NONRESIDENT
TRAINING
COURSE

April 1997

Fire Controlman

Volume 4—Fire-Control Maintenance Concepts

NAVEDTRA 14101

Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects:

- Planned Maintenance System,
- fault isolation,
- liquid-cooling systems,
- combat systems alignment (gun/battery), and
- collimation.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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Sailor’s Creed

“I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country’s Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all.”

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INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

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Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
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PENSACOLA FL 32559-5000

Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

https://www.advancement.cnet.navy.mil

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We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

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FAX: (850) 452-1370
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NETPDTC N311
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
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NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 3 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Fire Controlman, Volume 4—Fire-Control Maintenance Concepts*

NAVEDTRA: 14101 **Date**: ____________________

We need some information about you:

Rate/Rank and Name: ____________________ SSN: ____________ Command/Unit ________________

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Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00

CHAPTER 1

PLANNED MAINTENANCE SYSTEM AND FAULT ISOLATION

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Describe the purpose of maintenance systems.

2. Describe the methods used in identifying system faults.

INTRODUCTION

The increasing complexity of our equipments requires a viable maintenance program to ensure that the systems perform in a manner that will ensure maximum operational readiness. To overcome this problem, the Navy has developed an excellent preventive maintenance system—the Ships' Maintenance and Material Management (3-M) System. This system provides a standard means for planning, scheduling, controlling, and performing planned maintenance on all equipment.

It is not uncommon for a Fire Controlman Second Class to be in the position of a work-center supervisor. As such, you will need a broader knowledge of a variety of subjects to perform your duties in a professional manner. One area you cannot take lightly is maintenance. Your fire-control system is kept at its maximum level of readiness through maintenance. To help you in this area, this chapter briefly discusses the Planned Maintenance System (PMS) and fault-isolation procedures.

The information provided in this chapter is not intended to cover all aspects of the 3-M System. For more in-depth information on this system, refer to the *Ships' Maintenance and Material Management (3-M) Manual,* OPNAVINST 4790.4.

PLANNED MAINTENANCE SYSTEM

The Planned Maintenance System (PMS) provides a standard means for planning, scheduling, controlling, and performing planned maintenance to complex mechanical, electrical, and electronic equipments. PMS maintenance actions are the minimum required to maintain equipment in a fully operable condition and within specifications. The PMS includes a Maintenance Data System (MDS), which is used to record important scheduled and corrective maintenance information, and electronic data-processing capabilities, which are used to retrieve this information for maintenance analysis. The *3-M Manual* establishes the PMS and assigns PMS management responsibilities.

The PMS provides regularly scheduled tests to detect degraded performance and to aid in preventing failures during tactical operations. When failures do occur, the PMS provides formal corrective maintenance in step-by-step fault-isolation and repair procedures. Complete technical documentation (including combat systems, subsystems, and individual equipment manuals) is an integral part of the PMS. These manuals provide the necessary information for understanding, operating, and maintaining combat systems.

Shipboard maintenance falls into three categories: (1) maintenance within the capability of ship personnel (organizational level); (2) maintenance requiring assistance from outside the ship (intermediate level), such as tender or fleet technical support centers; and (3) maintenance requiring port facilities (depot level), such as shipyard maintenance. Since the objective of the PMS is to perform maintenance at the organizational or intermediate level, it does not reflect depot-level maintenance. Combat systems readiness requires efficient maintenance. The key to this capability is an organized system of planned maintenance that is designed to ensure the maximum operational readiness of the combat systems.

This section describes the PMS objective, the maintenance scheduling and data system, and the integrated maintenance.

PMS OBJECTIVE

The PMS objective is to maximize operational efficiency of all equipment and to reduce downtime, maintenance man-hours, and maintenance costs. Although the PMS provides methods and resources to accomplish each objective, it is not self-sufficient and does not replace the initiative of maintenance supervisors nor does it reduce the necessity for technically competent personnel. Recording and providing feedback of maintenance and personnel data allow continuing management analysis for the improvement of maintenance methods and personnel management. Full use of the planning methods, along with the acceptance and cooperation of technicians, supervisors, and management personnel, produces a maintenance system with the inherent confidence, reliability, and capability to help achieve maximum combat systems readiness.

A sampling of data gathered from the fleet shows conclusively that those ships that adhere to their PMS schedules maintain a significantly higher state of material readiness with no greater maintenance manpower usage than those ships that do not adhere to their PMS schedules.

The primary ingredients of the PMS program are

1. comprehensive procedures for planned maintenance of the combat systems, subsystems, and equipment;

2. system fault-isolation procedures;

3. maintenance task performance scheduling and control; and

4. methods, materials, tools descriptions, and personnel required for maintenance.

Adherence to the PMS program will produce

1. improved confidence in system maintenance,

2. reduced testing time,

3. elimination of redundant testing resulting from uncoordinated testing, and

4. detection of most malfunctions during scheduled maintenance events.

MAINTENANCE SCHEDULING

The normal flow of events that maintenance managers use in developing an integrated maintenance schedule is shown in figure 1-1. This figure shows maintenance management responsibilities and the sequence of events that flow from the department master and work-center PMS record books through the scheduling aids to test execution, unscheduled maintenance, and reporting.

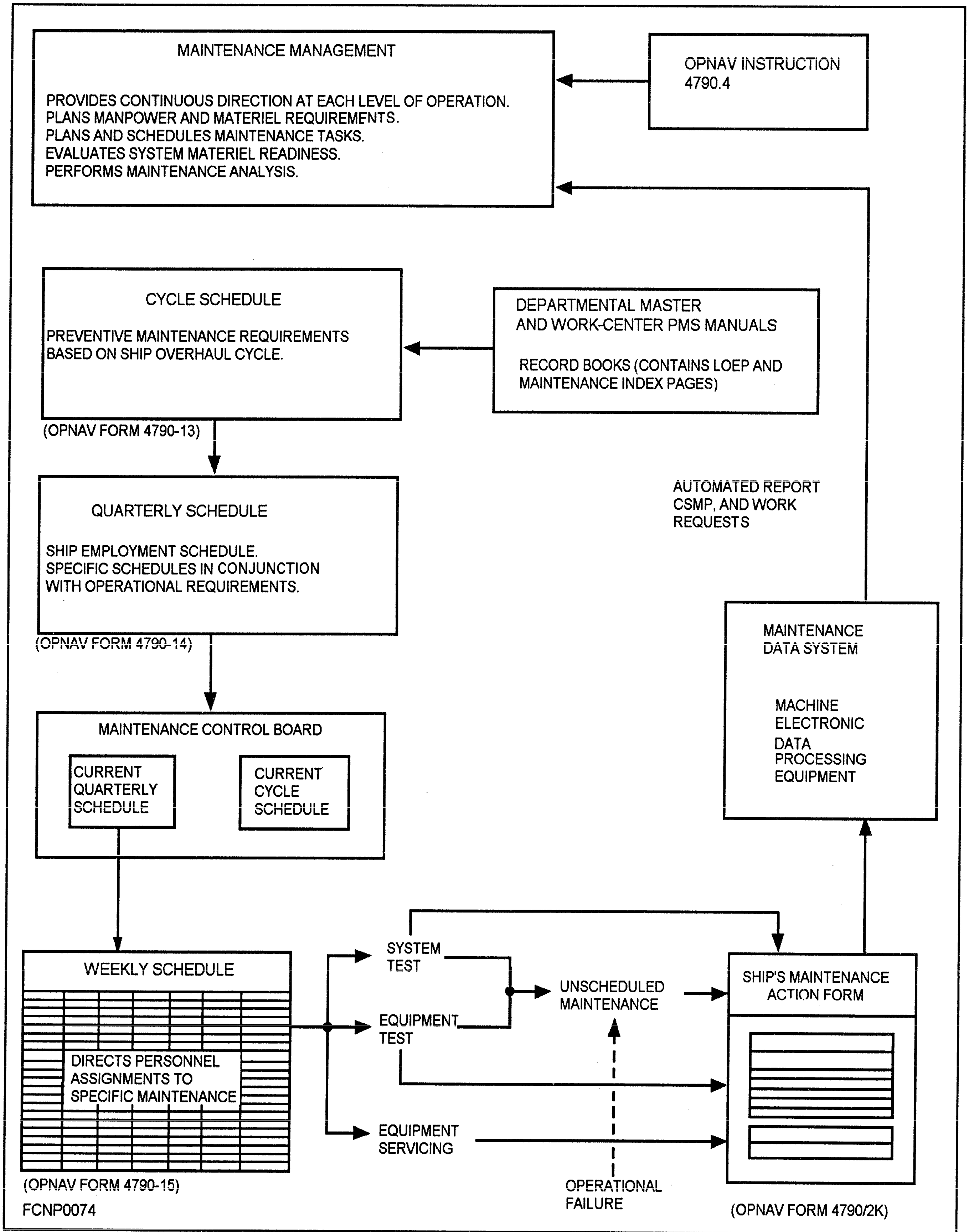


Figure 1-1.—Block diagram of the Planned Maintenance System.

The maintenance control board contains the cycle schedule and the current and subsequent quarterly schedules. The board summarizes the status of current and planned combat systems preventive maintenance. It is updated weekly by the division officer for all deferred and completed maintenance items.

This subsection describes the maintenance index page and the cycle, quarterly, and weekly schedules.

Maintenance Index Page

The maintenance index page (MIP) contains a brief description of the requirements on the maintenance requirement card for each item of equipment, including the periodicity code, the man-hours involved, the minimum required skill level, and, if applicable, the related maintenance requirements. The MIPs for all equipments in a department are maintained in the department's master PMS record, the record that is used by the department head to schedule maintenance on the PMS schedule forms. Each work center has a work-center PMS record that contains the MIPs applicable to that work center.

Cycle Schedule

The cycle schedule is a visual display of preventive maintenance requirements based on the ship's current overhaul cycle. It is used by department heads to assist in the quarterly planning of non-PMS-related activities, such as inspections and training.

Quarterly Schedule

The quarterly schedule, planned from the cycle schedule, is a visual display of the ship's employment schedule. It is prepared by department heads in cooperation with division officers and maintenance group supervisors. The schedule shows the current status of preventive maintenance for each group and assigns specific requirements in conjunction with the ship's operational schedule.

Weekly Schedule

The weekly schedule is a visual display that is normally posted in the working area of each maintenance group. The maintenance group supervisor uses the weekly schedule to assign specific personnel to perform maintenance on specific equipment. Assignments include system and equipment tests and service procedures.

MAINTENANCE DATA SYSTEM

The Maintenance Data System (MDS) has three functions. It provides a means of (1) recording maintenance actions, (2) processing the recorded data to define important facts about maintenance and equipment, and (3) retrieving information for analysis. Significant data identified by the system include the reason the malfunction occurred and the manner in which it was discovered, the man-hours expended, the exact equipment affected, any delays in repair, the reasons for delays, and the types of maintenance personnel required.

Recording Maintenance Actions

Maintenance personnel should record (document) certain shipboard maintenance actions and corrective maintenance on specific categories of equipment at the time the maintenance actions are performed or deferred. Information is recorded and submitted to the MDS for input on the Ship's Maintenance Action Form (OPNAV 4790/2K).

Processing Recorded Data and Analyzing Information

The MDS data-processing facilities collect, store, and analyze maintenance information inputs into the system. The MDS yields a data path concerning equipment maintainability and reliability, man-hour usage, equipment alteration status, material usage and costs, and fleet material condition. Various automated reports are produced periodically for ships, repair activities, unit commanders, and type commanders. These automated reports include current ship's maintenance project files, work requests, and preinspection and survey deficiency listings.

INTEGRATED MAINTENANCE

Combat systems maintenance is based on a concept of performing a comprehensive schedule of tests at three mutually supporting levels: (1) combat systems, (2) subsystems, and (3) equipment. These integrated tests are structured to challenge all combat systems fictions, parameters, and characteristics on a scheduled periodicity against specified tolerances. Successful performance of the tests as scheduled should provide a high level of confidence in the functional operability of the combat systems equipment.

Integrated maintenance requirements are established through engineering analysis based on the study of all factors having a significant effect on maintenance. The analysis defines system and equipment functions and establishes tolerances in terms of system parameters for determining acceptable system operations. The integrated maintenance procedures are intended to provide minimum preventive maintenance coverage of combat systems. The procedures are written to establish specific controlled conditions that challenge the fictions under test. In some cases, test efficiency and format restrictions make it difficult to determine the intent of a test from its procedural steps; therefore, the procedural sequences must be followed explicitly. Improvising or shortcutting procedural sequences often leads to incorrect troubleshooting or masking of actual faults.

The integrated maintenance concept is consistent with the PMS efforts, and it is the most effective means of achieving the goals of the PMS. Adhering to this concept enables maintenance managers to manage the combat systems maintenance effort and to achieve an optimum level of readiness with the most effective use of available personnel.

With combat systems testing being conducted at three levels, it is imperative that integrated maintenance tests be scheduled to reduce test redundancy whenever possible. The three levels of tests are combat systems testing, subsystems testing, and equipment testing.

Combat Systems Testing

Combat systems testing, defined as *testing that exercises a combat system as one entity,* is the highest level of testing that can be accomplished aboard ship. Combat systems tests are usually automated and are conducted and monitored from the ship's command and control center.

The overall combat system operability test (OCSOT) is the primary combat systems test tool. The OCSOT gives a good overview of detection, display and tracking, designation, acquisition, repeat-back position, and some status-signal monitoring. Simulated targets are used in the OCSOT. Although the test is conducted as if the combat systems were operating normally, certain operating stations dedicated to support the test are lost for normal operational use.

Although the OCSOT provides an overview of systems performance, it does not test the fill capacity of a combat system or its subsystems operability. It is impractical from an instrumentation and manpower standpoint to test all functional test requirements at the combat systems level. Therefore, confidence in operability or material readiness is mainly dependent on integrated testing at the subsystem and equipment levels.

Subsystems Testing

Testing that exercises two or more pieces of equipment fictionally contained within the same subsystem is defined as *subsystems testing.* Subsystems testing tests a subsystem in a stand-alone operation; however, some functions are provided by other subsystems, which require integrated testing.

Subsystems tests are functionally grouped and mode oriented so that related functions can be challenged using the same setup, procedures, and stimuli. Where practical, subsystems tests use tactical indicators for measurement, leaving the requirement for special hookups and test equipment to equipment-level testing.

A major combat ship contains most, or all, of the following subsystems:

1. Search-radar subsystem
2. Command and control subsystem
3. Countermeasure subsystem
4. Gun/missile weapon subsystem
5. External communications subsystem
6. Navigation subsystem

Equipment Testing

Equipment testing is defined as *testing that is generally directed toward power levels, frequencies, servos, special features, and output functions.* The PMS may require special external stimulating equipment and special- or general-purpose test equipment for testing measurements.

FAULT ISOLATION

The objective of fault isolation is the systematic application of fault-isolation tools needed to isolate the exact unit or fictional interface responsible for a fault or degraded operation during testing or tactical operation. To diagnose and effect timely repair of faults within a fire-control system, you must fully understand fault-isolation concepts, the fault-isolation tools available to you, and the capabilities and limitations of those tools when applied to system fault isolation.

Although the primary entry into fault isolation is from test-detected faults, improper operating conditions can be observed during tactical operations, including operator awareness, data extraction and reduction, and on-line monitoring.

Fault isolation leads to corrective maintenance. After a fault has been isolated to a specific unit or interface, corrective action in the form of repair, replacement, and/or alignment must be taken. The corrective maintenance performed may or may not be required to return the system to an operable condition. There may have been more than one fault contributing to the out-of-tolerance condition that initiated the fault-isolation process. The possibility of faulty replacement parts and incorrect adjustment or alignment exists. Instead of solving the problem, corrective maintenance may have added to it. Therefore, it is mandatory that each corrective action be followed by verification.

Normally, verification is accomplished by recreating the test environment and rechallenging the function. Where alignments are concerned, the interdependent effect upon other elements of the combat systems must be considered in the verification process.

FAULT-ISOLATION TOOLS

During testing or operational use of a weapons system, faults can occur in the interface between subsystems, in the interface between equipments of a subsystem, or in the equipment itself. Rapid fault isolation requires decisive action in selecting and implementing the most appropriate fault-isolation tools. A fault-isolation tool has the following three characteristics:

1. It requires the least amount of time, equipment, or service.
2. It is easily implemented.
3. It conveys the maximum intelligence regarding the source of the fault.

Tools used in fault isolation cover a wide range of applications, including (but not limited to) combat systems tests, subsystems tests, on-line/off-line testing, and diagnostic testing programs.

This section briefly covers these items and gives examples of their use, where appropriate.

Combat Systems Tests

Combat systems tests are the highest level of tests that can be performed to verify the readiness or alignment of a combat system. The OCSOT is one of the major combat systems tests; it is designed to test a combat system as a single, fictional unit. Major faults in the subsystems usually show up during the OCSOT; often, this is the first indication of a problem in a particular subsystem. Keep in mind, however, that the OCSOT does not test the full operability of a combat system or its subsystems; it provides only an overview of systems performance.

Another important test is the combat systems alignment test, which is a programmed test tool designed to measure the relative beam alignment (or misalignment) between a reference sensor and a sensor under test. The measure of misalignment is accomplished by collecting the range, bearing, and elevation data from the reference and test sensors. Then the test sensor data is compared to the reference data, and the results are shown on a display console for analysis. The sensors that can be tested include the gun or missile fire-control radars and surface-or air-search radars. A hard-copy printout can be obtained to provide a record.

Subsystem Tests

Subsystem tests aid in fault isolation by testing specific functions within a subsystem to determine if they are generated correctly. In many cases, these tests check the transmission of data between the subsystem under test and associated subsystems. Computer programs are available that provide specific test capabilities suited to subsystem testing. An example of such a program is the Programmed Operational and Functional Appraisal (POFA). The POFA programs, for which the subsystem test is named, are non-resident programs that detect and isolate malfunctions by transmitting selectively configured and controlled data between a computer and a computer ancillary equipment interface.

A typical example of a subsystem test is the fire-control system (FCS) daily system operability test (DSOT). The DSOT assesses weapons system readiness in the normal mode of operation for an antiaircraft (AA) target from designation through acquisition, track, weapons control, simulated firing, and post-firing evaluation.

Test procedures are controlled by the test conductor, who calls out the step numbers in sequence. The personnel performing the steps in the various spaces inform the test conductor when the action or observation required by that step is completed. No response restrictions are placed on personnel, except where the steps are underlined in the procedure. In this case, instruction words are also underlined, indicating the quantity or indication upon which the request for the response is based. Steps not underlined, but containing underlined instructions, denote the response requested (Mark, Fired, etc.). Underlined step numbers denote those steps to be recorded for evaluation and scoring.

All responses should be given as soon as practical after the completion of the step, particularly in those areas of the test where the timing is important or when a sequence of events must commence immediately after a required action or observation. Timely responses aid in decreasing time requirements.

When a fault occurs during combat systems or subsystems testing and before detailed fault-isolation procedures are initiated, the operational steps should be repeated to ensure that the fault is an actual fault and not an operator error. If the fault still exists, you should ensure that the combat system or subsystem is properly configured for the test event performed; that is, switches are properly set, correct function codes are selected, etc.

On-Line/Off-Line Testing

Based on the level of testing selected, on-line maintenance testing can assist in fault isolation by testing suspected equipment or systems with a minimum of interference with normal ship operation. If a suspected equipment or system checks out satisfactorily, then a possible source of the fault has been eliminated. This aids in the fault-isolation process. In general, the use of on-line testing provides a quick fault-isolation tool when you are trying to confirm equipment or system problems. When using on-line testing, you should be careful not to degrade the system or subsystem operational capability beyond the level specified by ship doctrine.

Some combat systems equipment has the capability of severing normal communications links and accepting preset or manual inputs when you are verifying system ability to correctly process data. This off-line testing offers a convenient method of isolating equipment or interface faults. As in on-line testing, care must be taken not to degrade the system or subsystem operational capabilities. One such off-line test is the system maintenance test (SMT) used in the Mk 86 gunfire control system (GFCS).

The SMP is a computer program that enhances fictional testing and troubleshooting of the FCS. The SMP provides test conditions to check the integrity of input/output circuits to and from the computer and to check the fictional integrity of various functional systems. It is loaded into the FCS computer in place of the normal (tactical) FCS operational program. Therefore, the FCS is not functional in a tactical sense until the FCS operational computer program has been reloaded into the FCS computer following the use of the SMP.

The program includes a configuration entry routine, an executive routine, and approximately 60 individual tests that are organized into groups according to the interface channels between the computer and the peripheral units. Configuration entry allows the technician to adapt the program to a particular modification of the FCS. The executive routine provides the basic timing requirements for each test program and establishes testing priority in the event two or more tests are selected concurrently.

The tests are grouped according to channel and unit numbers as follows:

- Channel 14 test programs are selected from units 1, 2, and 3.
- Channel 15 test programs are selected from unit 25.
- Channel 16 test programs are selected from unit 22.
- Channel 17 test programs are selected from unit 6.

A sample of channel 14 test programs is shown in table 1-1. Notice that the tests selected at unit 2 or 3 are selected with a test number select code. The procedures for setting up these codes are in table 1-2.

Table 1-1.—System Maintenance Program Channel 14 Test Programs

UNIT 2, 3 TEST NUMBER SELECT CODE	TEST SELECTED	
00000	Initial data display	
00001	Address decode test	
00002	NIXIE cycle test	
00003	WCC keyboard test	
00007	Mode sequence indicators test	
00009	WCC projectors test	
00010	Inputs test 10	
00011	Inputs test 11	
00020	RAM test	
00021	Symbol decoder test	
00022	Screen test	
00040	B-scan test	— standard
00041		—reduced
00042		—X standard
00043		—X reduced
00044		—Y standard
00045		—Y reduced
00050	Gun data test	
00060	Servo test	—(gain = 16)
00061		—(gain = 8)
00062		—(gain = 4)
00070	Encoder test	
00080	Gun align display	
00180	Memory call-up test — random	
000181	Memory call-up test — consecutive	
UNIT 1 DESIGNATOR SELECT SWITCH	**TEST SELECTED**	
ROS	COC select 1 and 2 input words	
NTDS	COC TDS input words	
TARTAR	COC select 2 and COC/CWI or	
SPA	WCS input words	
TDT1	COC control input words	
TDT2	SRM trackball	
TDT3	PPI test	
TDT4	PPI (X) test	
SPQ9	PPI (Y) test	
SEARCH	Marker test	
IDD	B-scan range gate test	
	PPI range gate test	

Table 1-2.—Procedures for Setting Up Test Number Select Codes

STEP	PROCEDURE
1	At the matrix selector (group of six switches) on unit 2 or 3, press the TEST pushbutton to light the legend green. (This causes the test matrix to appear. See figure 1-2.)
2	Press the TEST NO SEL pushbutton (located on the first column of the first row of the matrix) to light its legend green.
3	At the keyboard, press CLEAR, type in the test number select code, and press ENTER. (The selected test will begin running. It is not necessary to type in leading zeroes. For example, if the test code is given as 00011, it is only necessary to type in 11.)
4	To terminate the test, press CLEAR and ENTER. (This effectively enters test select code 00000, which terminates the test and calls back the initial data display.)

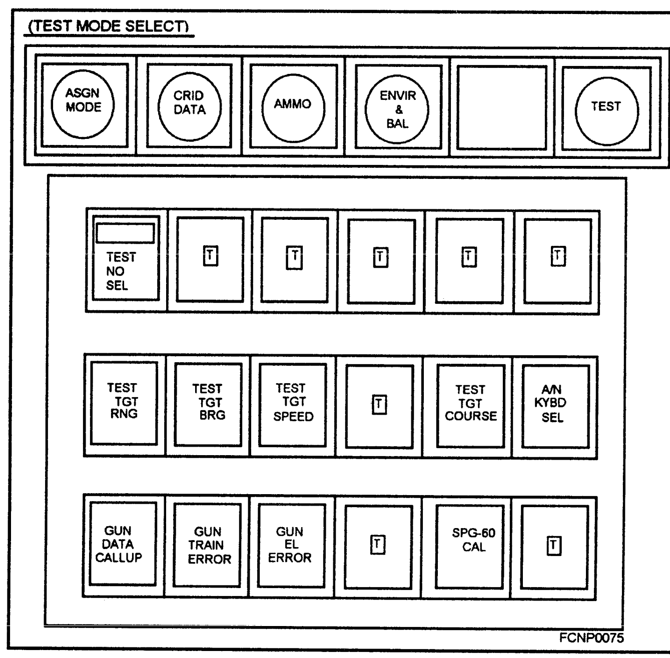


Figure 1-2.—Sample test mode matrix.

Since it is not practicable to list all the possible tests in the SMP, this discussion is limited only to channel 14 test programs. The channel 14 test programs consist of a scan generator test routine and various test routines that can be selected from unit 1, 2, or 3. Test routines are selected from unit 2 or 3 by using test number select keyboard code entries to the computer.

The DESIGNATOR SELECT switch positions at unit 1 select tests from unit 1. Table 1-1 lists units 2 and 3 test number select codes and unit 1 DESIGNATOR SELECT switch positions used to select the test routines.

The following paragraphs provide a synopsis of selected channel 14 test programs:

- **INITIAL DATA DISPLAY:** This test provides an initial data display to the A/N display for entering initial test data required for the channel 17 end-around, D/A converter, gun data, and encoder tests.

- **ADDRESS DECODE TEST:** This test outputs a unique number to each unit (1, 2, or 3) readout to verify proper address encoding and console address decoding.

- **NIXIE CYCLE TEST:** This test cycles all of units 1, 2, and 3 NIXIE readout digits from O to 9, in unison, in a 10-second period. The test checks the channel 14 output lines and the readout digital logic.

- **GUN DATA TEST:** This testis similar to the channel 17 end-around test, except that the test results are displayed on the A/N display, rather than on a printout. The test should be used for fault localization, rather than for fault detection.

- **SERVO TESTS:** These tests check out the stiff-stick data, the camera-assigned codes, and the TV sight 1 and sight 2 servo systems. The servo systems can be checked using a servo gain of 8, 4, or 2.

- **MEMORY CALL-UP TESTS:** These tests are used to monitor up to 12 randomly selected or consecutive computer memory locations and to display them on the A/N displays.

When the technician troubleshoots with the aid of the SMP, it is sometimes useful to know what data the computer is transmitting and receiving. The memory locations of all active computer input and output buffers can be called up by using this routine.

Diagnostic Testing Programs

Diagnostic testing programs are designed to isolate malfunctions that occur in the internal logic of the printed circuit boards. When other types of failures occur, manual procedures are required, but, in many cases, the diagnostics provide sufficient information to identify the fictional area of the failure.

Diagnostic testing programs are useful in locating a problem in a piece of equipment once the problem is isolated to a unit. The unit can be systematically tested with a printout or readout provided to the technician to indicate the problem area. Some diagnostic programs provide an error-code readout, whereas others provide the direct location of suspected faulty components.

An error-code readout requires searching an area-code table to locate the possible bad component, while the direct component-location readout tells the technician where the problem could be located. The direct component-location readout method is usually faster in producing the location of suspected failed components.

MAINTENANCE SUPPORT DOCUMENTATION

Maintenance support documentation falls into two general categories: (1) logic diagrams that contain a sequence of steps to isolate the faults causing a specific test- or operation-related fault symptom, and (2) system or equipment functional flow diagrams that allow the technician to determine a sequence of isolation steps.

1. LOGIC DIAGRAMS: Logic diagrams include troubleshooting logic charts (TLCs), fault logic diagrams (FLDs), fault isolation pyramid charts, and fault reference tables. The TLCs and the FLDs provide a simple yes-or-no, question-and-answer approach to fault isolation. They are generally based on either a ladder method or a bracket-and-halving fault-isolation technique.

- **Ladder Method:** The function is approached from its initiation or termination point and, in successive steps, is checked to the other end.

- **Bracket-and-Halving Fault-Isolation Technique:** The function is checked at its midpoint, then at the midpoint of the half containing the fault, etc., until it is isolated.

Pyramid charts take an output or terminal function (output, indicator, etc.) and break it down into its major subfunctions, which are individually checked until the fault is isolated. Fault reference charts generally relate symptoms to specific faults.

2. FUNCTIONAL FLOW DIAGRAMS: Functional flow diagrams include system functional diagrams, signal-flow diagrams, schematic diagrams, and relay-ladder diagrams. These are frequently used in isolating a fault that was not anticipated by the fault logic material provided.

In general, fault logic procedures are used more rapidly by inexperienced technicians than fictional diagrams in isolating a specific fault. When used with flow diagrams, fault logic procedures provide a means of teaching new or inexperienced personnel effective fault-isolation techniques. A fictional understanding gained through the use of maintenance documents is necessary for the development of experienced technicians. Experienced technicians frequently isolate specific faults addressed in fault logic procedures faster without referring to procedures. Their experience is essential in isolating problems that have not been anticipated by logic procedures.

Numerous approaches are possible in the application of fault-isolation procedures. The fact that most casualties occur within an equipment and are corrected by troubleshooting on an equipment-level basis leads to the tendency to troubleshoot all casualties on an equipment-level basis. It is to be expected that each technician might rely more heavily on certain troubleshooting aids and procedures than others. Few hard-and-fast rules apply to all troubleshooting situations, but one rule that should always be foremost is to determine the origin of a fault as precisely as possible.

System interrelationship is such that many casualties can be reflected in several areas as improper operation or fault indications. If each area of each equipment that does not function properly is checked separately, the equipment downtime and corresponding man-hour use can rapidly increase. On the other hand, familiarity with system reference materials, system fictional diagrams, and fault-isolation procedures can lead logically and expeditiously to the specific area of the fault.

All system fault isolation is interrelated. Its effective use depends on knowing what materials are available, how they are interrelated, and how to cross--reference between materials. The isolation materials that you will use in fault isolation are the system fault indicator director, the system function directory, the system functional diagram, the fault analysis matrix, a sample troubleshooting problem, and the equipment troubleshooting documentation.

System Fault Indicator Directory

The system fault indicator directory (FID) facilitates entry into the documentation required for troubleshooting a fault disclosed by a specific indicator during normal operation. A typical FID is shown in table 1-3. The material in this FID is grouped by system and further divided alphabetically by equipment, panel, and indicator. A complete listing of indicators is included.

Table 1-3.—Typical Fault Indicator Directory

EQUIPMENT	INDICATOR	INDICATOR TYPE	SPD FIGURE REFERENCE & SHEET NO.	SMT/FAM REFERENCE
FCS SPC-XX RDP	PS1 MULTIVOLT PS2 +5V SC ON	LAMP LAMP LAMP	12-13.1 (3) 12-13.1 (3) 12-13.1 (3)	
RSC 21A1	CWI GROUP EMCON/RADHAZ	LAMP	12-11.5	
	FCS ECM ALERT GROUP COHERENT ECM RESET NOISE ECM NOISE REPEAT			
	RDP GROUP ON/OFF TEST/READY	LAMP	12-11.2	W-1, Table 10-2.1 W-1, Table 10-2.1
	SYSTEM STATUS GROUP CONTROL ALARM GO PERMISSION TO TEST RDP FAULT	LAMP LAMP LAMP LAMP	12-11.2 12-13.1 (3) 12-14.1 (1) 12-13.1 (3)	W-1, Table 10-2.1
	TRACK GROUP EMCON/RADHAZ	LAMP	12-11.5	

The reference provided for each indicator includes a system functional diagram (SFD) and an applicable fault analysis matrix (FAM) reference. The SFD reference pertains to the SFD figure used to troubleshoot the fault on the system level, which the individual indicator indicates. The applicable FAM reference is used for troubleshooting and for verifying the operational status of the system on an equipment level.

System Function Directory

The system function directory is used with the FID. It contains an alphabetical listing of all system fictions contained in the SFDs. This directory can be used to start the troubleshooting process when there is no particular indicator associated with a fault. A sample fire-control system function directory is shown in table 1-4.

Table 1-4.—Sample Fire-Control System Function Directory

FUNCTION NAME	SYMBOL	ORIGIN/TERMINATION	APPROPRIATE VERIFYING TEST	SFD FIGURE NO.	DESCRIPTION PARTS 030 SECTION NO.
Noncoherent Video		FM: RDP TO: RSC		12-7.2 (2)	
Normal Track		FM: RDP		12-8.1 (1)(2)	
Ownship Heading	Cqo	FM: CS SWBD TO: RDP VIA: PDS		12-5.2 (4)	
Ownship Pitch	Eio	FM: CS SWBD TO: RDP VIA: PDS		12-5.2 (4)	
Ownship Roll	Zdo	FM: CS SWBD TO: RDP VIA: PDS		12-5.2 (4)	
Permission to Test		FM: C152 TO: RSC RTS VIA: SDC RDP		12-14.1 (1)	
Passive Track		FM: RDP		12-8.1 (2)	
Preheat Indicator		FM: CWI XMTR		12-11.1 (3)	
Pretrigger		FM: RDP TO: RFTTG		12-14.1 (1)(3)	
Pulse Radiate Command		FM: RDP TO: PULSE XMTR/ RCVR VIA: RSC PULSE PS TO: RTS VIA: RSC		12-11.6 (1)(2)	
Query Command		FM: ADP TO: RDP		12-13.1 (4)	
Radar Elevation Error		FM: RDP TO: RSC		12-7.2 (2)	
Radar Evaluation GO/NO-GO		FM: RDP TO: RTS VIA: RSC		12-14.3	
RF Power		FM: XTMR/RCVR TO: ANT		12-7.1 (4)	
Radar Traverse Error		FM: RDP TO: RSC		12-7.2 (2)	
RADHAZ		FM: CONT 178 TO: PULSE PS CWI XMTR VIA: RSC		12-11.5	
RADHAZ Supply		FM: PDS TO: CONT 178		12-16.1 (1)	
Radiate Indicate		FM: CWSI XMTR TO: CONT PS		12-11.1 (3)	

System Functional Diagram

A system fictional diagram (SFD) contains all primary and secondary circuits necessary for an understanding of the function of a particular mode, loop, or phase of system operation. Each function is shown from source to termination. Data flow is normally from left to right. All serial components of each piece of equipment in the loop that are significant to functional understanding are shown. All readout devices, test points, etc., in each equipment that are significant to system troubleshooting are included on the SFD. A sample weapons system fictional diagram is shown in figure 1-3.

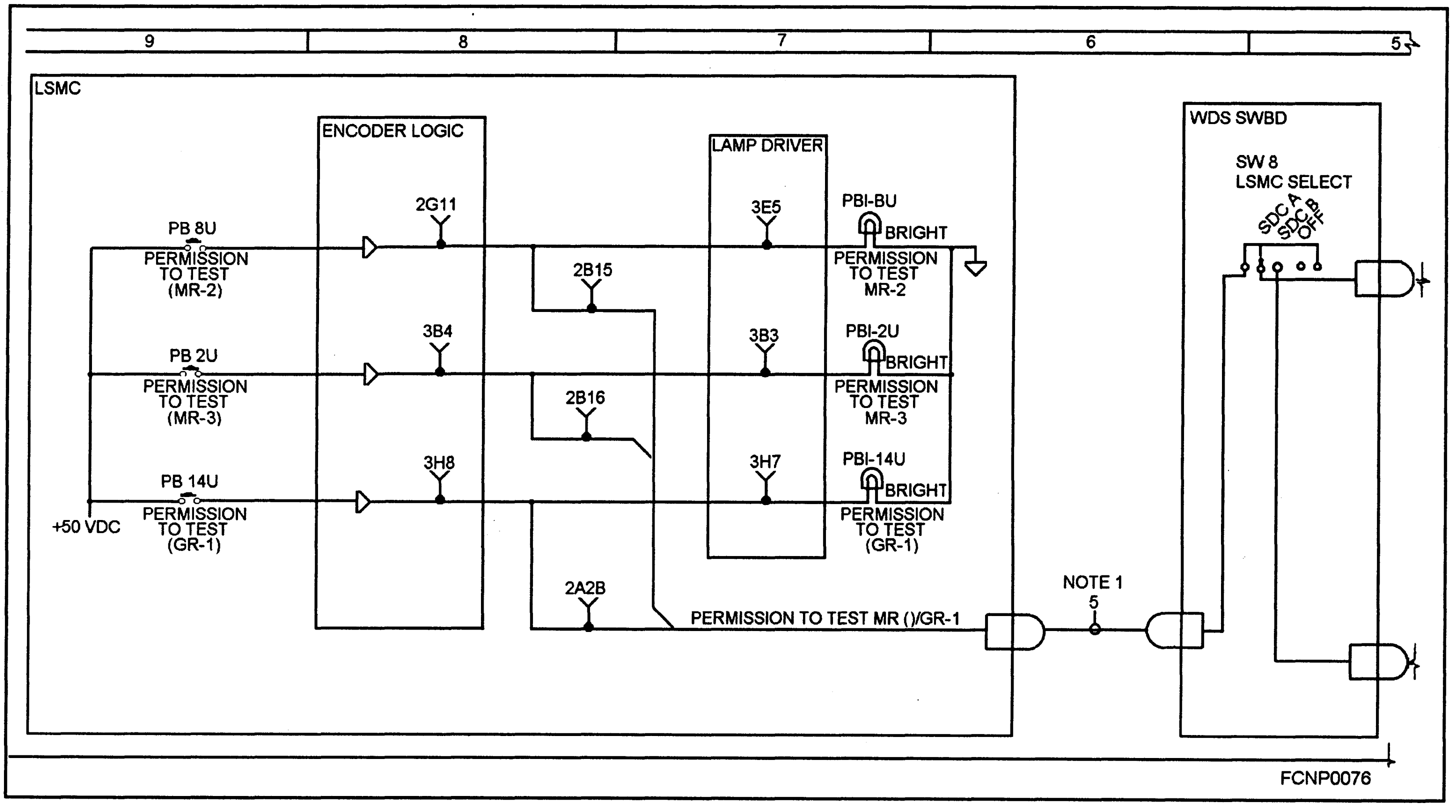


Figure 1-3.—Sample weapons system functional diagram.

Fault Analysis Matrix

The fault analysis matrixes (FAMs) and their associated troubleshooting procedures are related to each other and to the SMTs. Together, they provide maintenance personnel with an effective troubleshooting package.

To keep this material as specific as possible, the following assumptions are made:

- All equipment has been properly energized and indicator lamps have been tested.
- Associated switchboards are setup correctly, all power lamps are lit, and no fuses are blown.
- Troubleshooting faults do not begin until the test is completed, if possible. This procedure allows the technician to troubleshoot several related faults simultaneously, reducing troubleshooting time.
- Troubleshooting faults should occur in the same sequence in which the faults are discovered; for example, a fault discovered in step 9 of an SMT should be corrected before a fault discovered in step 14. Adherence to this sequence for correcting faults is

desirable because the initial fault observed during a test may be the cause of those observed thereafter. Thus, correcting the initial fault may correct those observed later in the test sequence.

The FAM is arranged in tabular form to provide a quick cross-reference of troubleshooting aids and reference materials. Table 1-5 is a sample fault analysis matrix.

Table 1-5.—Sample Fault Analysis Matrix

1	2	3	4	5	6	7
STEP	**FUNCTION**	**SOURCE***	**INTERMEDIATE UNIT‡**	**RELATED SMT◊**	**REFERENCE**	**SUGGESTED FAULT-ISOLATION PROCEDURE°**
1a	Restore/Delete MR-( )	FCSC	TDS C&C SWBD C152	W-2	Fig. 11-22.5	Perform WDS CMPTR diagnostics.
1b	MR-( ) AVAIL	FCSC	TDS C&C SWBD	W-2	Fig. 11.21-6	Perform WDS CMPTR diagnostics.
2	MR-( ) Go	C152	SDC WDS D SBD LSMC	W-2	Fig. 11-13.3	Perform WDS CMPTR diagnostics.
3	Ownship Display a. M at Ownship b. Ownship Heading c. Launcher Blind Zone d. MR-( ) Symbol	C152	WDS D SWBD		Fig. 11-24.1	Perform WDS CMPTR diagnostics.
4	Permission to Test	LSMC	WDS CS SWBD SDC C152 RDP	W-2	Fig. 12-14.1	a. Perform C-TASC IM/CB Test 877 b. Perform continuity check between RDP (J11-c) and RSC (J4-c). c. Perform ground check at RSC (J4-c) and P4-c). d. Perform SDC signal monitoring and fault monitoring (SM/FM) tests.

* This column lists the function source and test points, if applicable.

‡ This column lists units between source and destination.

◊ This column lists other SMTs and associated steps in which the parameter in the function column is tested, if applicable.

° This column provides suggested troubleshooting procedures for fault isolation; for example, applicable self-tests, alternate system configuration/substitution, etc. It should be emphasized that these are suggested troubleshooting procedures and are not meant to preclude or remove judgment for troubleshooting from the technician. The intent of the FAM is to serve as a troubleshooting aid, while allowing latitude for personal preference as to the approach and technique applied.

Sample Troubleshooting Problem

To show how troubleshooting documentation is used to isolate faults, this sample problem is provided with corresponding fault analysis procedures by using samples of fault-isolation materials previously covered in this chapter. The sample problem and associated fault analysis procedures are based on a fault revealed during SMT W-1. It is emphasized that these are *suggested* troubleshooting procedures and are not meant to preclude or remove judgment from the technician. For the sake of clarity, this problem is shown as separate steps. Refer to table 1-5 as you solve this problem.

1. Prior to the hypothetical fault, it is assumed that all turn-on procedures and preliminary test steps have been accomplished with no apparent malfunctions indicated. No PERMISSION TO TEST indication is observed at the radar set console (RSC).

2. After verification of all test setups, the test coordinator then refers to the FAM for SMT W-1, which lists all SMT response steps (column 1) and the associated functions that are tested (column 2).

3. From columns 3 and 4, the sources and intermediate units can readily be determined.

4. Column 5 lists related SMTs.

5. Column 6 lists SFD figure 12-14.1 as the reference for the permission to test the function. By using the available reference material, the test coordinator can proceed to column 7 and implement the suggested fault-isolation procedures.

6. In column 7, step 4a, C-TASC (a computer diagnostic program) is used to determine if logical output voltages are being (1) generated at the radar data processor (RDP), and (2) transmitted to the radar set console (RSC). The succeeding fault-isolation procedures listed in the FAM are then accomplished as required until the casualty is found or isolated to an equipment.

If the preceding problem had arisen at any time other than during a scheduled test, the system FID (see table 1-3) and/or the FCS function directory (see table 1-4) could have been used.

When the FID is used to facilitate solutions of problems encountered during normal operations or weapons system exercises other than scheduled testing, the faulty indication is identified and located in the Indicator column for the associated equipment listed in the Equipment column of table 1-3. Using the same hypothetical fault described above, refer to table 1-3 and locate the RSC in the Equipment column and PERMISSION TO TEST in the Indicator column. The applicable SFD and FAM may then be refereed to for trouble analysis. At the discretion of the test coordinator, the equipment may be setup as required in the referenced FAM, and the associated trouble analysis procedures accomplished as described in the above paragraphs. Where there is no readily identifiable indicator for a given function, reference maybe made to the SFD to cross-reference the applicable SFD.

Equipment Troubleshooting Documentation

Equipment operating procedures (OPs) contain a wealth of documentation to enable the rapid localization of faults that have been traced to a particular piece of equipment. The documentation includes (but is not limited to) fault logic diagrams, signal-flow diagrams, pyramid diagrams, relay and lamp indexes, and relay lamp ladder diagrams. In addition, maintenance turn-on procedures, shown in table 1-6, are provided for energizing the equipment. These procedures contain references to troubleshooting documents that are to be used if a given step of the procedure cannot be performed satisfactorily.

Table 1-6.—Sample Maintenance Turn-On Procedures

STEP	PROCEDURE	OBSERVATION	REFERENCE
1	Perform preliminary preparations in accordance with paragraph 2-17.		
2	At Control-Power Supply, perform the following: a. Press OFF-ON push button switch 14A2S5.	ON is lit.	4-5
	b. Observe PREHEAT indicator of PREHEAT switch 14A2S8.	PREHEAT is lit.	4-5
	c. Press COMMAND STANDBY pushbutton switch 14A2S9.	COMMAND is lit. STANDBY is lit after approximately 5 minutes.	4-5 4-5
	d. Observe LOW VOLTAGE lamp 14A2DS2.	Lamp is lit.	4-6

Some of the primary equipment troubleshooting documentations are covered in this subsection, including fault logic diagrams, signal-flow diagrams, pyramid diagrams, relay and lamp indexes, and relay lamp ladder diagrams. Also included is a sample equipment troubleshooting problem relating to a simple checkout procedure.

FAULT LOGIC DIAGRAMS.— Fault logic diagrams (FLDs) are used to speed troubleshooting by requiring the technician to answer a branching series of questions about an observed system fault. The questions, which permit only yes-or-no answers, pertain primarily to the status of external indications (lamps, dials, meters, scope displays, etc.), but they may also include internal indications at key test points. By a process of elimination, the technician is led to the area of probable trouble and is referred to equipment troubleshooting documents. Figure 1-4 shows a sample fault logic diagram.

SIGNAL-FLOW DIAGRAMS.— Signal-flow diagrams show the signal flow from an input to an output function. Adjustment procedures, replacement procedures, and schematics are referenced in the signal-flow diagram to provide the technician with quick access to the appropriate maintenance requirement cards and related troubleshooting documentation. Figure 1-5 shows a sample signal-flow diagram.

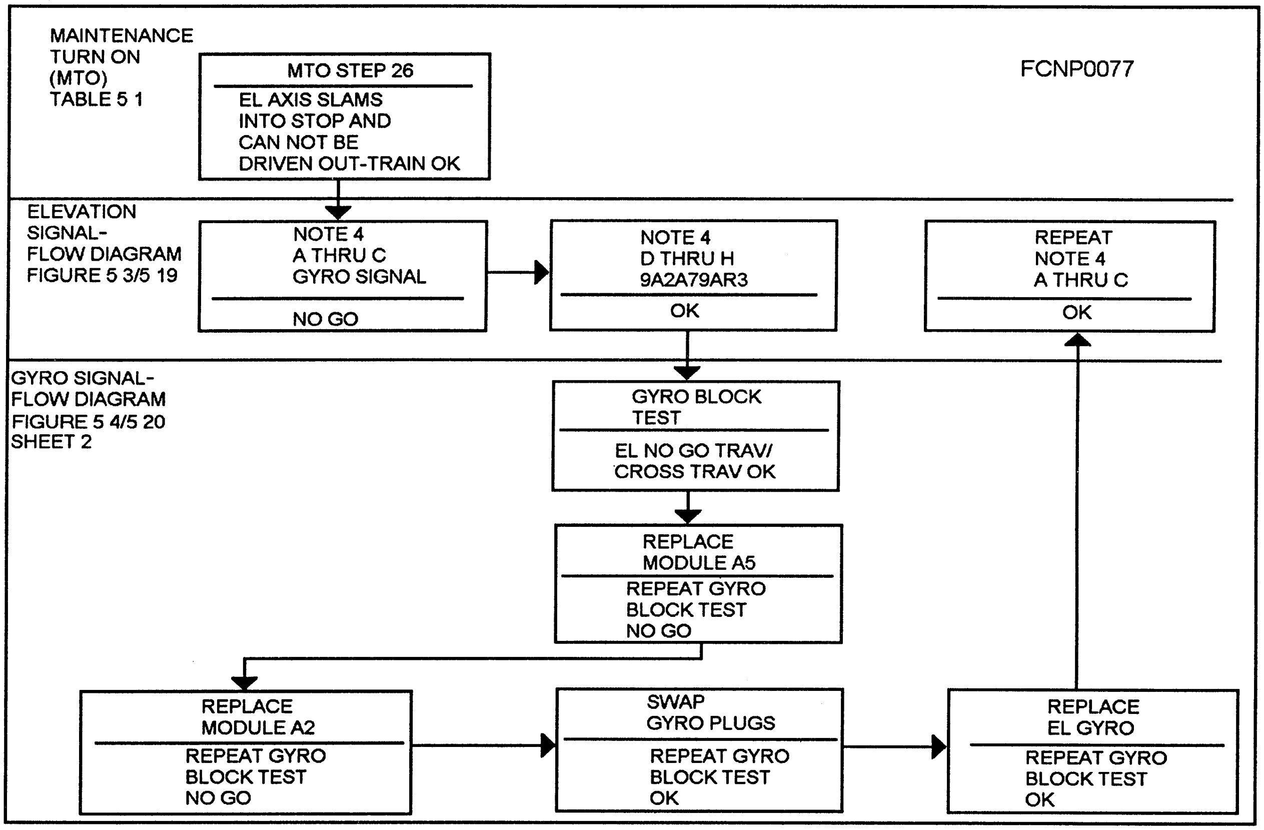


Figure 1-4.—Fault logic diagram.

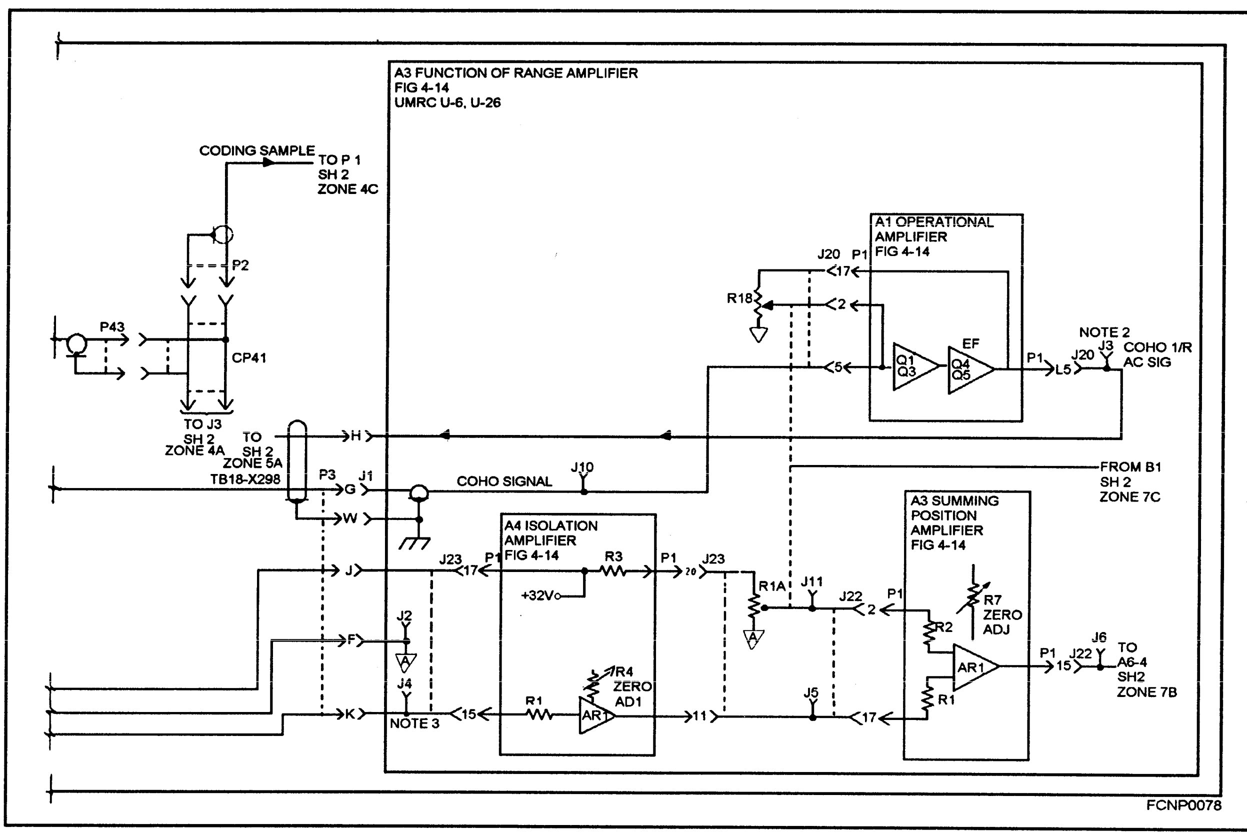


Figure 1-5.—Signal-flow diagram.

PYRAMID DIAGRAMS.— Pyramid diagrams pertain to the interdependency of the subassemblies essential to each function of a piece of equipment. The pyramid starts with an output function and, for a given local test setup, lists the values and allowable tolerances of that function. Subsequent checks of the various inputs that affect the function are contained in blocks, which radiate downward from the statement of the function.

The blocks contain recommended corrective action if the check of the input is at fault. Each leg of the pyramid is terminated by an input and a reference to other pyramids or related documents. Thus, the equipment troubleshooting pyramids should enable the technician to quickly localize faults and perform the necessary corrective action by referencing the associated material. Figure 1-6 shows a sample pyramid diagram.

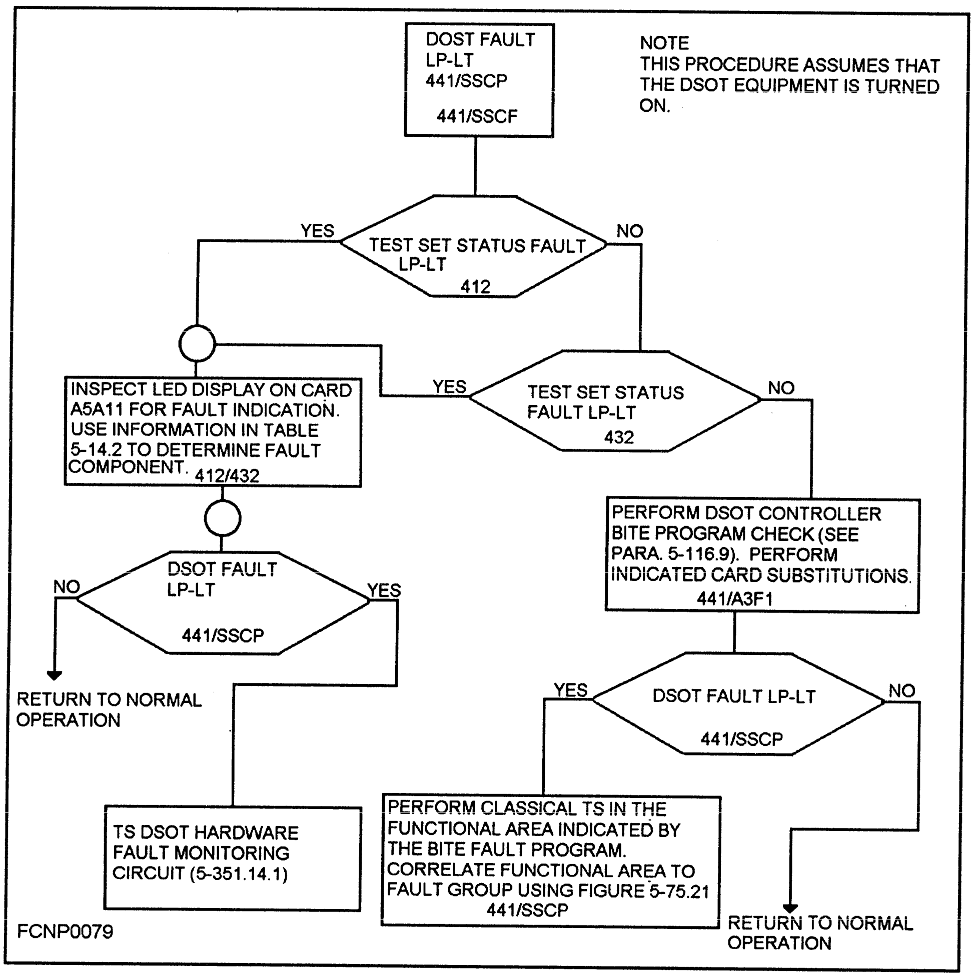


Figure 1-6.—Pyramid diagram.

RELAY AND LAMP INDEXES.— The relay and lamp indexes list all the relays and lamps shown on the troubleshooting diagrams. The indexes list, in unit designation sequence, all relay coils and related switches and indicator lamps. They cross-index (by figure, sheet, and zone) the location of the relay coil and indicator lamp energizing paths. Table 1-7 shows a sample relay index.

Table 1-7.—Sample Relay Index

RELAY	FUNCTION	COIL SUPPLY	FIGURE		SHEET	ZONE	CONTACT LOCATION			
							FIGURE			
			MOD 5	MOD 6			MOD 5	MOD 6	SHEET	ZONE
9A4K2	Missile in Flight (KMIF)	50 V dc	5-8	5-24	1	B6	5-9 5-6 5-7 5-8	5-25 5-22 5-23 5-24	1 1 1 1	C7 C1 A5 B5
9A4K3	Electronics Unplugged Interlock (KEUI)	50 V dc	5-7	5-23	2	A2	5-7 5-7	5-23 5-23	2 1	A1 A1
9A4K4	Electronic Voltage Supply (KEVS)	50 V dc	5-7	5-23	2	A2	5-9 5-7 5-7	5-25 5-23 5-23	1 2 1	C7 A1 A1
9A4K5	Director Running (KDR)	50 V dc	5-8	5-24	1	B4	5-8 5-9	5-24 5-25	1 1	B1, B2 C7
9A4K6	Director Test (KDT)	50 V dc	5-8	5-24	1	B6	5-8 5-10	5-24 5-26	1 1	B2, B3 C9
9A4K7	Train Overspeed (KTOS)	50 V dc	5-6	5-22	2	A4	5-9 5-9	5-25 5-22	1 2	B8 A4, B1, B3
9A4K8	Elevation Overspeed (KEOS)	50 V dc	5-6	5-22	2	A4	5-9 5-6 5-6	5-25 5-22 5-22	1 1 2	B8 B2 A4, B1, B2
9A4K9	Train Overspeed (KTOS)	50 V dc	5-6	5-22	2	A4	5-6 5-6	5-22 5-22	2 1	A6 B2, B3
9A4K10	Power Amplifier Test (KPAT)	50 V dc	5-10	5-26	1	C9	5-11	5-27	1	C7
9A4K11	Train Control (KTC)	115 V dc	5-9	5-25	1	B8	5-9 5-11	5-25 5-27	1 1	A5, B9 C8

RELAY LAMP LADDER DIAGRAMS.— Relay lamp ladder diagrams show the energizing paths for relays and indicator lamps that are not covered by signal-flow diagrams. They are used with relay and lamp indexes. Figure 1-7 shows a sample relay lamp ladder diagram.

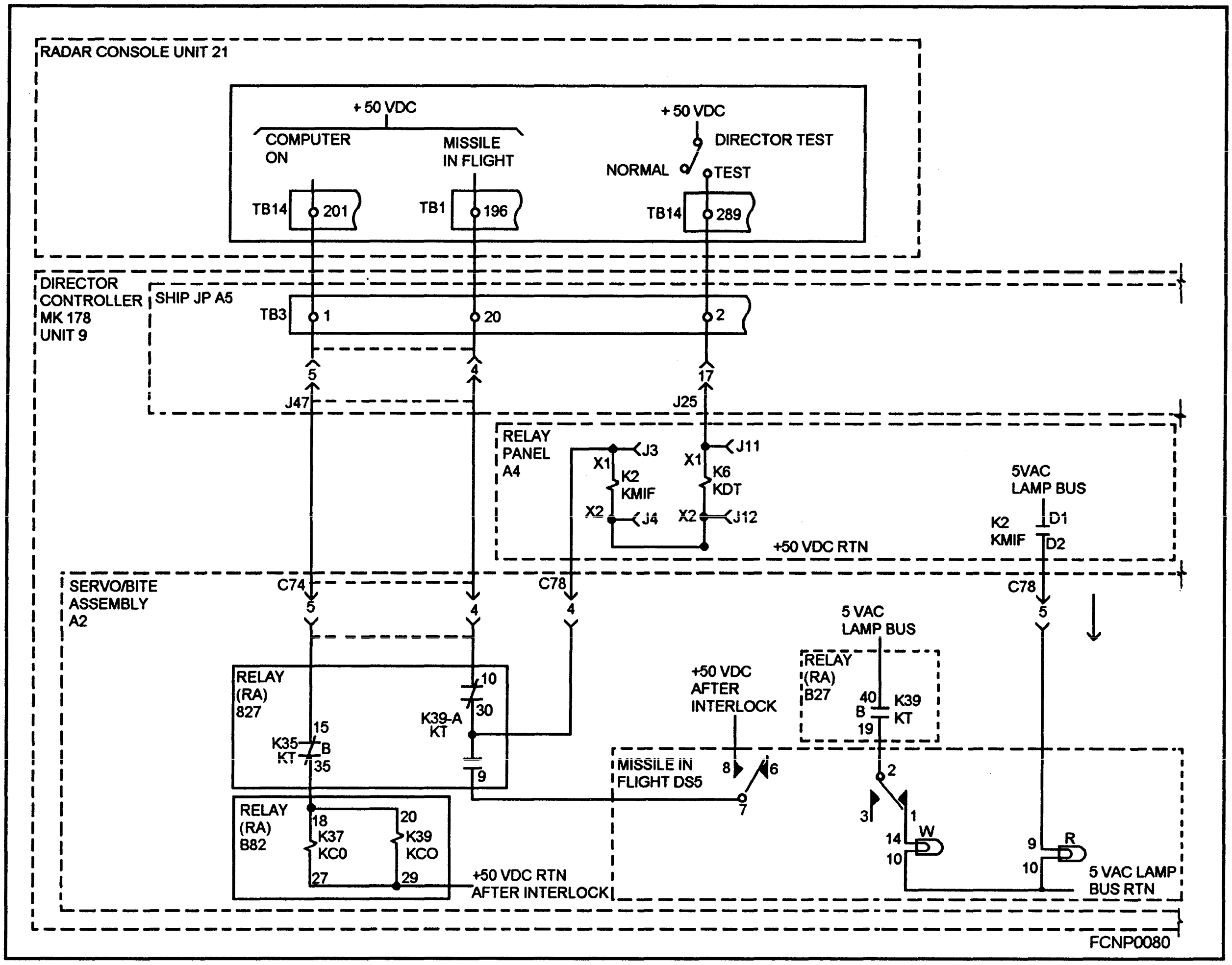


Figure 1-7.—Relay lamp ladder diagram.

The relay lamp ladder diagram is a troubleshooting support document for the signal-flow diagram and the maintenance turn-on procedure. It is also used as the prime troubleshooting document for equipment switching problems.

The relay lamp ladder diagram traces the energizing path for the relay coil or indicator lamp from a common interface point appearing on both the power-distribution diagram and the ladder diagram. It traces through the equipment, to the respective relay coil or indicator lamp, and to a common return power interface. The relay lamp ladder diagram shows cabling, terminal connections, relay contacts, switches, and lamps in the energizing path.

SAMPLE EQUIPMENT TROUBLESHOOTING PROBLEM.— Because of the inherent differences in fire-control equipment, each fire-control system has its own troubleshooting philosophy. However, they all use the basic troubleshooting documentation (or a modification or combination of the basic documentation) covered in this chapter.

This sample problem uses the checkout procedure, and the problem-directory and pyramid-diagram methods of troubleshooting. In these methods, the technician sets up, adjusts, and verifies equipment operation according to a set of steps in the checkout procedures shown in table 1-8.

If the function being tested at a particular step fails, the technician refers to that same numbered step in the problem directory to isolate the faulty component. A sample problem directory is shown in table 1-9.

Table 1-8.—Sample Video Processing and Distribution System Checkout Procedures

STEP	PROCEDURE
1	Set up radar video processing and distribution system troubleshooting initial conditions according to paragraph 7-13-8.
2	At unit 1, set SWEEP RANGE (NMI) switch to 5.
3	Adjust VIDEO GAIN and INTENSITY for optimum video and sweep presentation.
	•
	•
27	Set M/N SELECT switch to 10, and verify that all lamps on 25A38 are lit.
28	Set M/N SELECT switch to 4, and verify that all lamps on 25A38 are out.
29	Set M/N SELECT switch to 5, and verify that all lamps on 25A38 are out.
	•
	•

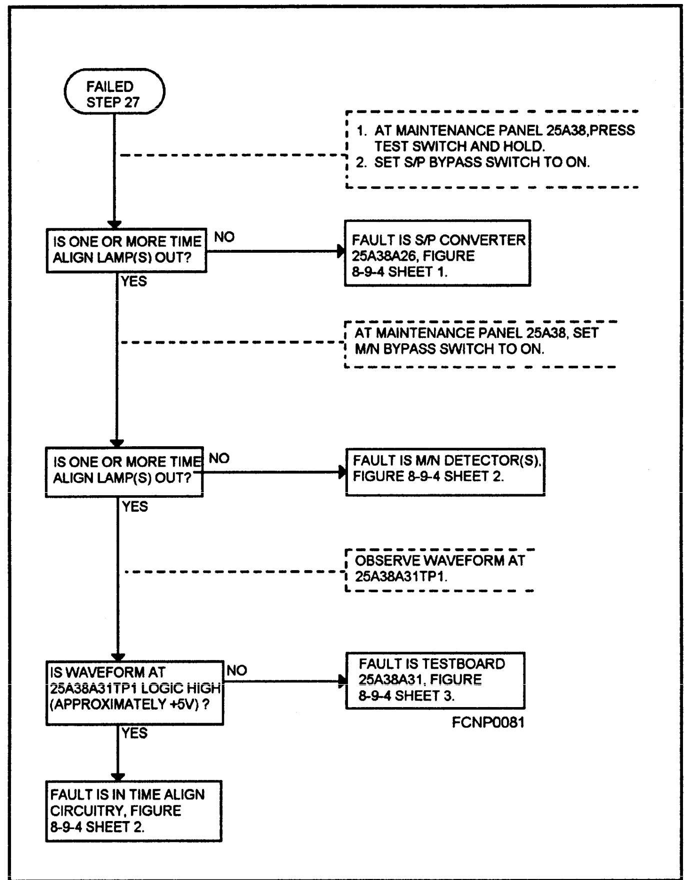


Figure 1-8.—Incorrect lamp pyramid diagram 7-13-2.

In our sample troubleshooting problem, the faulty component is Test Board 25A38A31. To isolate this component, the technician performs the checkout procedures shown in table 1-8. At step 27, the technician observes that none of the lamps on 25A38 are lit. From here, the technician proceeds to the problem directory (see table 1-9), step 27, where he is directed to set the S/P BYPASS switch to ON. After doing this, he notices that more than one lamp is out on 25A38. The problem directory refers the technician to the incorrect lamp indicator pyramid diagram, shown in figure 1-8.

Here, the technician follows the instructions outlined in the dashed blocks and answers the questions in the solid block. Eventually, the technician is instructed to measure the voltage at 25A38A31TPI. A zero-voltage reading at this test point indicates that Test Board 25A38A31 is the faulty component. The technician replaces the circuit board and verifies correct operation by repeating step 27 in the checkout procedures.

Figure 1-9 is a sample troubleshooting system fictional diagram.

Table 1-9.—Sample Problem Directory

FAILED CHECKOUT PROCEDURE STEP	INDICATION	PROCEDURE
3	Adjusting VIDEO GAIN and INTENSITY controls does not provide optimum video and sweep presentation.	Refer to the PPI display system troubleshooting, section 7-15.
4	Type 1 synthetic raw video is not present or is not well-defined.	Refer to figure 7-13-1.
5	ACQUIRE 1 does not light green.	Refer to operator-to-computer buffer system trouble-shooting, section 7-5.
•	•	•
•	•	•
27	All lamps on 25A38 out.	Set S/P BYPASS switch to ON. If lamps light, fault is in S/P Converter 25A38A26, figure 8-9-4, sheet 1. If lamps stay out, fault is in MN/SELECT Switch 25A38S5 or Test Board 25A38A31, figure 8-9-4, sheet 3.
	One or more lamps on 25A38 out.	Refer to figure 7-13-3.
	CLR PLOT VID lamp out.	Fault is in P/S Converter 25A38A27 or Test Board 25A38A31, figure 8-9-4, sheet 3.
•	•	•
•	•	•

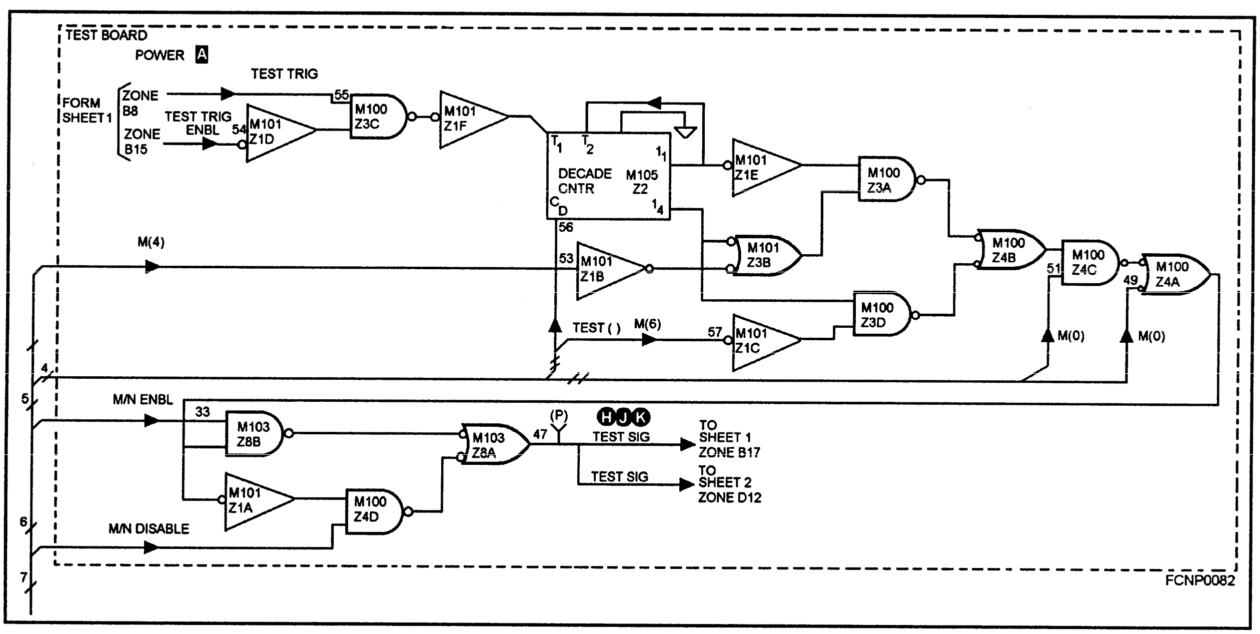


Figure 1-9.—Troubleshooting system functional diagram.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Ships' Maintenance and Material Management (3-M) Manual, OPNAVINST 4790.4, Chief of Naval Operations, Washington, DC, 1994.

All systems operating procedures that describe troubleshooting techniques and procedures applicable to each FCS on your ship class.

CHAPTER 2

LIQUID-COOLING SYSTEMS

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Identify the different types of liquid-cooling systems for electronic fire-control equipment.

2. Identify the components for the liquid-cooling systems.

3. Identify the maintenance responsibilities for the liquid-cooling systems used by Fire Controlmen.

INTRODUCTION

Cooling systems are essential to the satisfactory operation of a shipboard weapons system. In fact, some form of cooling is required for all shipboard electronic equipment, and liquid cooling is especially efficient for the transfer of large amounts of heat. To maintain cooling systems, you must have a broad understanding of the different types of liquid-cooling systems with which you are involved. As a Fire Controlman, and because you operate and maintain electrical and electronic equipment, you are required to have a thorough knowledge of liquid-cooling systems.

This chapter discusses basic liquid-cooling systems, liquid-cooling systems configurations, and liquid-cooling systems for the Mk 92 fire-control system (FCS). It also discusses the maintenance responsibilities you have as a Fire Controlman for these systems. For more detailed information on these and other cooling systems, consult your applicable operating procedures and *Basic Liquid Cooling Systems for Shipboard Electronics,* NAVSEA 0948-LP-122-8010.

BASIC LIQUID-COOLING SYSTEMS

The typical liquid-cooling system is composed of two basic cooling systems: primary and secondary. These two systems are discussed briefly in this section.

PRIMARY LIQUID-COOLING SYSTEM

The primary liquid-cooling system provides the initial source of cooling water that can be either seawater or chilled water from the ship's air-conditioning plant, or a combination of both. Figures 2-1, 2-2, and 2-3 show the basic arrangement of liquid-cooling systems that use seawater and chilled water. You are encouraged to refer to these three figures as you study this chapter.

In figure 2-1, seawater from a sea connection is pumped by a seawater circulating pump in one of the ship's engineering spaces through a duplex strainer to remove all debris and then is pumped through the tubes of a heat exchanger. Finally, the seawater is discharged back into the sea at an overboard discharge.

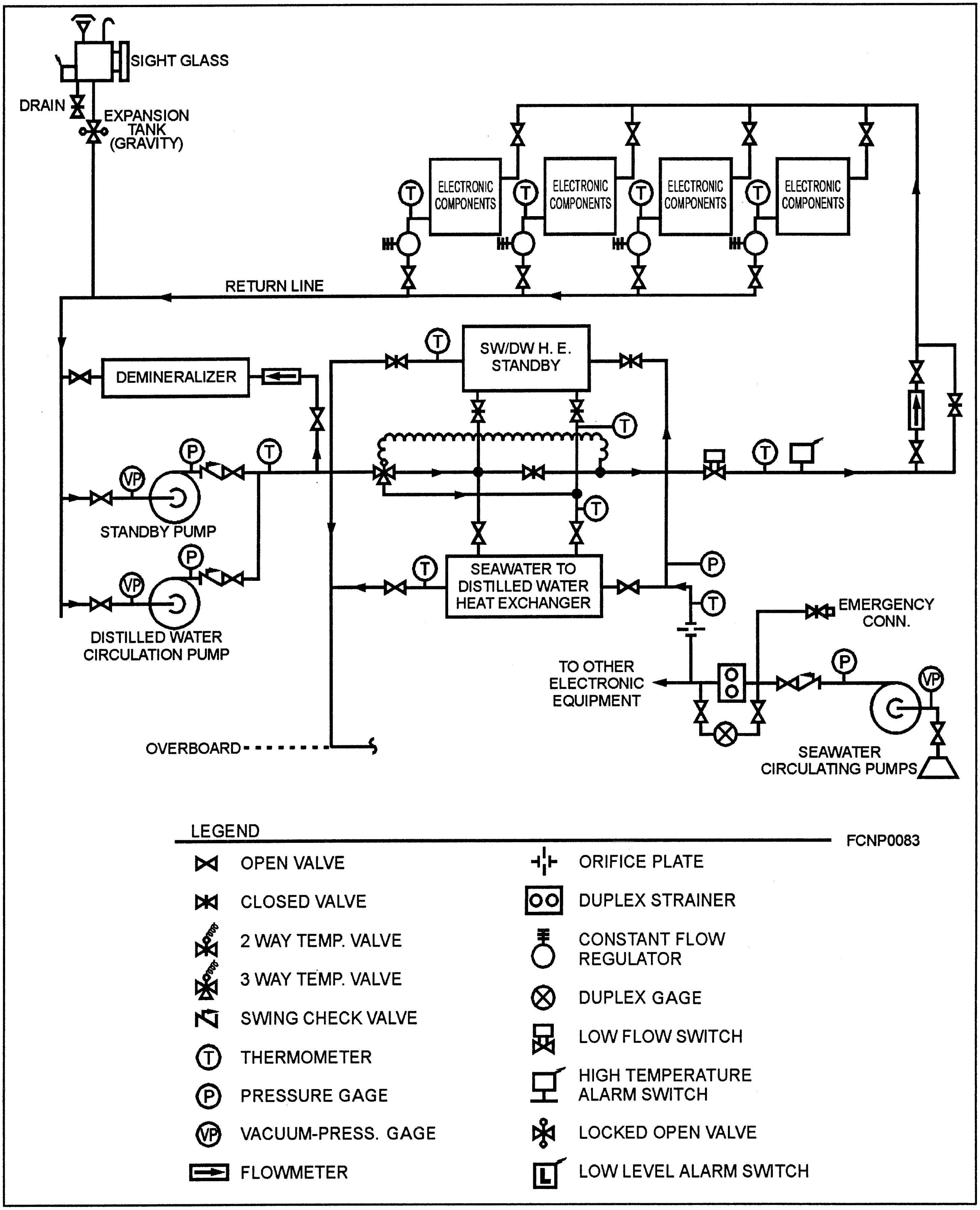


Figure 2-1.—Type I liquid-cooling system.

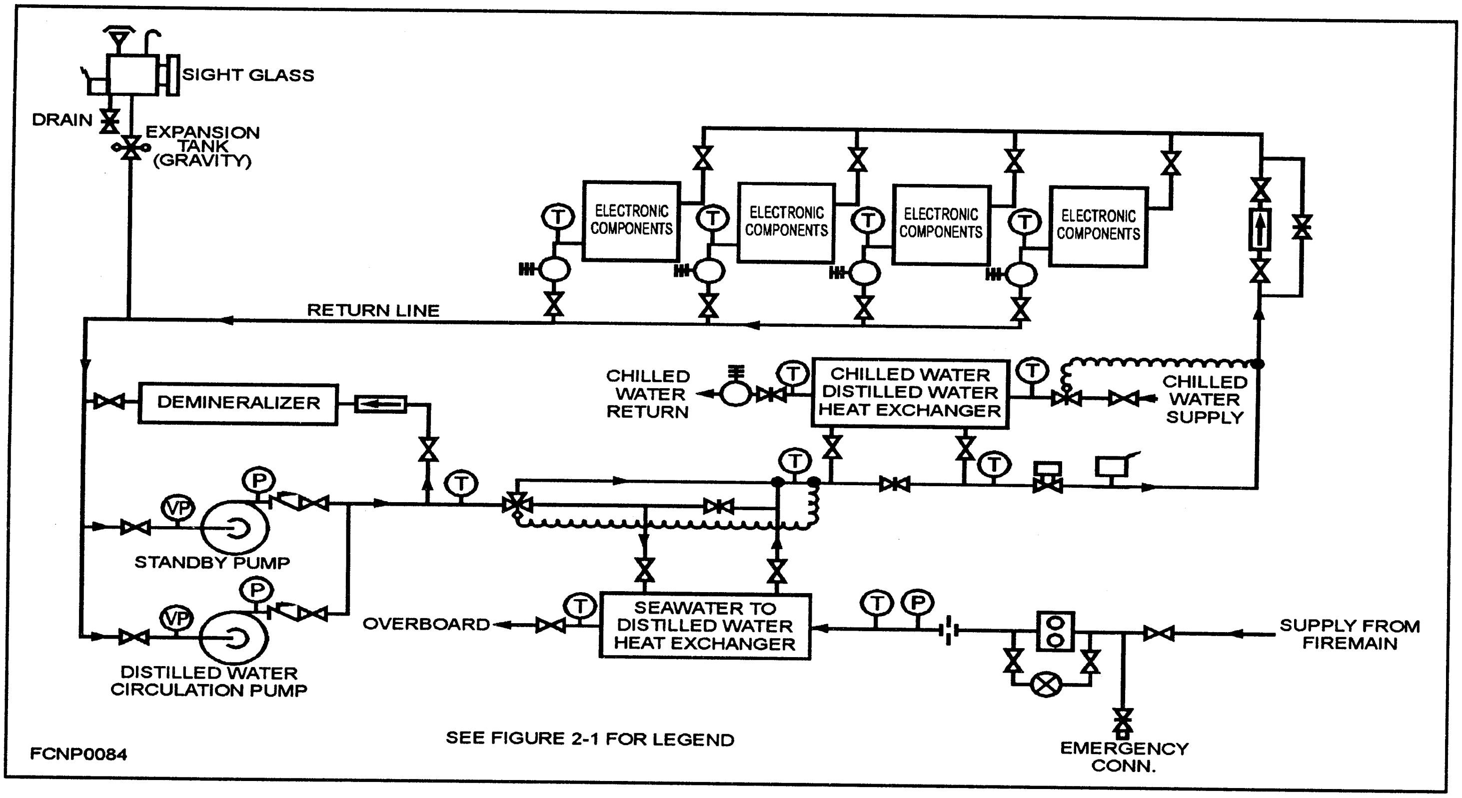


Figure 2-2.—Type II liquid-cooling system.

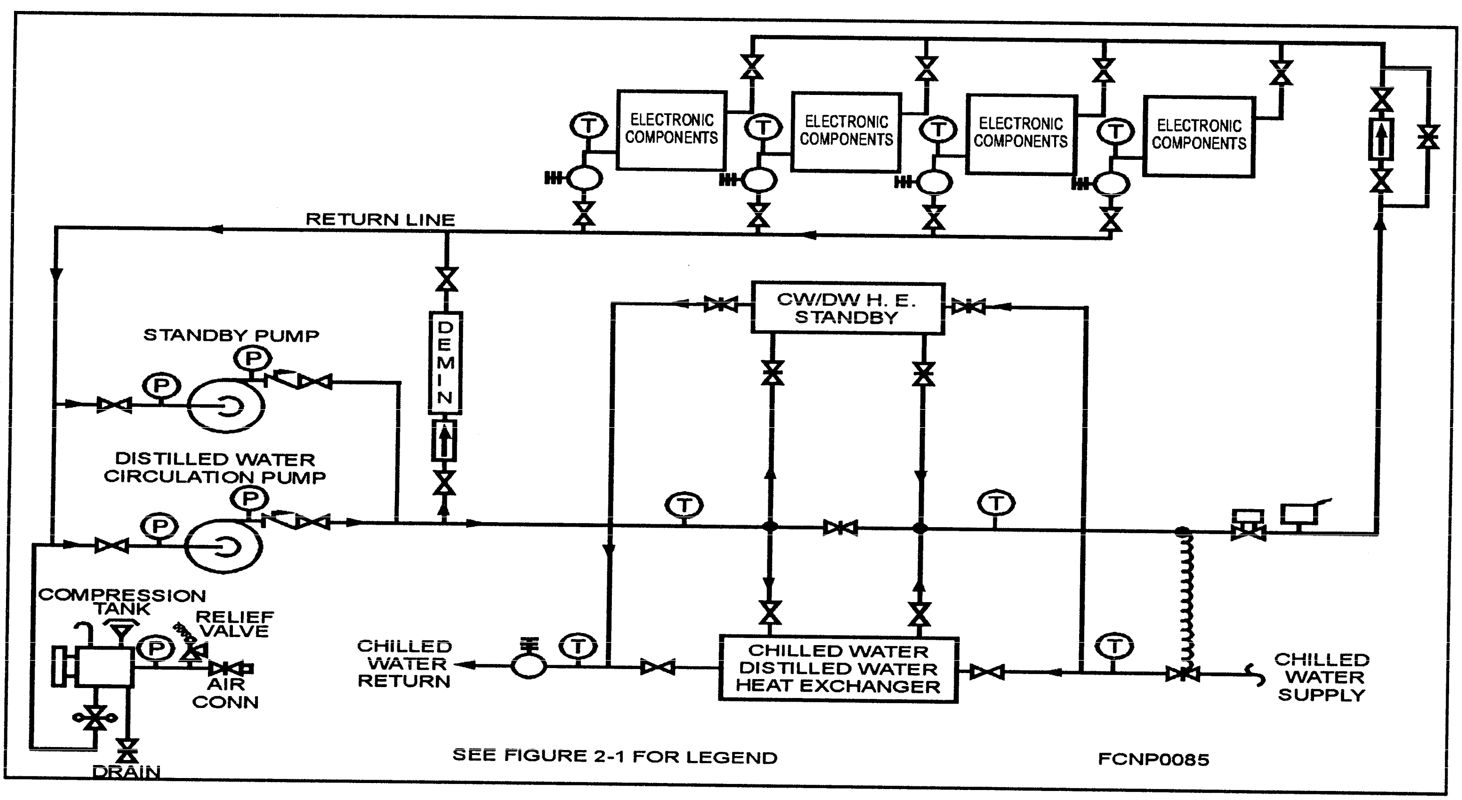


Figure 2-3.—Type III liquid-cooling system.

The seawater system shown in figure 2-1 is a multiple-branch system. As such, it supplies a number of heat exchangers for other electronic equipment. To regulate the proper amount of seawater to each cooling system, an orifice plate is installed in the line between each heat exchanger and the duplex strainer. The heat exchangers are referred to as *seawater-to-distilled-water heat exchangers.*

Another means of providing seawater is through the ship's fire main, as shown in figure 2-2. The seawater is taken from the fire main through a duplex strainer and a flow regulator (orifice plate) to and through the heat exchanger. It is then discharged overboard. The connection to the fire main is permanent.

The ship's fire pump, not shown in figure 2-3, is used to pump seawater into the fire main. The fire pump is similar in design to the previously mentioned seawater circulating pump, except it has a much larger capacity.

Another means of obtaining seawater as a primary coolant for types I and II liquid-cooling systems is by an emergency connection, which is used if the normal seawater supply is lost. The connection is usually by means of a 1 1/2-inch fire hose. The emergency supply comes from an alternate portion of the ship's fire main or a portable pump rigged by the ship's damage control party. The portable emergency hose is normally stored in the liquid-coolant machinery room.

In types II and III liquid-cooling systems, chilled water is taken from the supply main of the air-conditioning, chilled-water systems. The chilled water is used as a backup source of cooling water for the primary cooling system shown in figure 2-2, and as a normal and backup source for the system shown in figure 2-3. The chilled water flows through the tubes of the heat exchanger (chilled water to distilled water), a flow regulator, and back to the chilled-water system. A temperature-regulating valve at the inlet of the heat exchanger regulates the flow of chilled water through the heat exchanger to maintain the required water temperature in the secondary system (distilled water).

The ship's air-conditioning, chilled-water circulating pump is used to pump the chilled water through the heat exchanger. The chilled-water system is a closed-loop water system because the water is recirculated. The system must be kept tight and free from leaks to ensure satisfactory operation.

SECONDARY LIQUID-COOLING SYSTEM

The secondary liquid-cooling system transfers heat from the electronic equipment being cooled to the primary cooling system. The coolant normally used in the secondary system is distilled water, which is ultrapure and is maintained in that state by a demineralize. In some secondary systems, ethylene glycol is added to the water to prevent freezing when the system is exposed to freezing weather.

The secondary liquid-cooling system is usually comprised of a distilled-water circulating pump, a compression or gravity-feed expansion tank, the electronic equipment being cooled, a demineralizer, a temperature-control valve, the monitoring equipment with its associated alarms, and the heat exchanger, which is shared with the primary system. The secondary system is a closed-loop water system, as compared to the seawater system, which is a one-pass, or open-loop, system.

LIQUID-COOLING SYSTEM CONFIGURATIONS

The U.S. Navy uses three basic configurations of liquid-cooling systems, and you could be involved with all three of them, depending on the number and types of electronic equipment to be cooled. The specifications for the type of system installed on your equipment will depend on the operational requirements of the equipment. Some electronic equipments require very close regulation of the temperature of the distilled water, whereas others do not.

TYPE I LIQUID-COOLING SYSTEM

The type I liquid-cooling system is a seawater/distilled-water (SW/DW) heat exchanger with an SW/DW heat exchanger standby. This system is used for electronic system installations that can be operated satisfactorily with seawater temperature as high as 95°F, which should result in a distilled-water supply temperature to the electronics of approximately 104°F. Refer to figure 2-1 as you study this section.

Starting with the distilled-water pumps, distilled water under pressure flows to the temperature-regulating valve. The temperature-regulating valve is installed to partially bypass distilled water around the seawater-to-distilled-water heat exchanger so that a constant water temperature can be supplied to the electronic equipment. As the temperature in the distilled water increases, more water is directed to the heat exchanger and less to the bypass line, thus maintaining the output water temperature constant.

The standby heat exchanger is usually of the same design and is used when the on-line heat exchanger is inoperable or is undergoing maintenance. The size of the heat exchanger is designed to handle the full cooling load of the electronic equipment plus a 20-percent margin. From the heat exchanger, the water then goes through various monitoring devices, which check the water temperature and flow.

The water temperature and flow depend on the requirements of the electronic equipment being cooled. After the water moves through the equipment, it is drawn back to the pump on the suction side; thus, a continuous flow of coolant is maintained in a closed-loop system.

An expansion tank in the distilled-water system compensates for changes in the coolant volume and provides a source of makeup water in the event of a secondary system leak. When the expansion tank is located above the highest point in the secondary system and vented to the atmosphere, it is called a *gravity tank.* If it is below the highest point in the secondary cooling system, it is called a *conpression tank* because it requires an air charge on the tank for proper operation.

The demineralizer is designed to remove dissolved metals, carbon dioxide, and oxygen. In addition, a submicron filter (less than one-millionth of a meter) is installed at the output of the demineralizer to prevent the carry-over of chemicals into the system and to remove existing solids.

TYPE II LIQUID-COOLING SYSTEM

The type II liquid-cooling system is an SW/DW heat exchanger with a chilled-water/distilled-water (CW/DW) heat exchanger standby. This system is used in installations that cannot accept a DW temperature higher than 90°F. Refer to figure 2-2 as you study this section.

The secondary cooling system of the type II liquid-cooling system is similar to that of the type I secondary liquid-cooling system and uses many of the same components—the major difference is in the operation of the CW/DW heat exchanger. The secondary coolant is in series with the SW/DW heat exchanger and automatically supplements the cooling operation when the SW/D Wheat exchanger is unable to lower the temperature of the distilled water to the normal operating temperature.

The CW/DW temperature-regulating valve allows more chilled water to flow into the primary cooling system to the CW/DW heat exchanger. This causes the temperature in the secondary system to go down. Normally, this action occurs only if high seawater temperatures are encountered in tropical waters. The CW/DW heat exchanger is also used in an SW/DW heat exchanger malfunction.

TYPE III LIQUID-COOLING SYSTEM

The type III liquid-cooling system is a CW/DW heat exchanger with a CW/DW heat exchanger standby, and is used in installations where the temperature range is critical. It requires close regulation of the DW coolant to maintain temperatures between established limits. For example, the temperature limits might be between 70°F and 76°F. This system is used where tighter control is required. Refer to figure 2-3 as you study this section.

The type III secondary liquid-cooling system also operates in a similar manner to the type I secondary liquid-cooling system—the major difference is in the way that the temperature of the secondary coolant is regulated. A three-way temperature-regulating valve is not used, but a two-way temperature-regulating valve is used in the primary cooling loop to regulate the temperature of the secondary loop.

The duplicate CW/DW heat exchanger is installed parallel to the first heat exchanger and is used as a standby heat exchanger. If a malfunction occurs that requires the first heat exchanger to be removed from service, the standby exchanger can be put into service by manipulating the isolation valves associated with the two heat exchangers.

LIQUID-COOLING SYSTEM COMPONENTS

The main components of liquid-cooling systems are heat exchangers, expansion tanks, seawater strainers, temperature-regulating valves, flow regulators, flow-monitoring devices, circulating pumps, demineralizes, oxygen analyzers, and coolant-alarm switchboards. In some systems, there are specialized components to monitor cooling water to the electronic equipment.

You should be able to identify and describe the operation of the individual components of a typical liquid-cooling system to help you perform the required system maintenance and trouble isolation. You should never neglect the cooling system, because it will quickly deteriorate to a point where only extreme and costly maintenance will restore it to its proper performance.

HEAT EXCHANGERS

In liquid-cooling heat exchangers, the heat that has been absorbed by distilled water flowing through the electronic components is transferred to the primary cooling system, which contains either seawater or chilled water from an air-conditioning plant. In both cases, the heat exchangers are of the shell and tube type in which the secondary coolant (DW) flows through the shell, while the primary coolant (SW or CW) flows through the tubes.

A single-pass counterflow heat exchanger is more efficient than the double-pass heat exchanger, because there is a more-uniform gradient of temperature difference between the two fluids. The primary coolant (SW/CW) flows through the tubes in the opposite direction to the flow of the secondary coolant (DW). Heat transfer occurs when the seawater flows through the tubes, extracting heat from the distilled water flowing through the shell side of the heat exchanger. The distilled water is then directed by baffles to flow back and forth across the tubes as it progresses along the inside of the shell from inlet to outlet. In figure 2-4, the preferred method of double-tube sheet construction is shown. Single-tube sheet construction is shown in figure 2-5.

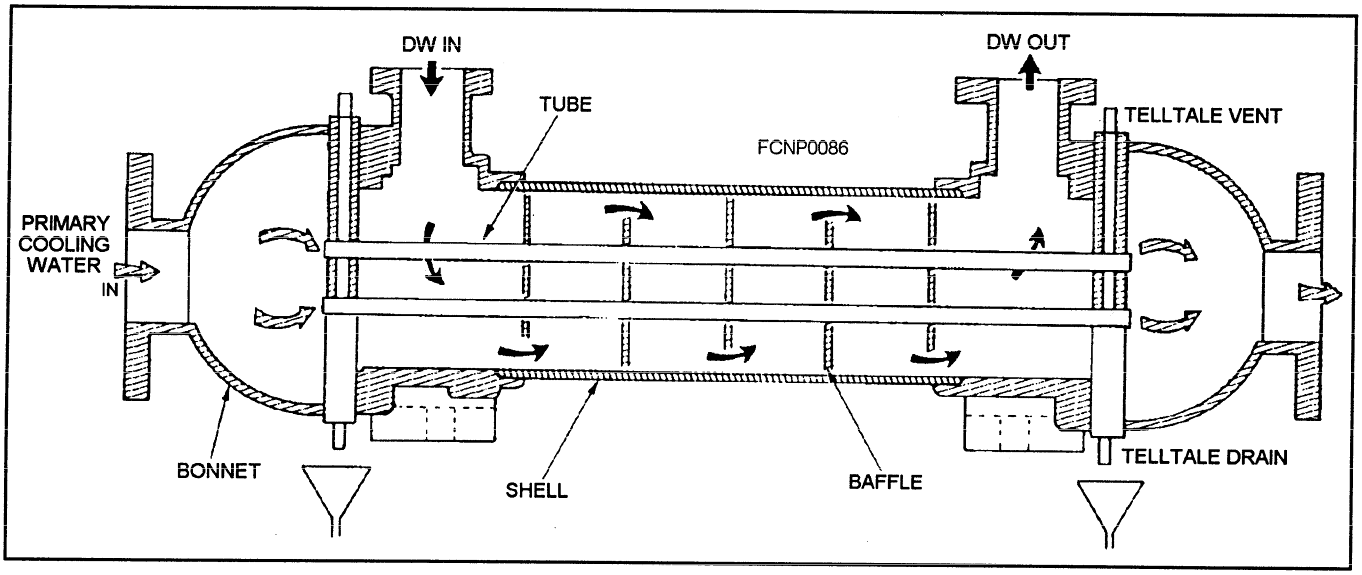


Figure 2-4.—Single-pass SW/DW heat exchanger with double-tube sheets.

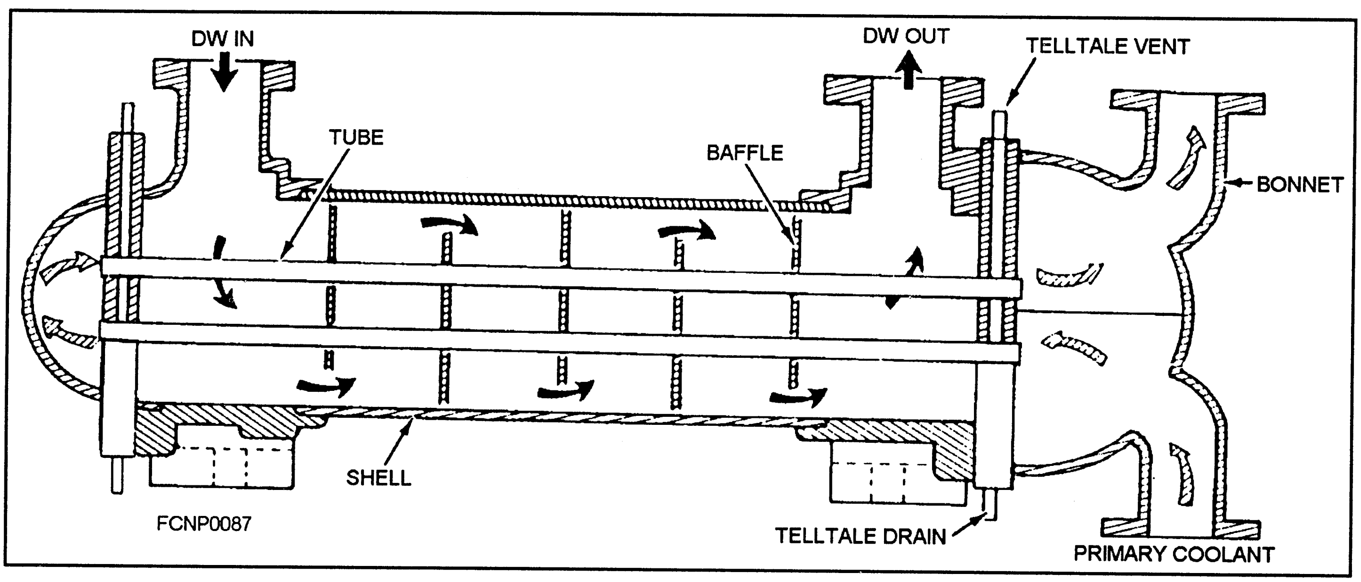


Figure 2-5.—Two-pass SW/DW heat exchanger with single-tube sheets.

Double-tube sheets are used at both ends of a tube bundle. A void space between the sheets prevents contamination of the distilled water and permits the monitoring of water loss due to tube leakage. You should be on the lookout to detect leakage at the "telltale drains," which indicates a failure of a tube joint. The type of water leaking out indicates whether the failure is in the primary or secondary system. The telltale drains should never be plugged or capped off.

A leak in one of the tubes shows up as a loss of water in the secondary side of the liquid-cooling system, because it operates at a higher pressure than the primary side. This is intentional, as it ensures that the distilled water is not contaminated with seawater when a leak develops in a heat exchanger.

A double-pass heat exchanger is generally used when there is limitation on the installation of the heat exchanger. This type of heat exchanger is less efficient than a single-pass exchanger and is subject to internal undetectable leakage across the flow divider in the inlet-outlet water box.

Heat exchangers must periodically be cleaned. The secondary section (distilled water) is cleaned by circulating chemicals through the secondary cooling system to remove any buildup of scale deposits that may accumulate on the surface of the tubes.

The procedure for routine cleaning of the primary section of the heat exchanger is to first secure the sea connections to prevent flooding. In some cases, an inspection port in the water box can be opened to remove any foreign matter lodged inside and against the tubes. If you are unable to get at the ends of the heat exchanger to remove the water boxes, then you must remove the heat exchanger from its location and place it on the deck or on a suitable work surface. Mark each unit removed so that it can be positioned in its proper place during reassembly. With the water boxes removed, an air lance should be passed through each tube and the passages washed out. Where severe fouling exists, a water lance should be pushed through each tube to remove foreign matter attached to the tube walls.

Where extreme fouling exists, special cleaning equipment operated by personnel skilled in its use is required. The ship's engineering officer is normally the best person qualified to determine which procedure to use and whether the job can be performed aboard ship or if it must be transferred to a repair facility. You should take precautions to ensure that tools, such as screwdrivers and wire brushes, are not used in such a way that they may scratch or mar the tube surfaces.

Over a period of time, electrolysis, which results because of dissimilar metals in the cooling system, will slowly dissolve the insides of various components in the primary seawater cooling system. Electrolysis is not a problem in chilled-water systems to the extent that it is in seawater systems. The type of metal used in the fabrication of the heat exchanger tubes is the deciding factor as to the use of zincs. Zincs are disks, rods, bars, or plates made of zinc metal that are installed inside the heat exchanger's water boxes. When they are installed, the electrolytic action is concentrated on the zinc and not on the metal of the heat exchanger tubes. As electrolysis dissolves the zincs instead of the heat exchanger tubes, they should be replaced. (The purity of distilled water inhibits electrolysis in the secondary system.)

In an older cooling system, you should be on the lookout for thin pipes in the seawater side of the cooling system. Check for bad pipes by gently tapping the empty pipes with the ball end of a ball-peen hammer. A bad piece of pipe will make a dull sound and will dimple as it is struck lightly.

The heat exchangers in the distilled-watercooling systems that cool electronic equipment are either liquid-to-air or coolant-jacket type of heat exchangers. The liquid-to-air heat exchangers are mounted inside cabinets containing the heat-producing electronic components.

A cabinet fan circulates the air across the heat exchanger and to the heat source in an airtight circuit. In the coolant-jacket type of heat exchangers, the distilled water is circulated through an integral water jacket in a large heat-producing component, such as a power-amplifier tube, a plate transformer, or the load isolators.

Vent and drain connections are provided to permit venting trapped air and draining water. Temperature gages may be provided in the inlet and outlet piping to check performance of the heat exchanger. Label plates indicate the water-flow direction through each cabinet.

Flow regulators (orifice plates or constant-flow devices) usually provide a constant flow of coolant to the individual component, cabinet, or bay of electronic equipment to be cooled. On critical electronic components that would be damaged without coolant to remove the heat, coolant-flow and temperature switches monitor the coolant.

EXPANSION TANKS

Expansion tanks may be either gravity tanks or pressurized tanks. The expansion tank serves a three-fold purpose in a liquid-cooling system. First, it maintains a positive pressure required on the circulating pump inlet for proper operation of the circulating pump. Second, it compensates for changes in the coolant volume because of temperature changes. Third, it vents air from the system and provides a source of makeup coolant to compensate for minor losses due to leakage or losses that occur during the replacement of radar equipment served by the system. Refer to figures 2-6 and 2-7 as you study this section.

When an expansion tank is used as a gravity tank, it is located above the highest point in the distilled-water system. This provides sufficient pressure to the suction side of the circulating pump. It also ensures a flow of water from the tank into the system when makeup water is required.

The tank is provided with a sight glass to check the level of water in the tank. The sight glass should normally show the tank to be from two-thirds to four-fifths full. The glass should be redlined at four-fifths of the tank capacity. A vent pipe is located on the top of the tank to prevent air pressure from building up in the system. A valve and funnel connection with a cap are located on the top of the tank to provide a means for filling the system with distilled water. A low-level alarm switch is usually set at 20 percent of tank capacity.

When the fluid level in the tank lowers to 20 percent of the full level, visual and audible alarms actuate at the alarm switchboard to warn personnel that the system is low on distilled water. If the tank runs out of water, air is drawn into the system, which results in increased corrective maintenance on the system to remove the trapped air or possible pump damage and/or failure of high-power transmitter components.

The pressurized expansion tank is normally located near the circulating pump suction in the return main of the secondary liquid-cooling system. The pressurized tank is airtight and is charged with com-

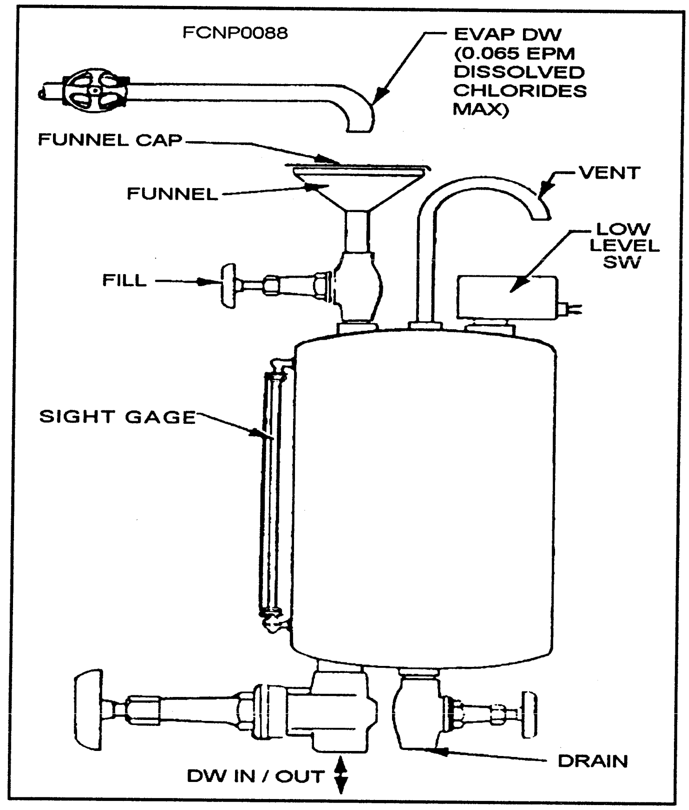


Figure 2-6.—Gravity expansion tank.

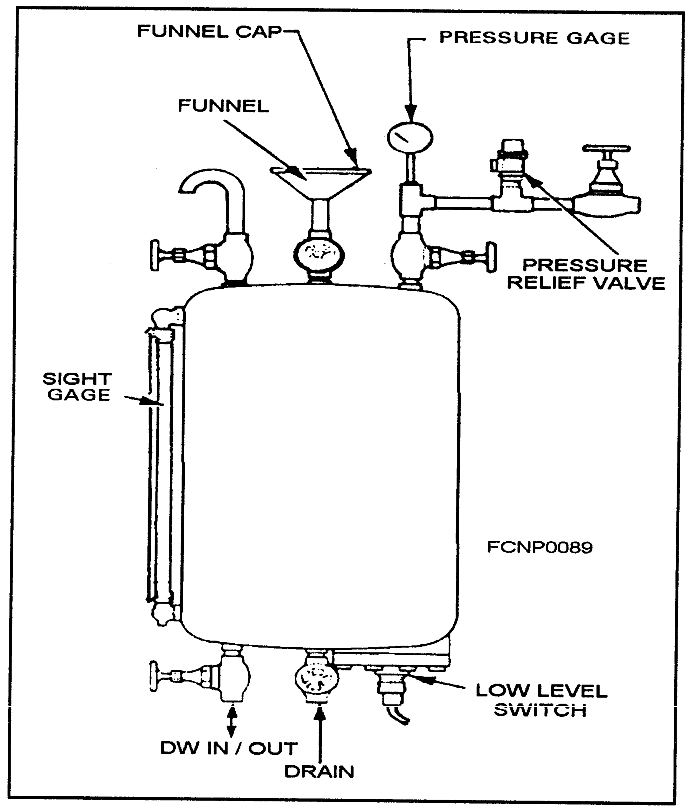


Figure 2-7.—Pressure expansion tank.

pressed air to an appropriate pressure from the ship's low-pressure air system. In some systems, a hose is used to pressurize the tank through a quick-disconnect valve. In other systems, a permanent pipe installation is connected to the expansion tank through a pressure-relief valve and an air shutoff valve.

The ship's low-pressure air system is used to charge the pressure tank, and then it is secured to prevent a possible flood back of coolant into the low-pressure air system. The relief valve protects the tank and the distilled-water system from being overpressurized. The sight glass and the low-level alarm switch function the same as those on the gravity expansion tank.

In both types of expansion tanks, the bottom of the tank is connected by piping to the return main of the secondary cooling system. Changes in coolant volume cause the coolant to flow into or out of the reservoir, as necessary, to maintain a stable return-line pressure.

Makeup water (distilled water) is added to the expansion tank through the funnel on the top of the tank. A funnel cap is provided for the funnel to prevent dirt from entering the system. When you fill the pressurized expansion tank, you must first isolate the tank from the cooling system and the air supply before you vent the air pressure off through the vent pipe at the top of the tank. The makeup water can be obtained directly from the ship's evaporators and preferably when the ship is making boiler-feed water, because the water is double distilled. At **no** time should potable (drinking) water or treated boiler-feed water be used in any electronic cooling systems.

After the water is drawn from the ship's evaporators, it should be transported only in a clean, capped container. You should take a sample of the water from the container and have it tested for chloride by the ship's water test facility before any of the water is used in the cooling system. The maximum permissible level of chloride is 0.065 ppm (equivalent parts per million). The supply system provides an alternate source of makeup water.

The expansion tank sight glass is your best indication of a coolant leak in the secondary cooling system. When the system uses excessive makeup water, you should inspect the whole secondary system, including the telltale drains on the heat exchanger, to locate the source of the leak. A small drip can amount to several gallons of water a day. On the pressurized expansion tank, a very small air leak (indicated by a pressure drop on a tank gage) can be located by brushing on a leak detector (a thick, clear, soapy liquid, such as concentrated liquid dishwashing soap) over the suspected area of the leak. The escaping air causes bubbles to form in the leak detector.

SEAWATER STRAINERS

Strainers are used in the seawater cooling system to remove debris and sea life, which could clog the pressure and flow-control device (orifice) and/or the tubes of the heat exchanger. The two types of in-line seawater strainers most commonly used in weapons cooling systems are the simplex (single) and duplex (double) basket strainers.

The simplex basket strainer, shown in figure 2-8, has a Y-pattern body. (Some simplex strainers have a small drain on the cover to allow you to drain the water off before removing the cover.) The basket is removed periodically for cleaning and inspecting for deterioration. This type of strainer requires that the seawater be secured before you clean the basket.

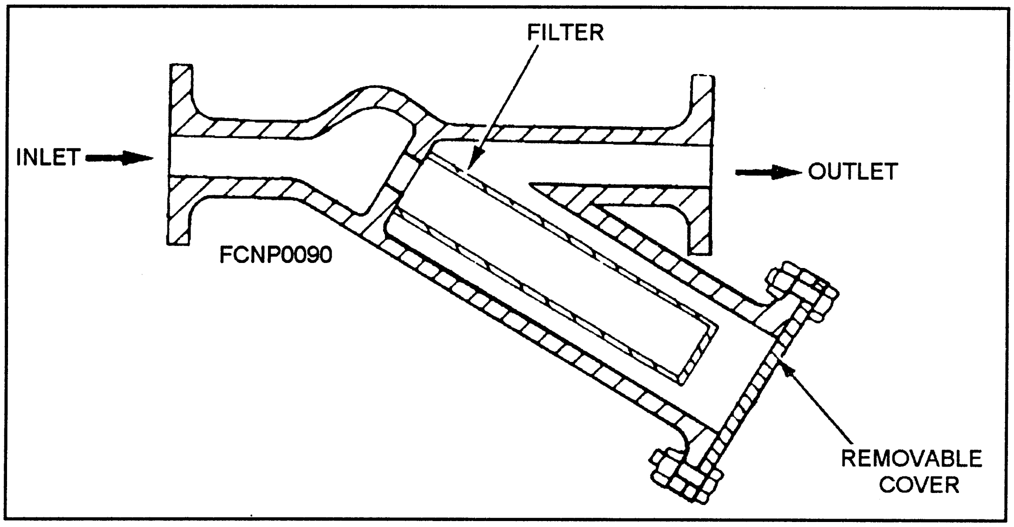


Figure 2-8.—Seawater simplex strainer.

The duplex strainer, shown in figure 2-9, consists of two removable baskets located in parallel at the seawater inlet. Seawater flows into the top of one basket and out through the perforated sides to the outlet. This arrangement allows maintenance to be performed on one basket while the system is in operation.

A selector valve is arranged so that, with the handle in one position, seawater flows through one of the baskets, leaving the other basket accessible for removal and cleaning. When the valve handle is switched to the alternate position, the flow is shifted over to the other basket.

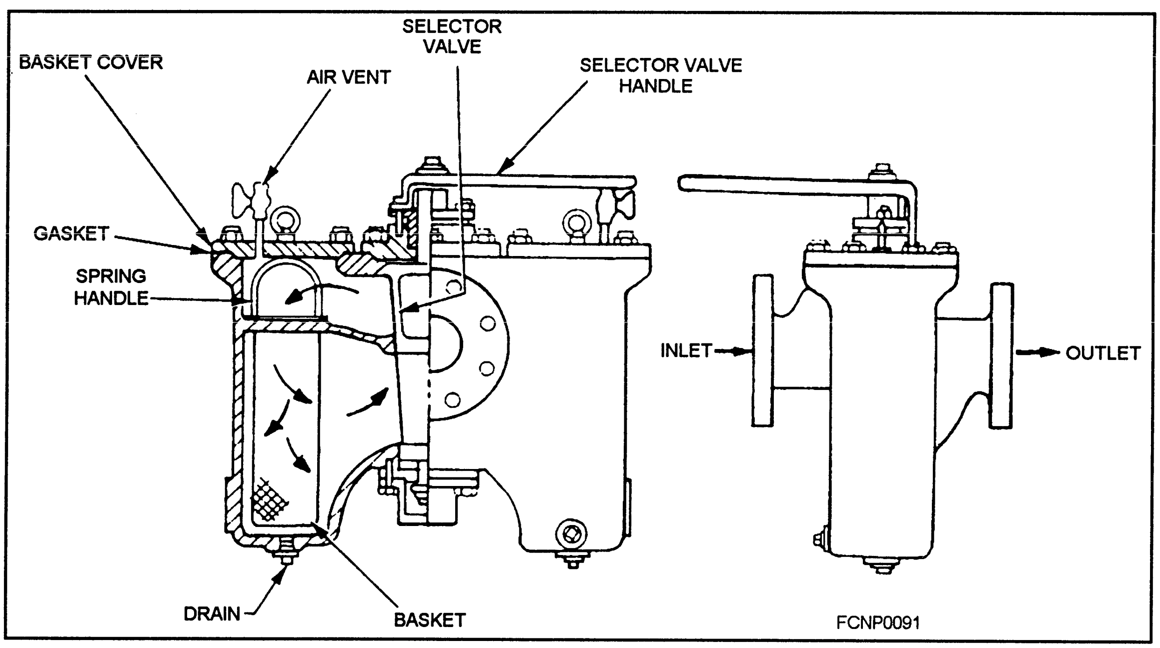


Figure 2-9.—Seawater duplex strainer.

The duplex pressure gage monitors the differential pressure between the inlet and outlet ports of the duplex strainer. The duplex gage provides a visual indication of a clogged strainer basket. To correctly use the gage, you should mark it when the basket is clean. When the basket is clogged, the pressure reading is usually 5 to 10 psi above the clean-basket reading. If the pressure drop is less than the clean-basket reading, you should check for a damaged or missing basket.

The basket handle (spring handle) acts as a spring-load to seat and hold the basket in the housing. A damaged spring handle will permit debris to bypass the strainer basket and clog the heat exchanger tubes. In some cases, the basket may spin inside the duplex strainer and physically wear away the basket seat and/or the side of the duplex strainer. The duplex strainer would then have to be removed for extensive repairs, possibly off the ship. New or replacement baskets should always be checked for proper spring-handle pressure against the top of the basket cover.

You should use only the correct gasket material for the basket covers, as specified in the Coordinated Shipboard Allowance List (COSAL). Inferior material can stretch and can be forced out from under the cover, permitting seawater to spray out and possibly flood the space.

TEMPERATURE-REGULATING VALVES

The temperature-regulating valves regulate the amount of cooling water flowing through or bypassing a heat exchanger to maintain a desired temperature of distilled water going to the electronic equipment. Temperature regulating is usually provided by a three-way or two-way temperature-regulating valve or a combination of both valves. The three-way valve is used where seawater is the primary cooling medium in the heat exchanger, whereas the two-way valve is used where chilled water is the primary cooling medium.

Three-Way Temperature-Regulating Valves

Three-way temperature-regulating valves are installed in liquid-cooling systems so that the incoming distilled water to the valve can be directed to the heat exchanger or caused to bypass the heat exchanger. More accurately, the distilled water is proportioned between these two paths.

The valve senses the temperature of the distilled water downstream of the junction between the heat exchanger outlet and the bypass and then proportions the two flows to obtain the desired temperature. The operating range of the three-way temperature-regulating valve is within ±5° of the setting on the valve.

The bulb contains a volatile liquid that vaporizes and expands when heated. The pressure generated in the bulb is a function of the temperature around it and is transmitted through the capillary tubing to the flexible bellows, which are loaded by the spring. Both the bellows and the spring rest on the end of the valve stem. Expansion or contraction of the bellows causes movement of the stem and the piston in the valve body. Movement of the bellows is opposed by the spring, which can adjust the operating temperature by the spring-tension adjustment wheel.

A drop in the temperature at the thermostatic bulb reduces the pressure in the thermostatic assembly, causing it to exert less force and resulting in an upward movement of the stem because of the force of the spring. As the stem is connected to the piston, the piston also moves upward, enabling more liquid to pass from the bottom inlet through the right outlet (bypass) side and, at the same time, restricting flow through the left outlet (heat exchanger) side. A rise in temperature at the thermostatic bulb results in a reversed effect.

Figure 2-10 shows a three-way temperature-regulating valve.

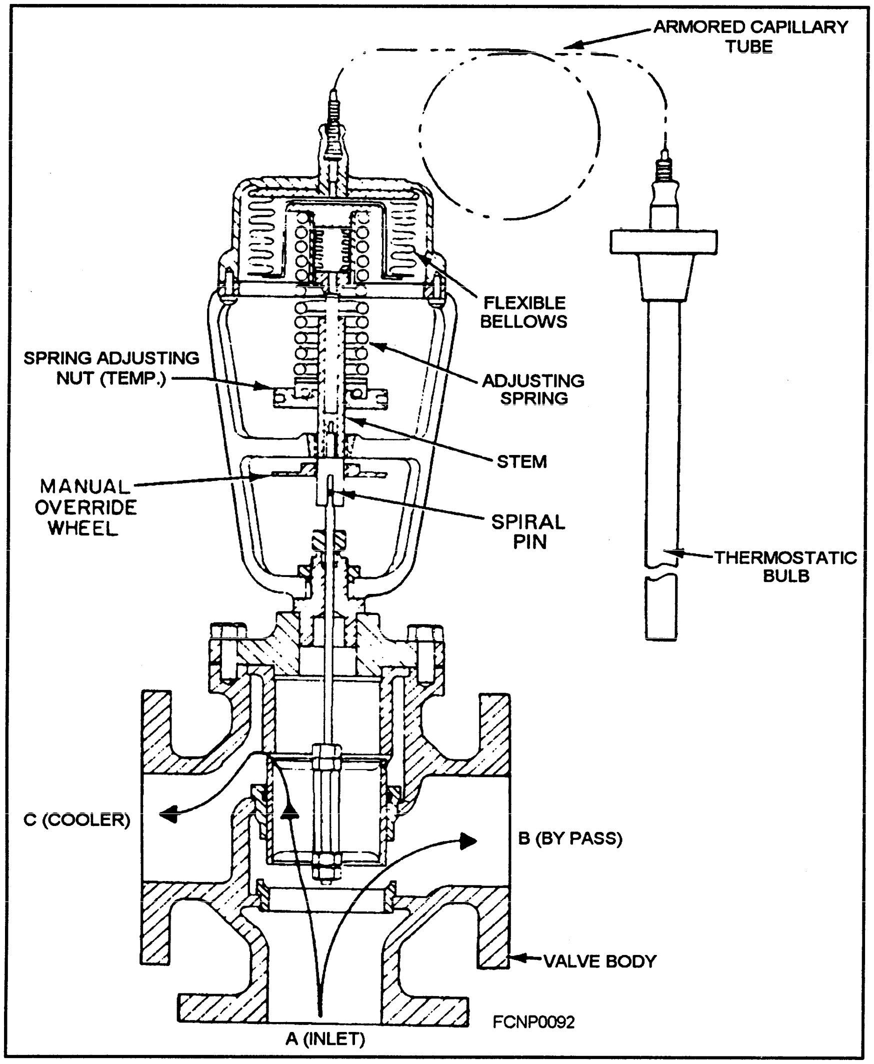


Figure 2-10.—Three-way temperature-regulating valve.

Two-Way Temperature-Regulating Valves

Two-way temperature-regulating valves in liquid-cooling systems are normally installed in the chilled-water supply to the heat exchanger with the thermostatic sensing bulb installed in the distilled-water outlet from the heat exchanger. The basic operation of the two-way temperature-regulating valve is the same as that of the three-way temperature-regulating valve. If the temperature of the distilled water is above the desired temperature, the two-way valve gradually opens to increase the flow of chilled water through the heat exchanger, which keeps the distilled-water temperature at the desired point.

Both the three-way and two-way temperature-regulating valves have a manual override feature to provide uninterrupted service, if the thermostatic assembly should fail due to damage to the capillary tubing or any other component of the thermostatic assembly. With the use of the manual override wheel, you can set the valve plunger/piston in the required position to operate the liquid-cooling system by turning the manual override wheel down (from right to left) until it touches the spiral pin in the valve stem. Beyond this point, the valve plunger/piston is forced down, allowing the flow of cooling medium through the valve. With the use of the installed thermometers, you can decide if more or less cooling is needed by turning the manual override wheel up or down. The use of the manual override inhibits the thermostatic assembly and should be used only when the thermostatic assembly is inoperable. Corrective maintenance of the regulating valve consists of inspecting the valve for leaks and for freedom of stem movement, adjusting the set point at which the valve regulates, renewing the thermostatic assembly, and cleaning and restoring valve parts. Any time that you remove a valve, you should center punch a dot code on each piece to ensure that the valve and the piping are installed in the original configuration.

Individual maintenance manuals for temperature-regulating valves should be closely followed. For example, if you remove the top of the thermostatic assembly without chilling the temperature probe, the bellows will expand and rupture, making the unit worthless. To verify that the thermostatic assembly has failed, close the valves upstream and downstream of the thermostatic bulb, drain the unit below the location of the bulb, and remove the bulb from its well. Place the bulb in a suitable vessel and observe the valve stroke while the bulb is alternately heated with hot water and cooled with cold water. If the valve thermostatic assembly does not respond, it has lost its thermostatic charge, and anew unit must be installed.

Figure 2-11 shows a two-way temperature-regulating valve.

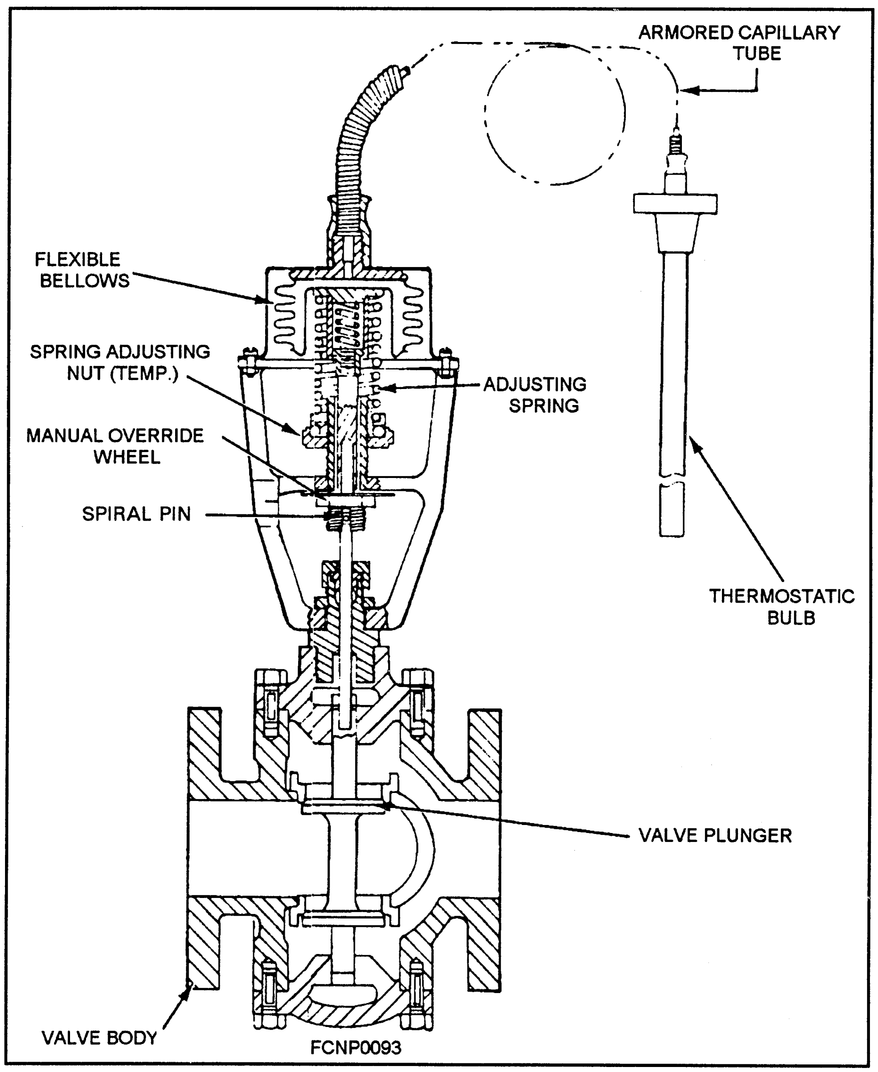


Figure 2-11.—Two-way temperature-regulating valve.

FLOW REGULATORS

Many different types and sizes of flow-regulating devices are used in both the primary and secondary cooling systems to reduce the pressure or flow of coolant through a cooling system. Figure 2-12 shows a constant-flow regulator.

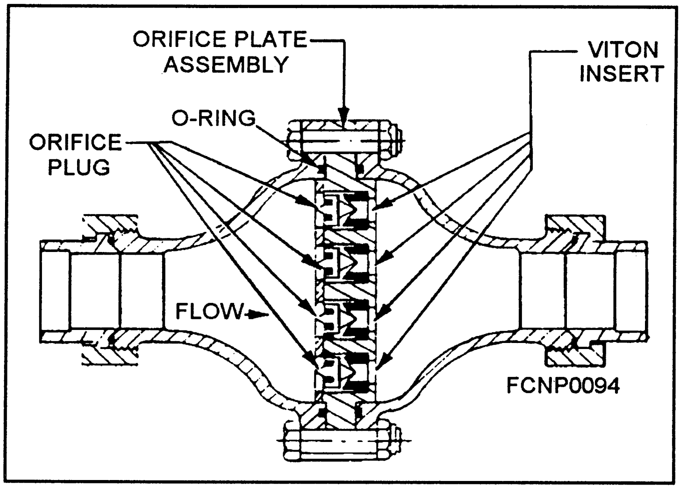


Figure 2-12.—Constant-flow regulator.

The orifice plate is found primarily in the seawater cooling system. It is the simplest design of a flow-regulating device and consists of a steel plate with a hole in it. With constant known seawater pressure and with a given hole size, the volume of water through the device can be determined. The use of an orifice plate is limited to where the input water pressure is essentially constant, such as the ship's fire main.

The orifice plate is normally installed between two pieces of flanged pipes upstream from the heat exchanger. This reduces the ship's fire-main pressure below the pressure in the secondary cooling system. If one of the heat exchanger tubes fails, the seawater pressure will be lower than the distilled-water pressure; therefore, it will not contaminate the secondary cooling system, as the secondary cooling system will force distilled water into the primary cooling system.

A ruptured heat exchanger tube or a bad single-tube sheet in a heat exchanger will give no visual indication of water loss except for the indication on the expansion tank sight glass.

To stabilize the flow of seawater and to prevent jet erosion of the heat exchanger and associated piping, the orifice plate should be installed with at least 15 pipe diameters of straight pipe upstream from the heat exchanger. When there is a drop in the heat exchanger primary input pressure and the seawater supply pressure has not changed, you should first check the duplex strainer differential pressure gage to ensure that the duplex strainer is clean. Then you should inspect the orifice plate for deposits or particles that could restrict the seawater flow. Also, you should inspect the orifice plate for erosion damage of the hole diameter. (Replace the orifice plate when there is an increased flow of seawater to the point that it could damage the heat exchanger.)

Never use the seawater valves to throttle (partially close) the flow of seawater in the primary cooling system, because the seawater will erode the internal parts of the valve. Such misuse would damage the valve, requiring extensive repair or replacement because it would no longer close properly.

When used with the chilled-water system, the constant-flow regulator (variable orifice) is installed downstream from the heat exchanger. This restricts the flow from the heat exchanger and keeps the heat exchanger fully submerged for greater efficiency (heat transfer). This flow regulator is not used in the seawater system because the internal parts would easily become fouled with marine growth and deposits. The operation is dependent on the movement of the orifice plugs (neoprene) to regulate the flow of water.

The equipment-flow regulator is used primarily with electronic equipment to regulate the flow of distilled water through the individual cabinets and components. It maintains a constant flow of distilled water with limited changes in the input pressure. At the minimum water flow, the total amount of water is passed through the device. As the flow of water increases to the flow regulator's maximum limit, the water flow is restricted by the movement of the insert, which causes the hole size to decrease, thereby regulating the flow of water. The amount of water that the flow regulator will pass is usually stamped on the side of the regulator. This is because the external dimensions are usually the same for differently rated regulators.

Normally used with a pressure-regulating valve, the nominal flow rate of the equipment-flow regulator, shown in figure 2-13, can be from 1/2 to more than 12 gallons per minute. However, this type of regulator can deteriorate over time, with the insert becoming distorted and causing a reduction in water flow. With a drill index set, you can use the back of a drill bit to measure the hole size and compare it to a known good constant-flow regulator or to the equipment manual. Do not drill out the insert to restore it to the proper size, because it will become distorted, thus preventing the insert from regulating the distilled-water flow.

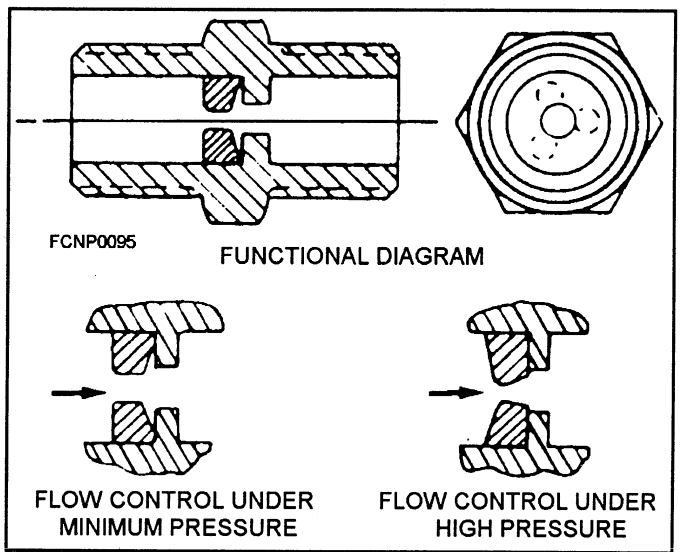


Figure 2-13.—Equipment-flow regulator.

The pressure-regulating valve is used to regulate a major section of the cooling system, whereas the flow regulator is normally used to regulate an individual feeder line to an individual component or cabinet. The pressure-regulating valve usually has a pressure-relief valve downstream from it to protect the equipment from becoming overpressurized. If a failure occurs in the pressure-regulating valve, the pressure-relief valve will keep the water pressure at a safe level to prevent equipment damage.

In a typical pressure-regulating valve, when a drop in downstream (outlet) pressure occurs, the pressure in the diaphragm chamber is lowered concurrently. The downstream side of the valve is connected to the diaphragm chamber through a narrow opening along the periphery of the piston.

The spring is allowed to force the diaphragm downward, releasing the tension on the rocker arm, and the inlet pressure opens the valve. The outlet pressure increases to the preset level, and the static control chamber pressure balances the valve spring to maintain a regulated downstream pressure to the served equipment.

You should take certain precautions with this type of valve. For example, ensure that the locknut is loose before you adjust the adjusting screw; otherwise, you could strip the threads of the brass spring chamber. If water starts leaking out of the vent, have the valve serviced for a leaking diaphragm before it ruptures. Never plug or paint over the vent to inhibit its operation.

If you remove a flow regulator or a pressure regulator, make certain that you reinstall it correctly, as it can be installed backwards. Look for an arrow for the direction of the flow or the inlet and outlet stamped on the body of the device. Pipe-joint sealant should be used only on the male pipe threads and not closer than one thread to the open end to seal the device. Figure 2-14 shows a pressure regulator.

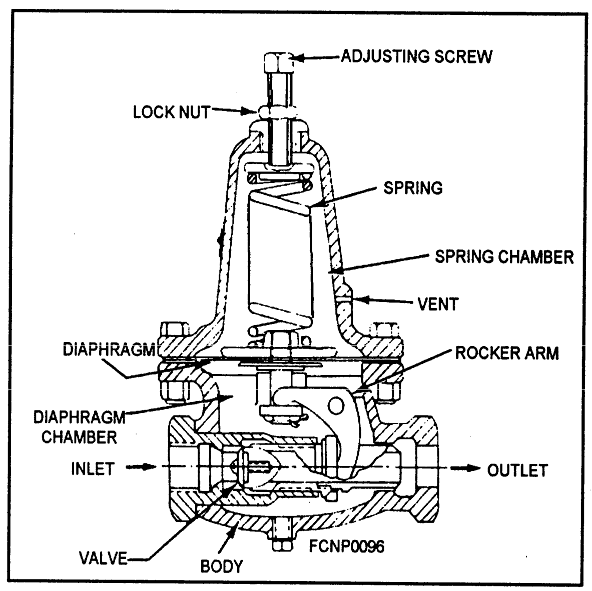


Figure 2-14.—Pressure regulator.

FLOW-MONITORING DEVICES

Most systems incorporate one or more types of devices to monitor the flow of distilled water through the system to ensure that the electronic equipment is supplied with an adequate flow of distilled water. A low-flow switch is normally found in the secondary cooling system to monitor the overall coolant flow. It is electrically connected to a common alarm circuit to warn personnel when the system flow rate drops below a specified minimum value. A typical cooling system low-flow switch is shown in figure 2-15.

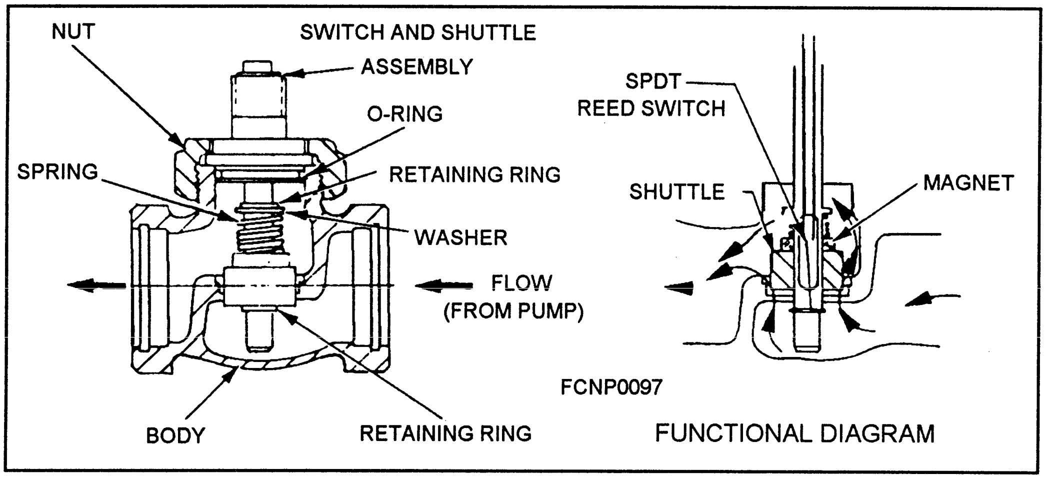


Figure 2-15.—Cooling system low-flow switch.

The main operating parts of the cooling system low-flow switch consist of a hermetically sealed reed switch and a permanent magnet attached to an internal shuttle. With the proper flow of coolant, the shuttle moves the magnet up and away from the reed switch, which keeps the reed switch contacts open. When the coolant flow drops below the minimum for a flow switch, the shuttle is forced down by the spring to a balanced condition against the flow of the distilled water. The magnetic field is now close enough to cause the reed switch to close and to activate the low-flow alarm.

A small flow switch is used in electronic equipment to monitor the flow to individual components. The flow of water through the orifice causes a pressure drop across it. This pressure drop causes the diaphragm to move against the spring. When the differential pressure (pressure drop) is sufficient, the microswitch activates to indicate that the switch has the proper flow through it. You should be sure that the flow switch is defective before overhauling or replacing it, as the problem could be a partially closed supply/return valve, an obstruction in the coolant line, an insufficient coolant pressure, or many other things. By using the coolant system pressure gages and/or the installation of a permanent or a temporary in-line flowmeter, you should be able to correctly isolate the problem.

In the secondary cooling system, a full-flow system flowmeter is provided to enable you to monitor the total system flow rate for troubleshooting purposes. Three types of system flowmeters are installed aboard ships; all of which monitor the coolant-flow rate. They are the venturi flowmeter, the orifice flowmeter, and the rotameter. Most systems incorporate one secondary coolant flowmeter and one or more smaller flowmeters to ensure that the electronic equipment is being supplied with an adequate flow of coolant.

A typical equipment-flow switch is shown in figure 2-16.

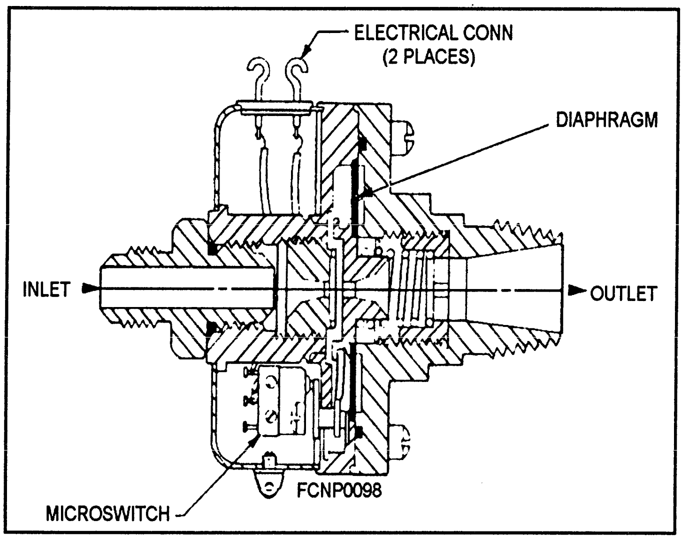


Figure 2-16.—Equipment-flow switch.

- **Venturi Flowmeter:** As the coolant approaches the contracted portion (throat) of the venturi flowmeter, the velocity of the coolant must increase as it flows through the contracted zone (throat). The angle of approach is such that no turbulence is introduced into the stream. A pressure tap is located at the side wall in the pipe ahead of the meter, and another one is located at the throat. The increase in velocity of the coolant water through the throat results in a lower pressure at the throat. The flow rate is proportional to the difference in pressure between the two taps. The gradual tapering of the meter walls back to pipe size downstream of the throat allows the coolant water to slow down with a minimum of lost energy. This allows a recovery of nearly 99 percent of the pressure on the approach side. To monitor the amount of flow through the venturi flowmeter, a differential pressure gage is used to monitor the pressure difference between the two pressure taps. A calibration chart is usually supplied with the flowmeter to convert the different pressure to gallons per minute (gpm), or the face of the meter may indicate readings in gpm. Figure 2-17 shows a venturi flowmeter.

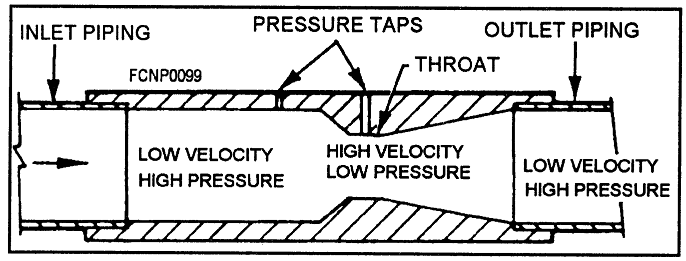


Figure 2-17.—Venturi flowmeter.

- Orifice Flowmeter: The orifice flowmeter works in the same manner as the venturi flowmeter, but its construction is much simpler and less expensive to manufacture. In place of the tapered throat, the orifice flowmeter uses a flat plate with a hole in it, which causes a considerable loss of pressure downstream. The efficiency of this type of flowrneter can be as low as 65 percent.

- **Rotameter:** The rotameter, shown in figure 2-18, is a variable area orifice meter that maintains a constant differential pressure with varying flow. The rotameter has a float positioned inside a tapered, tempered glass tube by the action of the distilled water flowing up through the tube. The flow restriction is the space between the float and the tube wall; this area increases as the float rises. The differential pressure is fixed, depending on the weight of the float and the buoyant forces resulting from the combination of float material and the distilled water's specific gravity. The tapered tube of the rotameter is usually glass, with calibration marks reading directly in gpm. The major advantage of a rotameter over a venturi meter is the visibility of the coolant, as it allows quick determination of excessive entrained air in the coolant.

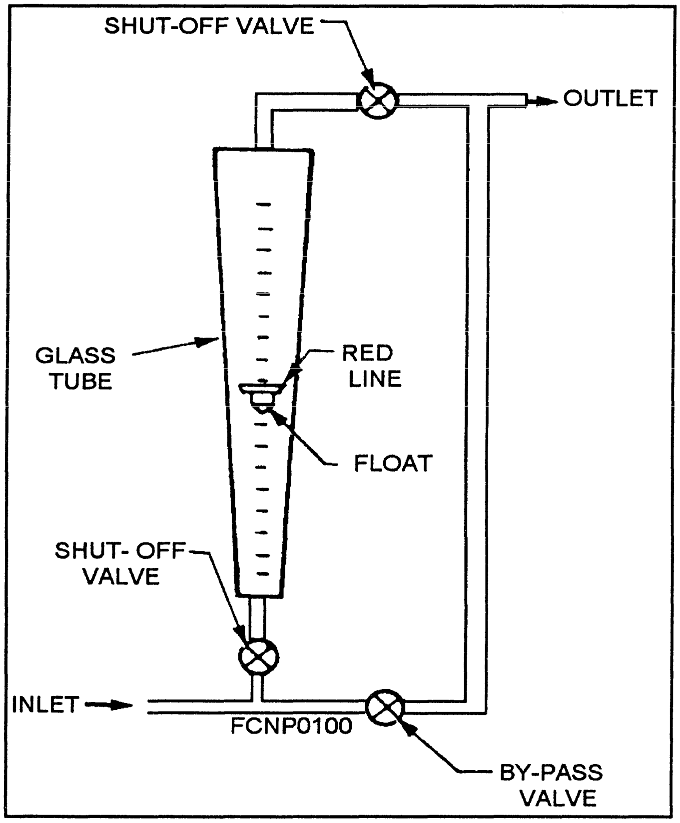


Figure 2-18.—Rotameter.

CIRCULATING PUMPS

Each cooling system has two secondary distilled-water circulating pumps. These pumps are identical in construction and capacity. One pump is designated for service, and the other is held in standby in case the designated pump fails. If the pump designated for operation fails, then the standby pump is used in its place. The pumps should be operated alternately (every other week) to prevent deterioration of the shaft seals, to equalize wear, and to permit Planned Maintenance System (PMS) actions to be performed regularly.

The two circulating pumps used in liquid-cooling systems are single-stage centrifugal pumps, closely coupled to a constant-speed electrical motor (the pump is built onto the motor). (Some older systems use a separate pump and motor joined by a flexible coupling.)

The centrifugal pump has two major elements—the impeller rotating on the extension of the electric motor shaft, and the casing (the impeller chamber). The impeller imparts the initial velocity to the coolant and collects the high-velocity coolant from the impeller and guides it to the pump outlet. A mechanical shaft seal is used to eliminate external leakage; this seal is lubricated and cooled by water ducted from a high-pressure zone of the pump. A vent valve is on the top of the pump casing to remove air and to ensure that the pump is primed with coolant.

Located at the outlet of each pump is a check valve to prevent coolant from the outlet side of the operating pump from circulating to the return side of the coolant system through the standby pump. Hand-operated valves at the pumps are used to isolate the pumps so that they can be removed for maintenance.

Each secondary circulating pump is rated in a gpm output at a specified head pressure in pounds per-square-inch-gage (psig) pressure, or in feet of water. The rating is usually at the pump's maximum efficiency point and varies depending on the pump design. On all pumps, as the output pressure increases, the output flow decreases, and vice versa. This relationship is almost linear, but varies with different pump designs. However, this condition means that if a restriction is placed in the pump output lines, the pressure will increase and the flow will decrease. The restriction could be a partially closed hand valve, a dirty filter, a damaged or crimped piping or hose, etc.

The pump performance indicators are the suction and discharge pressure gages and the system flowmeter. If you start a pump and the pressure fails to build up, you should exhaust air through the vent cock on the top of the pump casing. You should ensure that the suction valve is fully opened and that there is pressure on the pump suction pressure gage. If the flow doesn't develop, you should check for clogging and wear. *Never operate a pump without coolant flow.*

Some pumps have a small recirculating line that enables the pump to recirculate coolant from the discharge side of the pump to the suction side to provide for a flow of coolant through the pump if an inlet or outlet valve to the pump is closed with the pump running. Whatever the case, keep in mind that the operation of a pump without the normal flow of coolant through it will result in overheating and seizure of the pump. Included in the corrective maintenance of the circulating pump are repairing any leaks, replacing the mechanical seal, and cleaning the internal parts.

This type of maintenance is normally performed by the ship's engineering department; you should provide assistance if it is needed. Figure 2-19 shows a distilled-water circulating pump.

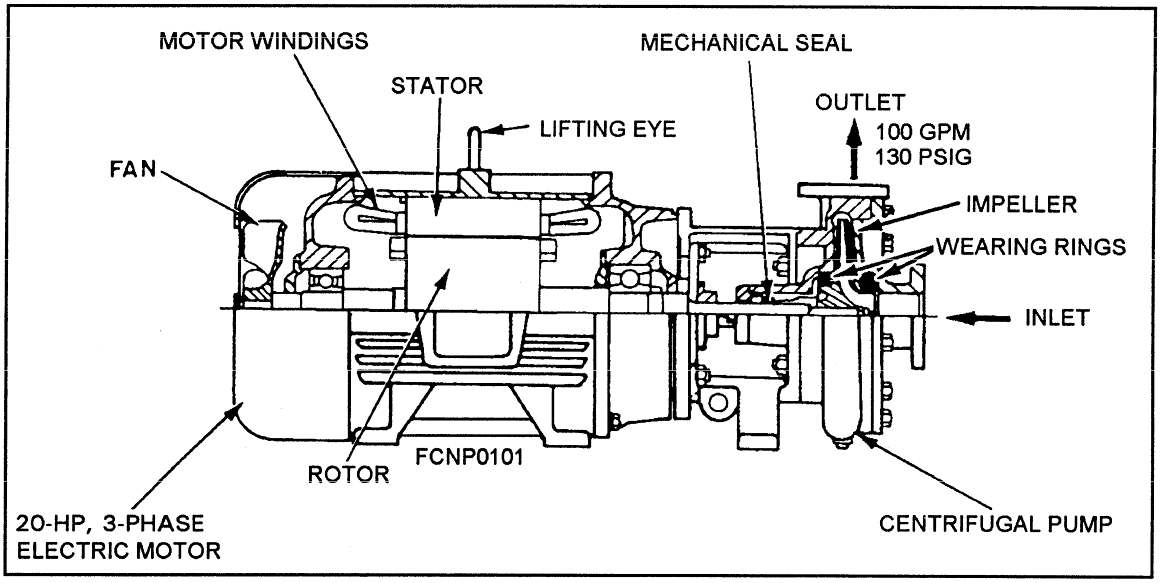


Figure 2-19.—Distilled-water circulating pump.

DEMINERALIZERS

Demineralizes are used to maintain the secondary cooling system's water purity in an ultrapure state. By maintaining the coolant at a high degree of purity, corrosion and scale formation is minimized on the radar unit.

Corrosion or scale on high-heat-density components, such as waveguide dummy loads and klystrons, results in the formation of a thermal barrier. The thermal barrier reduces the effectiveness of heat transfer at normal operating temperatures, which, in turn, leads to premature failure of the components.

The demineralizer is connected between the secondary cooling system supply and return lines to circulate water through it. The demineralizer is sized so that 5 percent of the cooling system volume passes through the demineralizer every hour. The coolant is purified by organic compound adsorption (if required), oxygen removal, ion exchange processes, and submicron filtration.

Figure 2-20 shows a typical three-cartridge demineralizer. Some demineralizers use only two cartridges, with one of the cartridges being a combination cartridge that provides organic compound adsorption, if it is required.

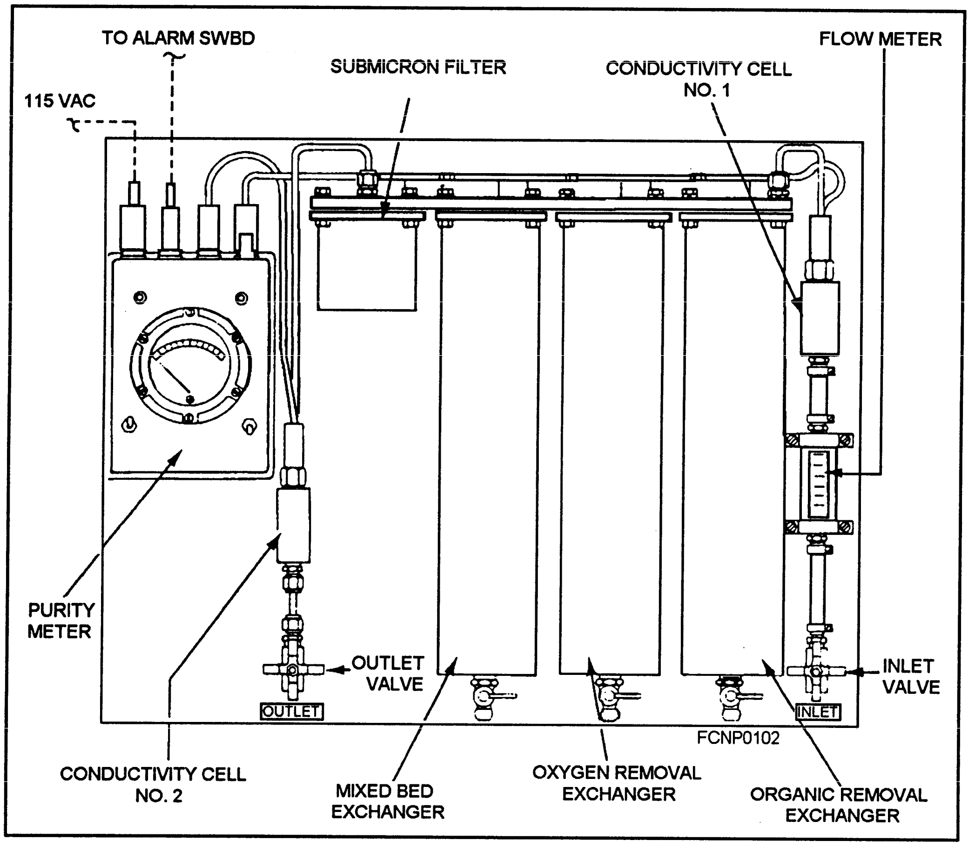


Figure 2-20.—Demineralizer.

The inlet supply valve to the demineralizer must be adjusted on system start-up and periodically thereafter to maintain the correct flow rate through the flowmeter. Too high a flow rate can damage the cartridges. If the flow rate cannot be increased to the proper rate with the inlet supply valve fully open, you should check to ensure that the outlet valve is filly open.

The submicron filter is used to remove small particles that have a size greater than 0.5 micron from the coolant flow. If the filter becomes clogged, it also reduces the flow of coolant, which necessitates a change of the filter cartridge or filter sheet (the membrane). To change the filter, you must properly position the demineralizer valves. If the filter cartridge or the membrane continually becomes clogged (about 1/2 hour or less after replacement), the usual cause in the distilled-water system is the presence of bacteriological impurities. Bacteriological impurities introduced into the secondary liquid-cooling system using distilled water may exist in the demineralizer cartridges and/or the whole secondary cooling system. If the impurities are in the whole secondary cooling system, the growth rate in a warmwater environment could be of a magnitude that exceeds the capability of the demineralizer. In that case, you must determine the source and magnitude of contamination. However, bacteriological contamination in a secondary cooling system that uses distilled water and ethylene glycol is highly improbable.

Improper handling or storage of the cartridges could cause them to be a source of contamination. Therefore, you should always store the cartridges in a cool, dry area, as exposure to heat hastens the growth of any biological contaminates that may have entered the cartridges. The three types of cartridges are organic removal, oxygen removal, and mixed bed.

- **Organic Removal Cartridge:** The organic removal cartridge, which contains granulated activated charcoal (carbon) to remove large organic molecules and chlorine by adsorption, is always installed in the first exchanger (if required) to prevent organic molecules from fouling the remaining cartridges.

Oxygen Removal Cartridge: The oxygen removal cartridge is composed of anion (negative charge) resins that remove oxygen from the water by ion exchange of sulfite ions to sulfate ions. By conducting a standard oxygen test (if the cooling system has an oxygen analyzer installed), you can test the quality of the outlet water from the demineralizer for oxygen content so that you will know when to replace an oxygen cartridge. When the oxygen cartridge is near exhaustion, it will have a urine odor, which is given off by the sulfate.

Mixed-Bed Cartridge: The mixed-bed cartridge is filled with cation (positive charge) and anion (negative charge) resins, which remove solids, dissolved metals, and carbon dioxide. The charged resins exchange ions with the contaminates, thereby removing them and leaving pure deionized coolant. Replace the mixed-bed cartridge when the purity meter indicates a low outlet purity.

Two conductivity cells monitor the coolant through the demineralizer. The first cell measures the purity of the coolant as it enters the demineralizer. The second cell measures the purity of the coolant as it leaves the demineralizer A conductivity cell consists of two electrodes immersed in the coolant flow path. The electrodes measure the conductivity of the coolant, which varies with the amount of ionized salts dissolved in it. If the impurity content increases in the coolant, the purity meter indicates higher conductance.

On some purity meters, the purity of the coolant is displayed as resistivity. In this typeof meter, an increase in the impurity of the coolant causes the meter to indicate a low resistivity. Conductance is the reciprocal of resistance, and is measured in siemens. Figure 2-21 shows a purity meter.

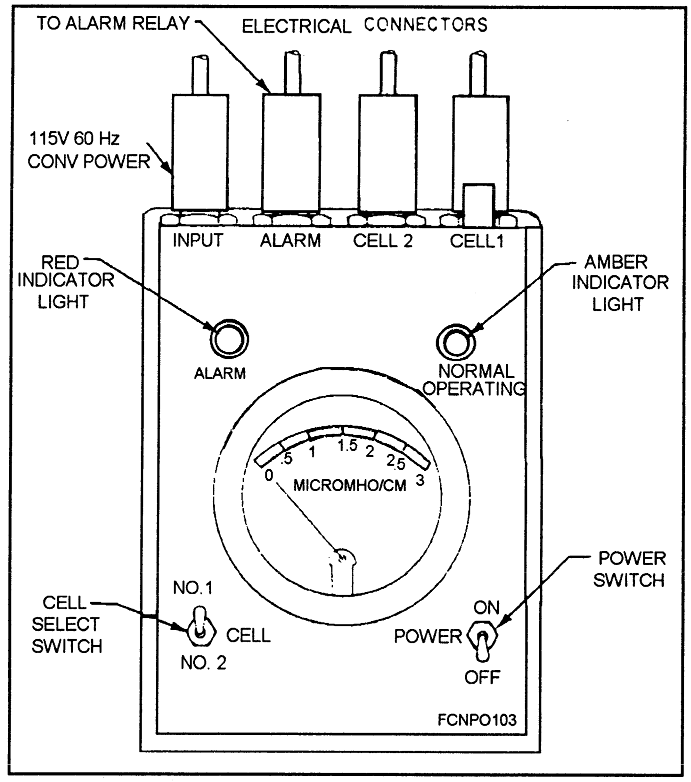


Figure 2-21.—Purity meter.

Resistivity is measured in megohms/cm. You can convert from conductivity to resistivity by taking the reciprocal of conductivity. Similarly, the reciprocal of resistivity is equal to the conductivity. A comparison of both ways of measuring the purity of the coolant is shown in table 2-1.

Table 2-1.—Distilled-Water Resistivity Versus Conductivity Data

Resistivity (Megohms/Centimeters)	Purity	Conductivity (Siemens/Centimeter)
10.0	} {	0.1
2.0	} Increasingly better {	0.5
1.0	} water purity {	1.0
0.5	} {	2.0
0.1	} {	10.0

The purity meter indication varies with ionized salt concentration and the temperature of the coolant flowing through the cell. The temperature effect is canceled by a built-in temperature compensation circuit.

The inlet conductivity is compared to a preset value of cell conductance to actuate an alarm circuit when the purity of the water drops below the preset level. In addition, the purity meter provides direct readings of the water purity at the inlet and the outlet of the demineralizer Typical operating requirements for the demineralizer are conductivity 1 micromho/cm at 77°F (resistivity 1 megohm/cm at 77°F), oxygen content 0.1 parts per million (ppm) by weight, and mechanical filtration 0.5 microns absolute.

When water has been circulated through the system for extended periods of time, a high-resistivity or low-conductivity reading may be indicated on both input and output samples. This condition is highly desirable and indicates that all ionizable material has been properly treated and that the demineralizer is maintaining a high degree of purity. When a system is filled with a fresh charge of water, it should be allowed to circulate for approximately 2 hours before comparing the input and output readings. During the initial circulation period, the resistivity readings vary because of the mixing action of water that has been treated by the demineralizer with the fresh charge of water.

A properly operating system can supply water of acceptable purity in 4 to 8 hours. Water in a system that has been secured for any length of time should be of acceptable purity within 2 hours. The resistivity or conductivity reading required for a specific installation must be maintained for optimum operation of the cooling water system.

The first indication of a problem in the demineralizer is usually indicated by abnormal purity meter readings (too low/high), an abnormal flowmeter reading, and/or alight and audible warning from the purity monitor. Some purity monitors can be tested for accuracy by a built-in test function on the meter to establish if the problem is in the purity monitor. If the purity monitor does not have a test feature, then use the calibration plug in place of one of the conductivity cells to test the operation of the purity meter. Most of the time, only routine maintenance is required to return the demineralizer to its normal operating condition.

Maintenance of the demineralizer consists primarily of the scheduled replacement of cartridges (before they are exhausted) and clogged filters. Obtaining satisfactory service life from the cartridges and filters is largely dependent on minimizing external contamination. Replacement cartridges must be kept sealed and stored in a cool, dry place until used. The circulating system must be kept tight to reduce the need for makeup water. Makeup water, in any case, should be as particle-free as possible and should not exceed 0.065 ppm chloride.

OXYGEN ANALYZERS

Oxygen analyzers are installed in some secondary cooling systems to measure the amount of dissolved oxygen in the liquid coolant. The presence of oxygen causes oxidation that leads to the formation of scale in the cooling system. An oxygen analyzer has an oxygen sensor installed in the supply side of the secondary cooling system.

The sensor is an electrolytic cell in an electrolyte solution or gel. The oxygen reacts with the electrolyte, causing a proportional change in the amount of current flow in the sensor. The sensor's electrical output is measured and displayed on the oxygen analyzer's meter, which is calibrated to read the oxygen content in parts per million or billion.

Because of the solid-state electronics and the few components used, the oxygen analyzer requires very little maintenance other than cleaning and changing the electrolyte in the sensor. When the meter on the analyzer requires frequent calibration because the meter readings are drifting or changing sharply, the analyzer has a bad sensor.

LIQUID-COOLING SYSTEM ALARM SWITCHBOARDS

The liquid-cooling system alarm switchboards (SWBDs) are installed in cooling systems to monitor various conditions to alert you to a problem that may develop in the cooling system. When an abnormal condition occurs, the alarm SWBD indicates the fault condition with both visual and audible alarms. The alarm SWBD usually has several remote bells and lights in the combat information center (CIC) and other electronic spaces aboard ship to indicate that a fault condition has occurred.

The alarm SWBD is in the CIC or the coolant pump room. There are several standard types of alarm switchboards used throughout the Navy.

A common type of alarm SWBD is shown in figure 2-22.

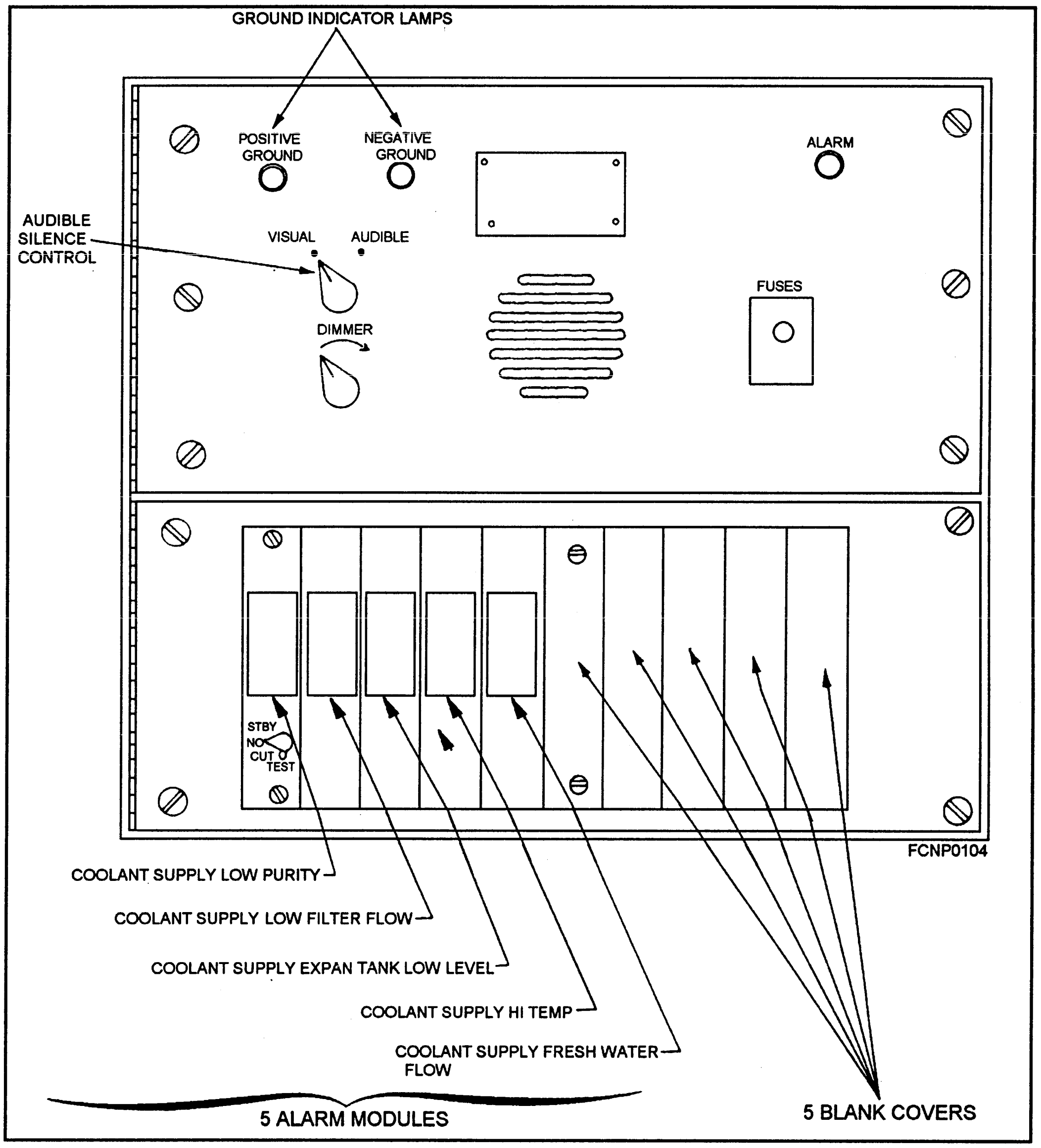


Figure 2-22.—Liquid-cooling system alarm switchboard.

On the main alarm panel, there are two ground indicator lamps to indicate the presence of a ground in the alarm system. All shipboard alarm panels and remote sensors are electrically isolated from the ship's ground. The only exception is the ground fault detector, which is connected to ground for ground monitoring.

If one or both lamps light, you should have the alarm SWBD and its remote sensors serviced by an electrician who has maintenance responsibility for removing a very dangerous shock hazard. The AUDIBLE silence control is a two-position switch that permits silencing (VISUAL position) the audible alarm on the main panel. The ALARM lamp on the main panel is lighted when the AUDIBLE silence control is placed in the VISUAL position, and the system is in an alarm condition.

The lower half of the alarm panel holds the alarm modules that are connected through the alarm panel to the remote sensors. If additional remote sensors are installed at a later date, a new alarm module is plugged into the lower panel for each sensor installed. Each alarm module includes a center-divided lighted display. Either half can independently display a steady red light, a flashing red light, or no light, depending on the circuit logic.

The six possible combinations of alarm module lights and the appropriate audible alarm are shown in figure 2-23.

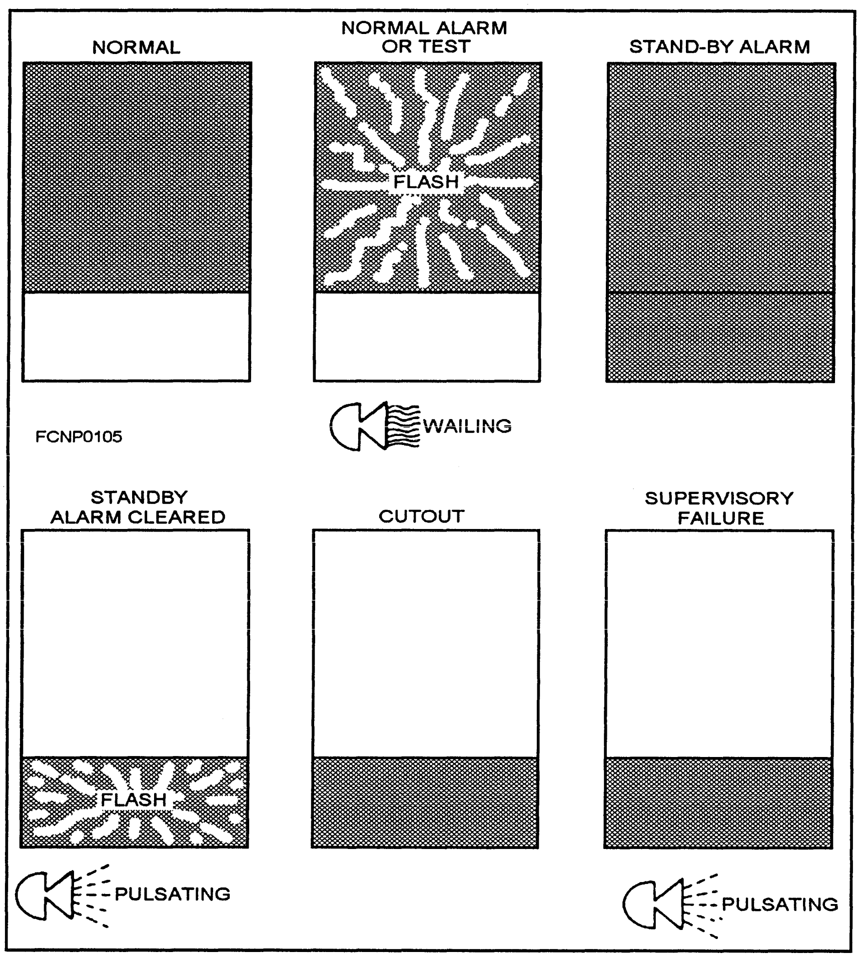


Figure 2-23.—Alarm switchboard visual displays and audible outputs.

On the lower half of each alarm module is a four-way position switch that allows you to place the individual alarm module in the following modes:

- **NORMAL:** This is the normal operation mode. With the sensor contacts open, the upper indicator lamp in the module is on steady while the lower lamp is off. If an alarm condition occurs, the sensor contacts will close; the upper lamp will then flash while the lower lamp remains off and an alarm command from the module actuates atone generator, producing a wailing alarm. If the sensor loop is open-circuited, with the selector switch in the NORMAL position, the alarm module will signal a supervisory failure. In this case, the upper lamp will be off while the lower lamp will be steadily on, and the tone generator will come on, producing a pulsating alarm.

- **STANDBY:** This is the position for acknowledging an alarm. If the selector switch is moved from the NORMAL to the STANDBY position during an alarm condition, both the upper and lower indicator lamps will be steadily on and the audible alarm will be silenced. When the alarm condition is cleared with the selector switch in the STANDBY position, the lower lamp will change to a flashing mode and the upper lamp will go out. Also, the command will be fed to the tone generator, producing a pulsating alarm.

- **CUTOUT:** With the selector switch in the CUTOUT position, the upper lamp is out while the lower lamp is steadily on. In this position, power is removed from the sensor loop to facilitate maintenance.

- **TEST:** The TEST selector switch position simulates an alarm condition. The upper indicator lamp flashes while the lower lamp is off, producing a wailing alarm.

LIQUID-COOLING SYSTEM MAINTENANCE RESPONSIBILITY

The most important responsibility that you have as a Fire Controlman that will extend the life of the liquid-cooling system components and increase the reliability of the cooling system is how you perform preventive and corrective maintenance according to the PMS. Properly performed preventive maintenance drastically reduces the amount of corrective maintenance necessary. When cooling systems are neglected, they deteriorate very quickly. To restore the cooling system to its proper performance, you may have to undertake extreme and costly repairs.

The PMS responsibility of the cooling system varies from one system to another. On some systems, the engineering department has the total responsibility of preventive and corrective maintenance. On other systems, you will share the maintenance responsibility jointly with the engineering department. In these situations, the Fire Controlman will probably perform the preventive maintenance, and the engineers will perform the corrective maintenance on major components.

When assigned the responsibility for maintaining the cooling system, you should perform the preventive maintenance in accordance with the maintenance requirement cards (MRCs) for that equipment to maximize the operation of the cooling system.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Basic Liquid Cooling Systems for Shipboard Electronics, NAVSEA 0948-LP-122-8010, Naval Sea Systems Command, Washington, DC, 1977.

All systems operating procedures that describe troubleshooting techniques and procedures applicable to each FCs on your ship class.

CHAPTER 3

COMBAT SYSTEMS ALIGNMENT (GUN/BATTERY)

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Describe the purpose of battery alignment.
2. Identify the primary equipment used in battery alignment.
3. Identify the alignment considerations needed for an accurate battery alignment.

INTRODUCTION

Combat systems alignment (gun/battery alignment) is the process of adjusting all the elements of a weapons system (including all gun bores, missile launchers, fire-control directors, radar antennas, and optics) to common reference points, lines, and planes, and maintaining them in this relationship. Battery alignment is a critical factor in the fighting effectiveness of any combat ship. Without proper battery alignment, the data exchanges between elements of the weapons systems would be in error.

The battery alignment of a ship is accomplished by two distinct procedures—original alignment (dry-dock alignment) and alignment afloat. Original alignment is the initial alignment made in a fire-control and weapons system at the time of original construction and installation. Original alignment is also performed when a new or modified major weapons system is installed. A check of this alignment is made when the ship is in dry dock.

Alignment afloat refers to alignment operations performed while the ship is in the water. Alignment afloat requires standards of accuracy just as high as those of the original alignment, with the primary difference being that alignment afloat is performed by combat systems department personnel with equipment available on the ship.

As a Fire Controlman, you must be able to correctly apply battery alignments. For more information on this topic, refer to the alignment procedures for your class of ship.

BATTERY-ALIGNMENT CONCEPTS

Battery alignment is based on the concepts of parallel lines, parallel planes, and a geometric coordinate system. Parallel lines are those lines in the same plane that, when extended indefinitely, do not intersect. Parallel planes are those planes that do not intersect. A geometric coordinate system provides a method for determining the position of a point, a line, a curve, or a plane in a space of given dimensions, called a *reference frame.* Figure 3-1 shows typical examples of parallel lines and planes.

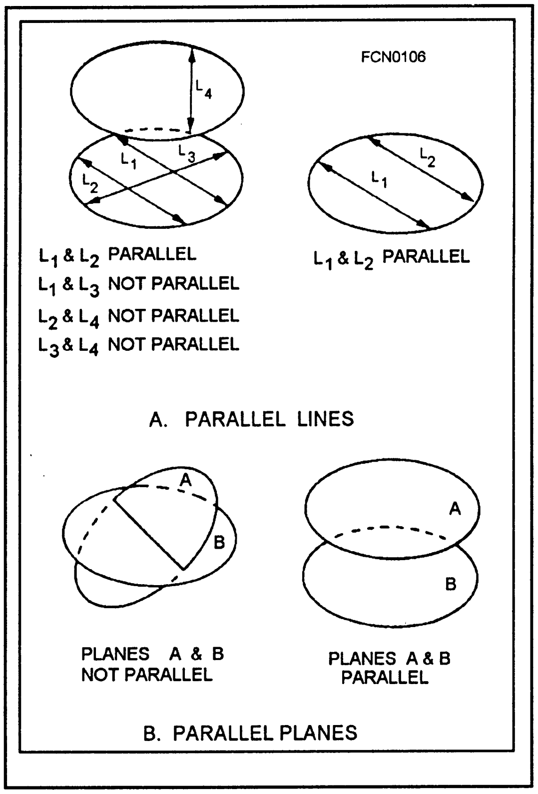


Figure 3-1.—Typical examples of parallel lines and planes.

Ultimately, the alignment of parallel lines, parallel planes, and coordinate systems is used to establish a pointing line for each piece of equipment in the ship's combat system. The line representing the direction in which apiece of equipment is pointing is the pointing line of that equipment. As previously indicated, the pointing line may be the bore axis of a gun, the line of sight of a director, or the propagation axis of a radar beam. Accurate alignment is not possible unless the pointing line is precisely determined.

FRAME OF REFERENCE

The reference point, the reference direction, and the reference plane form a geometric structure called the *reference plane.* In the complete reference frame, directions are specified by two angles (train and elevation), measured about the reference point. Figure 3-2 shows the measurement of an angle from a reference direction.

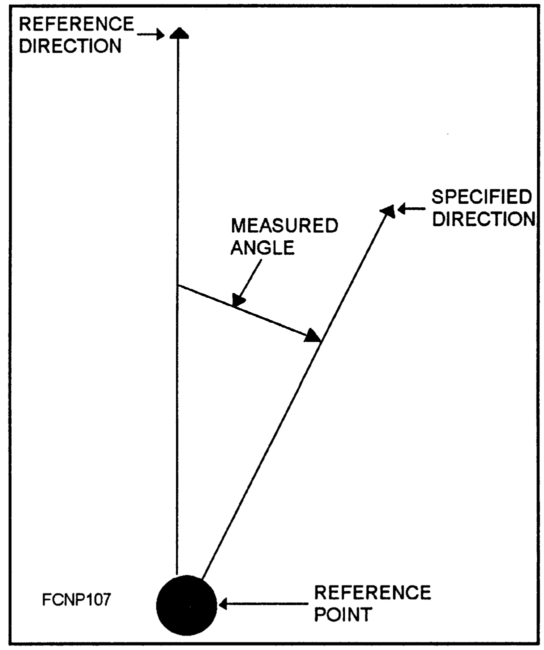


Figure 3-2.—Measurement of an angle from a reference direction.

A geometric measurement is based on a definite and complete set of geometric references. To permit clear and accurate definition of target position, a definite point on the ship (such as a director) is selected as the starting point for the measurement. As a reference point, a director center of rotation is selected arbitrarily because the director has interface with all the major equipment of a battery. Once the reference point is determined, it becomes apart of any future measurement made from it and must be clearly specified before subsequent measurements have any meaning.

Once the reference point is selected, a reference direction is established from which train angles are measured. Train angles are measured about the reference point, beginning at the reference direction. In naval combat systems, the ship's centerline, which points in the direction of the bow, is used as the reference direction.

Angles expressing direction cannot be described unless a means is available for specifying the plane in which the angle is to be measured. This plane is referred to as the *reference plane* and maybe any plane convenient for use. The horizontal plane is one of the most commonly used reference planes because of the ease of using a spirit level or similar device to determine the plane. In naval combat systems, the reference plane is parallel to the reference element (the director) roller path. Whichever plane is selected for reference, it must be clearly specified before subsequent measurements are of any significance. When the reference plane is used, a means must be established to denote the top of the plane to express the angle correctly. Train angles are measured clockwise from the reference direction on the top of the plane. Figure 3-3 shows a typical reference plane.

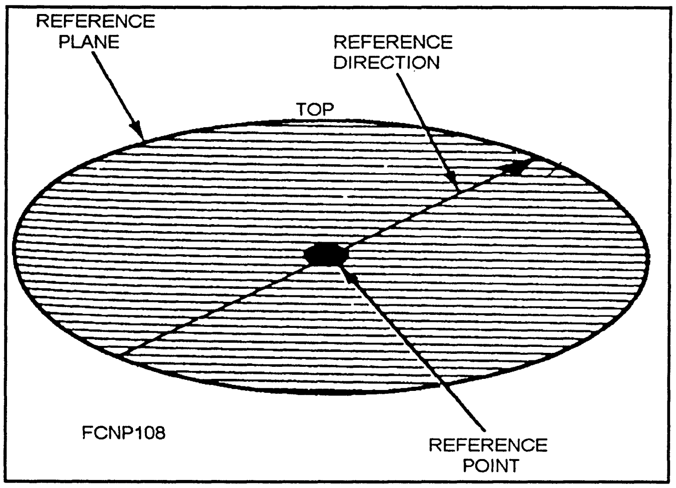


Figure 3-3.—Typical reference plane.

The elevation angle is in a plane perpendicular to the horizontal reference plane and is measured from the reference plane. The concept of a reference frame is important in the expression of a direction and the problems related to alignment. The reference point is a definite point aboard ship, and the reference plane and the reference direction have a definite orientation in respect to the reference point.

In fire control, it is often necessary to operate simultaneously with two or more reference frames. (For instance, these frames might be situated in different parts of a ship.) It maybe desirable to measure target data with several directors because of a need for flexibility in controlling different fire-control systems to obtain a wide range of view or if one director is out of commission. In such an event, you must be able to use the target data from either of the directors to get a fire-control solution. To interpret data measured in different frames, you must know how the frames are situated with respect to each other. Figure 3-4 is representation of a complete reference frame.

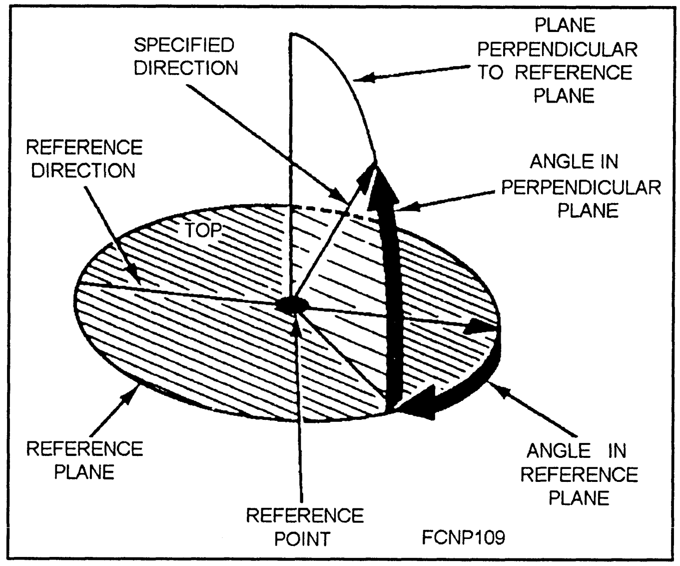


Figure 3-4.—Representation of a complete reference frame.

The difference or displacement between two frames may be of two kinds—linear and angular.

Linear Displacement

Linear displacement is the distance between two reference frames measured between their reference points. This displacement may be in the vertical direction, the horizontal direction, or both.

The corrections made necessary by the linear displacement between the reference points are called *parallax corrections* and are considered separately from corrections arising from the rotation between the frames. Parallax corrections can be separated into either dynamic parallax corrections or static parallax corrections.

DYNAMIC PARALLAX CORRECTIONS.— Position quantities computed for the reference frame are correct only for equipment located exactly at the reference point. Dynamic differences result because the motion of equipment not located at the reference point is different from the motion of equipment located at the reference point because of the rolling and pitching of the ship. These dynamic factors are usually negligible and are not normally corrected.

STATIC PARALLAX CORRECTIONS.— Static parallax is caused by the linear and angular displacements between the reference point and the equipment located elsewhere on the ship. Figure 3-5 shows two parallel reference frames (X and Y) displaced from each other by the distance (d). Frame X is the standard reference frame. The bearing of target (T), as determined from reference frame X, is 60°. If this is applied in a reference frame at Y, the line YT is determined. This line is parallel to XT, but it does not pass through the target because of the displacement between the reference frames. To cause the line from Y to pass through the target in this example, a parallax correction angle of 10° must be subtracted from the bearing value measured for frame X.

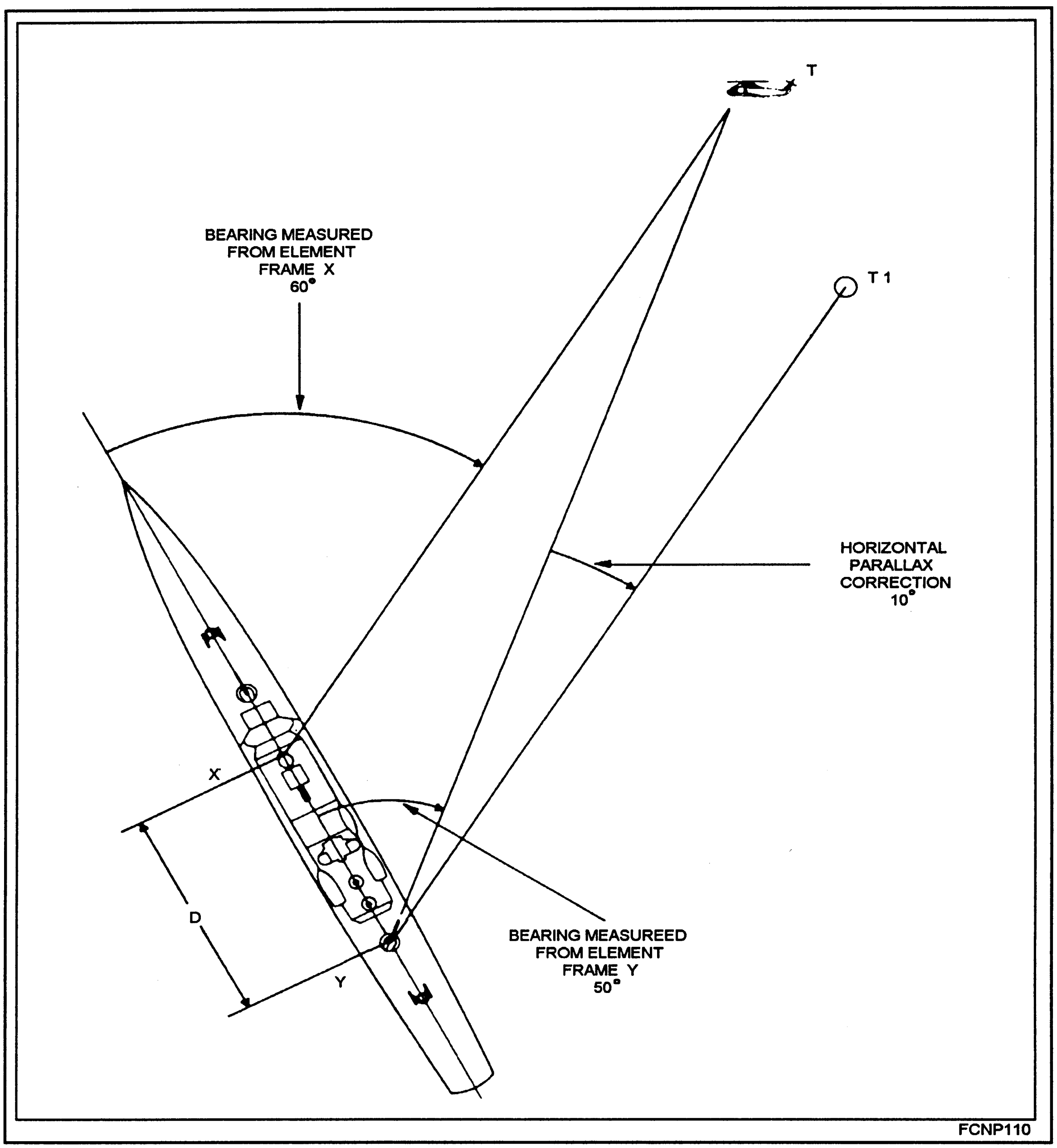


Figure 3-5.—Parallax resulting from linear displacement of two frames.

Elevation angles also are affected by displacements between reference frames. If elevation angles measured in one frame are to be used in another frame, they must first be corrected for parallax. The magnitudes of parallax corrections in train and elevation vary considerably with target bearing, elevation, and range, and the magnitude and orientation of the distance between the reference frames.

The basic point to remember is that whenever two reference frames are displaced from each other, data measured from one frame is, in general, not equal to data measured from the other frame. If the differences are significant, data measured in one frame must be corrected for parallax before it is applied in other frames.

Angular Displacement

Connections arising from reference directions or reference planes not being parallel are called *rotational corrections.* If the reference lines are both in a plane that is perpendicular to both reference planes, but the reference planes are not parallel, the bearing angles and the elevation angles are different.

When the angle between the reference planes is relatively small, the major difference is in the elevation angles; the difference in the bearing angles is usually small enough to be ignored.

Figure 3-6 shows rotational corrections between unparallel planes.

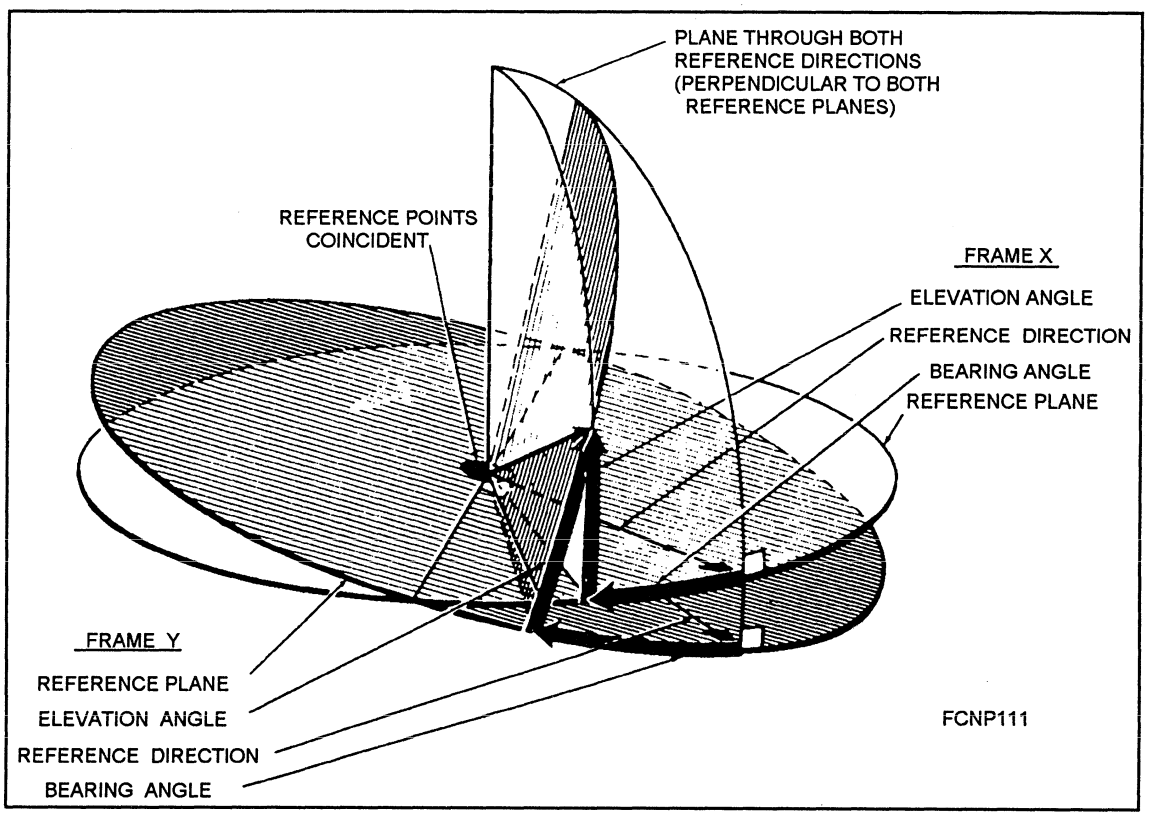


Figure 3-6.—Rotational corrections between unparallel planes.

ALIGNMENT EQUIPMENT

Alignment equipment is used by shipboard and shipyard personnel to align combat systems elements. Combat systems alignment checks and adjustments are usually accomplished with tools and test equipment normally found aboard ship. Because of required combat systems accuracy, special-purpose instruments are sometimes required for adjustments.

This section briefly describes the most commonly used alignment equipment, such as transits, theodelites, clinometers, levels, alignment sights, tram bars and blocks, benchmarks, and dials.

TRANSITS

A transit is an optical-surveying instrument that is used for measuring angles. Essentially, the transit provides an optical line of sight (LOS) that is perpendicular to, and supported on, a horizontal axis. The horizontal axis is perpendicular to a vertical axis about which it can rotate. Spirit levels are used to make the vertical axis coincide with the direction of gravity. Graduated circles with verniers are used to read the angles. A typical transit is shown in figure 3-7.

THEODOLITES

Theodolites are similar to transits, but they are normally more-precise instruments. Theodolites use micrometer microscopes that are especially designed for rapid and accurate readings and are used to read the graduated vertical (for elevation) and horizontal (for train) circles.

Micrometer microscopes create such precision that the accuracy of the optical reading device is governed by the circle and not by the way the circle is read. Different types of theodolites can be read directly to 10 inch, 1 inch, or 0.1 inch of arc. Figure 3-8 is an example of a typical theodolite.

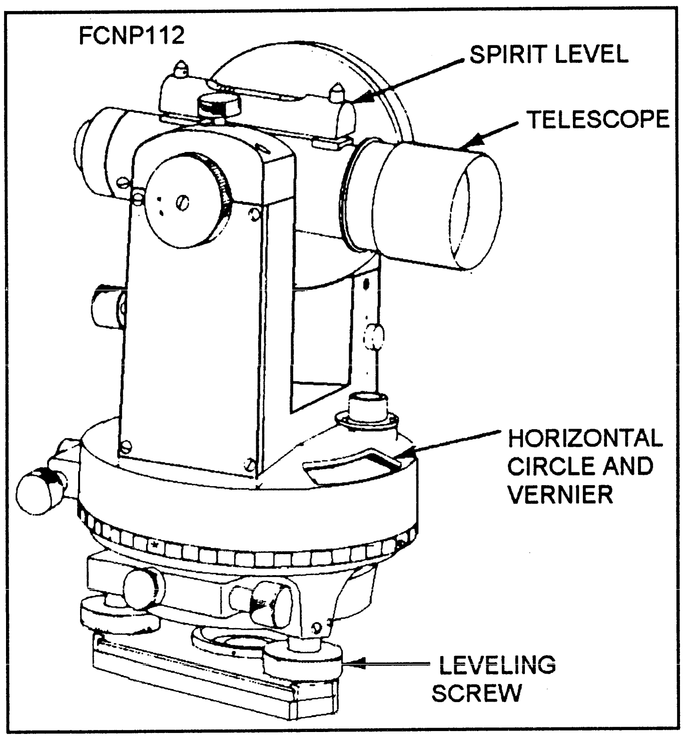


Figure 3-7.—Typical transit.

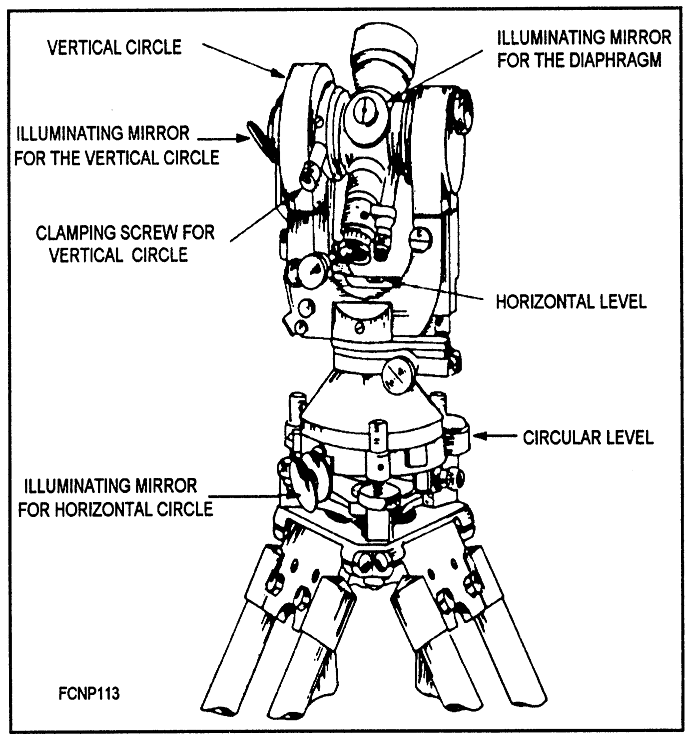


Figure 3-8.—Typical theodolite.

CLINOMETERS

Clinometers are used for measuring inclinations in the horizontal plane. They are used in naval shipyards principally to measure inclinations in equipment foundations and equipment roller-path inclinations (RPIs). All clinometers use a spirit level for indicating the true horizon and have some means of measuring inclinations of the base with respect to the horizon (spirit level).

Figure 3-9 shows the type of clinometer commonly used for making accurate RPI measurements. The micrometer drum 90° clinometer is read directly to 1 inch and can be interpolated to within 15 inches on the drum. The 6-inch-base length makes this type of clinometer suitable for many uses.

An adjustable base permits reading angles from zero, even when working surfaces are not perfectly horizontal.

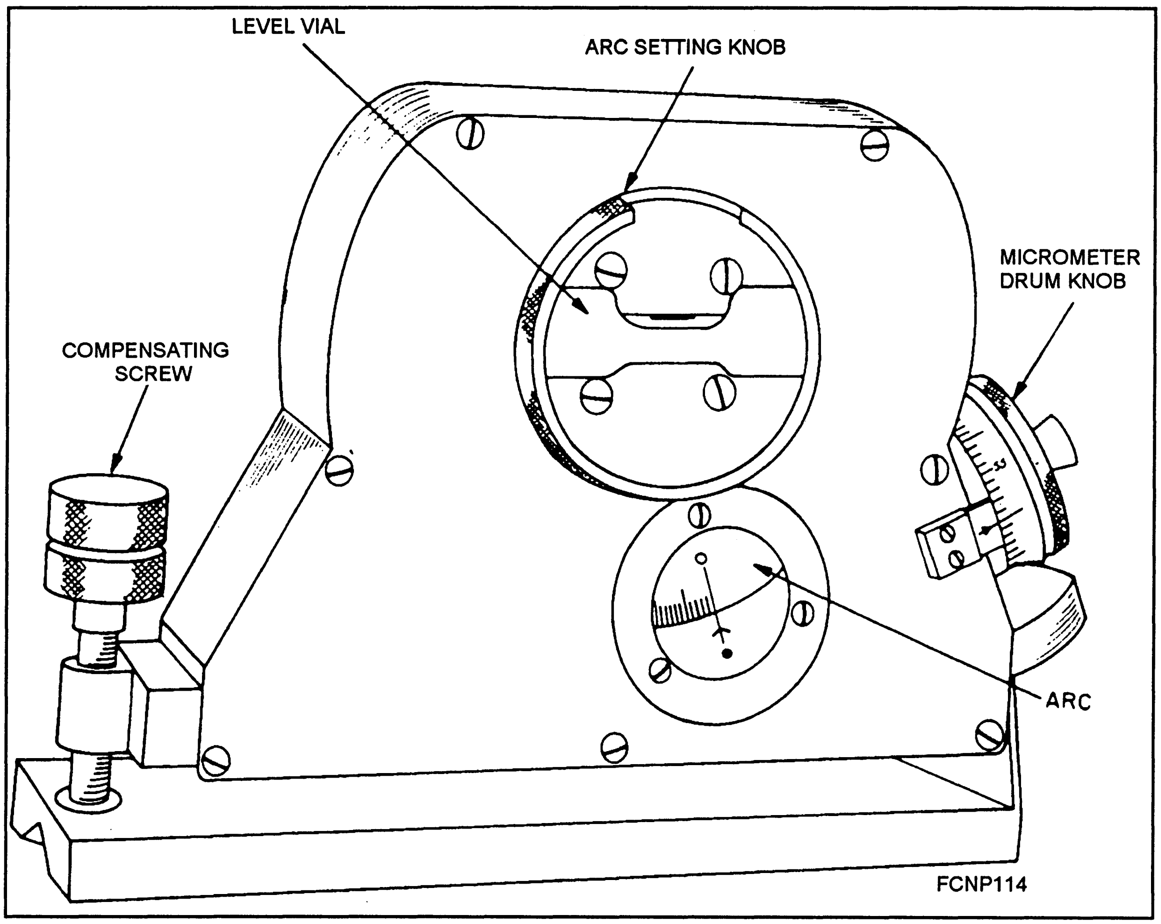


Figure 3-9.—Typical clinometer.

LEVELS

The two types of levels are (1) those that indicate entirely by means of graduations on the level vial, and (2) those adjustable types that are hinged at one end and have calibrated micrometer adjustments at the other end to extend the range beyond that on the level vial alone.

ALIGNMENT SIGHTS

Alignment sights are used to establish the pointing line of equipment. The pointing line maybe the bore axis of a gun, the centerline of a torpedo tube, the propagation axis of a radar beam, or some other similar line. Accurate alignment is not possible unless the pointing line is accurately determined. Some alignment sights are temporarily installed and are used for alignment and then removed from the equipment. Others are permanently installed and remain as part of the equipment.

Alignment sights include boresight telescopes and self-contained optics.

Boresight Telescopes

Boresight telescopes are used to represent the bore axis of a gun. These instruments are designed with self-contained optics in a single unit. The optics and features for positioning the instrument and securing it in the gun are all part of the unit. Most boresights of this class are provided with mounting surfaces that fit accurately into the gun bore. When the instrument is inserted into the gun bore, the LOS is brought into exact alignment with the gun-bore axis. Figure 3-10 shows atypical boresight with self-contained optics.

Self-Contained Optics

In alignments that use fixed, self-contained optics, the telescope is permanently mounted on a machined surface and accurately positioned so that the telescope LOS is parallel to the pointing axis of the antenna dish. Actual alignment is accomplished by mechanical movement of the antenna dish so that the radar beam is parallel to the telescope LOS or movement of the telescope so that it is parallel to the radar beam. Figure 3-11 shows typical fixed, self-contained alignment sights.

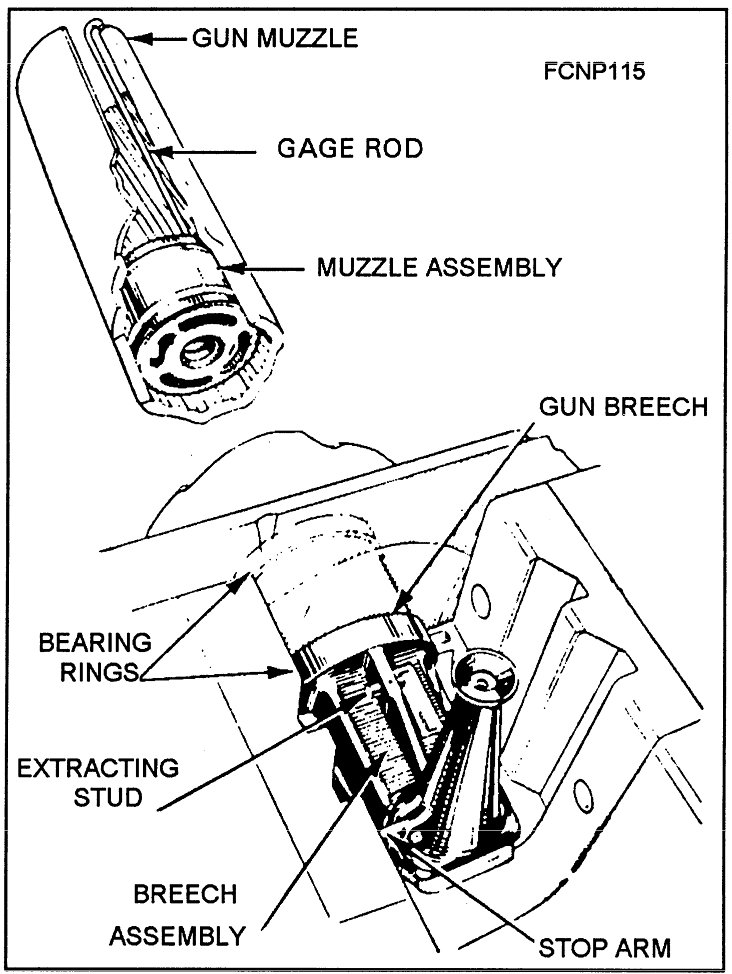


Figure 3-10.—Typical boresight with self-contained optics.

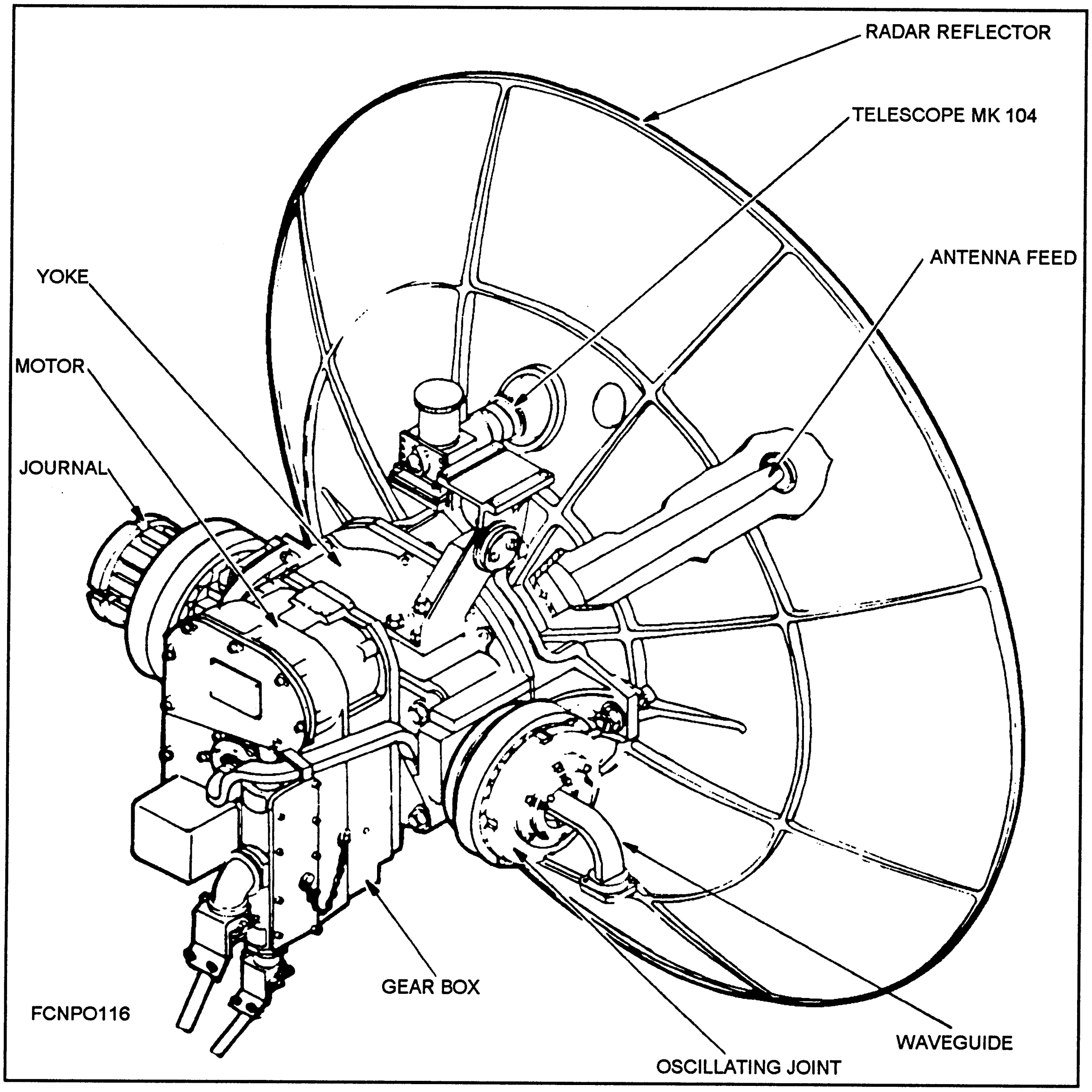


Figure 3-11.—Typical fixed, self-contained alignment sights.

TRAM BARS AND TRAM BLOCKS

Tram bars are used to set an element to an exact position, to determine the distance between two tram blocks that are fastened to the element. One block is fastened to the rotating structure of the element, and the other block is fastened to the fixed structure of the element. As shown in figure 3-12, the tram bar is used to ensure the correct positioning of the movable block.

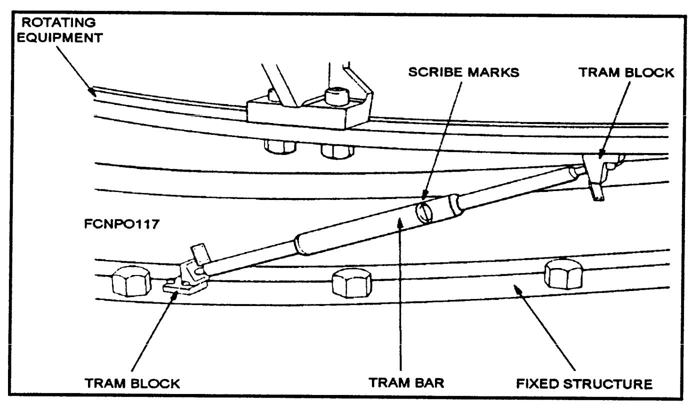


Figure 3-12.—Tram bar and tram blocks.

The two types of tram bars are rigid and telescopic. The rigid tram bar is of fixed length and does not allow for error. The telescoping feature of the telescopic tram bar makes it more convenient and safer to use. For this reason, this chapter discusses the telescopic tram bar. Both, however, accomplish the same purpose.

As shown in view A of figure 3-13, the telescoping tram bar consists of two parts, one bar sliding within the other. The parts of the bars have a small amount of movement with respect to each other and are extended by an internal spring. A scribe mark on the inner part is visible through an opening in the outer part. Engraved on the edges of the opening is a graduated scale that runs on each side of a zero mark. When the inner scribe mark and the outer zero mark are in line, the tram bar is at the correct length.

As shown in view B of figure 3-13, a gage is furnished with the instrument to check that the zero line and the scribe mark match when the length is correct.

As shown in view C of figure 3-13, the block has pins with cupped ends that fit the rounded ends of the bar. One block has a fixed pin, whereas the other has a movable pin. After the blocks are welded in place on the element, the movable pin can be adjusted so that the scribe mark and the tram bar zero line match exactly when the dials of the element are at some predetermined reading. The movable pin is then tack-welded in place. To protect the ends of the pins from damage and corrosion when the pins are not in use, the pin ends are covered with grease-filled caps.

Tramming operations should be performed with great care to prevent injury to personnel or damage to the equipment.

- The equipment power drives should not be used unless it is absolutely necessary.

- The equipment should be positioned to the approximate tram position and the bar inserted with the heavier end down.

- The bar should not be held in place while the tram blocks are moving with respect to each other. However, if necessary, holding should be done only while the blocks are moving away from each other.

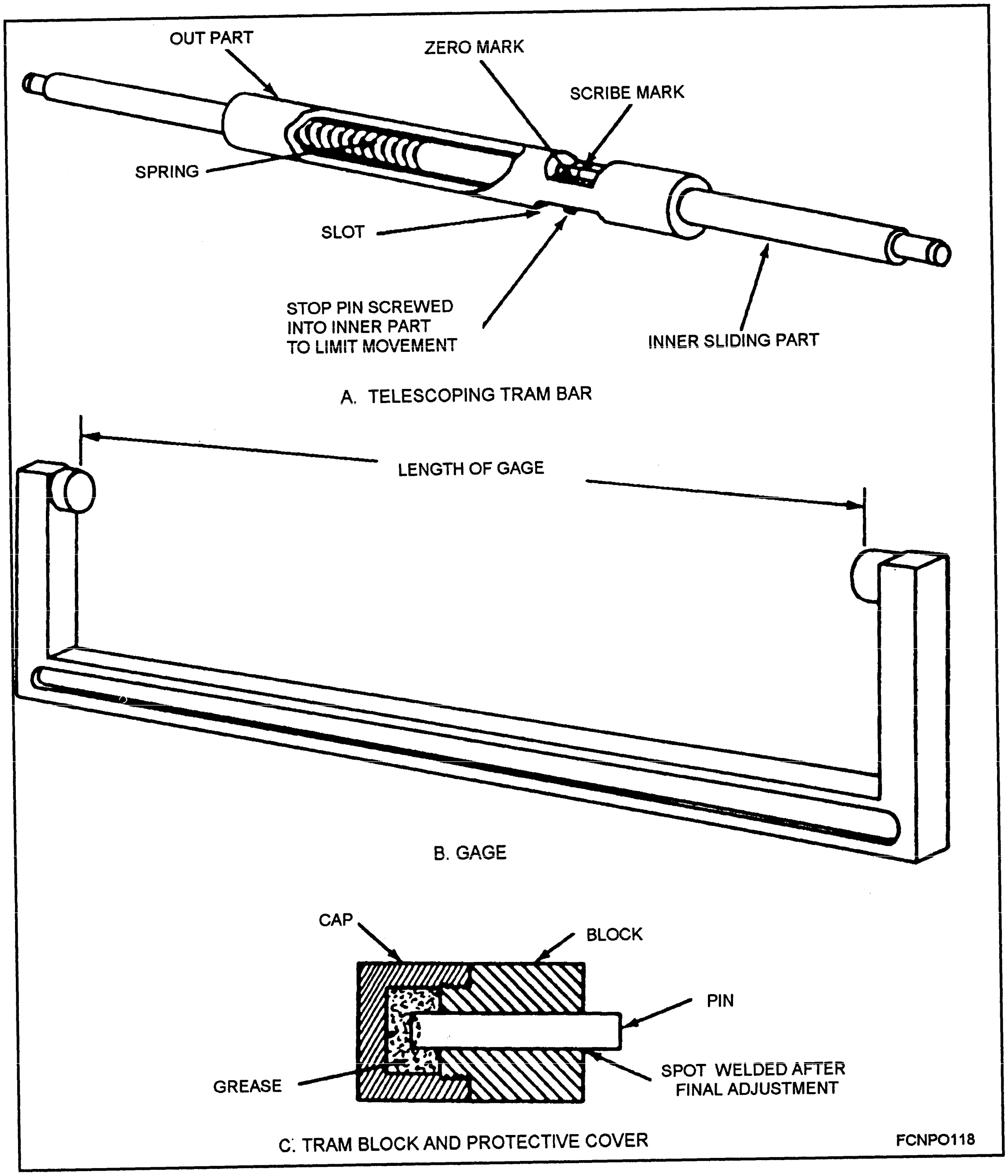


Figure3-13.—Telescoping tram bar and related equipment.

BENCHMARKS

Benchmarks are small metal plates that contain an engraved cross. The plates are either brazed or welded to some rigid portion of the ship's structure at a position where the engraved cross can be sighted on with the reference element (director). A benchmark maybe engraved on a flat plate for bulkhead mounting or on a block with an inclined surface so that the mark is clearly visible on the ship's deck. Benchmarks are reference marks used in alignment to establish the angular relationships (elevation and train) of an element's line of sight to the ship's structure. When an element is sighted at its benchmark, its dial readings should agree with recorded values. If there is disagreement, alignment of the element is necessary.

Figure 3-14 shows two typical benchmarks.

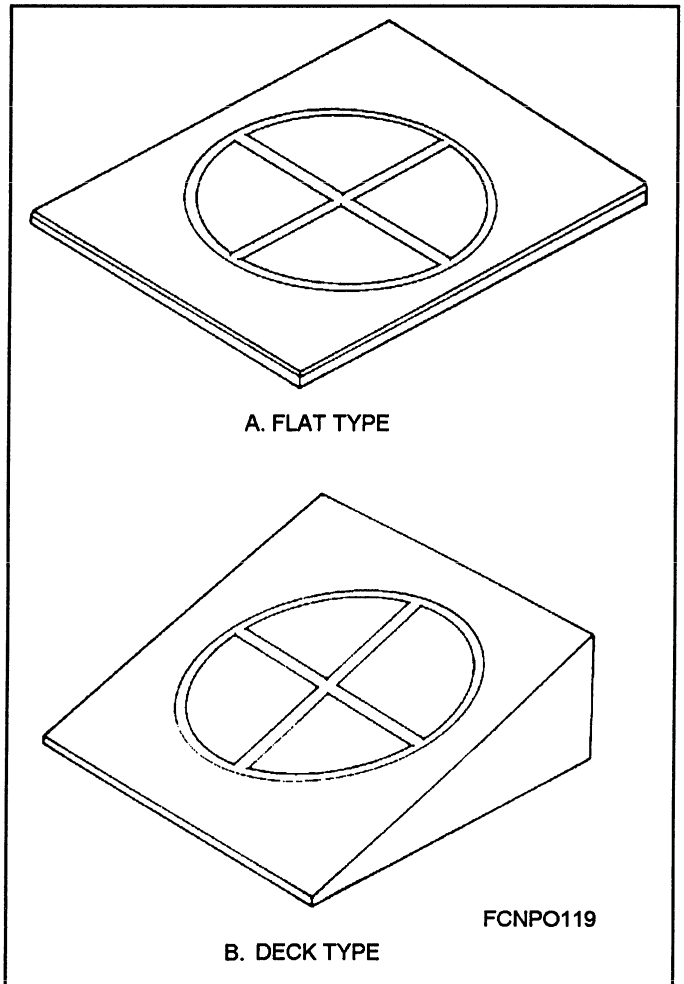


Figure 3-14.—Typical benchmarks.

DIALS

Although the dials that must be read by alignment personnel are part of the equipment being aligned and cannot properly be considered to be equipment requiring alignment, a brief review is given of the precautions to be observed in reading dials.

The correct reading of dials is extremely important in alignment work. A simple mistake. in reading a dial can cause great difficulty or unnecessary work. Such mistakes are often made, even by experienced personnel, and are made most often because of carelessness or undue haste.

Before you attempt to read a dial, it is essential that you familiarize yourself with the values of the graduations and the manner in which the dials operate. This is particularly important if the dials are not read frequently. In such cases, several trial readings should be taken and checked with someone else before starting the alignment. Even familiar dials should be read systematically and deliberately. Above all, no attempt should be made to hurry. A few extra seconds spent in making a careful reading may later save hours of work involved in performing an unnecessary adjustment procedure.

ALIGNMENT CONSIDERATIONS

There are certain major steps in combat systems alignment that must proceed according to a specified sequence. Strict adherence to the order in which the steps are conducted is essential to the successful completion of the alignment task. The sequence in which these steps are to be performed is shown in table 3-1.

Table 3-1.—Procedures for Combat Systems Alignment

STEP	PROCEDURE
1	Establish reference planes.
2	Place reference marks.
3	Establish parallelism.
4	Perform fire-control radar RF optical alignment.
5	Establish train and elevation zero alignment.
6	Perform train and elevation space alignment (star checks).
7	Establish initial benchmark and tram reference readings.

Initially, these steps are accomplished by the installing activity during ship construction. Thereafter, shipboard alignment checks and verification consist mainly of benchmark checks, tram checks, and star checks.

This section briefly discusses the establishment of reference planes, the placement of reference marks, the establishment of parallelism, the performance of fire-control radar radio-frequency-optical alignment, the establishment of training and elevation zero alignment, the performance of training and elevation space alignment, the establishment of benchmark and tram reference readings, and the combat/weapons systems smooth log.

ESTABLISHMENT OF REFERENCE PLANES

The first major alignment step accomplished by a support activity is the establishment of reference planes. Referencing surfaces consist of the ship base plane (SBP), master reference plane (MRP), centerline reference plane (CRP), and weapons-control reference plane (WCRP).

Ship Base Plane

The ship base plane (SBP) is the basic horizontal plane of origin. The SBP is perpendicular to the ship's centerline plane and includes the base line of the ship, but it is not necessarily parallel to the keel of the ship. The SBP is used in establishing the MRP.

Master Reference Plane

The master reference plane (MRP) is the first physical plane that is established for combat systems alignment. The MRP is parallel to the SBP and is represented by a master level block or plate, usually located on a lower deck of the ship. The plate is installed, aligned, and leveled only once after hull integration and is never adjusted thereafter. The master level plate serves as the reference for machining the foundations of the combat systems equipment throughout the life of the ship.

Centerline Reference Plane

The centerline reference plane (CRP) is established during ship construction by the installation activity. It is the plane containing the ship's centerline and is perpendicular to the MRP. The CRP is the reference used to establish train zero alignment of all combat systems equipment. The CRP is used throughout the life of the ship.

Weapons-Control Reference Plane

The weapons-control reference plane (WCRP) is the plane to which the foundations and the roller-path planes (RPPs) of all combat systems equipment are leveled. The WCRP is used throughout the life of the ship to determine RPP parallelism between the equipment of the combat/weapons systems.

PLACEMENT OF REFERENCE MARKS

The second major alignment step is the placement of centerline marks, offset centerline marks, and equipment benchmarks, which are performed by a shipyard or support activity.

Centerline Marks

Centerline marks are established during initial construction to represent the ship's centerline. Small plates (at least three forward and three aft) are installed at intervals along the centerline to mark its location. Small plates are also installed in certain ship spaces to mark the location of the centerline.

Offset Centerline Marks

Offset centerline marks are also established during initial construction to facilitate combat systems alignment. The offset centerline is normally established parallel to or perpendicular to the ship's centerline. Offset centerline marks not parallel or perpendicular to the ship's centerline are stamped or marked with the angles relative to the ship's centerline. Offset centerline marks are also established, as required, in interior compartments of the ship to facilitate the alignment of the combat systems. Both the centerline and offset centerline marks are installed to preclude the necessity for repeating the centerline surveying during subsequent alignment.

Equipment Benchmarks

Each equipment with an alignment telescope has a benchmark that can be sighted through the telescope. Equipment benchmarks are installed at any convenient location that is visible through the equipment telescope. These benchmarks are used throughout the life of the ship to verify that the alignment is still within tolerance.

ESTABLISHMENT OF PARALLELISM

The third major alignment step is the establishment of parallelism between the RPPs of all equipment in the combat system. The degree of parallelism required is based on the design and manufacturing criteria, the operational environment, and the requirements of the various operational modes. The steps necessary to achieve the degree of parallelism required are inclination verification, foundation machining, and interequipment leveling.

Inclination Verification

Inclination verification consists of measurements of the tilt between two RPPs. The amount by which one RPP is tilted with respect to another RPP is expressed as the *angle of inclination* between the planes and the bearing where this inclination occurs. The tilt of the RPP is usually determined by the two-clinometer method or the horizon-check method.

Foundation Machining

Foundation machining pertains to the physical processes required to attain a specified degree of parallelism and is performed by a support activity. Physical processes may involve using milling machines or welding premachined surfaces in place. Machining is accomplished with the ship afloat and loaded to simulate the fill-load-deflection curve and the strains of major concentrated loads. The ship is kept in the specified loaded condition for a sufficient period of time (48 hours) before the start of machining operations to allow ship structural members to adjust to the load. Strict adherence to normal shipyard techniques of machining during periods of minimum temperature changes is observed.

Interequipment Leveling

Interequipment leveling is achieved by leveling rings, shims, adjusting screws, or software compensation. Leveling capabilities are used to achieve the RPI tolerances imposed by the minimum acceptable requirements or the various operational modes of the combat system. Where leveling capabilities are not provided, RPI tolerances are achieved through foundation machining. In cases where foundation machining is initially used to meet these tolerances, RPI compensation through computer software changes may be introduced, if necessary.

PERFORMANCE OF FIRE-CONTROL RADAR RADIO-FREQUENCY OPTICAL ALIGNMENT

The fourth major alignment step is the verification of fire-control radar radio-frequency (RF) optical alignment (collimation). During initial installation, the RF optical alignment is established and the optics are secured in place. During subsequent alignment checks, the radar antennas or the optics, as applicable, are adjusted to correct any alignment error between the optical axis and the RF axis. When the radar is tracking, the RF axis is the reference used for target location. RF optical alignment is an equipment-level test and is performed on a certified shore tower facility or, in the case of some radars, may be performed while tracking a target.

ESTABLISHMENT OF TRAIN AND ELEVATION ZERO ALIGNMENT

The fifth major alignment step is the train and elevation zero alignment. This alignment, performed by the ship's force or a support activity, is conducted to ensure that all combat systems equipment points to the same point in space when so directed.

The two types of train and elevation zero alignment are equipment with alignment or boresight telescopes and equipment without telescopes.

- **Equipment with alignment or boresight telescopes:** Train zero is defined as the angle at which the telescope axis is parallel to the ship's centerline plane. Elevation zero is that angle at which the telescope axis is parallel to the RPP. Train and elevation zero alignment is carried out by physically positioning each equipment to train and elevation zero by using surveying techniques and zeroing the dials and synchros, or by compensating for the train and elevation errors through computer software changes.'

- **Equipment without telescopes:** Train and elevation zero alignment is accomplished by matching an indicator to a scribe mark or plate and zeroing the dials and synchros.

PERFORMANCE OF TRAIN AND ELEVATION SPACE ALIGNMENT (STAR CHECKS)

The sixth major step of initial alignment is train and elevation alignment between the alignment reference and other combat systems equipment. This is accomplished by comparing equipment position when the optical axes are made parallel by sighting on a celestial body. If the train and elevation readouts for the equipment do not agree within the operational tolerances previously established for that equipment, alignment is necessary. After corrective alignment is accomplished, a new set of tram or benchmark readings must be taken and recorded. This alignment check can be performed by a ship's force or a support activity.

ESTABLISHMENT OF BENCHMARK AND TRAM REFERENCE READINGS

The seventh and last major alignment step is the establishment of reference readings that are performed by a support activity or a ship's force. Reference readings are established to furnish an easy means of checking train and elevation alignment in the future. This is necessary because the dials or synchros may become misaligned as a result of vibration and normal wear or equipment disassembly for the replacement of worn parts.

Tram and benchmarks are provided to facilitate checking combat systems equipment at a definite train and elevation position. The position selected may be any convenient value within the limits of the equipment movement. The dial readings for these positions are recorded on the sheets provided in the alignment smooth log. If the equipment remains aligned correctly for zero train and elevation, the recorded dial readings are the same whenever the equipment is moved to the tram or benchmark position.

The alignment verification obtained by using a benchmark is accurate only if the angle between the reference line and the position of the pointing line established by the benchmark does not change as a result of hull distortion or some other cause. Adjustments to equipment should not be made by using the result of a single benchmark check. Instead, benchmark results should be recorded each time they are performed so that a determination can be made when a benchmark error begins repeating itself and becomes an indication that further alignment checks are required.

Tram bars and tram blocks may also be used to establish an angle by determining a definite distance between a point on the rotating structure of the equipment and a point on its fixed structure. An error, as defined by tram readings, may also result if the fixed structure shifts on its mounting. Any adjustments to equipment, like benchmarks, should not be made on the basis of a single tram check.

Some equipments have both benchmarks and trams. When the benchmark reading changes and the tram reading remains unchanged, the extent of hull distortion is revealed.

COMBAT/WEAPONS SYSTEMS SMOOTH LOG

The combat/weapons systems smooth log is similar to the former battery smooth log. and fire-control smooth log, among others. Thus, the combat/weapons systems smooth log is the title that maybe applied to all smooth logs that are required to be kept.

Most often, the combat/weapons systems log contains sections devoted to alignment, erosion, rounds fired, radar, and exercises and rounds fired.

- **Alignment:** Includes summaries of alignment data for fire-control systems, train checks, benchmarks established and recorded, roller-path compensator settings, horizon checks, radar antenna alignment records, etc.

- **Erosion:** Includes star gage data, erosion gage data, equivalent service rounds (ESRs), pseudo-equivalent service rounds (PESRs), and records of bore searchings.

- **Rounds Fired:** Includes entries in tabular form for gun barrels by serial numbers, which show rounds fired, types of projectiles, powder charges, powder indexes, and ESRs.

- **Radar:** Includes dates and results of radar adjustments, collimations, calibrations, double-echo checks, and any corrective measures taken, such as the negative range zero set from the results of the double-echo check.

- **Exercises and Rounds Fired:** Includes dates and types of exercises or action firings, overall results, complete summaries for unsatisfactory firings, corrective measures taken, and listing of the arbitrary corrections to hit (ACTH) or any other initial spots that were used.

Alignment data must be documented on completion to provide information for future checks and to inform responsible personnel of equipment and subsystem alignment status. A complete and accurate alignment data package is essential for effective combat systems alignment.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Combat System Alignment Manual for CG-47 Class, NAVSEA SW225-BN-CSA-010, Naval Sea Systems Command, Washington, DC, 1993.

Combat System Alignment Manual for DDG-51 Class; Alignment Verification and Corrective Alignment Procedures, NAVSEA SW225-CH-CSA-010, Naval Sea Systems Command, Washington, DC, 1993.

Combat System Alignment Manual for FFG-7 Class; Alignment Verification and Corrective Alignment Procedures, NAVSEA SW225-B6-CSA-010, Naval Sea Systems Command, Washington, DC, 1987.

Combat Systems Alignment Manual for your class of ship.

CHAPTER 4

COLLIMATION

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Describe the theory of radar collimation.

2. Describe the requirements for radar collimation of the Tartar/SM1 missile fire-control system.

3. Identify the basic equipment used during radar collimation with a shore tower.

INTRODUCTION

The collimation of fire-control radars is one of the major steps toward achieving a successful battery alignment. This chapter discusses the theory of radar collimation, collimation requirements, shore tower-based operation and requirements, and test equipment and procedures used in collimation and correlation, especially as applied to the Tartar (Standard) Guided-Missile, Fire-Control System (GMFCS). Keep in mind that although the specific equipment used on board your ship may be differ from the example used in this chapter, the purpose is still the same; that is, to achieve a successful battery alignment.

RADAR COLLIMATION THEORY

Collimation is an optical electronic technique used to establish parallelism between the radio-frequency (RF) beams radiated from a radar antenna or between the RF beam and the optical line-of-sight (LOS) axis of the antenna. This optical axis is called the *boresight axis* and is established with the optical telescope.

Radar collimation is the parallel alignment of the radar beam axis and the optical axis of the radar antenna. It can be accomplished by using either a shore-based tower or a portable ship's tower that supports both an optical target and a radar horn antenna.

The horn antenna is connected to the RF power-measuring equipment and is properly positioned in relation to the optical target. The horn antenna displacement, relative to the optical target, is determined by the relative displacement of the two axes (optical and RF), as measured at the radar.

The parallelism of the two axes is checked or adjusted by training and elevating the radar antenna until the cross hairs of the optical sight intersect the optical target. At that time, maximum RF energy should be directed into the horn antenna, as measured by the power-measuring equipment. If it is not, the axes will not be collimated, and appropriate adjustment procedures must be accomplished, as one axis must be aligned to the other axis until they are parallel.

The optical LOS or boresight axis is the fixed reference for some radars, while for others, it is not. On radars where the boresight axis is the fixed reference, the RF beams are aligned to the boresight axis. On radars where the foresight axis is not fixed, the telescope is moveable and is adjusted parallel to the reference RF beam. Figure 4-1 shows a radar collimation configuration with a shore-based tower setup.

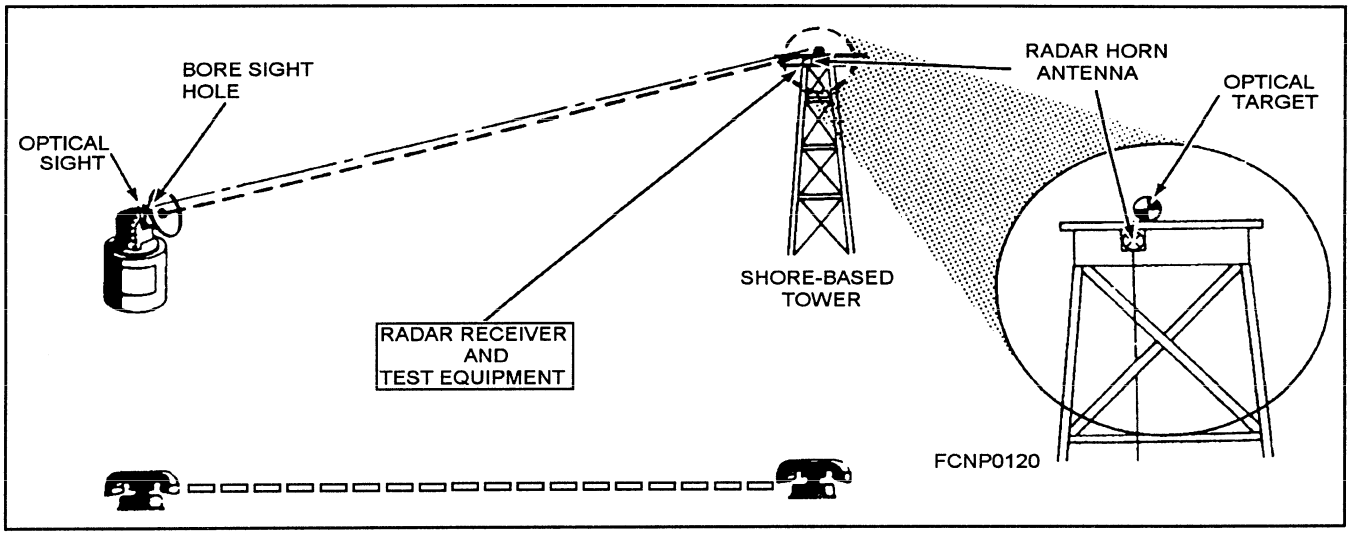


Figure 4-1.—Radar collimation with a shore-based tower setup.

TARTAR GMFCS RADAR COLLIMATION REQUIREMENTS

Because different types of radar are used in the missile and gun systems, the collimation requirements for each radar are different. This section briefly discusses the requirements for the Tartar GMFCS.

The primary radar for the Tartar GMFCS is the Radar Set AN/SPG-51C/D. It is an automatic target-acquisition and missile-guidance radar set that uses C-band, pulsed-Doppler techniques for target tracking and an X-band continuous-wave (CW) illuminator to provide guidance for the semiactive homing Tartar missile.

As shown in figure 4-2, the C-band and X-band feed horns on the radar antenna are effectively located at the same feed point so that the track and CW illuminator RF beams are parallel, within specified tolerance. A wide continuous-wave illuminator (CWI) reference beam is also generated by the X-band horn, which is located in the center of the antenna reflector to fill in any nulls in the CWI main beam and to provide missile rear reference information. The beam relationships are shown in figure 4-3.

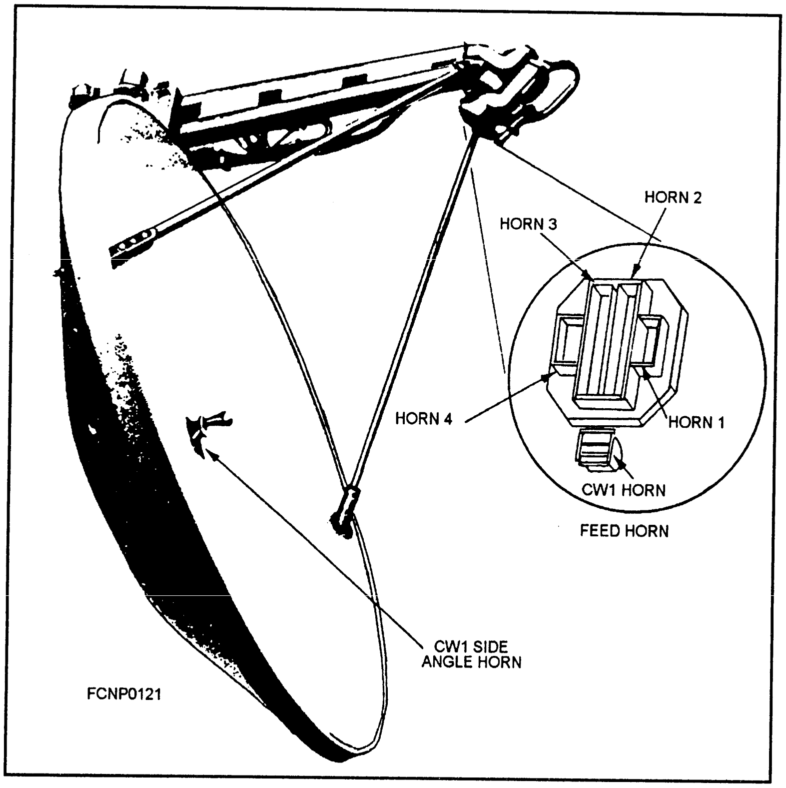


Figure 4-2.—Tartar radar C-band and X-band feed horns.

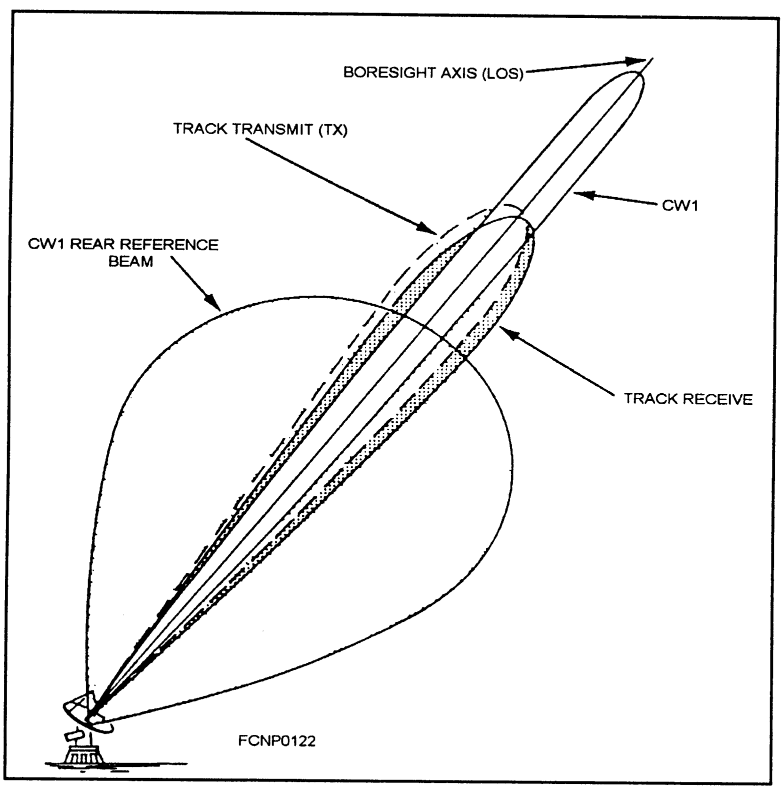


Figure 4-3.—Tartar radar CWI beam relationships.

For rapid target acquisition and proper tracking, the track radar beam must be parallel to the boresight axis, which is referenced to the ship's weapons system by benchmarks. An appreciable error between the axis along which the radar effectively receives the return pulses (called the track receive or the *TR axis)* and the axis along which the radar transmits (called the *track transmit* or the *TX axis)* reduces the rapid acquisition capability of the radar. An error between the TR axis of the tracking radar and the axis of the CW illuminator impairs Tartar missile performance by reducing target illumination power.

Collimation of the Tartar radar consists of determining the error between the RF beam axis and the boresight axis and the errors between the RF beams themselves.

In addition to determining the relative positions of the RF beam axis, collimation operations should ensure that

- the angle-error signals are generated properly in each quadrant when the antenna is off target axis,
- the specified angle-error sensitivity of the angle tracking circuitry is obtained, and
- the beam pattern is symmetrical.

Figure 4-4 shows Tartar radar collimation axes.

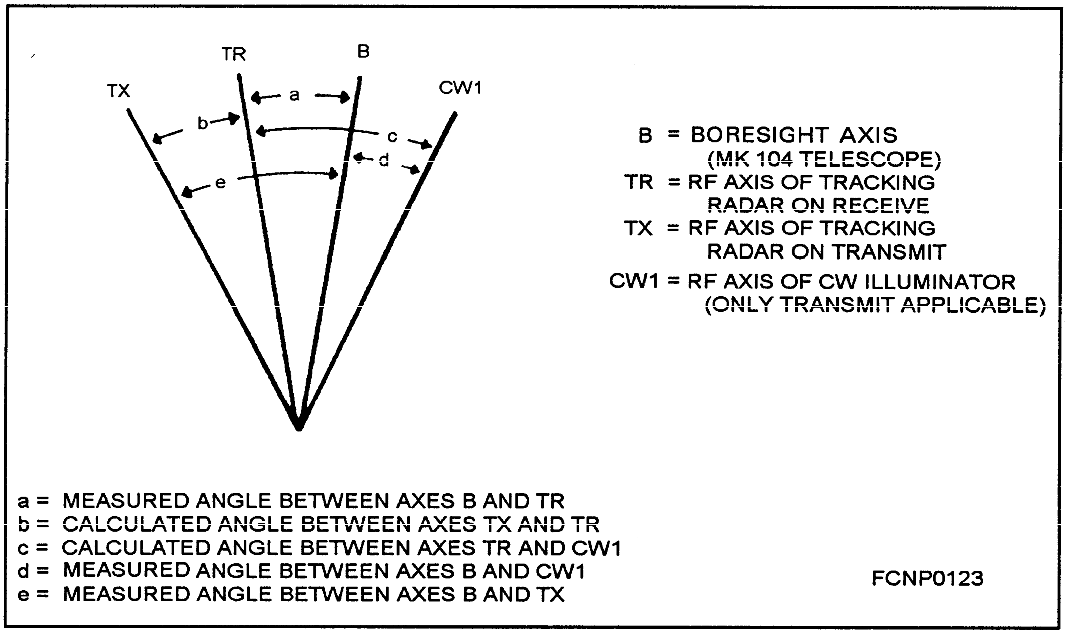


Figure 4-4.—Tartar radar collimation axes.

RADAR COLLIMATION SHORE TOWERS

Radar collimation shore towers are designed primarily to check antenna beam collimation and RF characteristics of GMFCSs. They also provide facilities for collimation and beacon checks of gunfire-control radars and RF alignment (azimuth only) of the three-coordinate search radars.

A radar collimation shore tower is 130 to 250 feet high with a moveable array on which test antennas and associated optical targets are mounted. Waveguide and coaxial transmission lines connect the antennas on the tower array to an equipment room at the base of the tower.

The equipment room contains all the test equipment necessary to perform collimation and to check RF characteristics on the various guided-missile/gunfire-control radars and the three-coordinate search radars found in the fleet. Figure 4-5 depicts a collimation tower.

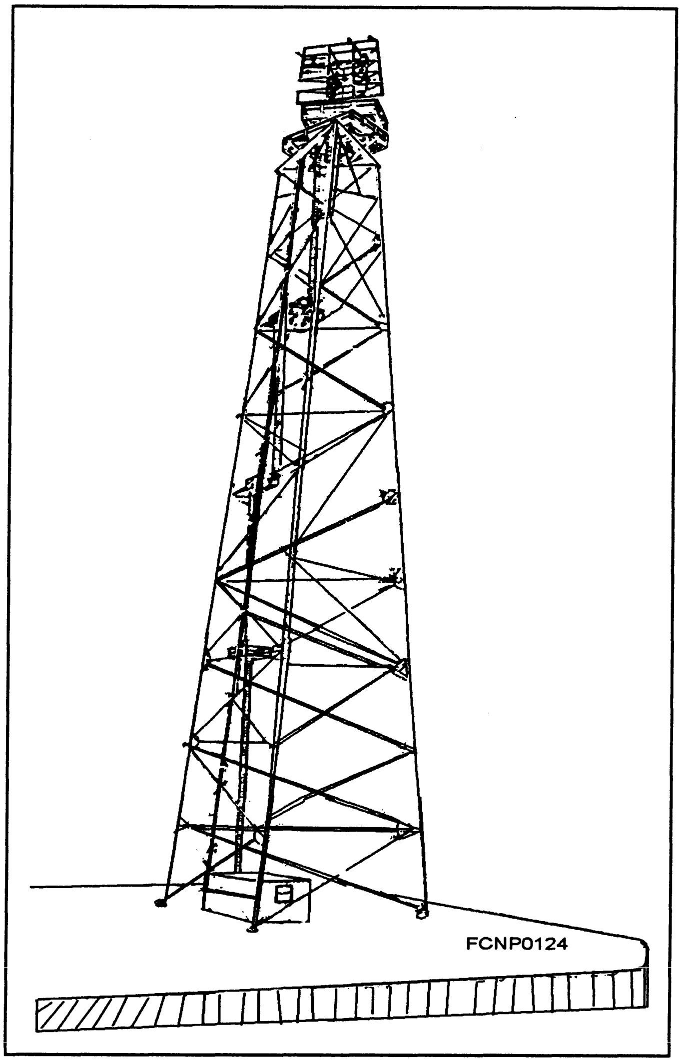
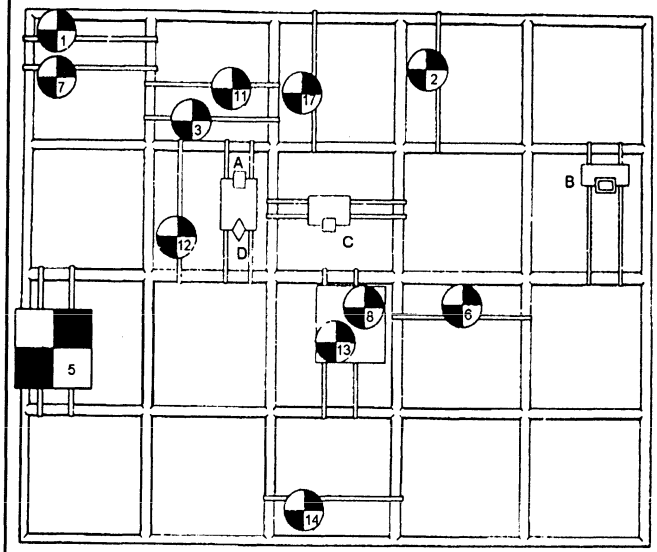


Figure 4-5.—Collimation tower.

TOWER ARRAY

The tower array can be moved in train and elevation by either powered or manual means. The array consists of a metal frame (usually constructed from aluminum piping) and test antennas and optical targets required for shore-tower checkout of shipboard radars. The test antennas and the optical targets are mounted on the metal frame and spaced to correspond to the spacing between the center of radiation (RF axis) and the telescope or boresight axis of each shipboard radar. This eliminates parallax errors caused by the small ship-to-tower distance involved during normal tower operations.

The targets are illuminated by either back lighting or floodlights. The four test antennas and their characteristics, the associated optical targets, and the applicable radar systems that can be tested are summarized in figure 4-6.



A

ARRAY USAGE

SYSTEM	RADER	BEAM	ANTENNA	TARGET
TERRIER	AN/SPG-55	GUIDANCE CAPTURE TRACK CW1 CUSTER DOPPLER	A A A D B B	1 2 1 7 3 1
TARTAR	AN/SPG-51	TRACK CW1 TV	C D	6 8 5
[redacted]				
MK 86	AN/SPG-60	TRACK TV	D	13 17
MK 92		TRACK TV(IF INTL)		11(STR IN LINE) 12 (CAS) 13 STR MK 104 17

TEST ANTENNAS

ANTENNA	MODEL	GAIN	POLARIZATION	TYPE
A	AV4517 OR 56C1	18db	VERTICAL	C-BAND HORN
B	MICROLAB/ FXR X638A	22db	VERTICAL	X-BAND HORN
C	AV 4517 OR 56C1	18db	HORIZONTAL	C-BAND HORN
D	AEL H6000	8.2db	CIRCULAR	X-BAND HORN

FCNPO125

B

Figure 4-6.—(A) Standard tower array; (B) Array usage.

COLLIMATION TEST EQUIPMENT

Each collimation tower is equipped with a set of test equipment for specific tower use. This equipment is stowed in the tower equipment room. The major items include

M. Radar Test Set AN/SPM-9,

Range Calibrator Set AN/UPM-115,

Range Calibrator Set AN/SPM-6,

Radar Beacon Test Set AN/TPN-7 or AN/UPN-32,

Continuous-Wave Acquisition and Track (CWAT) Tower Transponder, and

Microwave Power Meter HP 430.

Some of this test equipment is in the process of being replaced and can be identified in the combat systems alignment manual that is specific to your class of ship. A number of additional items of general-purpose test equipment, such as oscilloscopes, signal generators, coaxial cables, directional couplers, and variable attenuators are also used at both the tower and aboard the ship.

RADAR COLLIMATION PROCEDURES

Shore-tower checks between regular overhaul periods are generally not performed except when the Naval Sea Systems Command (NAVSEA) or the Naval Ship Weapon Systems Engineering Station (NSWSES) specifies a shore-tower check as a result of extensive shipyard or alteration work, or after a microwave casualty occurs that requires microwave component replacement. On ships outfitted with a portable ship's tower, the need for shore-tower service is established when ship tower checks indicate that tolerances are exceeded or when correlation data is in question.

Certain environmental condition requirements must be complied with before tower operation. These include the amount of ship motion and the weather conditions under which the collimation procedures are performed.

Because ships must be tested while afloat, certain methods of limiting the motion are used. One method consists of securing the ship snugly to a pier or dock or, in certain cases where excessive ship motion is created because of tide changes, by using various weighing methods, as shown in figure 4-7, to reduce the ship's motion.

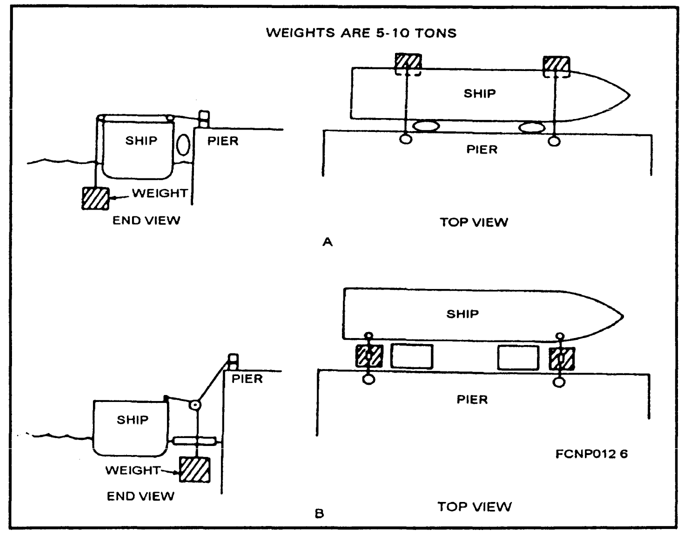


Figure 4-7.—Ship weighting for reducing motion.

Weather conditions must be considered because of the adverse effects they can have on collimation tests. For example, visibility between ship and tower, wind and water action, and heat radiation can affect collimation tests. Visibility should be good between the ship and the tower. High winds or rough water can cause ship motion to be so excessive as to invalidate test results. If refraction due to heat radiation is observed while viewing an optical target, consideration should be given to rescheduling operations at an earlier hour of the following day.

The Tartar/SM1 weapons system is employed aboard several classes of ships. Each class of ships has a unique configuration of the weapons system components. Consequently, each class has its own specific collimation procedures.

This section discusses track-receive axis collimation, track-transmit axis collimation, and CWI axis collimation. These procedures are discussed only in a general way and do not address specific procedures for any particular class of ships.

TRACK-RECEIVE AXIS COLLIMATION

In track-receive (TR) axis collimation, the angle-error null method of measurement is used to determine the error between the track receive axis and the borescope axis of the AN/SPG-51C/D radar. At the shore tower, the Range Calibrator Set AN/SPM-6 is connected to transmission line C, which connects to antenna C on the tower array. Aboard ship, the AN/SPG-51 radar director is manually pointed toward the shore tower.

The director is not energized during any AN/SPG-51C/D radar collimation checks. When the director is in the required position, the AN/SPG-51C/D radar track transmitter is set to RADIATE, thus triggering the AN/SPM-6 range calibrating set at the shore tower. When triggered by the radar signal, the AN/SPM-6 begins transmitting back to the radar set RF pulses identical to the pulses being received, which, when received by the radar, appear as target video on the A-scope of the radar operator's console. Only three to five of these video pulses are observable on the A-scope because of the high pulse-repetition frequency (PRF) of the radar set.

The radar is placed in range track when video pulses are observed on the A-scope. This is accomplished by gating one of the returned pulses. A Doppler target is required to ensure that an angle-error output voltage is generated whenever the antenna (director) is manually moved off target. This requirement is accomplished by setting the CLUTTER REJECT switch on the operator's console to the 0 KT position. The traverse- and elevation angle-error voltages generated from the angle-error detector module of the AN/SPG-51C/D data converter are monitored by two voltmeters.

With the radar in track, the director is held stationary on target (brakes set) in one axis (TRAIN or ELEVATION) and rocked through the angle error null point (as indicated by the variable time voltmeter [VTVM]) in the other axis. The mark method is used to correlate angle-error null voltage readings with borescope readings. The borescope readings (in roils) are taken with respect to the AN/SPG-51C/D track radar optical target 6 or 10 on the tower array. A minimum of 20 nulls and the borescope readings are taken to determine the collimation error between the TR axis and the borescope axis. This procedure is then repeated for the other axis (traverse or elevation).

Before actually determining the TR axis error by the angle-error null method, checks should be made to determine that an angle error of proper sensitivity (1 voltage per millimeter [v/mil]) can be generated in each quadrant and that conical-scan-on-receive-only (COSRO) phasing is correct (minimum crosstalk) to preclude offset of the angle-error null.

TRACK-TRANSMIT AXIS COLLIMATION

In track-transmit (TX) axis collimation, the beam-pattern plot method of measurement is used to determine the error between the track-transmit axis and the borescope axis of the AN/SPG-51C/D radar. There is no requirement for test equipment aboard ship during the performance of this test. The test setup aboard ship consists of placing the track transmitter in the RADIATE mode, pointing the radar antenna (director) toward the shore tower, and centering the AN/SPG-51C/D track radar optical target 6 or 10 in the borescope.

In the tower, the average power meter is connected through the calibrated attenuator (C-band) to the waveguide line connected to antenna C on the array. Attenuation is adjusted to allow the track transmitter power to be read conveniently on the power meter (in decibels or milliwatts, as preferred). After establishing a reference point (reading of maximum power) by coaching the director operators aboard ship via sound-powered telephone, the track transmitter output power at the tower as the antenna (director) is held stationary in one axis (traverse or elevation) and moved off target in the other axis is plotted. The offset readings in roils are given by the borescope observer aboard ship.

Usually, a 30-mil excursion on each side of the maximum power point is sufficient. After plotting the power readings to offset in mils on a graph, a horizontal line connecting the half-power points (3 decibels down) is drawn. By bisecting this line and observing where the bisecting line intercepts the mils axis, you can determine the collimation error between the TX axis and the boresight axis. Extreme care must be exercised in taking each power reading to obtain accuracy with this method.

The borescope operator may have to give several marks at each offset position to obtain a good average power reading. Figure 4-8 shows the TX axis beam-pattern plot-method graph.

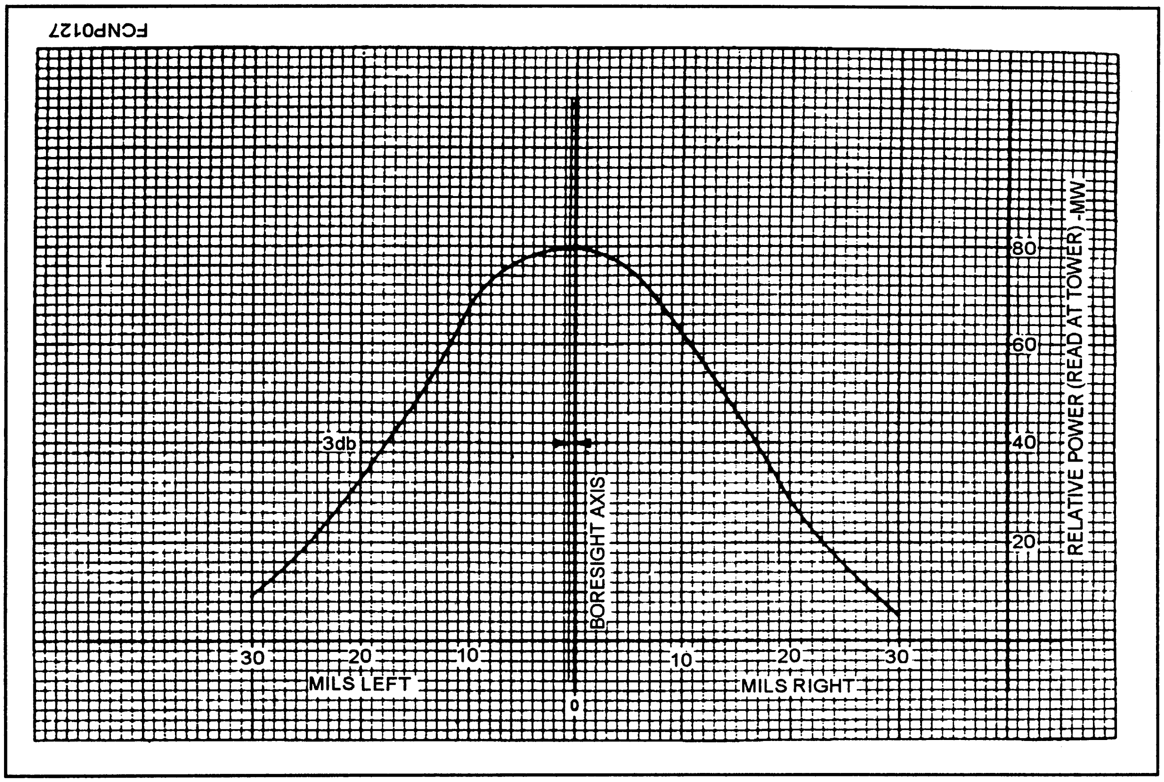


Figure 4-8.—Beam-pattern plot-method graph.

CWI AXIS COLLIMATION

The beam-pattern plot method of measurement is used to determine the error between the CWI axis and the borescope axis of the AN/SPG-51C/D radar. There is no requirement for test equipment aboard ship during the performance of this test.

The procedures for determining CWI axis error are similar to those for the track-transmit axis, except that the CWI radar is used.

The test setup aboard ship consists of placing the CWI transmitter in RADIATE, pointing the radar antenna toward the tower, and centering the CWI optical target 8 in the borescope.

In the tower, the average power meter is connected through the calibrated attenuator (X-band) to the X-band waveguide line going to antenna Don the tower array. The attenuator is adjusted to allow the C WI power to be read conveniently on the power meter (in decibels or milliwatts, as preferred). After establishing a reference point (maximum power reading) by coaching the director operators aboard ship, the CWI power at the tower as the antenna (director) is held stationary in one axis (traverse or elevation) and moved off target in the other axis is plotted. The offset readings in roils are given by the borescope observer aboard ship.

A power plot curve is drawn and the 3-decibel down points are connected by a horizontal line. The bisector of this line intercepts the mils axis of the graph to provide the collimation error similar to the TX procedures. Usually, a 15-mil excursion each side of the maximum power point is sufficient. After all three RF beam axes have been established, their data is plotted together on a beam position summary graph, as shown in figure 4-9. From their relative positions, the collimation errors can be determined and any corrective action, if required, can be made.

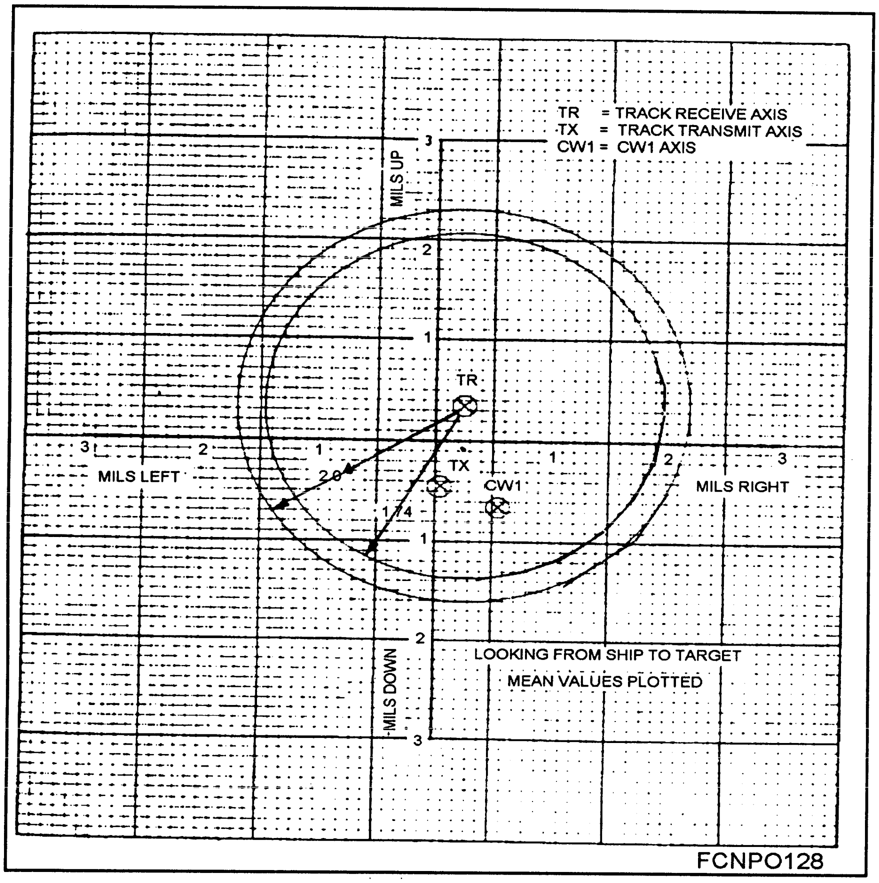


Figure 4-9.—Beam position summary graph.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Combat System Alignment Manual for DDG-51 Class, Alignment Verification and Corrective Alignment, NAVSEA SW225-CH-CSA-010, Naval Sea Systems Command, Washington, DC, 1993.

Combat System Alignment Manual for FFG-7 Class, Alignment Verification and Corrective Alignment Procedures, NAVSEA SW225-B6-CSA-010, Naval Sea Systems Command, Washington, DC, 1987.

Combat Systems Alignment Manual for your class of ship.

APPENDIX I

GLOSSARY

This glossary defines abbreviations and acronyms as they are used in this training manual.

AA— antiaircraft

ACTH— arbitrary corrections to hit

CIC— combat information center

COSAL— Coordinated Shipboard Allowance List

COSRO— conical-scan-on-receive-only

CRP— centerline reference plane

CW— continuous wave/chilled water

CWIDW— chilled water/distilled water

CWAT— continuous-wave acquisition and track

CWI— continuous-wave illuminator

DSOT— Daily System Operability Test

DW— distilled water

ESR— equivalent service round

FAM— fault analysis matrix

FCS— fire-control system

FID— fault indicator directory

FLD— fault logic diagram

GFCS— gunfire control system

GMFCS— Guided-Missile Fire-Control System

LOS— line of sight

MDS— Maintenance Data System

MIP— maintenance index page

MRC— maintenance requirement card

MRP— master reference plane

NAVSEA— Naval Sea Systems Command

NSWSES— Naval Ship Weapon Systems Engineering Station

OP— operating procedure

OSCOT— Overall Combat System Operability Test

PESR— pseudo-equivalent service round

PMS— Planned Maintenance System

POFA— Programmed Operational and Functional Appraisal

PRF— pulse-repetition frequency

psig— pounds per-square-inch gage

RDP— radar data processor

RF— radio frequency

RPP— roller-path plane

RSC— radar set console

SBP— ship base plane

SFD— system fictional diagram

SMT— system maintenance test

SW— seawater

SW/DW— seawater/distilled water

SWBD— switchboard

3-M— Maintenance and Material Management

TLC— troubleshooting logic chart

TR— track receive

TX— track transmit

v/mil— voltage per millimeter

VTVM— variable time voltmeter

WCRP— weapons-control reference plane

APPENDIX II

REFERENCES USED TO DEVELOP THIS TRAMAN

Basic Liquid Cooling Systems for Shipboard Electronics, NAVSEA 0948-LP-122-8010, Naval Sea Systems Command, Washington, DC, 1977.

Combat System Alignment Manual for CG-47 *Class,* NAVSEA SW225-BN-CSA-010, Naval Sea Systems Command, Washington, DC, 1993.

Combat System Alignment Manual for DDG-51 Class; Alignment Verification and Corrective Alignment Procedures, NAVSEASW225-CH-CSA-010, Naval Sea Systems Command, Washington, DC, 1993.

Ships' Maintenance and Material Management (3-M) Manual, OPNAVINST 4790.4C, Chief of Naval Operations, Washington, DC, 1994.

INDEX

Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Planned Maintenance System and Fault Isolation," chapter 1, pages 1-1 through 1-24; and "Liquid-Cooling Systems:" pages 2-1 through 2-19.

1-1. The Planned Maintenance System provides a standard means for which of the following tasks relative to complex mechanical, electrical, and electronic equipments?

1. Planning
2. Controlling
3. Scheduling
4. All of the above

1-2. The PMS has what total number of shipboard maintenance categories?

1. One
2. Two
3. Three
4. Four

1-3. Which of the following elements is a primary ingredient of the PMS Program?

1. Ship, shipyard, or system safety scheduling
2. System fault-isolation procedure
3. Redundant tasking eliminations
4. Testing time reduction

1-4. What schedule normally contains the assignment of specific personnel to perform maintenance on specific equipment?

1. Cycle
2. Weekly
3. Monthly
4. Quarterly

1-5. The Maintenance Data System has what total number of functions?

1. One
2. Two
3. Three
4. Four

1-6. Integrated maintenance requirements are established through what type of analysis?

1. PMS
2. Engineering
3. Combat systems
4. Shipboard safety

1-7. Which of the following types of testing is considered the highest level of testing that can be accomplished aboard ship?

1. Gun/battery alignment
2. Combat systems
3. Subsystems
4. Equipment

1-8. What is the primary combat systems test tool?

1. SMP
2. NIXIE
3. OCSOT
4. PPI X or Y

1-9. To diagnose and effect timely repair of faults within a fire-control system, you must fully understand fault-isolation concepts, the fault-isolation tools available to you, and the capabilities and limitations of those tools when applied to system fault isolation.

1. True
2. False

1-10. Which of the following characteristics applies to a fault-isolation tool?

1. It identifies personnel requirements
2. It identifies the proper test equipment
3. It is difficult to operate
4. It is easily implemented

1-11. OCSOT is what type of test?

1. On-line/off-line
2. Combat systems
3. Subsystems
4. Equipment

1-12. DSOT is what type of test?

1. On-line/off-line
2. Combat systems
3. Subsystems
4. Equipment

1-13. The systems maintenance test is an off-line test used in which of the following fire-control systems?

1. Mk 92
2. Mk 86
3. Mk 68
4. Mk 48

1-14. Diagnostic testing programs are designed to isolate malfunctions that occur in which of the following components?

1. Internal logic of printed circuit boards
2. External logic of printed circuit boards
3. Both 1 and 2 above
4. External CPU peripherals

1-15. Maintenance support documentation has what total number of general categories?

1. One
2. Two
3. Three
4. Four

1-16. TLCs are functional flow diagrams.

1. True
2. False

1-17. Fault logic procedures are generally used more rapidly by which of the following personnel?

1. Senior
2. Junior
3. Experienced
4. Inexperienced

1-18. The system function directory is an alphabetical listing of all systems functions and can be used to start the troubleshooting process when there is no particular indicator associated with a fault. With what other directory is the SFD normally used?

1. TLC
2. FLD
3. FAM
4. FID

1-19. In an SFD, data flow is normally in what direction?

1. From top to bottom
2. From bottom to top
3. From left to right
4. From right to left

1-20. The fault analysis matrixes and their associated troubleshooting procedures are related to each other and to what other test?

1. SMT
2. DSOT
3. NIXIE
4. OSCOT

IN ANSWERING QUESTION 1-21, REFER TO TABLE 1-5 IN THE TRAMAN.

1-21. Which column provides suggested troubleshooting procedures for fault isolation?

1. Seven
2. Two
3. Three
4. Four

1-22. Equipment troubleshooting documentation includes

1. relay and lamp indexes and relay lamp ladder diagrams only
2. fault logic diagrams, signal-flow diagrams, pyramid diagrams, and relay and lamp indexes only
3. signal-flow diagrams, pyramid diagrams, fault logic diagrams, and relay lamp ladder diagrams only
4. pyramid diagrams, relay and lamp indexes, fault logic diagrams, signal-flow diagrams, and relay , lamp ladder diagrams

1-23. To speed troubleshooting, the technician may use which of the following diagrams by answering a branching series of questions about an observed system fault?

1. Fault logic diagrams
2. Signal-flow diagrams
3. Pyramid diagrams
4. Both 2 and 3 above

1-24. What diagram shows the signal flow from an input to an output function?

1. Signal-flow diagram only
2. Fault logic diagram only
3. Signal-flow diagram and fault logic diagram
4. Pyramid diagram

1-25. Pyramid diagrams pertain to the sole dependency of the subassemblies essential to each function of a piece of equipment.

1. True
2. False

1-26. The relays and lamps are cross-indexed by which of the following characteristics?

1. Zone
2. Sheet
3. Figure
4. All of the above

1-27. Relay lamp ladder diagrams show the energizing paths for relays and indicator lamps that are not covered by which of the following diagrams?

1. Pyramid
2. Fault logic
3. Signal flow
4. Fault analysis

1-28. The relay lamp ladder diagram shows which of the following components in the energizing path?

1. Transistors and switches
2. Lamps and switches
3. Cabling and wiring
4. Coils and lamps

1-29. Cooling systems are essential to the satisfactory operation of which of the following equipments?

1. Shipboard weapons systems only
2. Heat exchangers/transferers only
3. Air conditioning units only
4. All shipboard electronic equipment

1-30. The typical liquid-cooling system used for electronic fire-control equipment has what total number of basic systems?

1. One
2. Two
3. Three
4. Four

1-31. Aboard ship, the initial source of cooling water is the

1. primary liquid-cooling system
2. secondary liquid-cooling system
3. air conditioner receptacles
4. expansion tanks

1-32. If you are in an emergency situation aboard ship wherein you need to immediately locate a portable emergency hose, where would you normally find that hose?

1. In the supply room
2. In the cook's galley
3. In the maintenance department
4. In the liquid-coolant machinery room

1-33. In types II and III liquid-cooling systems, chilled water is taken from the

1. fire main
2. supply main
3. alternate main
4. secondary main

1-34. What is the coolant normally used in the secondary liquid-cooling system?

1. Antifreeze
2. Fresh water
3. Saltwater
4. Distilled water

1-35. The Navy uses what total number of liquid-cooling systems?

1. One
2. Two
3. Three
4. Four

1-36. What type of water does the type I liquid-cooling system use?

1. Seawater
2. Distilled water
3. Both 1 and 2 above
4. Freshwater

1-37. Type II liquid-cooling systems are used in installations that cannot accept distilled-water temperatures higher than what degree Fahrenheit?

1. 85
2. 90
3. 95
4. 98

1-38. Liquid-cooling systems have which of the following main components?

1. Coolant alarm switchboards
2. Oxygen analyzers
3. Demineralizes
4. All of the above

1-39. What is the seconday coolant that flows through the heat exchanger?

1. Seawater only
2. Chilled water only
3. Seawater and chilled water
4. Distilled water

1-40. What person is normally the best qualified to determine what procedure to use where extreme fouling exists and whether the job can be performed aboard ship?

1. Supply officer
2. Operations officer
3. Engineering officer
4. Combat systems officer

1-41. The purity of what type of water inhibits electrolysis in the secondary system?

1. Sea
2. Salt
3. Chilled
4. Distilled

1-42. Expansion tanks are identified as which of the following types of tanks?

1. Fuel or gravity
2. Ballast or neutralized
3. Gravity or pressurized
4. Neutralized or fuel

1-43. Visual and audible alarms will actuate on the expansion tank when the fluid level is below what percent of being full?

1. 10
2. 20
3. 30
4. 40

1-44. What type of air system is used to charge expansion tanks?

1. Low pressure only
2. Low pressure, but with high-pressure capabilities
3. High pressure only
4. High pressure, but with low-pressure capabilities

1-45. Where is the best place to look in the expansion tank for an indication of a coolant leak in the secondary cooling system?

1. Visual alarm
2. Flood level
3. Sight glass
4. Water strainer

1-46. What type of strainer may have a small drain on the cover to allow for draining water off before you remove the cover?

1. Single
2. Duplex
3. Triplex
4. Simplex

1-47. What temperature-regulating valve is used when seawater is the primary cooling medium in the heat exchanger?

1. One-way
2. Two-way
3. Three-way
4. Omnidirectional

1-48. In the three-way temperature-regulating valve, distilled water is proportioned between what total number of paths?

1. One
2. Two
3. Three
4. Four

1-49. Two-way temperature-regulating valves are normally installed at what location on the heat exchanger?

1. In the distilled-water supply
2. In the chilled-water supply
3. On the cooling water side
4. On the seawater side

1-50. Both the three-way and two-way temperature-regulating valves have a manual override feature.

1. True
2. False

1-51. The orifice plate is found primarily in which of the following cooling systems?

1. Chilled water
2. Coolant water
3. Freshwater
4. Seawater

1-52. When used with the chilled-water system, the constant-flow regulator is installed at what location from the heat exchanger?

1. Upstream
2. Downstream
3. In parallel
4. In series

1-53. The amount of water that the flow regulator will pass is usually stamped whereon the regulator?

1. Bottom
2. Side
3. Top
4. End

1-54. A flow regulator or a pressure regulator can NOT be installed backwards.

1. True
2. False

1-55. A low-flow switch to monitor the overall coolant flow is normally found in which of the following cooling systems?

1. Primaly
2. Secondary
3. Air conditioning
4. Distillation

1-56. The flow of water through an orifice causes which of the following results?

1. The pressure stays the same
2. The pressure increases
3. The pressure fluctuates
4. The pressure drops

1-57. In the venturi flowmeter, the flow rate is proportional to the difference between the

1. two taps
2. both sides
3. top and bottom
4. fresh and saltwater sides

1-58. What is the major advantage of a rotameter over a venturi meter?

1. Size of equipment
2. Expense of maintenance
3. Complexity of operations
4. Visibility of coolant

1-59. Each cooling system has what total number of distilled-water circulating pumps?

1, One
2. Two
3. Three
4. Four

1-60. On all pumps, as the output pressure increases, the output flow

1. decreases
2. increases
3. stays the same
4. varies, depending on water pressure

ASSIGNMENT 2

Textbook Assignment: "Liquid-Cooling Systems," chapter 2, pages 2-20 through 2-27;
"Combat Systems Alignment (Gun/Battery)" chapter 3, pages 3-1 through 3- 17; and
"Collimation," chapter 4, pages 4-1 through 4-10.

2-1. Demineralizes are used to maintain what type of water purity in an ultrapure state?

1. Primary
2. Alternate primary
3. Secondary
4. Alternate secondary

2-2. The demineralize is sized so that what percent of the system's volume passes through the demineralize every hour?

1. 7
2. 5
3. 3
4. 4

2-3. The submicron filter is used to remove particles that have a size greater than what?

1. 0.5 micron
2. 1.0 micron
3. 1.5 micron
4. 5.0 micron

2-4. What total number of cartridge types are used in the demineralize?

1. One
2. Two
3. Three
4. Four

2-5. When it is near exhaustion, a urine order is emitted by which of the following cartridges?

1. Mixed bed
2. Oxygen removal
3. Organic removal
4. All of the above

2-6. A conductivity cell consists of what total number of electrodes immersed in the coolant flow path?

1. One
2. Two
3. Three
4. Four

2-7. On some purity meters, the coolant is displayed as

1. ohms
2. voltage
3. current
4. resistivity

2-8. When a system is filled with freshwater, it should be allowed to circulate for approximately how many hours before you compare the input and output readings?

1. 6
2. 2
3. 8
4. 4

2-9. A properly operating system can supply water of acceptable purity in what minimum number of hours?

1. 1 to 3
2. 2 to 5
3. 4 to 8
4. 6 to 8

2-10. Oxygen analyzers are installed in some primary systems to measure the amount of dissolved oxygen in the liquid coolant.

1. True
2. False

2-11. If the meter on the oxygen analyzer requires frequent calibration because the meter readings are drifting or changing sharply, the analyzer has a bad

1. sensor
2. cartridge
3. calibration
4. cooling alarm

2-12. When an abnormal condition occurs in a system, the alarm indicates the fault condition by what means?

1. Audible alarm
2. Visual alarm
3. Both 1 and 2 above
4. Sensory alarm

2-13. The system's main alarm panel has a total of how many ground indicator lamps?

1. One
2. Two
3. Three
4. Four

2-14. Either half of the system's alarm panel can independently display which of the following lights, if any?

1. Steady red light only
2. Flashing red light only
3. Steady red light, flashing red light, or no light
4. None; no lights are ever displayed on this panel

2-15. A four-way position switch on the lower half of each alarm module allows you to place the individual alarm module in which of the following modes?

1. Cutout only
2. Standby only
3. Normal only
4. Cutout, standby, normal, and test

2-16. In what position is power removed from the sensor loop to facilitate maintenance?

1. Test
2. Cutout
3. Normal
4. Standby

2-17. Which of the following switch positions simulates an alarm condition?

1. Test
2. Cutout
3. Normal
4. Standby

2-18. What is the best way to extend the life of components and to increase the reliability of the cooling system?

1. Preventive maintenance
2. Corrective maintenance
3. Both 1 and 2 above
4. Shipyard overhaul

2-19. The battery alignment of a ship is accomplished by which of the following distinct alignments?

1. Gun-bore and plane
2. Original (dry-dock) and afloat
3. Missile launcher and fire-control
4. Primary and fire-control

2-20. Battery alignment is based on which of the following concepts?

1. Geometric coordinate system
2. Parallel planes
3. Parallel lines
4. All of the above

2-21. In a complete reference frame, directions are specified by which of the following angles?

1. Train and elevation
2. Target direction only
3. Geometric measurement only
4. Target direction and geometric measurement

2-22. In naval combat systems, what is used as the reference direction?

1. Ship's bowline
2. Ship's sternline
3. Ship's centerline
4. Ship's stormline

2-23. What is one of the most commonly used reference planes because of the ease of using a spirit level to determine the plane?

1. Vertical
2. Horizontal
3. Parallel
4. Perpendicular

2-24. Train angles are measured in what direction from the reference direction on the top of the plane?

1. Clockwise
2. Counterclockwise
3. Bottom to top
4. Top to bottom

2-25. The difference or displacement between two reference frames may be of which of the following types?

1. Linear and angular only
2. Spatial and linear only
3. Angular and spatial only
4. Linear, angular, and spatial

2-26. What are the corrections made necessary by the linear displacement between the reference planes called?

1. Angular displacements
2. Parallax corrections
3. Typical references
4. Static angular corrections

2-27. Corrections arising from reference directions or reference planes not being parallel are called

1. parallax corrections
2. rotational corrections
3. static parallax corrections
4. dynamic parallax confections

2-28. When the angle between the reference planes is relatively small, where is the major difference?

1. In the horizontal plane
2. In the vertical plane
3. In the elevation angles
4. In the bearing angles

2-29. All of the following equipment is commonly used for battery alignment except which one?

1. Alignment sights
2. Frequency counters
3. Benchmarks
4. Dials

2-30. A theodolite is very similar to what other equipment used during alignment?

1. Alignment sights
2. Clinometers
3. Transits
4. Levels

2-31. Clinometers are used for measuring inclinations in what plane?

1. Vertical
2. Reference
3. Horizontal
4. Spatial

2-32. How many types of levels are used in systems alignment?

1. One
2. Two
3. Three
4. Four

2-33. The pointing line in alignment sights maybe of which of the following types?

1. The centerline of a torpedo tube only
2. The propagation axis of a radar beam only
3. The bore axis of a gun only
4. The centerline of a torpedo tube, the propagation axis of a radar beam, and/or the bore axis of a gun

2-34. What is brought into exact alignment with the gun-bore axis when the boresight telescope is inserted into the gun bore?

1. AOS
2. LOS
3. MTI
4. RPP

2-35. In alignments that use fixed, self-contained optics, which of the following equipment is/are permanently mounted?

1. Transit
2. Telescope
3. Theodolite
4. All of the above

2-36. Tram bars are of what two types?

1. Telescopic and rotating
2. Telescopic and rigid
3. Rotating and fixed
4. Fixed and rigid

2-37. What are used as reference marks to establish angular relationships of an element's line of sight to the ship's structure?

1. Dials
2. Tram bars
3. Tram blocks
4. Benchmarks

2-38. Which of the following equipment can NOT properly be considered to be equipment requiring alignment?

1. Dials
2. Tram bars
3. Tram blocks
4. Benchmarks

IN ANSWERING QUESTION 2-39, REFER TO TABLE 3-1 IN THE TRAMAN.

2-39. In alignment considerations, what step pertains to establishing parallelism?

1. 1
2. 5
3. 3
4. 7

2-40. What is the first major alignment step accomplished by a support activity?

1. The establishment of the horizontal planes
2. The establishment of the reference planes
3. The establishment of the vertical planes
4. The establishment of the ship's planes

2-41. The centerline reference plane is used to establish what alignment of all combat systems alignment?

1. Azimuth zero
2. Elevation zero
3. Bearing zero
4. Train zero

2-42. What is the minimum nunber of plates installed as centerline marks?

1. Two
2. Four
3. Six
4. Eight

2-43. Machining is accomplished with the ship afloat and fully loaded. The ship must be kept in this condition for what minimum period of time before starting machining operations to allow ship structural members to adjust to the load?

1. 12 hr
2. 24 hr
3. 36 hr
4. 48 hr

2-44. What is the fourth major step in the alignment procedure accomplished by a support activity?

1. The placement of reference marks
2. The establishment of initial benchmarks
3. The performance of elevation zero alignment
4. The verification of fire-control radar RF optical alignment

2-45. Train and elevation zero alignment is conducted to ensure that all combat systems equipment points to the same point in space when so directed.

1. True
2. False

2-46. Train and elevation alignment between the alignment reference and other combat systems equipment is accomplished by comparing equipment when the optical axes are made parallel by sighting on which of the following elements?

1. Ship's bow
2. Far horizon
3. Celestial body
4. Ship's antenna

2-47. Tram and benchmarks are NOT used to facilitate checking combat systems equipment at a definite train and elevation position.

1. True
2. False

2-48. All of the following records are normally contained in the combat systems/weapons smooth log except which one?

1. Rounds fired
2. Alignment
3. Erosion
4. Weather

2-49. What is radar collimation?

1. The parallel alignment of the radar beam axis only
2. The parallel alignment of the optical axis of the radar antenna only
3. The parallel alignments of the radar beam axis and the optical axis of the radar antenna
4. The displacement of the horn antenna

2-50. What is used to establish the boresight axis?

1. Feed horns
2. Horn antenna
3. Optical telescope
4. Audible measurement

2-51. During radar collimation, the horn antenna is connected to what type of power-measuring equipment?

1. RF
2. HF
3. UHF
4. VHF

2-52. What is the primary radar for the TARTAR GMFCS?

1. AN/SPG-48C/D
2. AN/SPG-51C/D
3. AN/SPG-55C/D
4. AN/SPG-68C/D

2-53. The AN/SPG-51C/D radar uses what band for CWI?

1. D
2. I
3. J
4. X

2-54. Collimation of the Tartar radar consists of determining the error between the_____ beam axis and the boresight axis and the errors between the _____ beams themselves.

1. RF/RF
2. RF/UHF
3. UHF/VHF
4. EHF/VHF

2-55. In addition to determining the relative positions of the RF beam axis, collimation operations should ensure that the beam pattern is in what formation?

1. Asymmetrical
2. Symmetrical
3. Horizontal
4. Oblique

2-56. A radar collimation shore tower is normally in what height range?

1. 130 to 250 ft
2. 140 to 275 ft
3. 150 to 300 ft
4. 160 to 350 ft

2-57. Where on the tower array are the test antennas and the optical targets mounted?

1. On the feedhorn
2. On the metal frame
3. On the side lobe
4. On the highest point

2-58. A total of how many test antennas are used in a tower array?

1. One
2. Two
3. Three
4. Four

2-59. Which of the following test equipment is NOT normally used in collimation?

1. AN/SPM-9
2. AN/SPM-6
3. AN/SPG-51
4. AN/UPN-32

2-60. Shore-tower checks between overhauls may be required by which of the following authorities?

1. PWO
2. CWAT
3. NAVSEA
4. CEO

2-61. In track-receive axis collimation, what method is used to determine the error between the track-receive axis and the borescope axis of the AN/SPG-51C/D radar?

1. Angle-error null
2. Electronic null
3. Mechanical null
4. Tracking angle null

2-62. What minimum number of nulls and the borescope readings should be taken to determine the collimation error between the TR axis and the borescope axis?

1. 10
2. 20
3. 30
4. 35

2-63. What test equipment, if any, is required aboard ship during track-transmit axis collimation?

1. AN/SPM-9
2. AN/SPM-6
3. AN/UPN-32
4. None

2-64. What method of measurement is used to detemine the error between the CWI axis and the borescope axis of the AN/SPG-51C/D radar?

1. Angle
2. Circle
3. Borescope plot
4. Beam-pattern plot