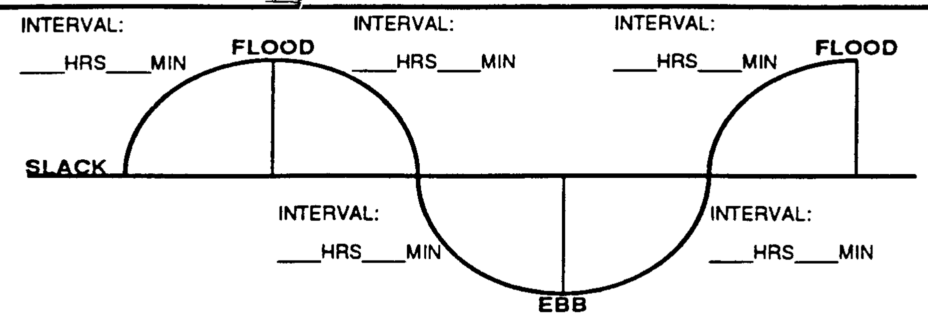
3. **VELOCITY INFORMATION**

FLOOD: SPEED RATIO ______ AVERAGE DIRECTION ______ °T   EBB: SPEED RATIO ______ AVERAGE DIRECTION ______ °T

4. a) TIME	**REFERENCE STATION** SPEED	TIME	SPEED(E/F?)	**b)** TIME	**SUBSTATION** SPEED	TIME	SPEED(E/F?)
____	SLACK	____	____	____	SLACK	____	____
____	SLACK	____	____	____	SLACK	____	____
____	SLACK	____	____	____	SLACK	____	____
____	SLACK	____	____	____	SLACK	____	____
____	SLACK	____	____	____	SLACK	____	____

5. **TIDAL CURRENT CHART**

INCIDENT TIME: ________ DATUM TIME: ________



6. **COMPUTING AVERAGE FACTOR OF CYCLE:**

a) Time interval from slack water to incident: ________HRS ________MIN (Same Half-Cycle)

Time interval from slack water to DATUM: ________HRS ________MIN (Same Half-Cycle)

b) FACTORS FOR THE FLOOD/EBB CYCLE (1)	b) FACTORS FOR THE FLOOD/EBB CYCLE (2)
_____ _____ _____ _____ _____	_____ _____ _____ _____ _____
_____ _____ _____ _____ _____	_____ _____ _____ _____ _____
_____ _____ _____ _____ _____	_____ _____ _____ _____ _____
_____ _____ _____ _____ _____	_____ _____ _____ _____ _____
_____ _____ _____ _____ _____	_____ _____ _____ _____ _____
c) TOTAL VALUE OF FACTORS IN THIS CYCLE: ________	c) TOTAL VALUE OF FACTORS IN THIS CYCLE: ________
Divided by: Total Number of Factors in Cycle: ________	Divided by: Total Number of Factors in Cycle: ________
Equals: Average Factor for Cycle: ________	Equals: Average Factor for Cycle: ________

7. **COMPUTING THE AVERAGE CURRENT SPEED FOR THE CYCLE:**

Maximum Current Speed for the Cycle: ______ KTS	Maximum Current Speed for the Cycle: ______ KTS
Multiplied by the Average Factor EQUALS the Average Speed for the Cycle ______ KTS	Multiplied by the Average Factor EQUALS the Average Speed for the Cycle ______ KTS

8. **COMPUTING TIDAL CURRENT VECTOR FOR THE CYCLE:**

	(1) F / E	(2) F / E
Time Duration of Drift through the Flood/Ebb Cycle:	_____ HRS	_____ HRS
Multiplied by the Average Current Speed:	_____ KTS	_____ KTS
EQUALS: Magnitude of Current Vector for the Cycle:	_____ NM	_____ NM

9. **CALCULATING THE TOTAL TIDAL CURRENT VECTOR:**

1st Current Vector: _____ °T _____ NM + 2nd Current Vector:_____ °T _____ NM

EQUALS: Total Reversing Tidal Current Vector ________°T ________NM

Other Currents Worksheet

1. There are many other currents that may effect a search object. Some of these are: Lake, Longshore, River, Surf, Rotary, etc. The form is self-explanatory.
2. Type of Current ________________________________
3. Source of Information ________________________________

		MINIMUM	MAXIMUM
4.	SET	__________ ° T	__________ ° T
5.	Drift	__________ KTS	__________ KTS
6.	Vector	__________ ° T	__________ ° T
	Direction from above and Drift X Drift Interval	__________ NM	__________ NM

National SAR School **LEEWAY WORKSHEET**

(rev. 5/31/91)

Case Title: ____________________ Planner's Name: ____________________ Date: __________

		MINIMUM	MAXIMUM
A.	**Incident Summary**		
1.	Latitude	________ N/S	________ N/S
2.	Longitude	________ W/E	________ W/E
3.	Surface Position DTG	______ Z ______	______ Z ______
4.	Datum DTG	______ Z ______	
5.	Drift Interval	________ HRS	________ HRS
B.	**Search Object(s)**	________	________

C. Average Surface Winds (ASW)

Reported Wind DTG	Wind Valid Period	Number of Hours (A)	Wind Direction (B)	Wind Speed (C)	Wind Contribution (B)/(AxC)
0000Z	2100 - 0300	______	______	______	____/____
0600Z	0300 - 0900	______	______	______	____/____
1200Z	0900 - 1500	______	______	______	____/____
1800Z	1500 - 2100	______	______	______	____/____
0000Z	2100 - 0300	______	______	______	____/____
0600Z	0300 - 0900	______	______	______	____/____
1200Z	0900 - 1500	______	______	______	____/____
1800Z	1500 - 2100	______	______	______	____/____
0000Z	2100 - 0300	______	______	______	____/____
0600Z	0300 - 0900	______	______	______	____/____
1200Z	0900 - 1500	______	______	______	____/____
1800Z	1500 - 2100	______	______	______	____/____
0000Z	2100 - 0300	______	______	______	____/____
	Total Hours	______	**Total Wind Vector**		____/____

Divide Total Wind Vector by total hours to get: ASW ________ °T ________ KTS

D. Downwind LEEWAY

1. Average Surface Winds (ASW) ________ °T
   ________ KTS
2. Set (**ASW Direction ±180°**) ________ °T
3. Formula (if used) ________
4. Drift (LEEWAY SPEED GRAPH OR EXPONENTIAL FORMULA) ________ KTS
5. Drift Interval ________ HRS
6. Leeway (LW) Vectors ________ °T ________ NM

National SAR School — **LEEWAY WORKSHEET**
(rev. 5/31/91)

Select One Situation	MINIMUM	MAXIMUM

Drift Rate Uncertainty. Leeway with minimum and maximum drift rates, e.g., drogue/no drogue or search object uncertainty. Used for two search objects.

		MINIMUM	MAXIMUM
1.	Average Surface Winds (ASW)	______ °T	______ °T
		______ KTS	______ KTS
2.	Set (ASW Direction ±180°)	______ °T	______ °T
3.	Formulas (if used)	________	________
4.	Drift (LEEWAY SPEED GRAPH OR EXPONENTIAL FORMULA)	______ KTS	______ KTS
5.	Drift Interval	______ HRS	
6.	Leeway (LW) Vectors	______ °T	______ °T
		______ NM	______ NM

Time Uncertainty. Used when incident time is unknown.

		MINIMUM	MAXIMUM
1.	Drift Interval	______ HRS	______ HRS
2.	Average Surface Winds (ASW) (two required)	______ °T	______ °T
		______ KTS	______ KTS
3.	Set (ASW Direction ±180°)	______ °T	______ °T
4.	Formula (if used)	________	
5.	Drift (LEEWAY SPEED GRAPH OR EXPONENTIAL FORMULA)	______ KTS	______ KTS
6.	Leeway (LW) Vectors	______ °T	______ °T
		______ NM	______ NM

Directional Uncertainty. DIVERGENCE - time and search object known. Used when there is only one object and one time.

		MINIMUM	MAXIMUM
1.	Average Surface Winds (ASW)	______ °T	______ °T
		______ KTS	______ KTS
2.	Set (ASW Direction ±180°)	______ °T	______ °T
3.	Formula (if used)	________	
4.	Divergence	± ______ °	± ______ °
5.	Drift (LEEWAY SPEED GRAPH OR EXPONENTIAL FORMULA)	______ KTS	______ KTS
6.	Drift Interval	______ HRS	
7.	Leeway (LW) Vectors	______ °T	______ °T
		______ NM	______ NM

National SAR School **DATUM WORKSHEET**

(rev. 5/31/91)

Case Title: ____________ Planner's Name: ____________ Date: ________

Surface Position Desc: ____________ Datum #: ____ Search Plan: A B C ___
CIRCLE ONE

A. Aerospace Drift (d_a)

1. Bailout Position — Latitude ____________ N/S; Longitude ____________ W/E
2. Bailout Position DTG ________ Z ________
3. Total Vector from Aerospace Worksheets ____________ °T; ____________ NM

B. Position Where Surface Drift Will Start

	MINIMUM	MAXIMUM
1. Surface Position from Aerospace Worksheets, Last Known Position/Incident Position, Previous Datum (non-minimax), Previous D_{min} and D_{max} Positions. TARGET(S)	________	________
2. Time	______ Z ______	______ Z ______
3. Latitude	________ N/S	________ N/S
4. Longitude	________ W/E	________ W/E

C. Datum Time

1. (Commence Search Time/Mid-Search Time) ________ Z ________

2. Drift Interval	________ HRS	________ HRS

D. Total Water Current

1. Observed Total Water Current (TWC)

a. Source (DMB, debris, oil) ______________________

b. Set	________ °T	________ °T
Drift	________ KTS	________ KTS
c. TWC Vector	________ °T	________ °T
Direction from above and Drift x Drift Interval	________ NM	________ NM
2. Tidal Current Vector	________ °T	________ °T
Use Substations of Both positions If drifting from D_{min} and D_{max} **(Attach Tidal Current Worksheet)**	________ NM	________ NM

	MINIMUM	MAXIMUM
3. Sea Current (SC)		
a. Information Source	________	________
b. Set	________ °T	________ °T
c. Drift Use lat/long of both positions if drifting from D_{min} and D_{max}	________ KTS	________ KTS
d. Sea Current (SC) Vector	________ °T	________ °T
Direction from above and **Drift x Drift Interval**	________ NM	________ NM
4. Wind Current (WC)		
Wind Current (WC) Vector	________ °T	________ °T
Use Latitude of both positions if drifting from D_{min} and D_{max} **(Attach Wind Current Worksheet)**	________ NM	________ NM
5. Other Water Current		
Use information for both positions if drifting from D_{min} and D_{max}	________ °T	________ °T
(Attach Other Water Current Worksheet)	________ NM	________ NM
E. Leeway (LW)		
1. Leeway (LW) Vector (Attach Leeway Worksheet)	________ °T	________ °T
	________ NM	________ NM
F. Total Surface Drift (d_{min} and d_{max}) From Chart, UPS, or calculator		
1. Direction	________ °T	________ °T
2. Distance	________ NM	________ NM
G. Datum (D_{min} and D_{max})		
1. Latitude	________ N/S	________ N/S
2. Longitude	________ W/E	________ W/E
H. Distance between D_{min} and D_{max}	________ NM	
I. $Datum_{minimax}$		
1. Latitude	________ N/S	
2. Longitude	________ W/E	
3. $Datum_{minimax}$ DTG	________ Z ________	
4. Direction from SP to $Datum_{minimax}$	________ °T	

National SAR School | **SEARCH AREA WORKSHEET**
(rev. 5/30/91)

Case Title ________________ Planner's Name ________________ Date ______

I. Coastal Model Search Area

A. Search Radius ____6.0____ NM

B. Optimum Search Area Size ____________ SQNM
Use Graphic Solution from Chart or UPS

II. Oceanic Model Search Area

A. Individual Drift Errors (d_e)

1. Aerospace Drift Error (d_{ea})
   a. Aerospace Drift Distance (d_a) ____________ NM
   b. Drift Error Confidence Factor (CF) ____0.3____
   c. Aerospace Drift Error ($d_{ea} = d_a \times CF$) ____________ NM

2. Surface Drift Error

	MINIMUM	MAXIMUM
a. Minimax		
1. Sum of all previous Drift Errors ($d_e$min and $d_e$max)	____________ NM	
2. Surface Drift Distance (d_{min} and d_{max})	____________ NM	____________ NM
3. Drift Error Confidence Factor	____0.3____	
4. Drift Error Min and Max ($d_e$min and $d_e$max)	____________ NM ($d_{min} \times CF$)	____________ NM ($d_{max} \times CF$)
5. Distance between latest D_{min} and D_{max} positions		____________ NM
6. $d_e$minimax = $\frac{(\text{Sum} + d_e\text{min} + d_e\text{max} + \text{Distance})}{2}$ =		____________ NM

   b. Non-minimax
      1. Surface Drift Distance (d) ____________ NM
      2. Drift Error Confidence Factor (CF) ____0.3____
      3. Individual Drift Error ($d_e = d \times CF$) ____________ NM

B. Total Drift Error (D_e)

1. Minimax ($D_e = d_{ea} + d_e\text{minimax}$) ____________ NM
2. Non-minimax ($D_e = d_{ea} + d_{e1} + d_{e2} + ...$) ____________ NM

C. Initial Position Error (X)

1. Navigational Fix Error (FIX_e) ______ NM
   Based on ______
2. Navigational DR Error (DR_e) ______ NM
   (if applicable)
3. Initial Position Error (X) ______ NM
   ($X = FIX_e + DR_e$)

D. SRU Error (Y)

1. Navigational Fix Error (FIX_e) ______ NM
   Based on ______
2. Navigational DR Error (DR_e) ______ NM
   (if applicable)
3. Initial Position Error (Y) ______ NM
   ($Y = FIX_e + DR_e$)

E. Total Probable Error (E)

1. $E = \sqrt{D_e^2 + X^2 + Y^2}$ $\sqrt{\quad + \quad + \quad}$
   $E = \sqrt{\quad}$ ______ NM

F. Safety Factor (f_s) 1.1 1.6 2.0 2.3 2.5
circle one

G. Desired Search Radius (R)

1. Search Radius ($R = E \times f_s$) ______ NM
   (round up to next tenth (0.X) mile)

H. Optimum Search Area (A)

1. Square ($A = 4 \times R^2$) ______ SQNM
2. Circle ($A = \pi \times R^2$) ______ SQNM
3. Rectangle ($A = L \times W$) ______ SQNM
   L = length of side
   W = width of side
4. Graphic Solution ______ SQNM
   From Chart or UPS

EXPANDED SQUARE WORKSHEET

****

S=3NM	9k	12k	15k	18k						
S=2NM	6k	8k	10k	12k	20k	24k				
S=1NM				6k	10k	12k	15k	20k		
S=0.5NM					5k	6k	7.5	10k	15k	
S=0.2NM								4k	6k	12k
S=0.1NM										6k

****

Start______	______°T	______°C	20′	15′	12′	10′	6′	5′	4′	3′	2′	1′
#2 ______	______°T	______°C	20′	15′	12′	10′	6′	5′	4′	3′	2′	1′
#3 ______	______°T	______°C	40′	30′	24′	20′	12′	10′	8′	6′	4′	2′
#4 ______	______°T	______°C	40′	30′	24′	20′	12′	10′	8′	6′	4′	2′
#5 ______	______°T	______°C		45′	36′	30′	18′	15′	12′	9′	6′	3′
#6 ______	______°T	______°C		45′	36′	30′	18′	15′	12′	9′	6′	3′
#7 ______	______°T	______°C			48′	40′	24′	20′	16′	12′	8′	4′
#8 ______	______°T	______°C			48′	40′	24′	20′	16′	12′	8′	4′
#9 ______	______°T	______°C				50′	30′	25′	20′	15′	10′	5′
#10______	______°T	______°C				50′	30′	25′	20′	15′	10′	5′

****

1. Select Track Spacing "S" in NM
2. Select Speed in knots
3. Circle Corresponding Leg Time Column
4. Add leg time to Start for previous leg for next Start Time
5. True courses rotate 90° to the right
6. Correct for Variation & Deviation and record Compass courses

****

Reference Data:

1. Datum ____

2. Other ____

SECTOR SEARCH WORKSHEET

****

R=5NM	15k	20k	25k	30k					
R=4	12k	16k	20k	24k					
R=3	9k	12k	15k	18k	30k				
R=2	6k	8k	10k	12k	20k	24k	30k		
R=1			5k	6k	10k	12k	15k	20k	30k
R=0.5					5k	6k	7.5	10k	15k

****

Start ________	________ °T	________ °C	20′	15′	12′	10′	6′	5′	4′	3′	2′
#2 ________	________ °T	________ °C	20′	15′	12′	10′	6′	5′	4′	3′	2′
#3 ________	________ °T	________ °C	40′	30′	24′	20′	12′	10′	8′	6′	4′
________	Pass through Datum										
#4 ________	________ °T	________ °C	20′	15′	12′	10′	6′	5′	4′	3′	2′
#5 ________	________ °T	________ °C	40′	30′	24′	20′	12′	10′	8′	6′	4′
________	Pass through Datum										
#6 ________	________ °T	________ °C	20′	15′	12′	10′	6′	5′	4′	3′	2′
#7 ________	________ °T	________ °C	20′	15′	12′	10′	6′	5′	4′	3′	2′
________	Return to Datum										

****

1- Select Pattern Radius "R" in NM.

2- Select Speed in knots.

3- Circle Corresponding Leg Time Column.

4- Add leg time to Start time for next Start time.

****

Reference Data:

1- Datum

2- Other

TOW PLANNING WORKSHEET

20 FOOT (2.5 TONS) AUXILIARY FACILITY

AUX Facility ____________________ Actual Disp. ________ tons

Max Cont Cruise __________ RPM Speed ____ knots Slip _____ %

Towline Type ____________________ Towline Length _________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type ____________ Waterline Length ____ feet TOW Speed _______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] ____________ pounds

SUMMARY

Standard Shock Force [2] _________ pounds

Double Braid 1.6 x [2] = [3] ________ " (use only if applicable)

Heading ___ x [3] = [4] ________ "

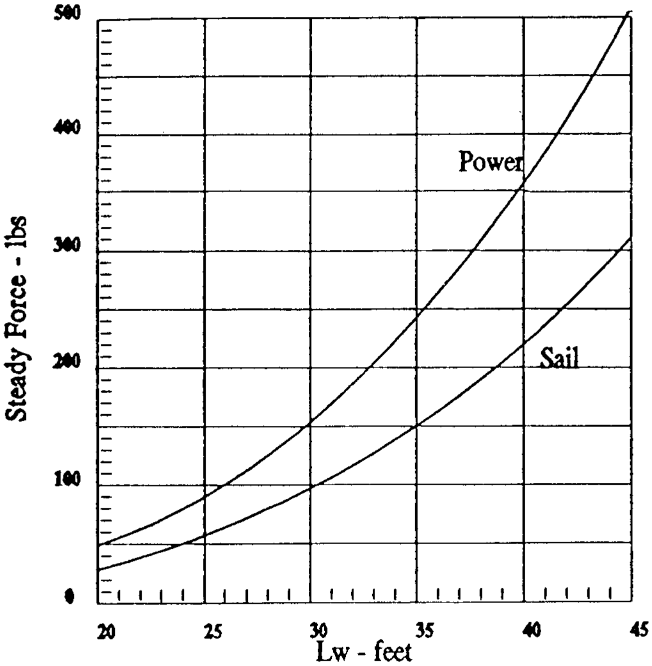
Adjusted Shock Force [4] _______________ pounds

Steady Force [1] _______________ pounds

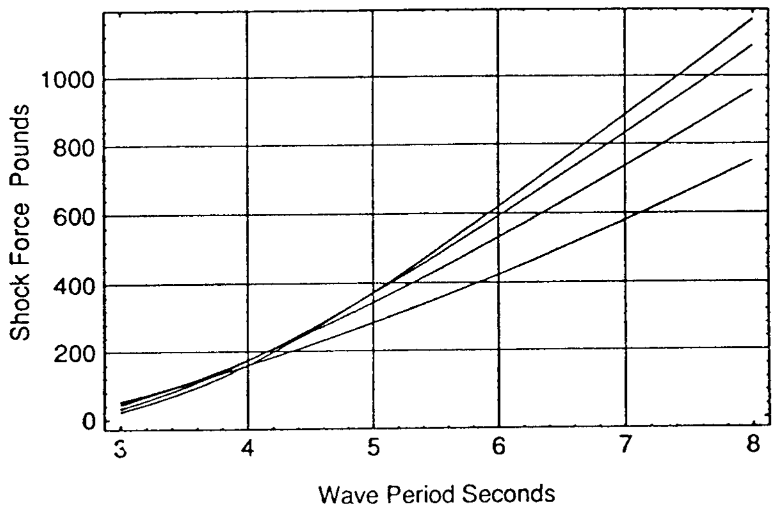
Maximum Peak Force [1] + [4] _______________ pounds

LIMIT 850 pounds

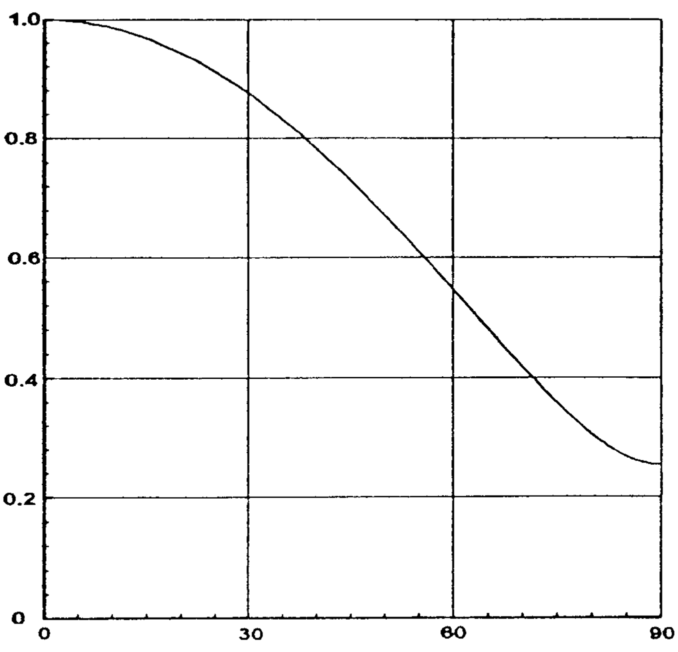
20 foot Facility



Steady Force vs Lw



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The four curves above are (reading from the bottom up on the right hand side) for a 20, 25, 30, and 35 foot waterline-length boat to be towed.

NOTE: The Shock Force curves are for ⅝", 3-Strand Twisted nylon towline. If Double Braided nylon is used, multiply the Shock Force by a factor of 1.6.

NOTE: The Shock Force curves are for a 100 foot long towline. A line that is 50 feet long will experience double the Shock Force; a 150 foot line will reduce the Shock Force by a factor of 0.6.

TOW PLANNING WORKSHEET
25 FOOT (4 TONS) AUXILIARY FACILITY

AUX Facility ____________________ Actual Disp. ________ tons

Max Cont Cruise __________ RPM Speed ____ knots Slip _____ %

Towline Type ____________________ Towline Length _________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type ____________ Waterline Length ____ feet TOW Speed _______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] ____________ pounds

SUMMARY

Standard Shock Force [2] _________ pounds

Double Braid 1.6 x [2] = [3] ________ " (use only if applicable)

Heading ___ x [3] = [4] ________ "

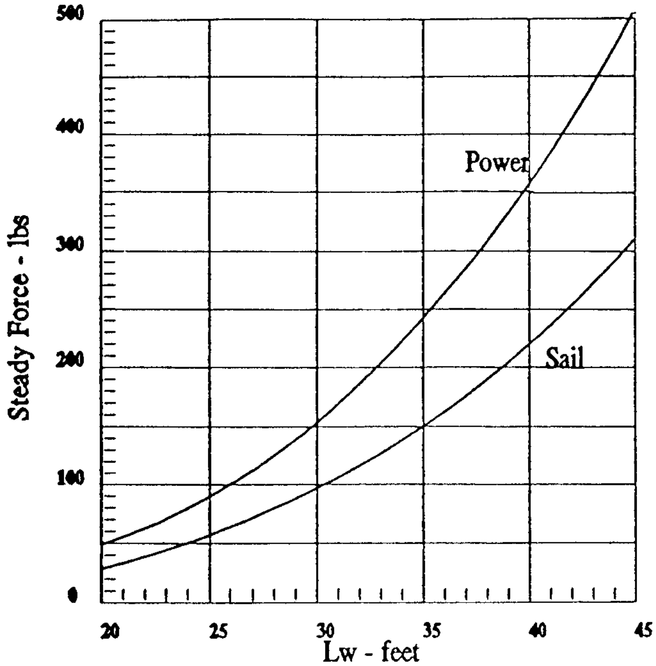
Adjusted Shock Force [4] _______________ pounds

Steady Force [1] _______________ pounds

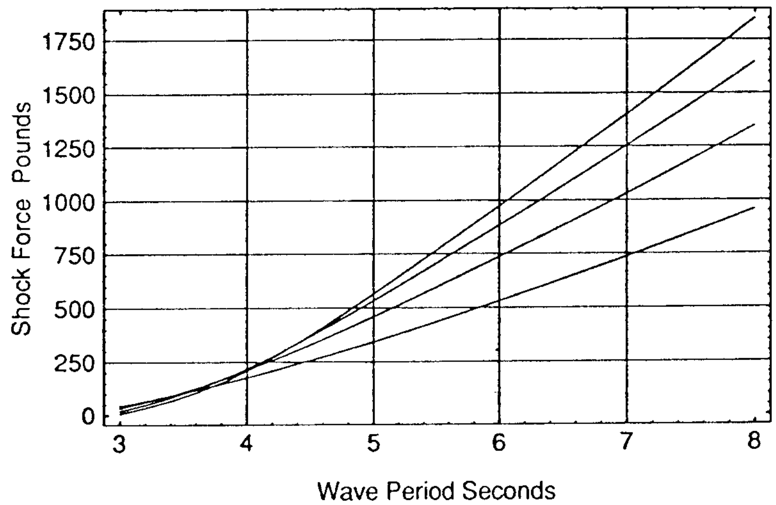
Maximum Peak Force [1] + [4] _______________ pounds

LIMIT 850 pounds

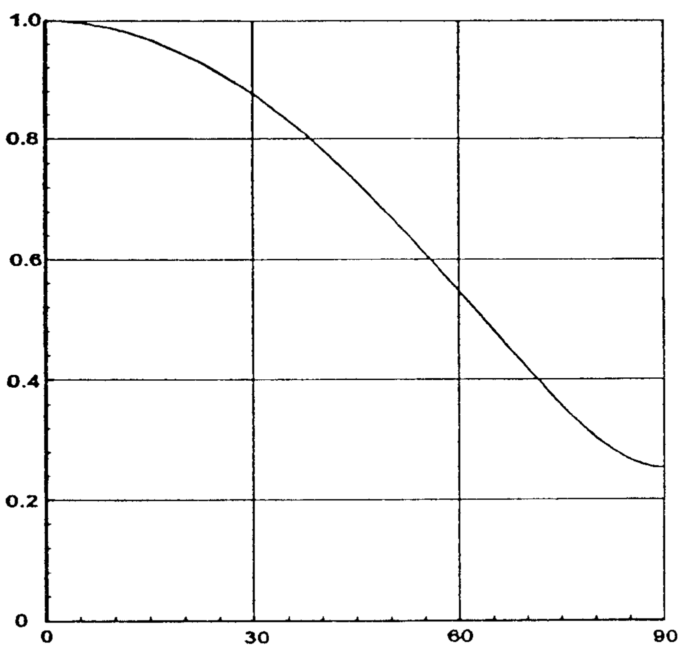
25 foot Facility



Steady Force vs L_W



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The four curves above are (reading from the bottom up on the right hand side) for a 20, 25, 30, and 35 foot waterline-length boat to be towed.

NOTE: The Shock Force curves are for ⅝", 3-Strand Twisted nylon towline. If Double Braided nylon is used, multiply the Shock Force by a factor of 1.6.

NOTE: The Shock Force curves are for a 100 foot long towline. A line that is 50 feet long will experience double the Shock Force; a 150 foot line will reduce the Shock Force by a factor of 0.6.

TOW PLANNING WORKSHEET

30 FOOT (6.5 tons) AUXILIARY FACILITY

AUX Facility ____________________ Actual Disp. ________ tons

Max Cont Cruise __________ RPM Speed ____ knots Slip _____ %

Towline Type ____________________ Towline Length ________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type ____________ Waterline Length ____ feet TOW Speed ______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] ____________ pounds

SUMMARY

Standard Shock Force [2] ________ pounds

Double Braid 1.6 x [2] = [3] ________ " (use only if applicable)

Heading ___ x [3] = [4] ________ "

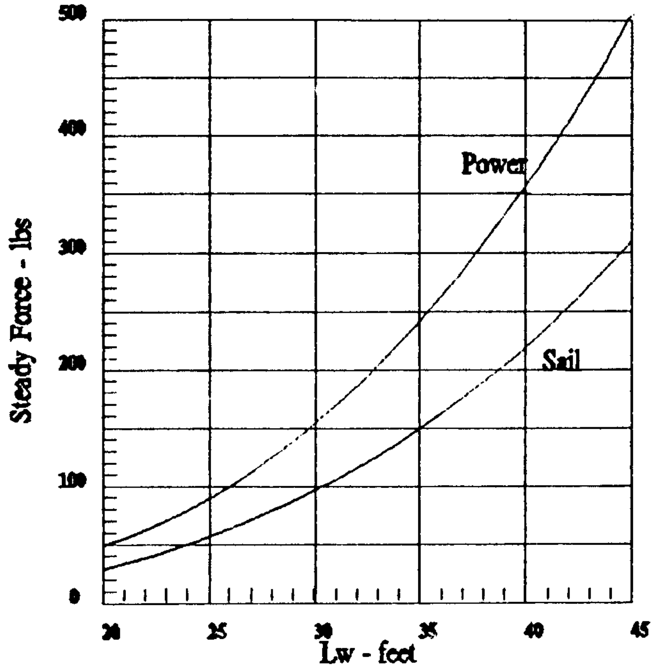
Adjusted Shock Force [4] ______________ pounds

Steady Force [1] ______________ pounds

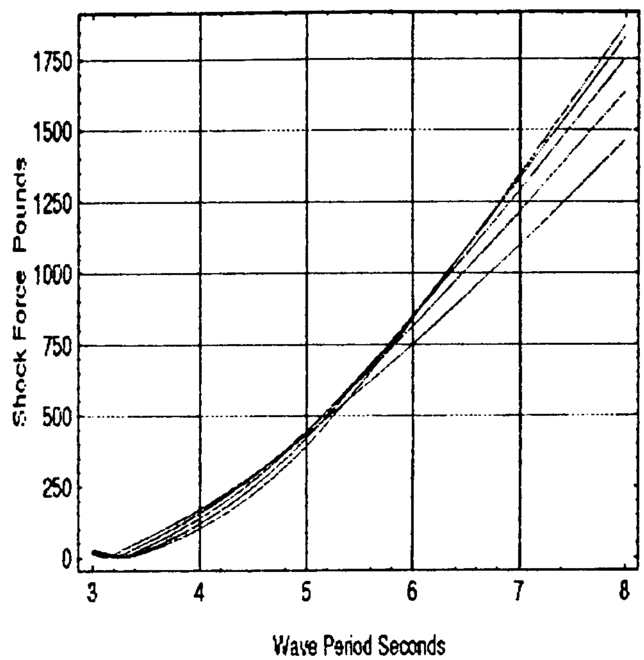
Maximum Peak Force [1] + [4] ______________ pounds

LIMIT 1500 pounds

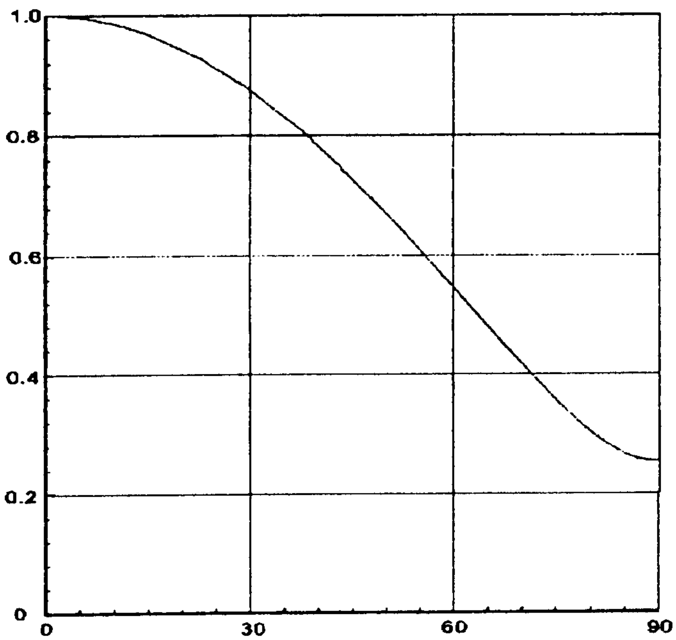
30 foot Facility



Steady Force vs Lw



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The five curves above are for - reading from the bottom up on the right hand side - 30, 35, 40, 45, and 50 foot waterline length boats to be towed.

NOTE: The Shock Force curves are for 3-Strand Twisted towline. If Double Braided line is used multiply the Shock Force by 1.6.

NOTE: The Shock Force curves are for 200 foot towline. A 100 foot line may more than double the Shock Force; for a 300 foot line use a factor of 0.6

TOW PLANNING WORKSHEET

35 FOOT (10.3 tons) AUXILIARY FACILITY

AUX Facility ____________________ Actual Disp. ________ tons

Max Cont Cruise __________ RPM Speed ____ knots Slip _____ %

Towline Type ____________________ Towline Length ________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type ____________ Waterline Length ____ feet TOW Speed ______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] ____________ pounds

SUMMARY

Standard Shock Force [2] ________ pounds

Double Braid 1.6 x [2] = [3] ________ " (use only if applicable)

Heading ___ x [3] = [4] ________ "

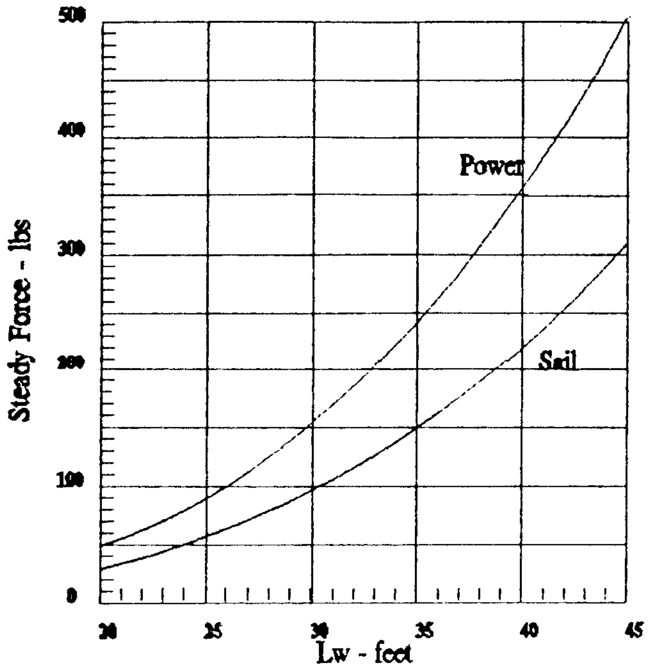
Adjusted Shock Force [4] ______________ pounds

Steady Force [1] ______________ pounds

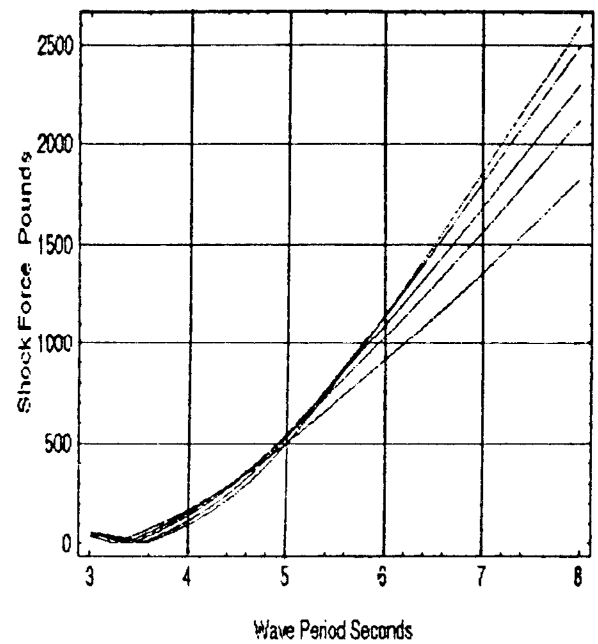
Maximum Peak Force [1] + [4] ______________ pounds

LIMIT 1500 pounds

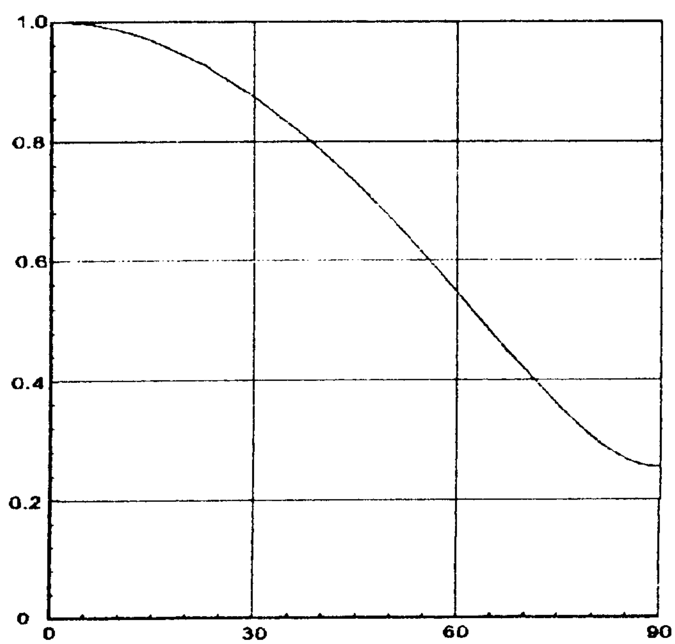
35 foot Facility



Steady Force vs Lw



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The five curves above are for - reading from the bottom up on the right hand side - 30, 35, 40, 45, and 50 foot waterline length boats to be towed.

<u>NOTE</u>: The Shock Force curves are for 3-Strand Twisted towline. If Double Braided line is used multiply the Shock Force by 1.6.

<u>NOTE</u>: The Shock Force curves are for 200 foot towline. A 100 foot line may more than double the Shock Force; for a 300 foot line use a Shock Force factor of 0.6

TOW PLANNING WORKSHEET

40 FOOT (15.4 tons) AUXILIARY FACILITY

AUX Facility ______________________ Actual Disp. ________ tons

Max Cont Cruise __________ RPM Speed ____ knots Slip _____ %

Towline Type _____________________ Towline Length _________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type _____________ Waterline Length ____ feet TOW Speed ______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] _____________ pounds

---

SUMMARY

Standard Shock Force [2] _________ pounds

Double Braid 1.6 x [2] = [3] ________ " (use only if applicable)

Heading ___ x [3] = [4] ________ "

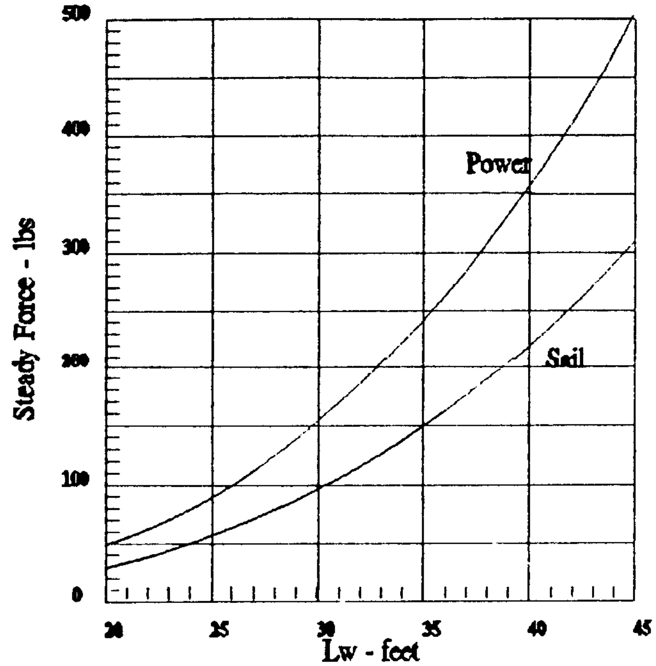
Adjusted Shock Force [4] _______________ pounds

Steady Force [1] _______________ pounds

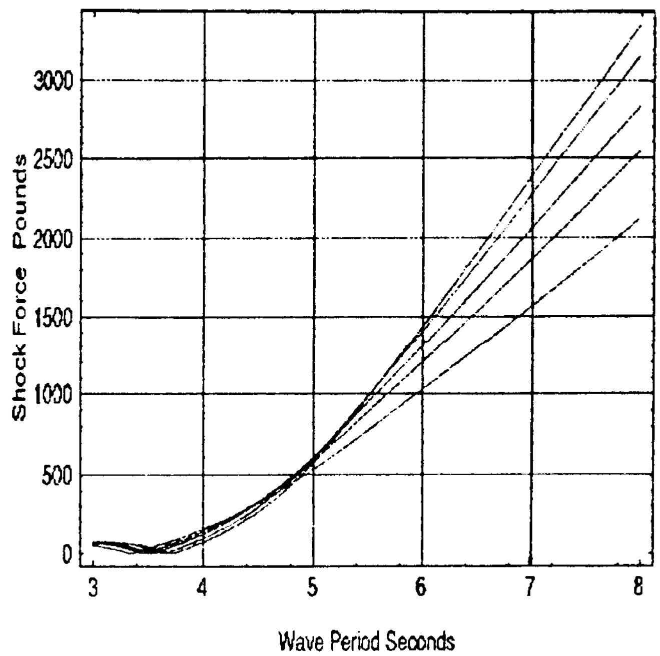
Maximum Peak Force [1] + [4] _______________ pounds

LIMIT 1500 pounds

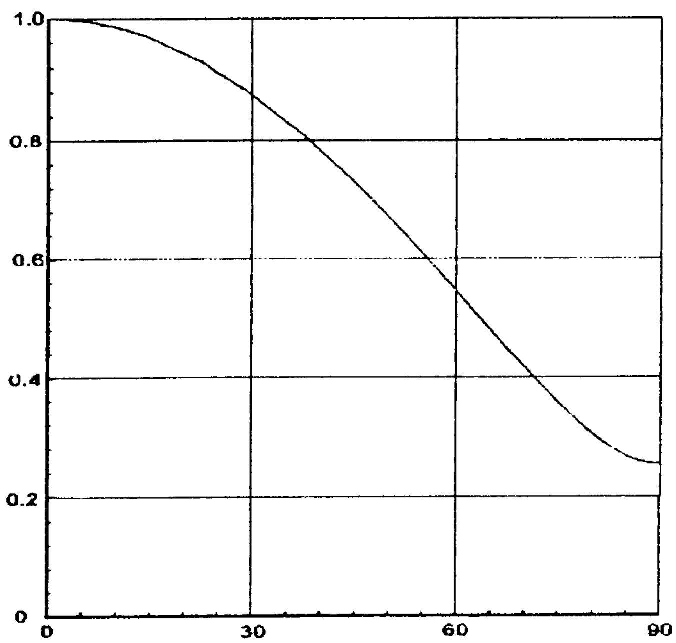
40 foot Facility



Steady Force vs Lw



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The five curves above are for - reading from the bottom up on the right hand side - 30, 35, 40, 45, and 50 foot waterline length boats to be towed.

NOTE: The Shock Force curves are for 3-Strand Twisted towline. If Double Braided line is used multiply the Shock Force by 1.6.

NOTE: The Shock Force curves are for 200 foot towline. A 100 foot line may more than double the Shock Force; for a 300 foot line use a factor of 0.6

TOW PLANNING WORKSHEET

45 FOOT (22 tons) AUXILIARY FACILITY

AUX Facility ______________________ Actual Disp. ________ tons

Max Cont Cruise ___________ RPM Speed ____ knots Slip _____ %

Towline Type ______________________ Towline Length _________ feet

TOW Speed knots

Max RPM while towing

TOWED VESSEL

Type _____________ Waterline Length ____ feet TOW Speed _______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] _____________ pounds

SUMMARY

Standard Shock Force [2] _________ pounds

Double Braid 1.6 x [2] = [3] ________ * (use only if applicable)

Heading ___ x [3] = [4] ________ *

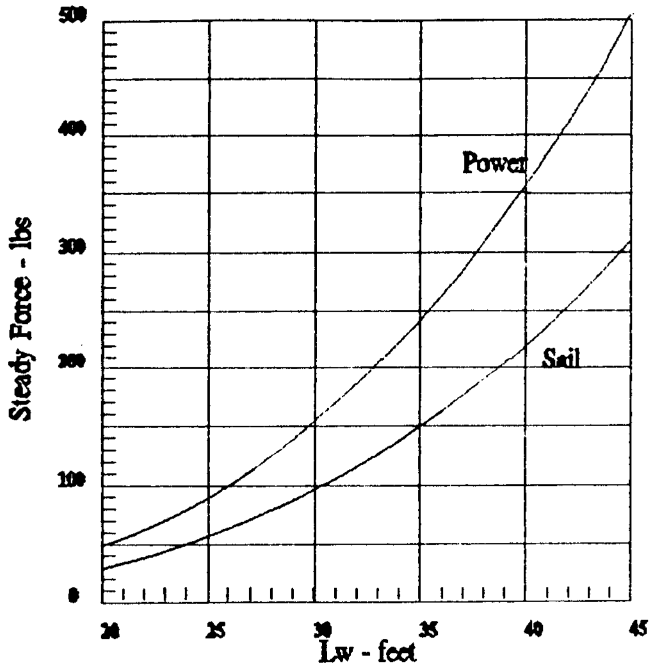
Adjusted Shock Force [4] ________________ pounds

Steady Force [1] ________________ pounds

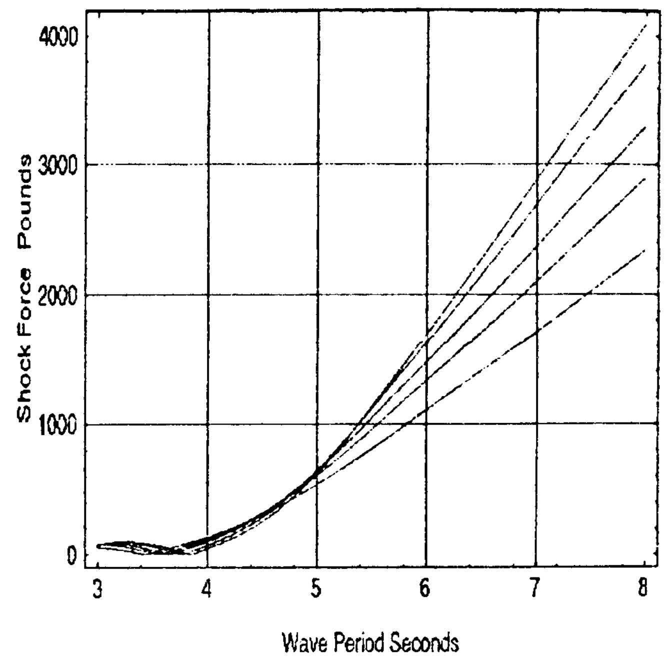
Maximum Peak Force [1] + [4] ________________ pounds

LIMIT 1500 pounds

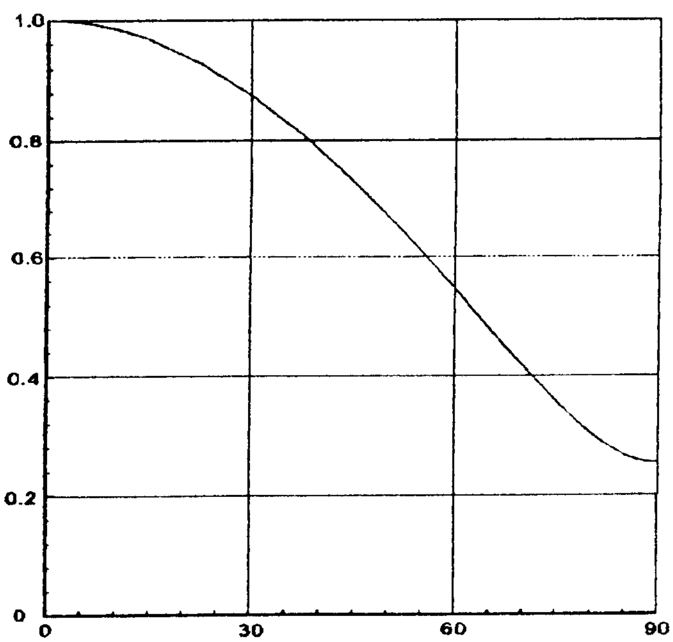
45 foot Facility



Steady Force vs Lw



Shock Force vs
Average Period



Shock Force Factor vs
Course Correction

The five curves above are for - reading from the bottom up on the right hand side - 30, 35, 40, 45, and 50 foot waterline length boats to be towed.

<u>NOTE</u>: The Shock Force curves are for 3-Strand Twisted towline. If Double Braided line is used multiply the Shock Force by 1.6

<u>NOTE</u>: The Shock Force curves are for 200 foot towline. A 100 foot line may more than double the Shock Force; for a 300 foot line use a Shock Force factor of 0.6.

TOW PLANNING WORKSHEET

30 FOOT (6.5 tons) AUXILIARY FACILITY

AUX Facility *SeaScape* Actual Disp. *6* tons

Max Cont Cruise *3000* RPM Speed *18* knots Slip *35* %

Towline Type *⅝" 3-strand nylon* Towline Length *300* feet

TOW Speed knots

0.0	*1.8*	*3.6*	*5.4*	*7.2*	*9.0*	*10.8*	*12.6*	*14.4*	*16.2*	*18.0*
1770	*1890*	*1980*	*2100*	*2220*	*2340*	*2460*	*2580*	*2730*	*2850*	*3000*

Max RPM while towing

TOWED VESSEL

Type ____________ Waterline Length ____ feet TOW Speed ______ knots

Steady Force [1] __________ pounds

SEA STATE

Average Period _____ seconds Standard Shock Force [2] ____________ pounds

SUMMARY

Standard Shock Force [2] ________ pounds

Double Braid 1.6 x [2] = [3] ________ * (use only if applicable)

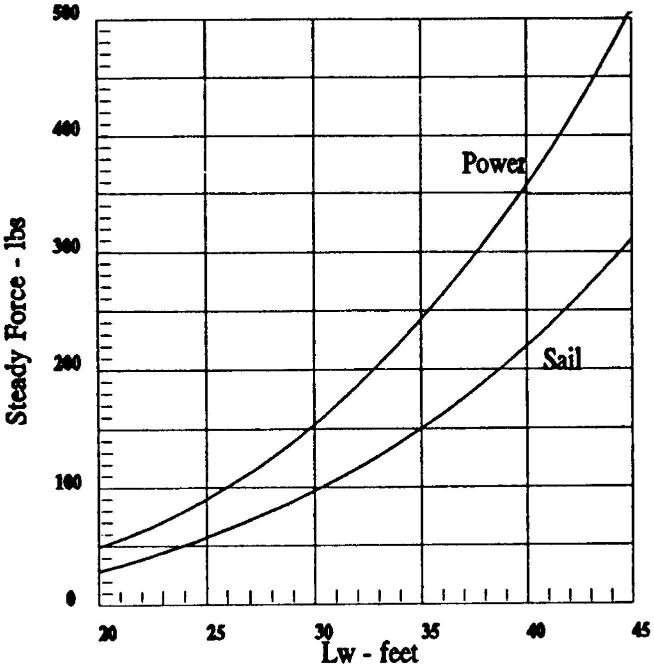
Heading _____ x [3] = [4] ________ *

Adjusted Shock Force [4] ______________ pounds

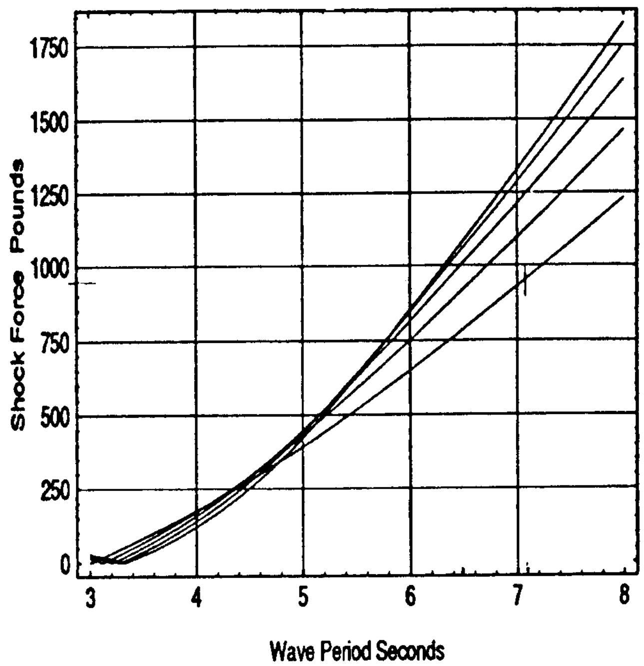
Steady Force [1] ______________ pounds

Maximum Peak Force [1] + [4] ______________ pounds

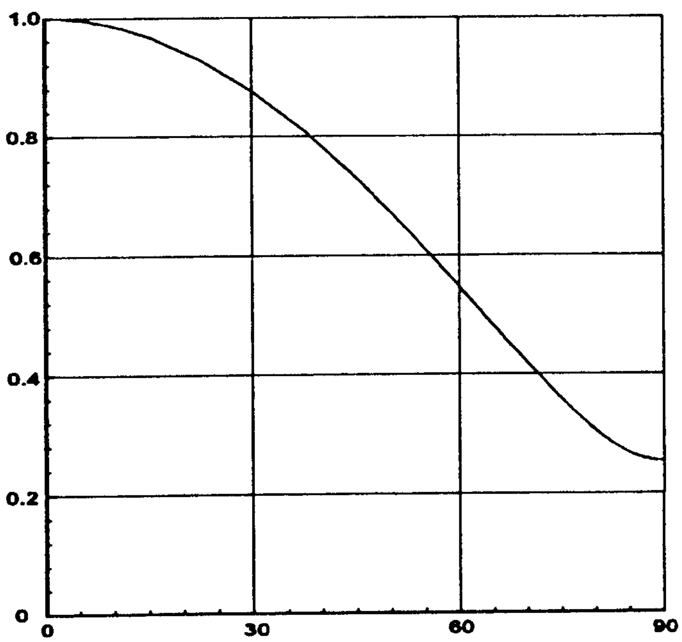
30 foot Facility



Steady Force vs L_w



Shock Force vs
Average Period



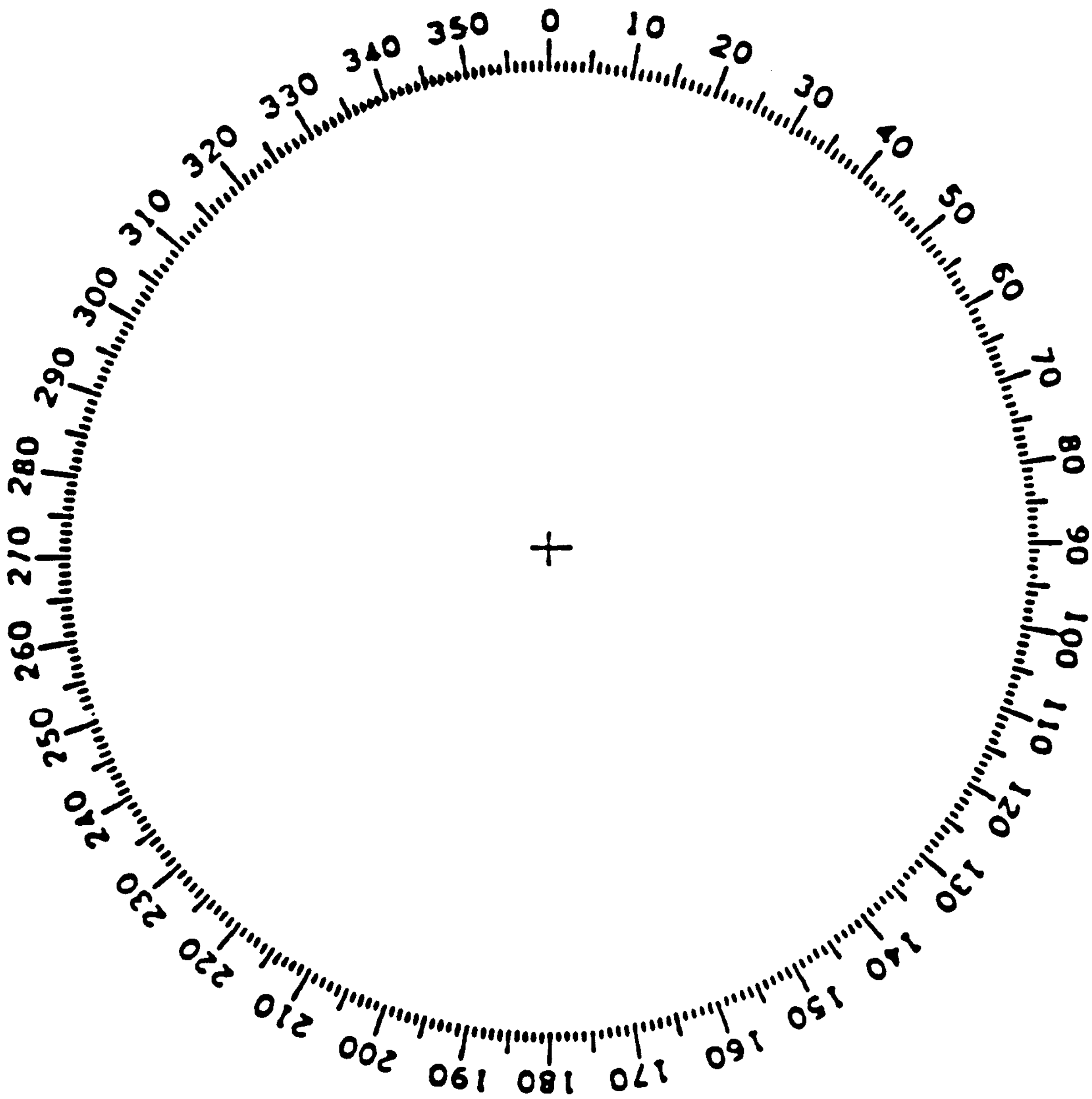
Shock Force Factor vs
Course Correction

The five curves above are for - reading from the bottom up on the right hand side - 30, 35, 40, 45, and 50 foot waterline length boats to be towed.

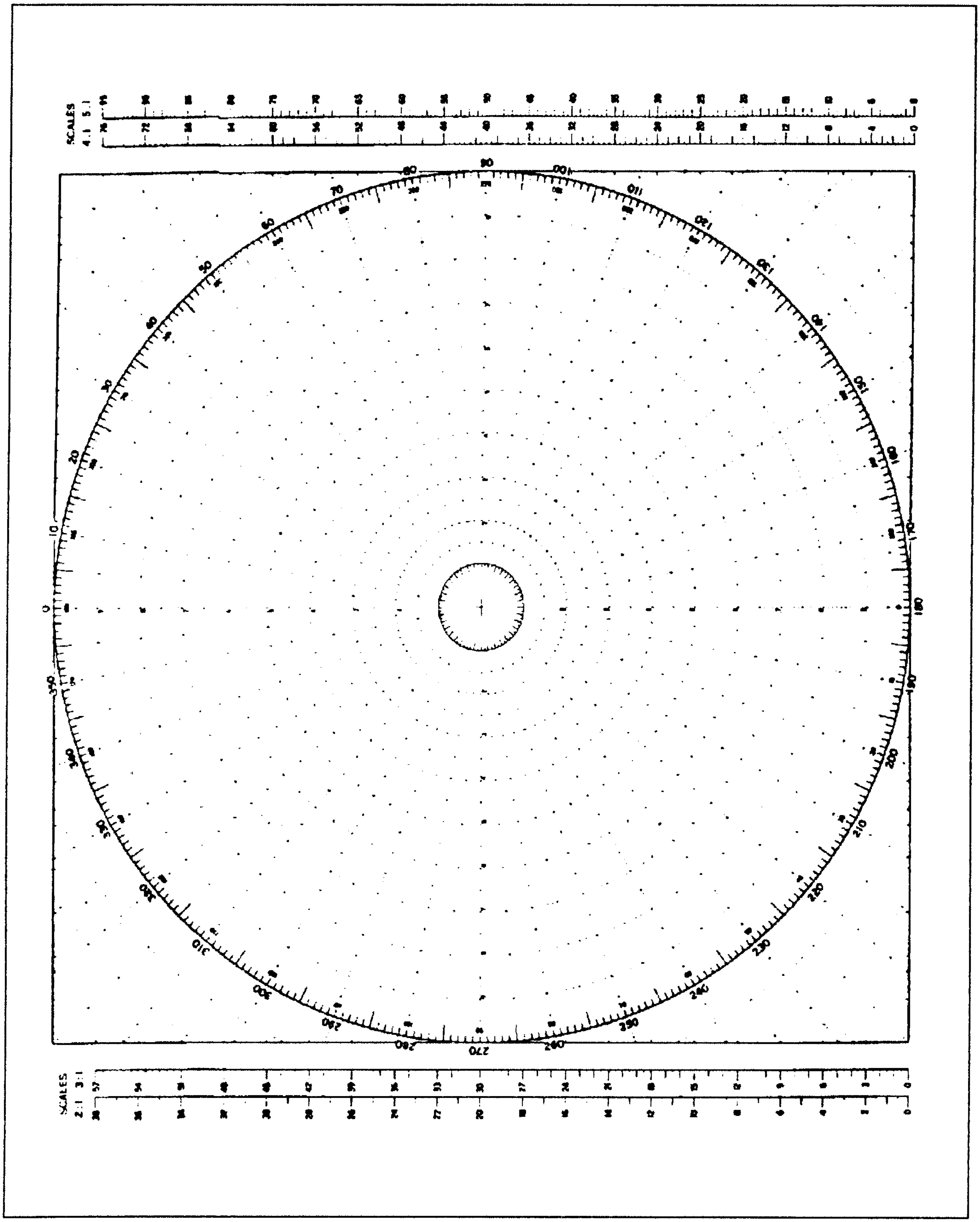
NOTE: The Shock Force curves are for 3-Strand Twisted towline. If Double Braided line is used multiply the Shock Force by 1.6.

NOTE: The Shock Force curves are for 200 foot towline. A 100 foot line may more than double the Shock Force; for a 300 foot line use a factor of 0.6

Scale ________________



VECTOR WORKSHEET



AUXILIARY SPECIALTY COURSE
PRACTICAL DEMONSTRATION WORKLIST

SEARCH AND RESCUE

1. Use a LEEWAY WORKSHEET and either a Maneuvering Board or Vector Worksheet; demonstrate how to determine the Leeway Vector for the following scenario:

Search Object	30′ L_w CC w/o drogue
Incident Time	111630 T MAR 93
Datum Time	120245 T MAR 93

Synoptic Winds:	111200 Z	180°	3 knots
	111800 Z	240°	12 "
	120000 Z	270°	15 "
	120600 Z	240°	8 "
	121200 Z	190°	5 "

2. Use the *SeaScape* Tow Planning Worksheet and determine the Maximum Peak Force for the following scenario:

Distressed Vessel:	32′ L_w Cabin Cruiser
Sea State:	90 wave crests pass in 9^m 45^s

Use **300** feet of **Double Braid** towline, and **No heading correction.**

Student Name ______________________________

Student Member Number ______________________________

Instructor Signature ______________________________

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APPENDIX B. THE SARSAT SYSTEM

History. About 15 years ago, the United States, France and Canada, jointly sponsored a search and rescue system that employs satellites. The Soviet Union (now the Russian Federation) joined the program in 1980. The concept was this: if a vessel (or person, or aircraft) carried a beacon that could be activated in a distress situation the beacon signal would be detected by a satellite and the ground SAR resources notified. Simply detecting a beacon signal is not, however, enough as the area "seen" by a low-orbit satellite is thousands of square miles. So the system concept was that the satellite, or associated ground station, would detect the Doppler shift in the beacon frequency caused by the relative motion of the satellite with respect to the beacon, and from that information deduce the position of the beacon with considerable accuracy.

The global network of satellites and ground receiving stations are known today as the COSPAS/SARSAT Search and Rescue system. Initially the system used only 121.5MHz as the beacon signal; that is the standard aircraft emergency frequency, and is the frequency used by crash-locator beacons carried by aircraft. The original concept of the SARSAT system was that it would primarily depend on a unique frequency, and that the beacon would have more extensive capability than is possible with the 121.5MHz beacons. The improved system, using 406MHz as the beacon frequency, and a much more sophisticated beacon coding system, was activated in 1985. The 406MHz system represents a major improvement over the earlier system. Many companies have designed EPIRBs to the new standard, and many countries have made the carriage of 406MHz EPIRBs mandatory on commercial fishing and other vessels involved in off-shore voyages.

Table B-1 shows some of the important characteristics of the beacons designed for maritime use that are on the market. The SARSAT system now accommodates the 406MHz beacons and also continues to detect the 121.5MHz beacons, although the accuracy of the 121.5MHz part of the system is much less than the 406MHz part. The Table also indicates that the 406MHz beacons may also carry a low-power 121.5 transmitter; this is to enable the search resource to use standard direction finding equipment and not as an alternative alert to the SARSAT system. Class C beacons are included in the Table as these are popular for near-coast passages; they do not alert the SARSAT system.

The 121.5MHz System. The EPIRB aboard a vessel in distress is activated-either automatically or manually-and transmits a signal that is received by a polar-orbiting satellite. The satellite retransmits the signal immediately (on 1544.5MHz), and it is received by one or more ground-based Local User Terminals (LUT) that analyze the original signal. The LUT sends the information to the national Mission Control Center (MCC) which, in turn, sends the information to the appropriate Rescue Coordination Center (RCC). The problems with this system are:

1. 121.5MHz is the standard VHF-AM civilian aircraft emergency frequency (243MHz is a standard military frequency) and some normal communication can trigger an alert. Some 95% of the alerts are false.

2. The satellite rebroadcasts the detected signal immediately, ie, the satellite acts as a repeater. If there is no LUT within range, the signal is not received by the ground part of the system and no action can be taken. As a result there is almost no coverage in the southern hemisphere.

3. The stability requirement of the 121.5MHz units is relatively poor with the result that the distress position has an uncertaincy of up to 10 miles, ie, the search area is therefore over 300 square miles.

Type	Frequency	FCC Type Accepted	USCG Approved	Automatic Activated	Required to Float
Cat I	406MHz 121.5Mhz	Yes	No*	Yes	Yes
Cat II	406MHz 121.5Mhz	Yes	No*	No	Yes
Class A	121.5MHz 243MHz	Yes	Yes	Yes	Yes
Class B	121.5MHz 243MHz	Yes	No	No	No
Class C	VHF Chan 15 & 16	Yes	No	No	No
Class S	121.5MHz 243MHz	Yes	No	No	Yes

* Undergoes CG review before FCC Type Acceptance.

Table B-1. EPIRB Types

The 406MHz System. The same satellites carry additional equipment to handle the new frequency and to process and store the signal data on board. The advantages of the 406MHz system are:

1. The beacon signal frequency-actually 406.025MHz-is not used internationally by any other service; it is unique and normal communication is less likely to cause false alerts.

2. Although the satellite rebroadcasts the processed signal immediately, it also stores the Doppler information and the exact time of receipt and rebroadcasts it when challenged by a LUT. This makes the coverage worldwide and has the satellite take over some of the Doppler processing from the LUT.

3. The stability requirement for the 406.025MHz carrier in the EPIRB is greatly improved with the result that the location can be determined with an accuracy of 1 to 3 miles. This reduces the search area enormously. Besides an optional low-power 121.5MHz transmitter for homing, the beacon may also carry a high-intensity strobe to improve night detection.

4. The transmission sequence of the beacon includes digitally-coded information about the country of origin, make, model and serial number of the beacon itself, and if the transmission is a test. As of September 13, 1994 the FCC (FCC 94-170) **requires** users to register EPIRBs, thus the MCC can look up the registered owner and include it in the distress alert message transmitted to the responsible RCC. The RCC that receives the data from the MCC can verify the alert by a telephone call.

5. The processing of the doppler data in the satellite is much more sophisticated, particularly in the ability to handle many simultaneous alerts and to identify interference.

How the System Works. The NOAA satellites operate at an altitude of 528 miles and have an optical range of about 2000 miles. Figure B-1 shows the detection range limits of the satellite. The y-axis is the distance from the satellite to the horizon measured along the satellite's path; the x-axis is the offset (along the ground) of the satellite's path, ie, a zero offset means the satellite passes directly over the Beacon.

Figure B-2 shows the Doppler frequency (for the 406MHz beacon) seen by the satellite as a function of distance along the track, for seven different values of offset: 0, 300, 600, 900, 1200, 1500, and 1800 nautical miles. The curves in Figure B-2 are basic to understanding how the satellite determines the position of the beacon. What the satellite has to do is determine the *Clock Time* the exact instant the Doppler shift goes to Zero, and also measure the Slope of the Doppler shift curve at that instant. The Slope uniquely measures the offset distance the instant the beacon is precisely at right angles to the satellite track. The satellite achieves maximum accuracy if it receives at least three bursts from the beacon, which triggers slightly faster than once per minute, so the satellite must "see" the beacon for about four minutes (note the 2-Minute Window in Figure B-1). Figure B-3 shows the slope of the curves in Figure B-2 at zero crossing as a function of slant range offset. It follows then that if zero

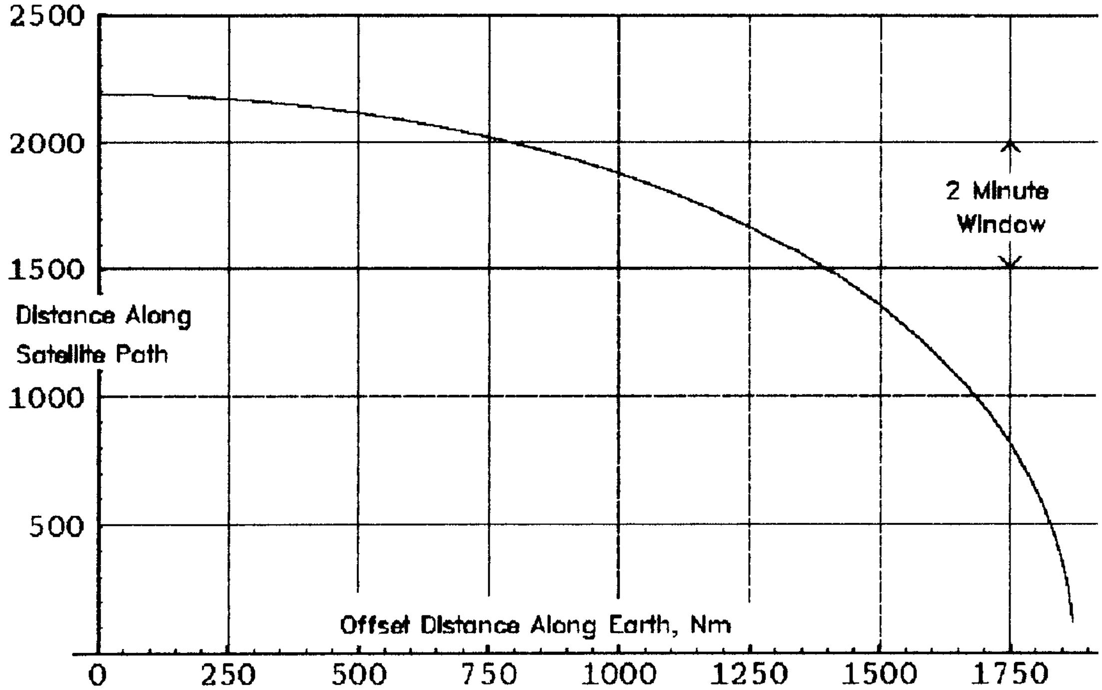

Figure B-1 Geophysical Range

crossing can be determined, the offset can be calculated and the position of the Beacon determined. (The 180° ambiguity is resolved by a second pass.)

Figure B-3 shows how zero crossing is determined; the curves are the first derivative of the Doppler frequency and show that the instant the satellite path is exactly at right angles to the Beacon can be determined with considerable precision, and only requires that the Beacon mid-term frequency stability be extremely high. The offset distance determines the amount of time the satellite has the Beacon in view (note that the greater the distance-off the shorter the curves in Figures B-2 and B-3), and that contributes to the system's ability to qualify the "hit". However, in terms of information for calculation, the satellite sees the beacon for a very long time (if it sees it for the minimum four minutes) and has a relatively enormous amount of information from which it can extract the exact position of the beacon.

<u>SARSAT System Responsibility</u>. COSPAS/SARSAT represents a model program of international cooperation. When the program was founded, Canada was selected to supply the space-based repeaters, France the space-based processors for the 406MHz frequency, and the United States the satellites. When the Soviet Union joined

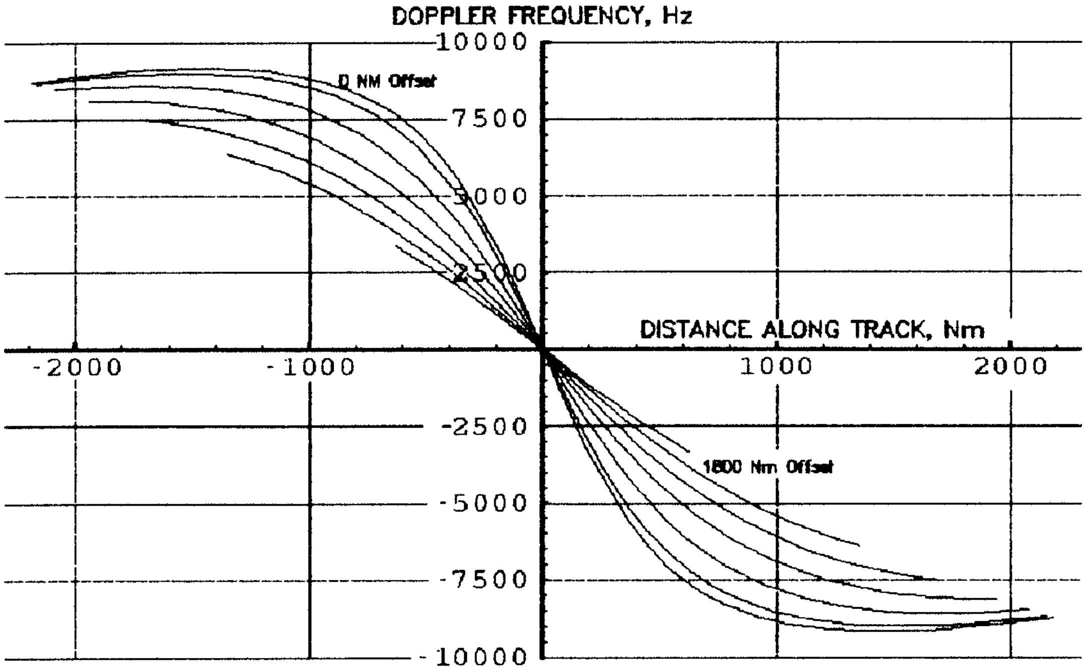

Figure B-2 Doppler Frequency vs Distance Along Track

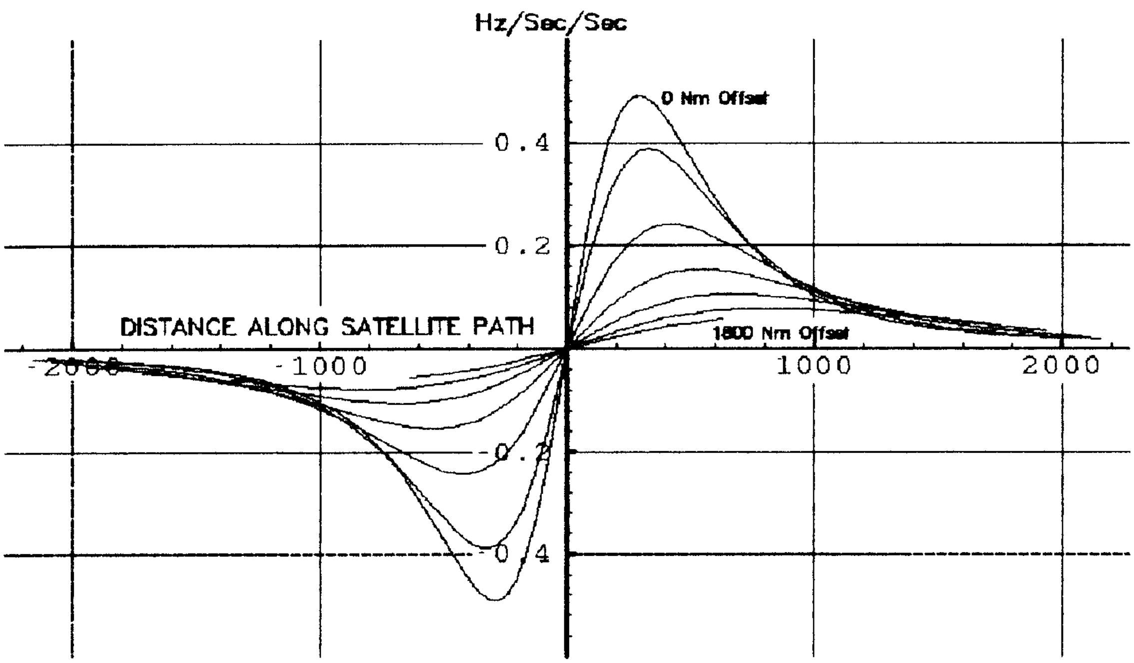

Figure B-3 First Derivative of Doppler Frequency the program they agreed to equip their COSMOS satellites with COSPAS repeaters and processors. There are 27 countries who are participants; a total of 17 MCCs are in operation, in test, or planned; and a total of 30 LUTs are in operation, test or planned. The United States MCC is in Suitland, New Jersey; and LUTs are located in Hawaii, Puerto-Rico, Houston, Fairbanks, Vandenberg AFB, and Guam. There are three COSPAS and three NOAA satellites in operation (the nominal system requires four satellites). There are over sixty COSPAS/SARSAT Type-Approved 406MHz EPIRB models manufactured by twenty manufacturers, and (in 1995) over 20,000 registered owners.

Beacon Technical Data. There are three basic forms of beacons: Emergency Locator Transmitters (ELTs), Emergency Position-Indicating Radio Beacons (EPIRBs), and Personal Locator Beacons (PLBs). This Appendix is devoted only to the EPIRB beacons, of which there are two Types: Type I is automatically activated by immersion or release from its mounting bracket, and Type II is manually activated. There are two Classes for each Type; Class 1 has an operating temperature range of -40°C to +55°C, and Class 2 has an operating temperature range of -20°C to +55°C. All beacons are required to "warm up", ie, get the crystal oven up to temperature, within 15 minutes; they do not start broadcasting until the crystal is stabilized. Beacons may have a "short" message length (112 bits), or "long" message length (144 bits), in addition to a carrier burst. The pulse interval of the beacon is 50±5sec.

The broadcast format is 160 ms (0.160 seconds) carrier, used by the system to determine the doppler shift, followed by either 112 or 144 data bits of information sent at 400 bits/sec. There are a total of nine protocols for the message bits; these protocols are used to identify the purpose of the beacon, eg, ELT, EPIRB, or PLB, and subcategories of these purposes. All of the protocols share the same general arrangement of the message bits, as follows:

Bit Field Name	Bit field Location
1. Bit synchronization	bits 1 through 15
2. Frame synchronization	bits 16 through 24
3. Protected field	bits 25 through 85
4. Error-correcting code	bits 86 through 106
5. Emergency-Code/National Use	bits 107 through 112
6. Long message (optional)	bits 113 through 144

Of the nine protocols two are presently unassigned. Three of the protocols are for maritime use: one includes Long/Lat entered by the vessel, eg, by GPS, one uses generic "maritime data", and one uses serial number and owner identification (the one most often used by off-shore vessels).

The stability requirement is very strict. The specifications require a transmitter frequency of 406.025MHz ± 2kHz that may not drift more than ± 5kHz, including the initial offset, in 5 years. The absolute accuracy is less important than the stability, and the latest satellite systems are designed to allow a much larger range of beacon frequencies. This allows the system to handle many more simultaneous beacon signals. The medium-term stability requirement is 1 part in 10^9 per minute; it is this medium-term frequency stability that determines the accuracy with which the satellite can determine the exact *CLOCK TIME* the first derivative of the doppler shift is zero.

Satellite Technical Data. The System is designed to use at least four satellites; usually there were six in orbit with two nearing their useful life.

The SARSAT antennas and receiver piggyback on NOAA weather satellites, now into series L,M and K. These satellites operate at an altitude of 528 miles, in orbits inclined 99° to the equator, and take 100 minutes to complete an orbit.

The COSPAS antennas and receiver piggyback on Russian COSMOS navigation satellites which orbit 620 miles above the earth in orbits inclined 83° to the equator and take 105 minutes per orbit.

NOAA has installed a 406MHz receiver on its GOES geostationary satellites. Although a geostationary satellite cannot "see" any doppler shift, it records the serial number thus allowing the MCC to look up the name of the registered owner. In the U.S. more than 30% of the 406MHz distress alerts are first detected by a GEO satellite. If the EPIRB is connected to a GPS receiver, its transmission of position information is received by the GOES satellite and relayed to the appropriate RCC.

Shortcomings. The 406MHz beacons are substantially more expensive than the 121.5MHz units, although the price has been declining rapidly as the system becomes accepted. The internal lithium batteries have a shelf life of 4 to 6 years, but are not rechargeable, and, containing a toxic substance, must be disposed of carefully. These shortcomings are overpowered by the reliability of the system, the ability to distinguish test transmissions, and the fact that alerts can be verified as false (if they are) without dispatching SAR units. So the system is cost effective in spite of the expense of the beacon units themselves.

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APPENDIX C. MATHEMATICS TUTORIAL

A. Algebra. We are all used to doing algebra problems in our heads, whether we know it or not. For instance, if we are in a car and average 50 mph how far will we go in an hour and a half? We instinctively know to multiply the 50 by the 1½ to get 75. Some people find it somewhat more difficult to do a related problem such as: we travel 200 miles in 4 hours; what has been our average speed? Most people will recognize that the answer is gotten by dividing 200 by 4.

Algebra is simply a way to formalize, and generalize these kinds of relations so that any set of numbers can be used. For instance the generalized expression of the examples above is

$$Distance\ Travelled = Speed \times Time$$

or, to put it into algebraic form

$$D = S \times T$$

which shows the generalized relation between Distance, Speed and Time.

There are three properties of an algebraic equation that are important, and help us "solve" equations:

1. When sides are interchanged the equality remains. This means that

$$D = S \times T$$

can be rearranged without effecting the equality as

$$S \times T = D$$

This is important because it is the custom (and the way we think) to have the "unknown" on the left-hand side of the equal sign.

2. For multiplication and addition, the **ORDER** of processing variables does not change the value, for instance

$$D = S \times T$$

is exactly the same as

$$D = T \times S$$

3. The equality of an equation is unaffected if both sides of an equation are multiplied by, divided by, added to, or subtracted from the same value. For instance

$$D \times 10 = S \times T \times 10$$

The "same value" need not be a number, it can be any constant. For example

$$\frac{D}{C} = \frac{S \times T}{C}$$

We use these characteristics to help "solve" equations. For instance if we know Distance and Time and want to solve for Speed we first swap sides so that the "unknown" (S) is on the left hand side

$$S \times T = D$$

But we want only the unknown on the left hand side. We can get rid of the "T" on the left hand side by dividing both sides of the equation by "T".

$$\frac{S \times T}{T} = \frac{D}{T}$$

The "T's" on the left hand side cancel and we're left with the equation in the form we want it

$$S = \frac{D}{T}$$

B. Where did 60D=ST come from? The usual form of the S/T/D equation used in SAR is D=SxT where D is in Nautical Miles, S is in knots, and T is in Hours. We can check this equation to see if it really is an equality by substituting the "units" used for each of the variables, viz.,

$$NauticalMiles = Knots \times Hours$$

which becomes

$$NauticalMiles = \frac{NauticalMiles}{Hours} \times Hours$$

The Hours on the right-hand side cancel and we're left with the identity NM=NM.

If we want to express Time in Minutes, instead of Hours, we know that we have to multiply Hours by 60, the number of minutes in an hour. But if we multiply the Hours on the right-hand side of the equation we must also multiply the left-hand side of the equation. Thus

$$60 \times \mathbf{\mathit{NauticalMiles}} = \mathbf{\mathit{Knots}} \times \mathbf{\mathit{Hours}} \times 60$$

But 60 x Hours is simply Minutes, hence our popular

$$60 \times D = S \times T$$

where T is now in Minutes.

C. Vector Arithmetic. The problems at the end of this Appendix illustrate the different situations that face a SAR Mission Cordinator during his search planning work. A "sharp" student should be able to do all these problems in about one-half hour; if it takes longer than that the student should ask his Instructor to give him more practice problems. The only tools needed are 1) a pad of Maneuvering Board sheets (available at any marine supply store), 2) a plotting instrument such as a Weems Parallel Plotter, 3) a set of dividers, and 4) a hand-held four-function calculator. Copies of the Vector Worksheet can be substituted for Maneuvering Boards.

Vector Notation. A vector can be specified on a polar diagram by a line whose length—to some specified scale—represents the value, and whose direction represents the direction. When a vector is specified in this text the value is written (with the units included) and the direction is a number of degrees preceded by an angle symbol, viz."∠". The angle symbol looks a little like the "<" symbol, but "<" is the "less than" symbol—not the angle symbol.

1. <u>Speed/Time/Distance</u>. The relationship between Speed, Time and Distance is expressed in the usual formula

$$60D = ST$$

where D is Distance in nautical miles, S is the Speed in knots, and T is the Time in minutes. Note that both Distance and Speed have directions as well as values and, hence, are Vectors. A more correct representation of this formula is

$$60\vec{D} = \vec{S}T$$

where the small arrows over the D and S show that they are Vectors. In this simple illustration any Speed, Time and Distance problem can be solved without recourse to a graphical method, because the <u>direction of the two Vector</u>

quantities is the same, ie, the direction of the Distance vector is the same as the direction of the Speed vector.

The "60 D Street" formula is useful in many navigation problems because the problem being solved is appropriate to TIME measured in Minutes. But in Search Planning the more useful measure of time is Hours and decimal fractions. The formula most often used in Search Planning is therefore

$$\vec{D} = \vec{S}T$$

where T is in Hours.

2. Speed Made Good (SMG). A vector problem that requires a graphical solution is one that involves two vectors that have different directions. For example, assume a vessel is travelling at 12kt through the water (called Speed, or Speed-Through the Water, STW) on a course of 180°, and is experiencing a CURrent of 2.5kt in the direction of 090°. What is the speed over the ground (SMG) and direction? The mathematical representation of the problem is

$$\vec{S}_{smg} = \vec{S}_{stw} + \vec{S}_{cur}$$

and the graphical solution is shown in Figure C-1. The problem is plotted on a Maneuvering Board with a scale of 2:1. Note: a scale is selected that will make the lines fill as much of the sheet as possible; this gives the greatest accuracy to the answer. First the 12kt vector is drawn from the origin in the direction of 180° with a length of 12 units. This represents the course and STW of the vessel with respect to the water. Next the 2.5kt vector is drawn from the tip of the 12kt vector in the direction of 090° and with a length of 2.5 units. The sum vector is then in amount the distance from the origin to the end of the 2.5kt vector, in the direction that can be read from the scale at the edge of the diagram. The length scales to 12.2kt in the direction of 168°. (Round to the nearest 0.1kt and degree)

3. Current. Subtracting two vectors can also be done graphically, although this is seldom encountered in search-area planning. Finding the current when STW and SMG are known is an example. Assume the STW is 14kt at 045° and the SMG is determined to be 11kt at 060°. What is the current that has caused this difference between the STW and the SMG? Figure C-1 shows the solution. The mathematical representation is

$$\vec{S}_{cur} = \vec{S}_{smg} - \vec{S}_{stw}$$

When subtracting two vectors they are drawn "tail-to-tail" and the difference vector is drawn from the head of one vector to the head of the other. In this case the difference vector has a magnitude of 4.5kt in the direction of 185°. Why 185° instead of 005°? It is easy to examine the plot of the STW and SMG vectors to see in which direction the Current vector has to be sensed; in which direction must the current be added to the STW to result in the observed SMG?

4. Wind. Calculation of Datum usually involves determining the combined effect of several wind values. If some time has elapsed between the distress incident and the Datum time the wind may have changed during that interval. This sort of situation requires that the net average wind be determined before the wind can be used to calculate total Drift. There is an additional complication; although both Wind and Current are expressed in knots they cannot be added together. The search object experiences the Current directly, ie, a search object in a 1.5kt current will experience a 1.5kt SMG. But if the search object experiences a 12kt wind it will only experience a speed that results from the wind hitting the superstructure. Table 3-1 and Figure 3-10, for example, show the speed that results from wind for several classes of search objects. Therefore, for Wind problems the Average Wind is determined first. For example, assume the search object experiences a wind of 10kt from 125° for 1.5 hours and a wind of 13kt from 145° for 2.5 hours. What has been the average wind speed and direction? The two wind vectors cannot be added directly because they have occurred over different amounts of time. To solve the problem each wind amount is multiplied by the time it lasted (thus creating displacement vectors) and then the two displacement vectors are added graphically. The magnitude of the resulting displacement vector is then divided by the total amount of time to give the average wind vector. For this example, worked out in Figure C-2, the Average Wind is 11.6kt from 139°.

5. Summary. There are several caveats to remember when doing vector arithmetic graphically:

a. The same scale must be used for all of the vectors in any problem.

b. The units of the amount portion of all the vectors must be the same.

c. The scale should be selected to use as much of the maneuvering board as possible.

d. When a different amount of time is related to each vector, convert velocity vectors to displacement vectors, and divide the final displacement vector amount by the total elapsed time. When a vector is multiplied, or divided, by a scalar quantity, eg, TIME, only the quantity part of the vector is multiplied or divided; the direction value does not change.

PRACTICE PROBLEMS

1- What is the *SMG* (Speed Made Good) that results from a *STW* (Speed Through the Water) of 18kt and a *CUR* (Current) of 2.1kt $\angle 200°$?

2- What is the *SMG* that results from a *STW* of 9kt $\angle 275°$ and a *CUR* of 2.5kt $\angle 160°$?

3- What is the *SMG* that results from a *CUR* of 2kt $\angle 180°$ and a *STW* of 8.2kt $\angle 300°$?

4- What is the *CUR* that causes a *SMG* of 8kt $\angle 270°$ when the *STW* is 9kt $\angle 240°$?

5- What is the *CUR* that causes a *SMG* of 8.5kt $\angle 043°$ when the *STW* is 8kt $\angle 050°$?

6- What must be the planned *STW* if the *CUR* is 1.1kt $\angle 150°$, and the desired *SMG* is 8kt $\angle 350°$?

7- What must be the planned *STW* if *CUR* is 1.1kt $\angle 150°$ and the desired *SMG* is 8kt $\angle 190°$ /

8- The wind blows 20 kt from 270° for 2.5 hrs, and 15 kt from 200° for 3.5 hrs. What has been the Average Wind?

9- The wind blows 18 kt from 252° for 3.6 hrs and 22 kt from 275° for 4.6 hrs. What has been the Average Wind?

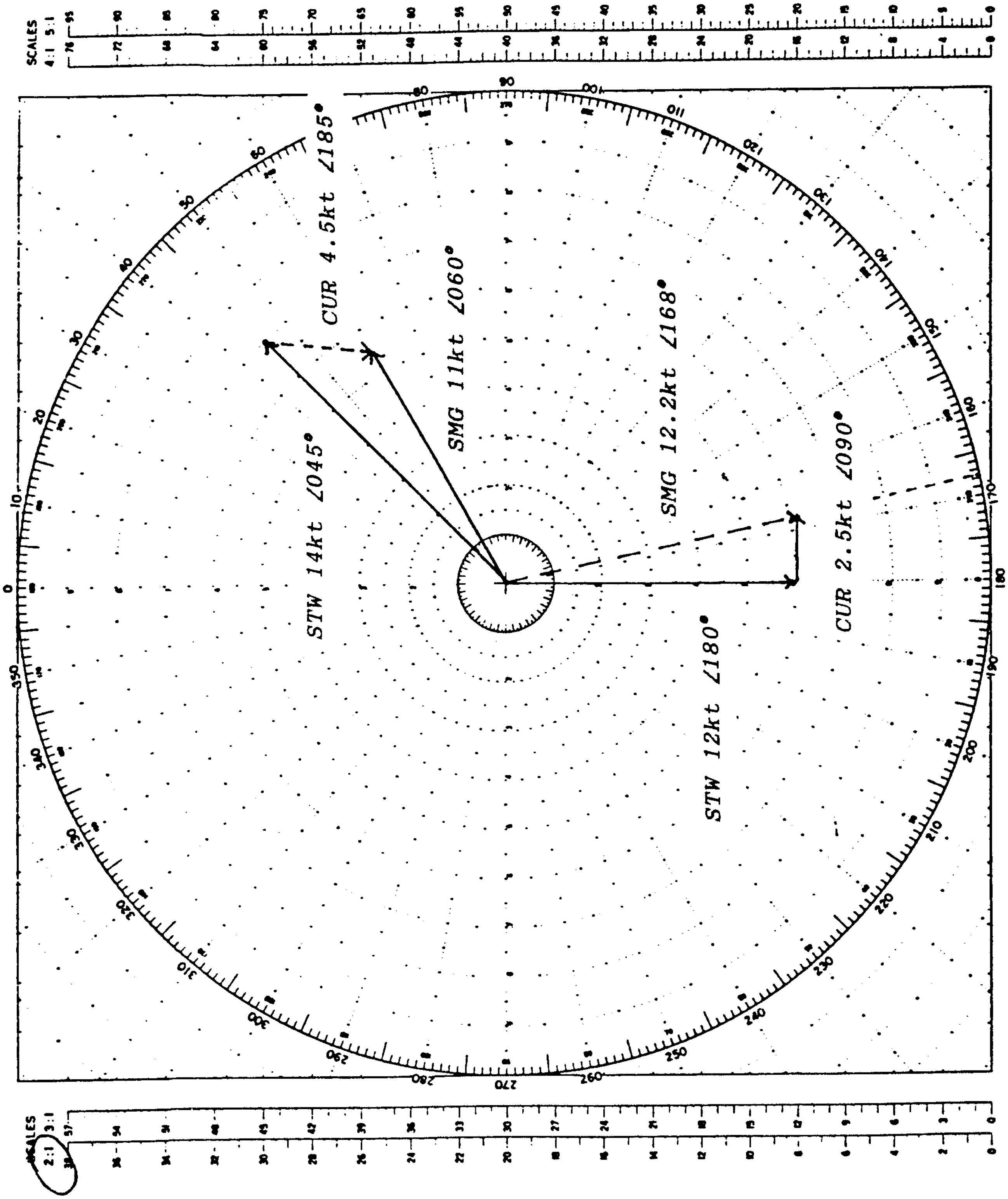

Figure C-1 Vector Illustration

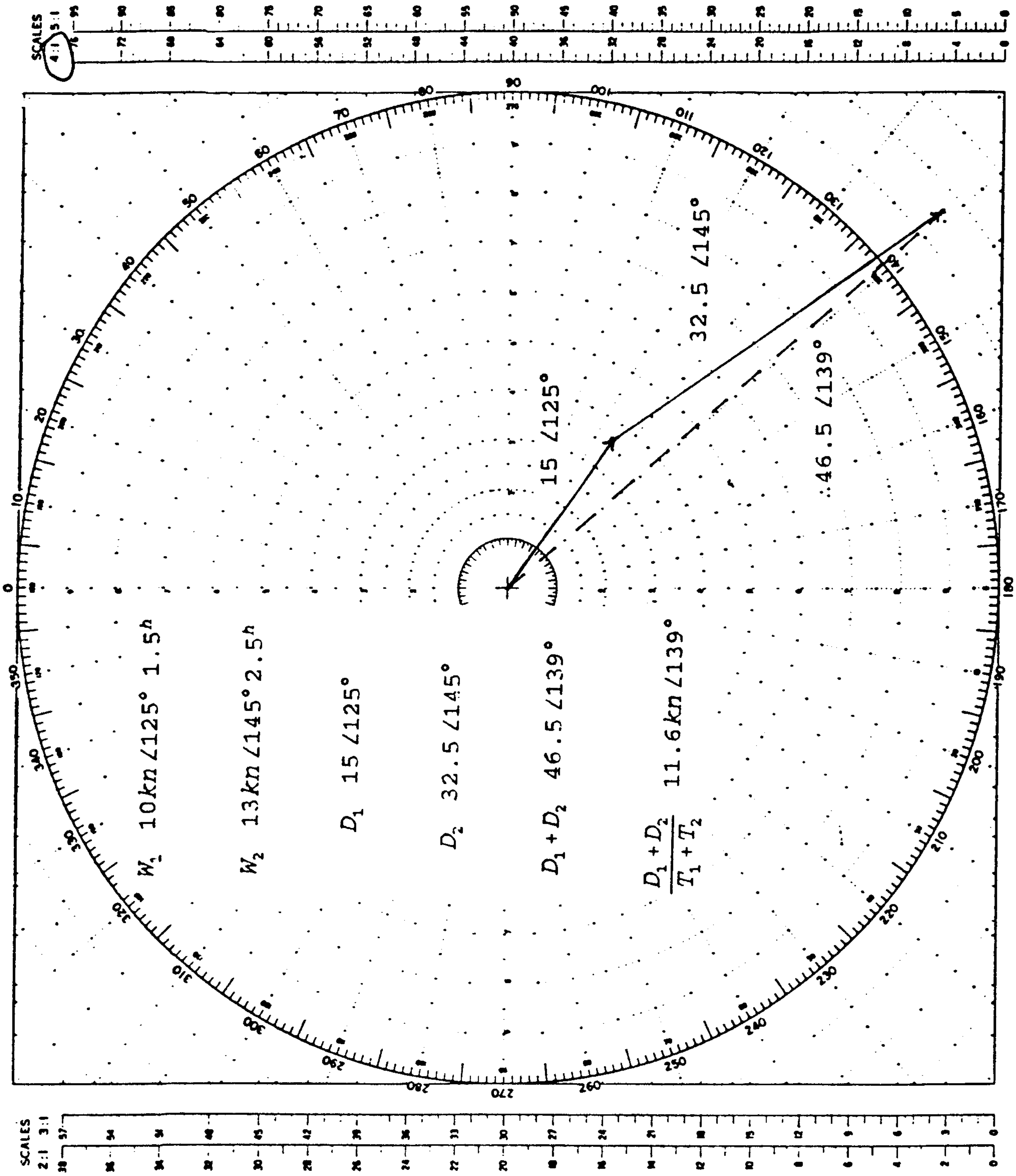

Figure C-2 Vector Illustration

ANSWERS TO PRACTICE QUESTIONS

1- *SMG* is 17.2kt $\angle 091°$.

2- *SMG* is 8.3kt $\angle 259°$.

3- *SMG* is 7.4kt $\angle 286°$.

4- *CUR* is 4.5kt $\angle 358°$.

5- *CUR* is 1.2kt $\angle 345°$.

6- *STW* is 9.0kt $\angle 347°$.

7- *STW* is 7.2kt $\angle 196°$.

8- 20 x 2.5 = 50.0 $\angle 270°$
15 x 3.5 = 52.5 $\angle 200°$

---

vector sum = 84.0 $\angle 234°$
÷ 6 hrs = 14.0kt $\angle 234°$

Average Wind 14.0kt $\angle 234°$

9- 18 x 3.6 = 64.8 $\angle 252°$
22 x 4.6 = 101.2 $\angle 275°$

---

vector sum = 163 $\angle 266°$
÷ 8.2 hrs = 19.9kt $\angle 266°$

APPENDIX D AIRCRAFT\BOAT COORDINATION

A. Introduction. This Appendix expands on the conditions which make the CSC pattern practical; the advance of the boat equals the creep of the aircraft. This is illustrated in Figure D-1 on the next page; this maneuver takes considerable coordination between the boat and the aircraft. This Appendix describes the conditions under which the coordination is made as simple as possible.

B. If the pattern is a Creeping Line Single-unit Coordinated, communications and visual contact are established before arriving at the CSP. The coordination between vessel and aircraft is more difficult than it appears at first glance. The Coxswain on the vessel is usually the OSC since he has time to handle communications and precise navigation; the Pilot of the aircraft concentrates on flying an exact course (compensating for wind), executing turns accurately, and searching for the target.

C. Coordinated search patterns are no longer used very often by the Coast Guard since Coast Guard aircraft can navigate as accurately as Coast Guard vessels. However, many CG Auxiliary aircraft do not have LORAN and, for them, coordinated search patterns are very efficient.

D. Figure D-1 illustrates what is probably the ideal situation; the aircraft travels at such a speed that a 180° turn made at "standard rate", ie, one needle width, or 3° per second, translates along the vessel track exactly the assigned aircraft track spacing. The variables are vessel speed, V_s, aircraft speed, V_a, and aircraft leg length, L. Table D-1 gives the Track Spacing for various aircraft speeds; Table D-2 gives the Leg length in nautical miles for various combinations of vessel and aircraft speeds; and Table D-3 gives the time, in minutes and seconds, for the aircraft to go from immediately over the vessel until it starts its procedure turn. The Pilot (or Observer) can time by a stop watch, or the vessel can do the timing and inform the Pilot when it is time to turn. Note that only half of each leg is timed. Shaded blocks correspond to impractical options. Auxiliary aircraft usually fly at 1000ft altitude, and at that altitude the winds should be modest. However, the Pilot will probably have to compensate for wind, especially at the slower speeds. He can do that by adjusting speed slightly, or making turns slightly earlier or later. It is probably not worth while to plan the adjustments in advance but make them as the search progresses. By timing only one half each leg, starting with the instant the aircraft crosses the vessel path, the pattern tends to correct for winds aloft.

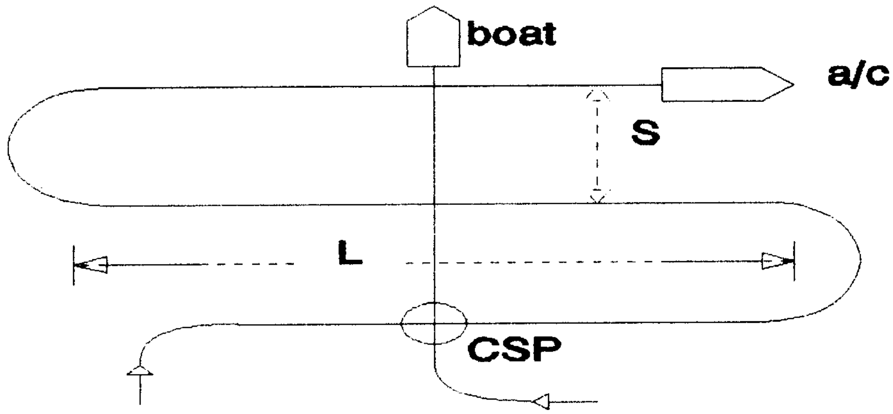

Figure D-1 CSC Pattern

a/c kts	80	100	120	140	160	180
S NM	0.8	1.1	1.3	1.5	1.7	1.9

Table D-1. Track Spacing for Figure D-1 Pattern

	Aircraft Speed, knots					
vessel	80	100	120	140	160	180
8.0	7.2	11.6	17.1	23.7	31.3	40.0
10	7.5	8.9	13.3	18.5	24.5	31.4
12	4.3	7.2	10.7	15.0	20.0	25.6
14	3.5	5.9	8.9	12.5	16.7	21.6
16	2.9	5.0	7.5	10.7	14.3	18.5
18	2.4	4.2	6.5	9.2	12.4	16.1
20	2.1	3.6	5.6	8.1	10.9	14.2

Table D-2. L (NM) for Figure D-1 Pattern

vessel	Aircraft Speed, knots 80	100	120	140	160	180
8.0	2:42	3:30	4:18	5:06	5:54	6:42
10	2:00	2:42	3:18	4:00	4:36	5:12
12	1:36	2:12	2:42	3:12	3:42	4:18
14	1:18	1:48	2:12	2:42	3:12	3:36
16	1:12	1:36	2:00	2:24	2:48	3:12
18	0:54	1:18	1:36	2:00	2:18	2:42
20	0:48	1:06	1:24	1:42	2:00	2:24

Table D-3. Time (minutes:seconds) for L/2 for Figure D-1

E. The equation relating the values of L, S, V_a, and V_s is:

$$L = S\left[\frac{V_a}{V_s} - \frac{\pi}{2}\right]$$

If the aircraft turn is made at the standard rate, it takes exactly 60 seconds to make the 180° turn. Under these conditions the equations for S, L, and T (the Time to fly one-half L) are:

$$S = \frac{V_a}{94.3}\ NM$$

$$L = \frac{V_a(V_a - 1.571\,V_s)}{94.3\,V_s}\ NM$$

$$T = \frac{(V_a - 1.571\,V_s)}{3.14\,V_s}\ minutes$$

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APPENDIX E VESSEL BEHAVIOR ANALYSIS

A. Introduction. This Appendix contains background material that may help the student understand the Tables and Figures in Chapter 5; some Students (and Instructors), especially those with a technical background, do not want to accept the Figures and Tables without an explanation of how they are derived. There is very little literature on towing forces and therefore much of the information is derived from "first principles". However, the sections on Boat Charateristics and Wind Wave Characteristics are based on established authorities, and these are cited. There are several classic books on boat design[‡], and these should be consulted for a formal treatment of the subject. The more a Coxswain knows about boat design the better he is at estimating the forces involved in a tow.

B. Boat Characteristics. The Steady Force is dependent only on the characteristics of the boat being towed, but all the Coxswain can determine with any certainty is the Waterline Length, and Type (Sail or Power). So all of the tow forces have to be deduced from these observable characteristics.

There are three characteristics of a boat that determine how it behaves when it is being towed: *Length/Displacement Ratio*, *Speed/Length Ratio*, and *Prismatic Coefficient.*

1. *Length/Displacement Ratio* (δ) is defined as

$$\delta = \frac{D}{(.01L)^3}$$

where D is the displacement (in 2240-lb tonnes), and L is the water-line length in feet. δ is a measure of the density of the boat; planing hulls have a δ as small as 150, and deep-keel cruising yachts have a δ as large as 350. Figure E-1 shows the Displacement (in 2000-lb tons) as a function of water-line length (in feet) for three classes of vessels, one with a δ of 150, and one with a δ of 215 and one with a δ of 350. Only deep-keel ocean cruising yachts have a δ of 350 and these are not the kinds of boats the Auxiliary is likely to assist. On the other hand the small power boats that represent most of our "customers" have planing hulls, and the small day-sailers are light displacement hulls, so assuming a δ of 215 is almost always on the safe side.

[‡] An excellent reference is *Skene's Elements of Yacht Design*, Francis S. Kinney. Dodd, Mead & Company.

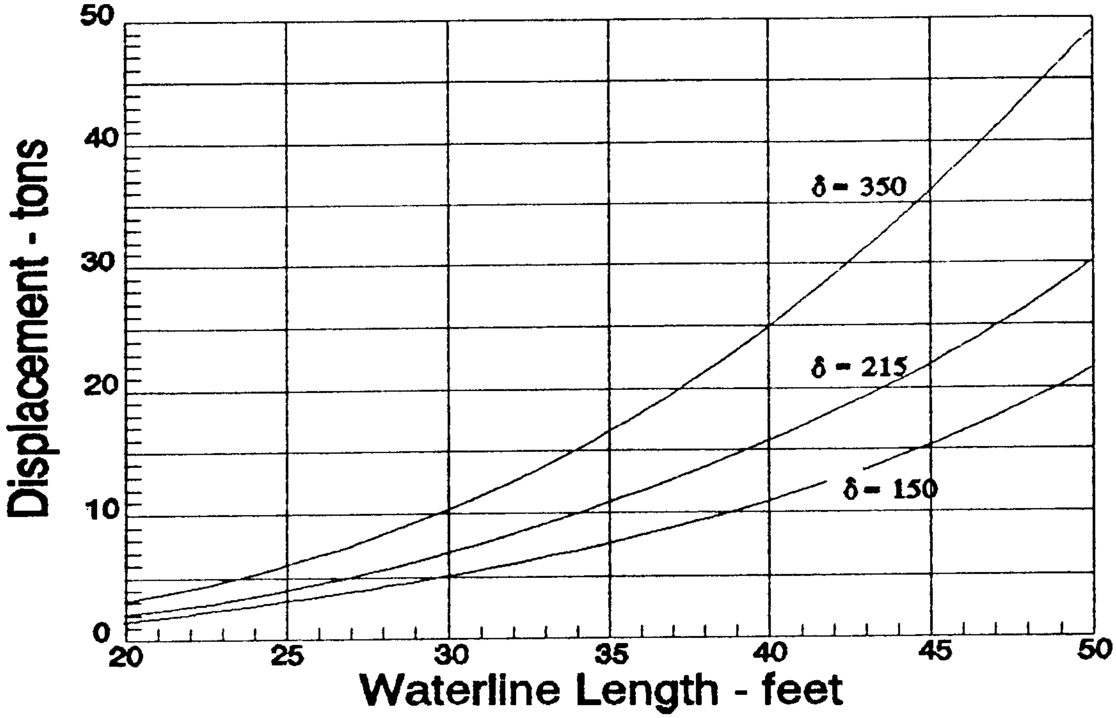

Figure E-1 Displacement vs L_w

2. *Speed/Length Ratio* is defined as

$$\frac{S}{\sqrt{L}}$$

where *S* is the speed in knots, and *L* is the water-line length in feet. When the Speed/Length ratio is 1.34 the boat is said to be going at "hull speed", the speed at which the transverse bow wave exactly matches in phase the transverse stern wave and the boat "sits" in its own displacement wave. If the boat has enough power, either sail or engine, and $\delta<200$, it can climb up over the wave and achieve a Speed/Length ratio of 2 or 3. (A boat is not considered to be planing until the Speed/Length ratio is 2). However, for boats with $\delta\geq200$, no reasonable amount of power can bring the boat out of the hole; that means no amount of power can tow a boat with a $\delta\geq200$ faster than represented by a Speed/Length ratio greater than 1.34. Below a Speed/Length ratio of 0.95 there are two or more transverse bow waves along the hull ahead of the transverse stern wave and the boat can ride her lines without sinking into her own displacement wave. For these reasons all of the discussions on towing forces assume the tow is proceeding at a speed where the Speed/Length ratio of the towed boat is 1.0, ie, **the speed in knots**

equals the square root of the waterline length in feet. If an attempt is made to tow a boat faster, it is impossible to forecast how great the force becomes, as the force increases dramatically above a Speed/Length ratio of 1.1. Speed of the tow, in terms of Speed/Length Ratio of the Towed boat, does not enter into the calculations of tow forces explicitly, but all of the tow forces are calculated using coefficients that are applicable only for a Speed Length Ratio of 1.0.

3. *Prismatic Coefficient*, C_p, (also called Block Coefficient) is defined as the ratio of the volume of displacement (of the boat) to a solid having a section the shape of the widest part of the boat at the waterline, multiplied by the waterline length. D is the Displacement in ft^3, A_m is the area of the largest section in ft^2, and L_w is the waterline length in feet.

$$C_p = \frac{D}{A_m \times L_w}$$

A log, floating in the water, has a Prismatic Coefficient of 1.0; keel sailboats, with fat midsections, have Prismatic Coefficients between 0.51 and 0.54; planing power boats have Prismatic Coefficients as high as 0.70. Although a large Prismatic Coefficient is necesary for a boat to plane (provided $\delta<200$), it causes the boat to have very high wave-making resistance at low speeds. In Figure E-3 Resistance (in pounds) is plotted as a function of waterline length (in feet) for two classes of vessels, sail and power, **each assumed to have $\delta=215$**. The difference in Total Resistance comes from the different Prismatic Coefficient of the Sailboat (C_p of 0.55) and Power Boat (C_p of 0.70).

C. The Steady Force to tow, (R_T) is the combination of Frictional Resistance (R_F) and Wavemaking Resistance (R_W).

$$R_T = R_F + R_W$$

The curve labeled Power assumes a C_p of 0.7 with a corresponding R_W of 13 lbs/ton; the curve labeled **Sail** assumes a C_p of 0.5 with a corresponding R_W of 4 lbs/ton. Both curves assume R_F is 10 lbs/ton at a Speed/Length Ratio of 1.0.

D. Shock Forces are generated when the towing and towed boats are on different phases of a wind wave, viz., are "out of step". Waves generated by a local wind have a

Figure E-2 Wind Wave Shape

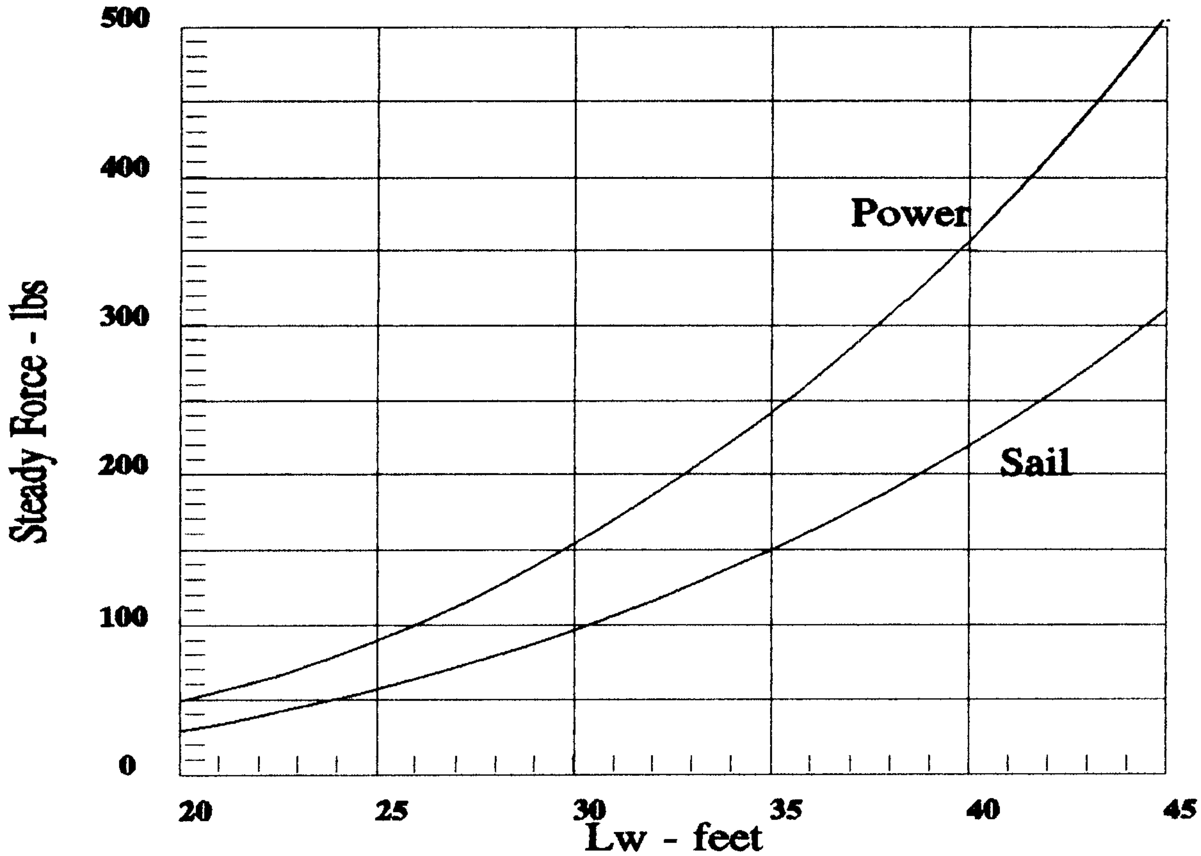

Figure E-3 Steady Force to Tow

trochoidal shape as illustrated in Figure E-2. The spectrum (the range of wave-lengths and periods) of Swells is very narrow, but the spectrum of Wind Waves is very broad, the wavelength, for instance, keeps jumping around. Consequently Wind Waves must be analyzed by statistical methods[‡].

If a steady wind blows over enough fetch for a long enough time the seas don't continue to build but become "fully developed". Fully-developed seas can be analyzed statistically and their various characteristics determined. Figure E-4 gives the important statistical characteristics of a fully-developed sea as a function of Average Period; many of these are used in calculating the Shock Force caused by Wind Waves. Curve #1 is the wind speed (in knots) that would fully develop the sea; the actual observed wind is likely larger. Curve #2 is the Average Period in seconds for the highest 10% of all the waves. Curve #3 is the minimum height in feet of the 10% highest waves. Curve #4 is the average wavelength in

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[‡] Much of the material in this section is condensed from *Oceanography and Seamanship*, William G. Van Dorn, Dodd, Mead & Company.

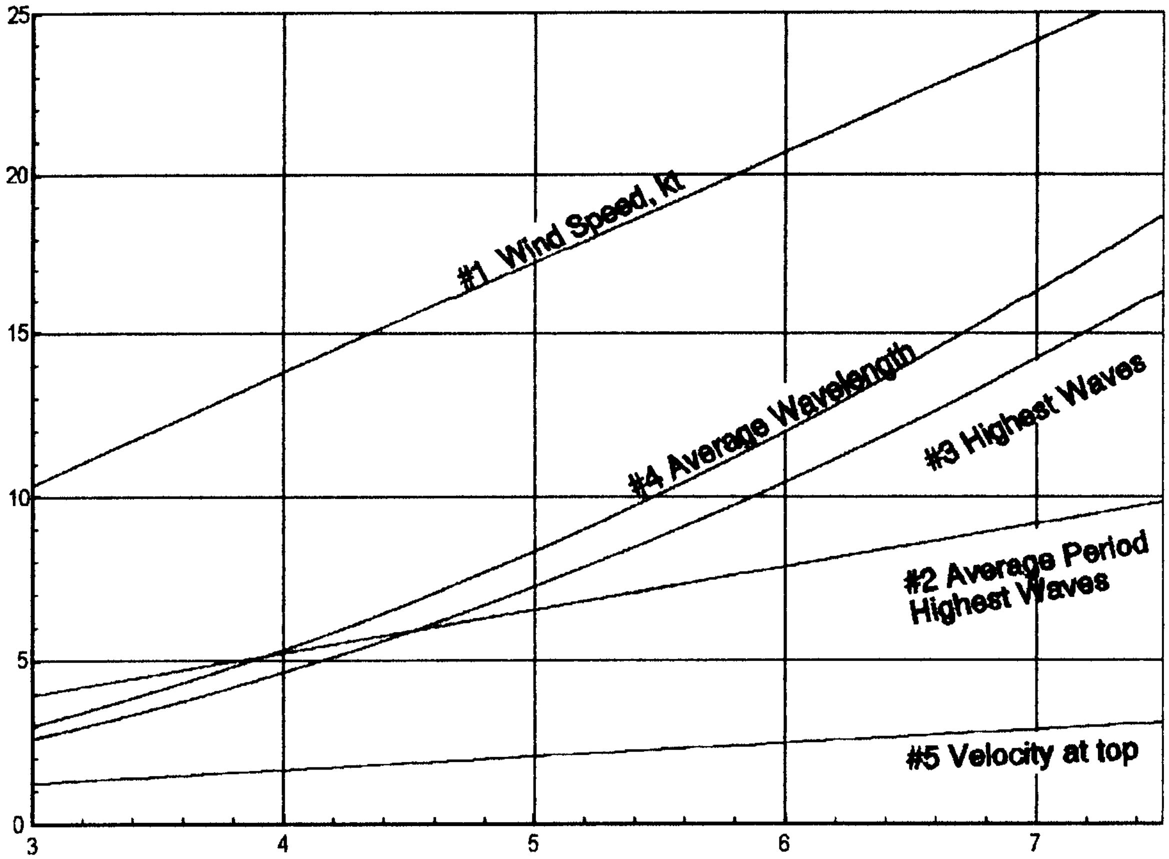


Figure E-4 Wind Wave Characteristics vs Average Period

feet/10 for all waves. Curve #5 is the particle velocity in knots at the top (or bottom) of the 10% highest waves. The formulas for the five curves in units of P (Average Period) are as follows:

$$Wind\ Speed = \frac{P}{.29}\ knots$$

$$Average\ Period\ Highest\ Waves = 1.31\ P\ seconds$$

$$Minimum\ Height\ of\ Highest\ 10\%\ of\ all\ Waves = .29\ P^2\ feet$$

$$Average\ Wavelength = 3.33\ P^2\ feet$$

$$Peak\ Particle\ Velocity = .412\ P\ knots$$

A very useful characteristic of a wind-driven wave system is that the statistics before the sea becomes fully developed are much the same as a fully-developed sea at a lower wind speed. In other words, if we experience a 40kt wind, but measure the Average Period as 6 seconds, we can assume that the statistics of the waves are the same as they would be for a fully developed sea from a 21kt wind. (In Figure E-4 the 6 second line intersects curve #1 at 21kt). Thus we can determine all of the average characteristics by measuring the Average Period; we cannot use observed Wind Speed because the sea is not yet fully developed. Incidentally, if the measured wind speed is larger than the wind speed corresponding to the measured Average Period, the Coxswain can be sure that the seas are going to continue to build and that he should complete his mission as quickly as possible.

Average Period is measured by counting the number of seconds it takes for about 50 waves to pass, and dividing the number of seconds by the number of waves. Ideally the boat should be in one place while this measurement takes place; the average period measured will be too short if the boat is travelling against the waves, and too long if the boat is travelling with the waves. But a skilled Coxswain can adjust approximately for that.

The wave height (curve #3) and period (curve #2) determine the velocity of the water at the top and bottom of the wave, (see §G below) and it is the vector sum of the velocities experienced by the towing and towed boats that cause the shock force. There are two important adjustments that have to be made to the velocity read from #5; these adjustments are incorporated into the Standard Shock Force graphs on each Tow Planning Worksheet.

1. Since each boat has length, it experiences several particle velocities at once and it is the net velocity the boat experiences that is important. This factor is so signifigant that there has to be a Tow Planning Worksheet for each length Facility. And for each length facility there are curves for five different length towed boat.

2. The longer the towline-measured in wavelengths-the less likely the facility and distressed vessel are on opposite phases of the wave system. (This sensitivity to towline length is entirely different from the fact that a longer towline reduces the Shock Force because it can stretch more).

Finally, the net velocity difference is applied to the highly non-linear stress/strain curve for the 3-strand twisted towline being assumed. The result is the Peak Shock Force vs Average Period curves on the back of the Worksheet.

E. Adjustments. If the sum of the Steady Force and the Shock Force is near (or greater than) 1500 pounds the Coxswain must make adjustments to reduce the Peak Force. He has several options:

1. Tack. The curve on the back of the Tow Planning Worksheet shows the factor (always less than 1 hence always reducing) if the direction of the tow is not directly parallel with the wind. Very often the course to the nearest safe harbor is not parallel to the wind and using this factor does not extend the tow time. Even if the tow is in the direction parallel to the wind the tow can tack 45° and reduce the Shock Force appreciably. Tacking only reduces Shock Force; it does not change the Steady Force.

2. Examine the assumptions carefully, particularly the Displacements. All of the Forces are calculated assuming the δ for each boat is 215. The Forces are essentially proportional to Displacement; so if the towed boat is obviously lighter, both the Steady and the Shock Forces are less; if only the towing boat is lighter only the Shock Force is less. Keep in mind, however, if **either** is a heavy displacement boat the Forces on the Worksheets are **understated.**

3. Use a longer towline. Towline length influences **only** Shock Force but the dependence is non-linear; a 100 foot towline experiences **more** than twice the Shock Force of a 200 foot line. The towline length dependence is sensitive to the Displacements of the two boats and a generalized table for the effect cannot be generated. Tying two lines together can reduce the Shock Force some, but less that one would expect. The greater length-greater than 200 feet-reduces the probability that the towing and towed boats are simultaneously on a 10% highest wave; but the knot tying the two lines together has **half** the strength of the weakest line.

4. Slow Down. The Steady Force is essentially proportional to the tow speed; so if the Steady Force is appreciable it can be reduced by slowing down. If the Peak Shock Force is larger than the Steady Force the towline will occasionally go slack, and then snap taunt. This is nothing to be surprised about.

F. Gravity Waves. Free non-breaking waves in the ocean are described by the expression

$$V=\sqrt{\frac{g\lambda}{2\pi}\tanh\frac{2\pi h}{\lambda}}$$

where V is the velocity of the wave in ft/sec, g is the acceleration of gravity, λ is the wavelength in feet, and h is the water depth in feet.

In deep water, where h is large,

$$\frac{2\pi h}{\lambda} \gg 1$$

The hyperbolic tangent of a large number is *1*, so the wave equation becomes

$$V=\sqrt{\frac{g\lambda}{2\pi}}$$

Using appropriate values for the constants this becomes the familiar "hull speed" equation with which most boaters are familiar.

$$V=1.34\sqrt{\lambda}$$

In "shallow" water h is much less than λ; the hyperbolic tangent of a small number is the number, and the wave equation becomes

$$V \approx \sqrt{gh}$$

It is interesting to note that it was with this equation that oceanographers first "measured" the average depth of the Pacific Ocean by noting how fast tsunamis travel (360kn).

G. Wave Motion. A surface particle in a deep-ocean wave follows a circular path; its horizontal displacement is given by

$$\varepsilon=\frac{W}{2}\cos\frac{2\pi}{\lambda}\ (x-Vt)$$

and the vertical displacement is given by

$$\eta=\frac{W}{2}\sin\frac{2\pi}{\lambda}\ (x-Vt)$$

The particle horizontal velocity is given by

$$\frac{d\varepsilon}{dt} = \frac{W}{2}\,\frac{2\pi V}{\lambda}\sin\frac{2\pi}{\lambda}(x-Vt)$$

Since the *sin* varies between +1 and -1 the maximum particle velocity in either direction is

$$\frac{W\pi V}{\lambda}\quad ft/sec$$

In the expression on Page 5-12, W_b is the same as W in the equations above. V/λ is equal to $1/W_i$ so the one way particle velocity is

$$C = \frac{W}{W_i}\times\pi\times\frac{3600}{6069}\quad knots$$

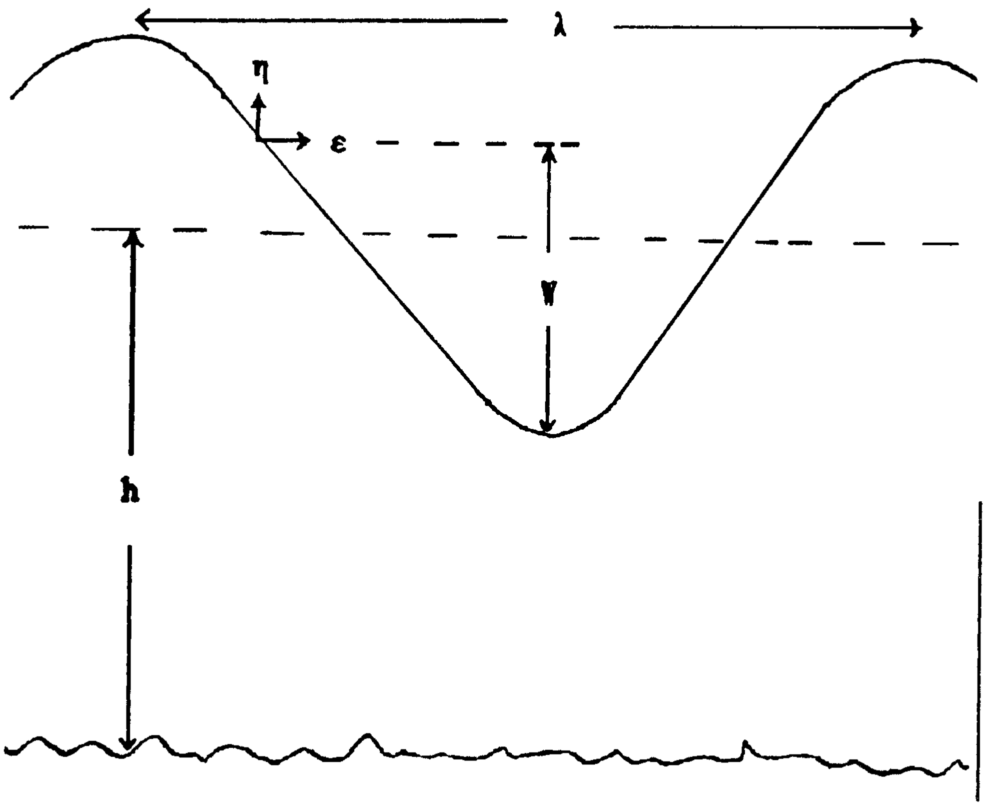


Figure E-5 Gravity Wave Characteristics

H. Maximum Towing RPM. The Allowable Fraction of Max Cruise RPM while Towing, as given in Table 5-1, is based on some theory and some logic. First the logic.

When a vessel is under tow, the propeller slip of the towing boat must be greater than it is without the tow. The tow represents an increase in displacement and therefore the Speed Through the Water (STW) is less for the same RPM. Since the STW is lower, it follows that the thrust loading on the propeller is greater, and the horsepower is greater. The question is-how much? We know that the horsepower is the product of Torque times RPM. If we limit the Torque we have to reduce the RPM so that the horsepower required does not exceed the continuous-duty Torque limit.

As the ratio of V_t/V_c goes from .0 to 1.0, the tow has less and less effect on the horsepower required, and there is no reason why the effect should not be proportional, ie, the change in the Fraction of Max Cruise RPM while towing should be proportional to the ratio of V_t/V_c. The Tow RPM to Cruise RPM fraction is 1.0 for a V_t/V_c of 1.0; that is a logical limit. So generating the table simply requires figuring out the fraction of Max Cruise RPM that can be used for a V_t/V_c of zero, viz, when the towed boat is anchored.

It also follows logically that for any V_t/V_c, the Fraction of Cruise RPM as a function of Slip must increase until at a Slip of 1.0 the ratio is 1.0. Thus, if we can determine the value of the Cruise/Towing fraction at a V_t/V_c of 0, for <u>any</u> Slip, we can interpolate for other values of Slip and V_t/V_c.

Second the theory. The technical analysis of the relation between SOA, Slip, and Horsepower comes from work done on marine propeller theory. A good reference is an article by Robert Kress and E.L. Lorenz that appeared in the 1970 Society of Automotive Engineers (SAE) Transactions. Table 1 of the article is a table of values for a constant "C" for a range of SOA, including very small SOAs. (In 1970 what we now call STW was called SOA, Speed of Advance.) The constant "C" divided into the propeller blade area gives the shaft horsepower required (assuming a nominal propeller efficiency and no cavitation). These relationships determine the RPM reduction that would, when multiplied by the constant Torque, result in the required horsepower when the STW is zero. For a Slip of 0.25 the reduction is 50%, hence Table 5-1.

The rest is simply extrapolation.

APPENDIX F DATE/TIME/GROUP NOTATION

The Date/Time Group, a series of twelve numbers and letters, is used primarily for reference purposes. The first two numbers indicate the day of the month, the second two indicate the hour of the day, the third two indicate the minutes of the hour. The seventh position is an alphabetical character that indicates "zone" time. The next three positions are alphabetical characters that abbreviate the month, and the last two positions are numbers that indicate the last two digits of the year. All twelve positions are filled; if the date is not two digits the first digit position is "0".

Table F-1 shows the Zone designator (for the United States) and the number of hours each zone differs from Zulu. For reference purposes, Universal Coordinated Time (UTC)-Z(ulu) Zone-is always used since it removes any ambiguity about time. Local time is used in the body of Coast Guard messages, but "Z" time is always used when a Time reference is required.

Longitude Range		Time Difference	Zone Suffix
52.5W to 67.5W	(EDST)	+4 hrs	Q
67.5W to 82.5W	(EST)	+5	R
82.5W to 97.5W	(CST)	+6	S
97.5W to 112.5W	(MST)	+7	T
112.5W to 127.5W	(PST)	+8	U
127.5W to 142.5W	(Alaska)	+9	V
142.5W to 157.5W		+10	W
157.5W to 172.5W	(Hawaii)	+11	X

Table F-1 Zone Time

The Time Difference column shows the number of hours added to Local (Standard) Time to convert to Zulu. In the continental United States the Standard Time is not precisely in the Longitude Range indicated and Local Time is what the community uses rather than the exact Longitude. At sea, the Longitudes are used exactly.

During the summer when Daylight Saving Time is used, the Zone Suffix changes to the Zone immediately to the East of the local Zone. For instance, on the Pacific Coast, which uses Pacific Standard Time during the winter (Zone Suffix "U"), uses Zone Suffix "T" during the months when local time is Pacific Daylight Saving Time.

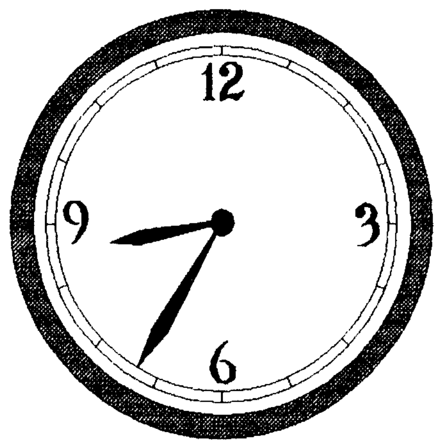
When converting from local to Zulu time it is sometimes necessary to change the day as well as the hours. For example, if the local time is

212015SAUG92

which translates into 8:15 PM, Central Standard Time, August 21, 1992, convert to Zulu by adding 6 hours to the time. But 2015 + 6hrs = 2615; this is 2^{h} 15^{min} past midnight–obviously the next day. So the conversion to Zulu becomes

220215ZAUG92

In converting from Zulu to local the process is simply reversed. Statistical data–like Tide Tables–are always in Local Standard Time, not Local Daylight Saving Time. Whenever Time is written down for any purpose it is a good idea to include the Zone Suffix.



APPENDIX G Reference List

1- COMDTINST M16120.5A National Search and Rescue Manual. This manual is published in two volumes: Vol I is the National Search and Rescue System, and Vol II is the Planning Handbook.

2- COMDTINST M16130.2B (Also called CGADDNSM). U.S Coast Guard Addendum to the National SAR Manual. This manual functions as the primary U.S. Coast Guard-specific search planning and rescue operations guidance and policy manual, and serves as the standard reference for the Coast Guard to use in conducting the SAR mission.

3- COMDTINST M16798.8 Boat Crew Manual. This is the original reference manual for the Boat Crew Program. It specifies the operations standards that are to be followed by the Auxiliary.

4- COMDTINST M16798.22 Auxiliary Boat Crew Qualification Guide/ OPERATOR/COXSWAIN. This manual specifies the standards required to become certified as an operator/coxswain on an operational Coast Guard Auxiliary facility.

5- COMDTINST M16798.28 Auxiliary Boat Crew Training and Qualification Guide/ CREWMAN AND COXSWAIN. This manual supersedes the manual described in item 4, which will be cancelled two years after the issue of this manual.

6- Oceanography and Seamanship, William G. Van Dorn. Dodd Mead & Company. This book is about boats and the sea from the vantage of a research oceanographer. It is particularly good at explaining heavy weather and is probably the premier reference for modern wave theory.

7- Skene's Elements of Yacht Design, Francis S. Kinney. Dodd Mead & Company. This book is a rewrite of a text first published in 1904. It is mostly concerned with sailboat design but has useful information related to power boats. The book is rigorous and detailed, although slightly dated.

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