Naval Education and Training Command

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Training Manual (TRAMAN)

Fire Controlman First Class

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Naval Education And Training Program Management Support Activity

FIRE CONTROLMAN FIRST CLASS

NAVEDTRA 10278

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CONTENTS

CHAPTER 1

THE MAINTENANCE SYSTEM

As an FCl your responsibilities will include more than the repair and upkeep of equipment. Your responsibilities will also include being a division administrator, training subordinate personnel, and, in many cases, having the final say on the many aspects of maintenance and the procedures for reporting maintenance actions. This chapter is designed to help you in the maintenance aspects of your new responsibilities.

THE 3-M SYSTEMS

The Ship's Maintenance and Material Management (3-M) Systems were designed to overcome the problems of maintaining increasingly complex weapon systems and to obtain fleetwide data on the reliability of equipment. The primary objective of the 3-M Systems is to provide for managing maintenance and maintenance support to ensure maximum equipment operational readiness.

The 3-M Systems require careful administration and hard work to ensure success. The systems are a tool to help solve maintenance problems and to collect data concerning those problems. They establish uniform maintenance standards, criteria, and procedures; reduce administrative burdens on maintenance personnel; document maintenance requirements and performance; identify the cost of maintenance in terms of manpower, material, and funds; and reduce cost through increased efficiency.

The Navy Ship's Maintenance and Material Management (3-M) Systems are composed of the planned maintenance system (PMS) and the maintenance data system (MDS).

THE PLANNED MAINTENANCE SYSTEM (PMS)

The PMS system provides each ship, each department, and each supervisor with the means to plan, schedule, and control shipboard maintenance effectively. The PMS objective is to maximize operational readiness of all equipments and to reduce downtime, maintenance man-hours, and maintenance costs.

The primary ingredients of the PMS program are as follows:

- Comprehensive procedures for planned maintenance of the combat system, subsystems, and equipment
- Scheduling and control of maintenance task performance
- Description of the methods, materials, tools, and personnel required for maintenance

Adherence to the PMS program will produce the following results:

- Improved confidence in system maintenance
- Reduced testing time
- Elimination of redundant testing resulting from uncoordinated testing
- Detection of most malfunctions during scheduled maintenance events

If you are the senior petty officer in a work center, you will be the work center supervisor.

As a work center supervisor, you will have the responsibility of scheduling the weekly and daily work center maintenance and supervising its proper accomplishment. You will be responsible for reporting this to your division officer and assisting him in updating the PMS quarterly schedule. This requires that you be familiar with the commonly used tools of the PMS system. These tools include, among others, the 3-M manual (OPNAVINST 4790.4A), the PMS manual, the maintenance index page (MIP), maintenance requirement cards (MRCs), the list of effective pages (LOEP), the equipment guide list (EGL), and the type commander's maintenance manual.

PMS Manual (43P1)

A PMS manual is made up for each department of the ship, listing all work centers in the department. The departmental master PMS manual contains a list of effective pages (LOEP) and a MIP to work center file, which provides a listing of all the MIPs in the department and the work centers responsible for the MIPs. Each MIP is a complete listing of the maintenance requirements for an equipment, with the frequency of maintenance and a brief description of each maintenance requirement.

Work Center PMS Manual

The work center PMS manual is that portion of the departmental master PMS manual that contains only the planned maintenance requirements applicable to a particular work center. It is designed to provide a ready reference of planned maintenance requirements for the work center supervisor and should be retained in the working area, near the weekly PMS schedule, in the holder provided.

Maintenance Requirement Cards (MRCs)

The MRC defines the job in a step-by-step procedure listing tools, parts, test equipment, and materials required to perform the job, as well as the recommended skill level and the approximate amount of time needed to complete the job. Some cards may have blank spaces for data (relative sensitivity, system sensitivity, and the like, which may vary from ship to ship) to be filled in by the ship's company. If the data necessary to fill in the blanks is not available to ship's company, a PMS Feedback Report requesting the required data should be submitted.

When classification of MRCs is required due to content, an unclassified single-page or multipage locator card (fig. 1-1) is provided for each classified MRC. The locator card duplicates the information in all of the MRC blocks down to, but not including, the procedure block. The procedure block only includes notes used to amplify an R periodicity code or to continue entries too numerous for the space provided in one of the fixed blocks, and it includes one of the following statements:

> "Maintenance procedure with the requirement is CONFIDENTIAL. Maintenance requirement card is stowed in ______________"

> "Maintenance procedure with the requirement is SECRET. Maintenance requirement card is stowed in ________"

The page number, SYSCOM MRC control number, and Data block of these locator cards, which are unclassified, are the same as those on page 1 of the classified MRC. The classified MRC is printed on pink stock with the classification indicated at the top and bottom of each page. Classified MRCs will be handled in accordance with OPNAVINST 5510.1 (current edition), *Department of the Navy Information and Personnel Security Program Regulation.*

It will be up to you, as a first class petty officer and possibly as the work center supervisor, to see that maintenance personnel use these cards and follow the procedures on them. All MRCs must be returned to the holders provided when not in use.

Changes to MRCs

MRCs must be accurate with as few errors as possible. But occasionally errors do show up. There may be instances where an obvious typographical error has been made on the MRC. For example, the card might state "*Turn Switch To ON*," although the switch may already be ON; thus, the card should read "*Turn Switch To OFF*." In these cases, obvious typographical errors should not deter the performance of maintenance or marking complete performance of the maintenance correctly on the schedules; however, you should be certain these are typographical errors before performing maintenance. A PMS Feedback Report (FBR) (OPNAV 4790/7B) should be submitted immediately. In any case, MRCs should not be permanently altered until authorized by the cognizant agency.

Another source of error on the MRC is the need for a change in the maintenance procedures or in the periodicity of the MRC. In these instances, a feedback report should be submitted, detailing the suggested changes, and then forwarded to the Naval Sea Support Center (NAVSEACEN) via the TYCOM. Each command has the prerogative to increase the

SHIP SYSTEM	SUBSYSTEM	MRC CODE
		R-28 M-1

SYSTEM	EQUIPMENT	RATES	M/H
	AN/SPS-39A Radar Set	FC3	3.9
		FCSN	3.9

TOTAL M/H 7.8
ELAPSED TIME 3.9

MAINTENANCE REQUIREMENT DESCRIPTION

1. Test coordinate data computer and display console angle accuracy.
2. Test display console range accuracy.
3. Test azimuth gated variable ELSCAN operation.

SAFETY PRECAUTIONS

1. Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series.
2. When BATTLE SHORT switch is on, protective interlock switch is bypassed and voltages dangerous to life are present. Do not work alone.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

TEST EQUIPMENT
1. [0637] Headset-chest set, electrical, type H-200/U, sound-powered

MISCELLANEOUS
1. [0945] Oscilloscope, 50 MHz 7 ns (SCAT 4308)
2. [1529] Voltmeter, Diff AC/DC (SCAT 4208)

NOTE: Numbers in brackets can be referenced to Standard PMS Materials Identification Guide (SPMIG) for stock number identification.

PROCEDURE

Maintenance procedure with this requirement is CONFIDENTIAL.
Maintenance requirement card is stowed in ______________.

PAGE 1 OF 10

C A2 CBP1 N

LOCATION

DATE October 1982

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4790/82 (REV 2-82)

173.702

Figure 1-1.—Single page locator card for classified MRC.

frequency for performance of specified planned maintenance to meet local conditions.

Changing the data printed in the TOOLS, PARTS, MATERIALS, and TEST EQUIPMENT blocks are the only changes shipboard personnel are permitted to make to MRCs. As the supervisor, you must ensure that any substitutions satisfy the basic requirements of the MRC.

Corrections to erroneous PMS documentation that affects the safety of personnel or that could cause possible damage to equipment are issued by the cognizant design activity or in-service engineering agent of that particular equipment. (For example, the Naval Ship Weapon System Engineering Station [NSWSES] is the in-service engineering agent for the surface missile systems.) These corrections (pen and ink changes) are issued by message and are temporary until hard copy changes are made and issued by NAVSEACEN.

EQUIPMENT GUIDE LIST
OPNAV 4790/81 (2-75)
S/N 0107-LF-047-9005

PAGE ____ OF ____

MIP NO. (Less last 2 characters) ____________ MRC PERIODICITY ____________

EQUIPMENT NAME/NOMENCLATURE	SERIAL NO. QUANTITY	LOCATION	APPLICABLE DATA AS REQUIRED BY MRC

173.703

Figure 1-2.—Standard EGL (equipment guide list).

TAG GUIDE LIST
OPNAV 4790/107 (10-80) S/N 0107-LF-047-8545

MIP & MRC NO. ____________
EQUIPMENT ____________

NUMBER OF TAGS PER EQUIP

NOTIFICATION DATA		
COLD IRON	INPORT STEAMING	UNDERWAY

EQUIPMENT SERIAL NO.	SERIAL NO. SWITCH/VALVE	LOCATION OF SWITCH/VALVE	POSITION OF TAGGED ITEM	AMPLIFICATION DATA

VERIFICATION/APPROVAL SIGNATURES

WCS	DIV OFF	DEPT HEAD	CO

173.704

Figure 1-3.—Standard TGL (TAG guide list).

Advance Change Notice (ACN)

Advance change notices to MRCs may be issued by NAVSEACENs in some instances. A PMS advance change notice is authorization to change an existing MIP or MRC or to add a new MRC. A PMS ACN that affects a particular MRC is issued in the format of a maintenance requirement card and can be attached to the MRC to which it applies. The subject matter of the ACN may involve changing the periodicity of accomplishment of the MRC; adding or modifying MRC procedures; or adding or changing the listing of tools, parts, materials, and test equipment.

Each PMS ACN is serialized. The serial number consists of the originating activity code, the MIP number, the serial number, log number, and data. The ship's 3-M coordinator keeps a record of each ACN in the ship's master accountability log and distributes the change(s) to the appropriate department(s). These ACNs should also be entered on the 43P1 record of change page by the work center supervisor.

Equipment Guide List (EGL), OPNAV Form 4790/81

The EGL is used with a controlling MRC when the MRC applies to a number of identical items; that is, motors, controllers, valves, test equipment, and so on. Standard EGLs are available from the naval supply system (fig. 1-2). The work center supervisor is responsible for the preparation of EGLs for equipment in his work center. In preparing the EGL, consideration must be given to the skill level of the person to be assigned and the time required to do the maintenance on each item. Each page of an EGL should contain no more than a single day's work. If more than one day is required, separate EGL pages should be prepared for each day and numbered consecutively.

Tag Guide List (TGL), OPNAV Form 4790/107

The TGL (fig. 1-3) is a card similar in size to an MRC and contains the information necessary for equipment tag-out incidental to PMS accomplishment. The TGL contains the number of tags required, location of tags, position of the tagged item (open, shut, off, on, etc.), and permission or notification requirements. Each ship prepares its own TGLs. TGLs are laminated after final approval. TGLs are available from the naval supply system.

List of Effective Pages (LOEP)

The departmental LOEP (fig. 1-4) provides a listing of the MIPs assigned to each department,

NAVAL SEA SUPPORT CENTER PACIFIC
PLANNED MAINTENANCE SYSTEM MIP TO WORK CENTER FILE

REPORT NO PMS 4 A

REPORT DATE 01/17/8_
SFR 1-8_
PAGE 19 2628

UNIT — CGN 0035 DEPARTMENT — WEAPONS DECK

MIP	NOMENCLATURE	--WORKCENTER DISTRIBUTION--				
4818/002-14	RADAR SET AN/SPG-53F	CSG1				
4818-007-73	COMPUTER MK 47 MOD 9	CSG1				
4818/009-14	FCS GUN MK 88 MOD 8	CSG1				
4821/005-44	MFCS HARPOON CANISTER TEST	CSG1				
4821/014-44	MFCS HARPOON CANISTER 4821	CSG1				
4821/602-44	(HGMS) MK 78 MOD 0/1	CSG1				
4832/202-13	TEST SET MK 432 MOD 2	CSS2				
4834/212-93	FCG. ASROC MK 114 MOD 12	CSS2				
4901/R01-83	AN/SQQ-18A	CSS1				
5221/001-83	MAGAZINE SPRINKLER SYSTEM	CSG2	CSM1	CSS2		
7000/X01-A3	EXP ORD SFTY INSP	CSG2				
7111/004-14	MOUNT 5 54 CAL MK42 MOD10	CSG2				
7212/102-14	DIRECTOR, DUMMY MK 6 MOD 1	CSM1				
7500-46A-A3	AIRBORNE MK 46 TORPEDO	CSS2				
7500-46S-A3	TORPEDO MK 46 MOD 1 & 2	CSS2				
7501/090-44	TUBE, TORPEDO SV MK32 MOD9	CSS2				
7601/007-14	MT. SALUTING 40MM MK11 MOD0	CSG2				
8443/001-C1	INTEGRATED COMBAT SYS TEST	CSM2	CSN1	CS00		
* A — 040/108-A2	PUMP AIR COND CHILLED WATER	CSE1	CSE3	CSM3	CSN1	CSS1
A — 147/019-83	ELECTRONICS DRY AIR SYSTEM	CSM2	CSM3	CSW1		
A — 147/027/83	LOW PRESSURE AIR DRYER	CSM3				
* A — 147/097-53	ELECTRONIC DRY AIR SYSTEM	CSE1				
* A — 160/048-34	ELECTRONIC COOLING SYSTEM	CSE1	CSM3	CSN1	CSS1	
A — 183/001-13	N2 CHARGING EQUIPMENT	CSS2				
A — 192/001-43	PUMP TURBOPELLER	CSM1				

173.705

Figure 1-4.—Sample LOEP (list of effective pages), report PMS 4A.

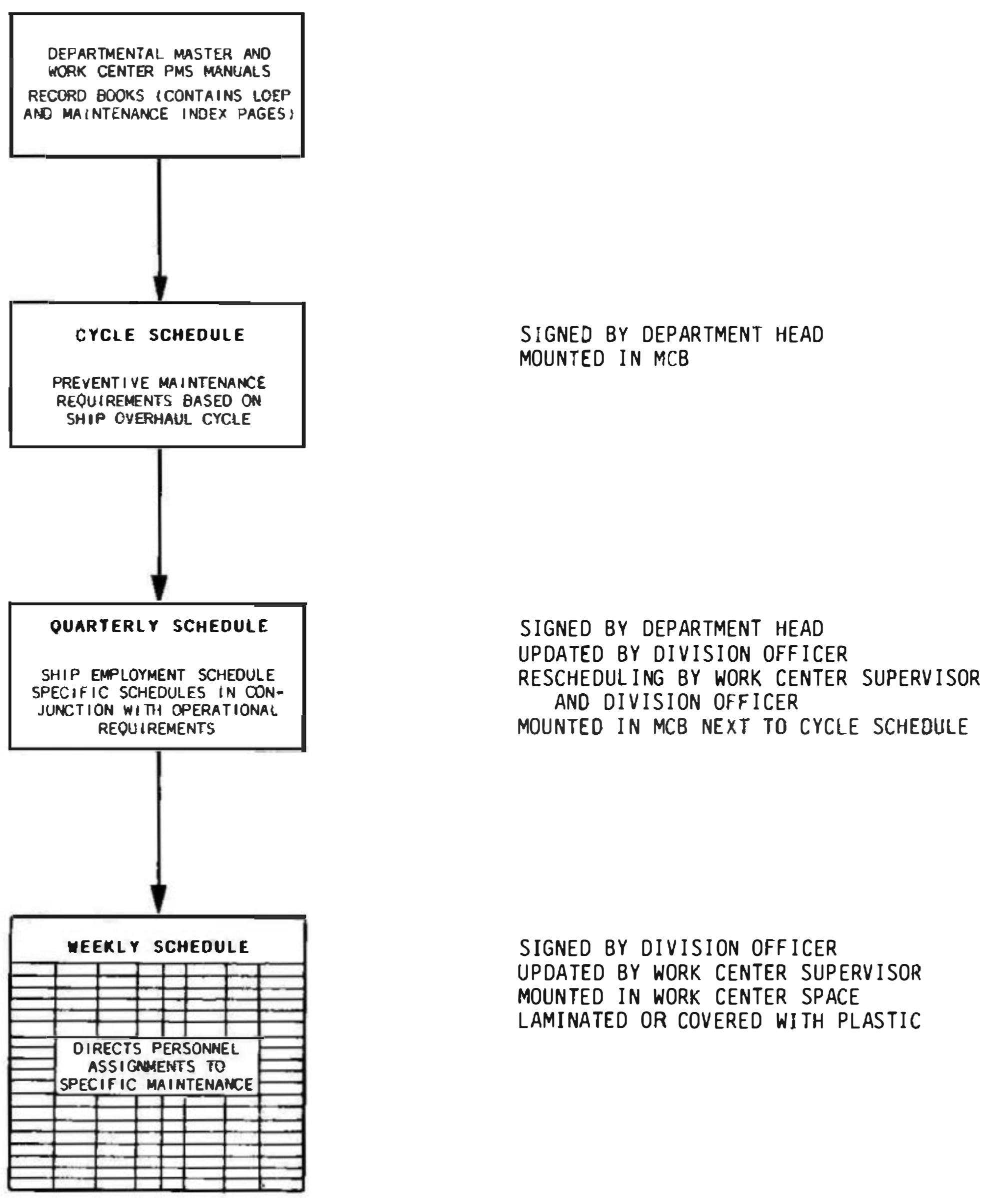
divided by work centers. The LOEP is issued periodically, and each issue is assigned a semiannual force revision (SFR) number. This number should be verified for accuracy by comparison with the automated library issue document (ALID) held by the ship's 3-M coordinator when new issues are received.

PMS SCHEDULES

The normal flow of events maintenance personnel use in performing work center PMS is shown in figure 1-5. This figure shows maintenance management responsibilities and the sequence of events that flow from the departmental master PMS manual through the scheduling aids (cycle, quarterly, and weekly schedules) to preventive maintenance execution.

Cycle Schedule

The cycle schedule is a visual display of preventive maintenance requirements to be performed during the period between major overhauls of the ship. It is used by department heads



173.706

Figure 1-5.—Departmental PMS flow.

to plan and schedule maintenance requirements during each calendar quarter.

Quarterly Schedule

The quarterly schedule displays each work center's PMS requirements to be performed during a specific 3-month period. This schedule is prepared by the department heads in cooperation with division officers and work center supervisors.

Maintenance Control Board

The completed and signed cycle schedule and current quarterly schedule are mounted in holders called maintenance control boards (MCBs). MCBs are available in various sizes to provide an adequate number of surfaces for mounting all work center cycle and quarterly schedules.

Weekly Schedule

The weekly schedule displays the planned maintenance schedule for accomplishment in a given work center during a specific week. The work center supervisor uses the weekly schedule to assign specific personnel to perform maintenance on specific equipment. The weekly schedule is either laminated or covered with plastic after permanent information is entered. Information that changes weekly is written on the laminate or plastic.

To prepare the weekly schedule, you will need information from the cycle and quarterly PMS schedules, the LOEP, and applicable MIPs. Some of the information on the weekly schedule (fig. 1-6) must be permanent (in ink, typed,

WEEKLY PMS SCHEDULE (CONVENTIONAL)

WORK CENTER			PMS SCHEDULE FOR WEEK OF				APPROVAL SIGNATURE		
MIP	COMPONENT	MAINTENANCE RESPONSIBILITY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT SUN	OUTSTANDING REPAIRS AND P M CH'CKS DUE IN NEXT 4 WEEKS
2560/1	CIRC & COOLING SEA WATER SYSTEM								
	SW CIRC PUMP		D-1	D-1	D-1	D-1	D-1	D1/D1	R-1
	PIPING & MISC								
4411/1	LOW FREQUENCY COMMUNICATIONS								
	AN/SRR-19								R-1
	#1,AN/WRR-38								
	#2,AN/WRR-38								R-1,R-2
	CU-2007/SRR								
	LF"N"SUB-SYSTEM								
4821/P1	MISSILE FIRE CONTROLSYS(HARPOON)		W-1,2						
5831/1	BOAT HANDLING & STOWAGE SYSTEM								
	BOAT DAVIT								
	BOAT WINCH								Q-1R
6230/1	LADDERS (EGL-1)								

173.707

Figure 1-6.—Sample weekly schedule containing permanent information.

or printed), while other information can be nonpermanent marking (grease pencil) (fig. 1-7). Enter the permanent information first as follows: Type or print the work center identification code. Type or print the MIP code and component nomenclature, line for line, to match the cycle PMS schedule. Leave off the date portion of the MIP because this date changes periodically with semiannual force revisions (SFRs). List all weekly requirements in the Monday column, and daily requirements in each day-of-the-week column. Schedule 2D periodicity on Monday, Thursday, and once in the SAT-SUN column. Schedule 3D periodicity on Monday, Wednesday, Friday, and once in the SAT-SUN column. List all situation requirements (R-1, S-2R, and so on) in the column labeled Next Four Weeks. The schedule can now be either laminated or covered with plastic so it can be cleared and updated each week.

Now you can add the nonpermanent information with a grease pencil. Using the quarterly PMS schedule, the work center supervisor transposes all PMS requirements from the column for the week being scheduled to the weekly PMS schedule (fig. 1-7). Here, you will have to review the MIPs for any related maintenance actions. Next, assign personnel, by name, to specific line entries. Finally, submit the completed weekly schedule to your division officer for review, approval and signature, and post it in the work center.

In using the weekly PMS schedule, maintenance personnel obtain PMS assignments from the schedule and report completed and uncompleted actions to the work center supervisor.

WEEKLY PMS SCHEDULE (CONVENTIONAL)
OPNAV FORM 4790/15 [illegible]
S/N 0107-LF-770-3280

WORK CENTER			PMS SCHEDULE FOR WEEK OF				APPROVAL SIGNATURE		
MIP	COMPONENT	MAINTENANCE RESPONSIBILITY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT SUN	OUTSTANDING REPAIRS AND P M CHECKS DUE IN NEXT 4 WEEKS
2560/1	CIRC & COOLING SEA WATER SYSTEM								
	SW CIRC PUMP		D-1	D-1	D-1	D-1	D-1	D1/D1	R-1
	PIPING & MISC		M-1		Q-1				M-1, Q-1
4411/1	LOW FREQUENCY COMMUNICATIONS								
	AN/SRR-19		M-1						R-1 M-1
	#1,AN/WRR-38								
	#2,AN/WRR-38								R-1,R-2
	CU-2007/SRR		M-1	M-2		Q-1			M-1,2 Q-1
	LF "N" SUB-SYSTEM								
4821/P1	MISSILE FIRE CONTROL SYS (HARPOON)		W-1,2	Q-1		Q-2			Q-1,2
5831/1	BOAT HANDLING & STOWAGE SYSTEM								
	BOAT DAVIT								
	BOAT WINCH								Q-1R
6230/1	LADDERS (EGL-1)								

173.708

Figure 1-7.—Sample weekly schedule showing permanent plus nonpermanent information.

If the work center supervisor is satisfied that the work has been properly completed, he crosses off the maintenance requirement with an *X*. If not completed, the maintenance requirement is circled and rescheduled. Each Monday morning, the division officer compares the preceding week's PMS schedule with the quarterly schedule and updates the quarterly schedule accordingly.

MAINTENANCE DATA SYSTEM (MDS)

The purpose of MDS is to provide information about certain fleet maintenance and maintenance support action for use by various levels and areas of management throughout the Navy, with particular emphasis on providing information at the shipboard level. The objectives of the MDS include providing the means to develop the current ship's maintenance project (CSMP) and for generating automated work requests for maintenance actions deferred for outside assistance. As a first class petty officer, you must be knowledgeable of the MDS. You are also responsible for ensuring that MDS reports and forms generated by maintenance personnel under your supervision are accurate and reflect the true condition of your equipment. In the following paragraphs, we will discuss selected topics of the MDS.

MDS Reports

Two types of reports are required to meet the MDS objective: deferred and completed maintenance actions. Deferred maintenance actions are those that (1) require outside assistance, (2) cannot be accomplished by ship's force within 30 days, or (3) describe uncorrected INSURV (board of inspection and survey) deficiencies. An example of a deferred maintenance action form is shown in figure 1-8. Completed maintenance action (fig. 1-9) reports are required in the following instances:

- Completion of previously deferred maintenance.
- Maintenance on equipment on the selected equipment list (SEL) by ship's force. SEL reporting is described in the 3-M manual, OPNAVINST 4790.4A.
- Actions significant for material history purposes.

Maintenance deferred for outside assistance is reported by all ships. Ship's force reports all maintenance actions on designated selected equipment. Selected equipments are those new or modified equipments and systems in the fleet for which no reliability information exists, and certain equipments or systems that have proved unreliable. From the data gathered on reliability and maintainability, it can be determined whether actions related to equipment design, maintenance procedures, or supply support are required.

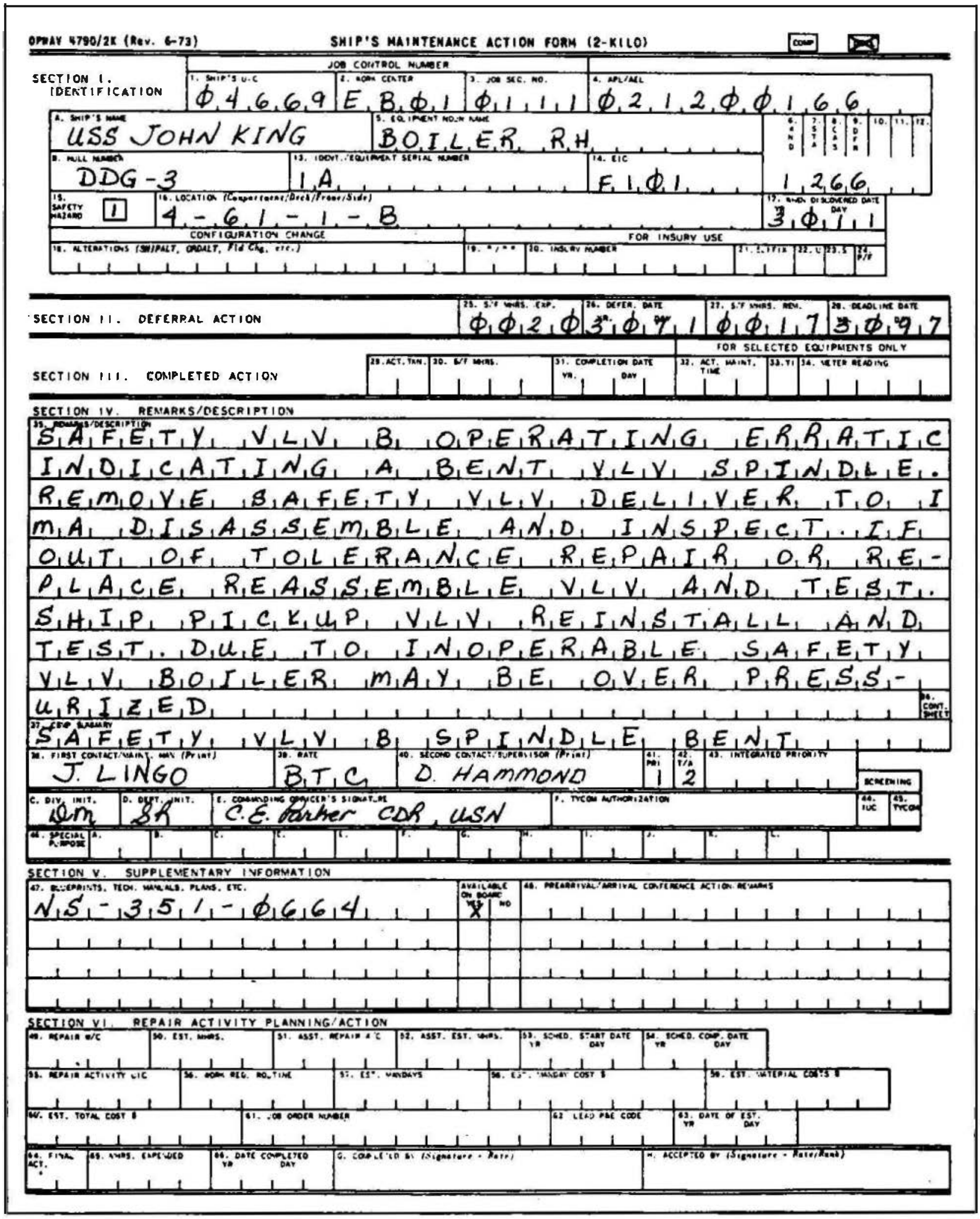
Another type of report is for failed parts. This report is required for engineering analysis. Ideally, only one item is listed as the cause of failure, even though it may have caused other parts to fail. Maintenance personnel must use sound judgement to avoid the accumulation of unnecessary failed part information in the data bank.

NOTE: A worn but serviceable part that is replaced to ensure continued equipment operation is not a failed part.

The MDS depends on accurate, complete reporting from fleet units. As a first class petty officer and possibly a work center supervisor, it will be your responsibility to ensure that a high quality level is achieved and maintained in all MDS reporting from your work center. To do this you will have to become completely familiar with the 3-M manual, OPNAV 4790.4A, and applicable type commander directives that may amplify portions of the 3-M manual. Although the 3-M manual is the basic document, it does not address some new systems being introduced to fleet units that support the 3-M Systems in general. This is particularly true of the shipboard nontactical automated data processing (SNAP 2) programs. SNAP 2 automates supply procedures and both PMS and MDS procedures. Documents describing how to use SNAP 2 will be on board if your ship has the system installed. You will have to become knowledgeable of the procedures in the SNAP 2 documents as well as the 3-M manual and type commander directives in order to do your job as a supervisory-level petty officer and potential work center supervisor.

MAINTENANCE ORGANIZATION

As part of the continuing effort to keep the fleet in a peak condition of readiness, the Navy has developed an overall maintenance strategy. Ship's maintenance is one of the two major components of the Navy's ship maintenance and modernization program, which, in its entirety, defines the material condition and configuration of Navy ships. The ship's maintenance program is designed to keep the ship at an adequate level



OPNAV 4790/2K (Rev. 6-73) SHIP'S MAINTENANCE ACTION FORM (2-KILO)

SECTION I. IDENTIFICATION

JOB CONTROL NUMBER

1. SHIP'S UIC	2. WORK CENTER	3. JOB SEQ. NO.	4. APL/AEL
Φ4669	EBΦ1	Φ111	Φ212ΦΦ166

A. SHIP'S NAME	5. EQUIPMENT NOUN NAME
USS JOHN KING	BOILER RH

B. HULL NUMBER	13. IDENT./EQUIPMENT SERIAL NUMBER	14. EIC	
DDG-3	1A	F1Φ1	1266

15. SAFETY HAZARD	16. LOCATION (Compartment/Deck/Frame/Side)	17. WHEN DISCOVERED DATE YR. DAY
1	4-61-1-B	3Φ11

CONFIGURATION CHANGE — 18. ALTERATIONS (SHIPALT, ORDALT, Fld Chg, etc.)

FOR INSURV USE — 19. */** 20. INSURV NUMBER 21. 22. 23. 24.

SECTION II. DEFERRAL ACTION

25. S/F MHRS. EXP.	26. DEFER. DATE	27. S/F MHRS. REM.	28. DEADLINE DATE
ΦΦ2Φ	3Φ71	ΦΦ17	3Φ97

SECTION III. COMPLETED ACTION — 29. ACT. TKN. 30. S/F MHRS. 31. COMPLETION DATE YR. DAY — FOR SELECTED EQUIPMENTS ONLY: 32. ACT. MAINT. TIME 33. TI 34. METER READING

SECTION IV. REMARKS/DESCRIPTION

35. REMARKS/DESCRIPTION

SAFETY VLV B OPERATING ERRATIC INDICATING A BENT VLV SPINDLE. REMOVE SAFETY VLV DELIVER TO IMA DISASSEMBLE AND INSPECT. IF OUT OF TOLERANCE REPAIR OR RE-PLACE REASSEMBLE VLV AND TEST. SHIP PICKUP VLV REINSTALL AND TEST. DUE TO INOPERABLE SAFETY VLV BOILER MAY BE OVER PRESS-URIZED

36. CONT. SHEET

37. CSMP SUMMARY: SAFETY VLV B SPINDLE BENT

38. FIRST CONTACT/MAINT. MAN (Print)	39. RATE	40. SECOND CONTACT/SUPERVISOR (Print)	41. PRI	42. T/A	43. INTEGRATED PRIORITY
J. LINGO	BTC	D. HAMMOND	1	2	

C. DIV. INIT.	D. DEPT. INIT.	E. COMMANDING OFFICER'S SIGNATURE	F. TYCOM AUTHORIZATION	44. IUC	45. TYCOM
Dm	SR	C.E. Parker CDR, USN			

SCREENING

46. SPECIAL PURPOSE A. B. C. D. E. F. G. H. I. J. K. L.

SECTION V. SUPPLEMENTARY INFORMATION

47. BLUEPRINTS, TECH. MANUALS, PLANS, ETC.	AVAILABLE ON BOARD YES	NO	48. PREARRIVAL/ARRIVAL CONFERENCE ACTION REMARKS
NS-351-Φ664	X		

SECTION VI. REPAIR ACTIVITY PLANNING/ACTION

49. REPAIR W/C 50. EST. MHRS. 51. ASST. REPAIR W/C 52. ASST. EST. MHRS. 53. SCHED. START DATE YR DAY 54. SCHED. COMP. DATE YR DAY

55. REPAIR ACTIVITY UIC 56. WORK REQ. ROUTINE 57. EST. MANDAYS 58. EST. MANDAY COST $ 59. EST. MATERIAL COSTS $

60. EST. TOTAL COST $ 61. JOB ORDER NUMBER 62. LEAD PAC CODE 63. DATE OF EST. YR DAY

64. FINAL ACT. 65. MHRS. EXPENDED 66. DATE COMPLETED YR DAY G. COMPLETED BY (Signature - Rate) H. ACCEPTED BY (Signature - Rate/Rank)

173.709

Figure 1-8.—Sample deferred maintenance action.

OPNAV 4790/2K (Rev. 6-73) SHIP'S MAINTENANCE ACTION FORM (2-KILO)

SECTION I. IDENTIFICATION

JOB CONTROL NUMBER

1. SHIP'S UIC	2. WORK CENTER	3. JOB SEQ. NO.	4. APL/AEL
52692	WTØ5	Ø344	89774550

A. SHIP'S NAME	5. EQUIPMENT NOUN NAME
USS GRIDLEY	AN/SPS-49

B. HULL NUMBER	13. IDENT.-EQUIPMENT SERIAL NUMBER	14. EIC	6-9
CG-21	E-12	P34A	527

15. SAFETY HAZARD	16. LOCATION (Compartment, Deck, Frame, Side)	17. WHEN DISCOVERED DATE
☐	Ø1-114-1-Q	4Ø95

CONFIGURATION CHANGE — 18. ALTERATIONS (SHIPALT, ORDALT, Fld Chg, etc.)

FOR INSURV USE — 19. — 20. INSURV NUMBER — 21. — 22. — 23. — 24. P/F

SECTION II. DEFERRAL ACTION — 25. S/F MHRS. EXP. — 26. DEFER. DATE YR. DAY — 27. S/F MHRS. REM. — 28. DEADLINE DATE YR. DAY

SECTION III. COMPLETED ACTION

29. ACT. TKN.	30. S/F MHRS.	31. COMPLETION DATE	32. ACT. MAINT. TIME	33. TI	34. METER READING
1	ØØ11Ø	4Ø95	ØØ55	5	Ø7744

SECTION IV. REMARKS/DESCRIPTION

35. REMARKS/DESCRIPTION

KLYSTRON FAULT WILL NOT RESET
NO OUTPUT FROM KLYSTRON. RE-
PLACED KLYSTRON 2V1 AND BOTH
MODULATOR SWITCH TUBES 2A5V1
AND 2A6V1
METRED-2A1M1

36. CONT SHEET

37. CSMP SUMMARY

38. FIRST CONTACT MAINT. MAN (Print) — 39. RATE — 40. SECOND CONTACT/SUPERVISOR (Print) — 41. PRI — 42. T/A — 43. INTEGRATED PRIORITY

C. DIV. INIT. — D. DEPT. INIT. — E. COMMANDING OFFICER'S SIGNATURE — F. TYCOM AUTHORIZATION — SCREENING 44. IUC 45. TYCOM

46. SPECIAL PURPOSE A. B. C. D. E. F. G. H. I. J. K. L.

SECTION V. SUPPLEMENTARY INFORMATION

47. BLUEPRINTS, TECH. MANUALS, PLANS, ETC. — AVAILABLE ON BOARD YES NO — 48. PREARRIVAL/ARRIVAL CONFERENCE ACTION REMARKS

SECTION VI. REPAIR ACTIVITY PLANNING/ACTION

49. REPAIR W/C — 50. EST. MHRS. — 51. ASST. REPAIR W/C — 52. ASST. EST. MHRS. — 53. SCHED. START DATE YR DAY — 54. SCHED. COMP. DATE YR DAY

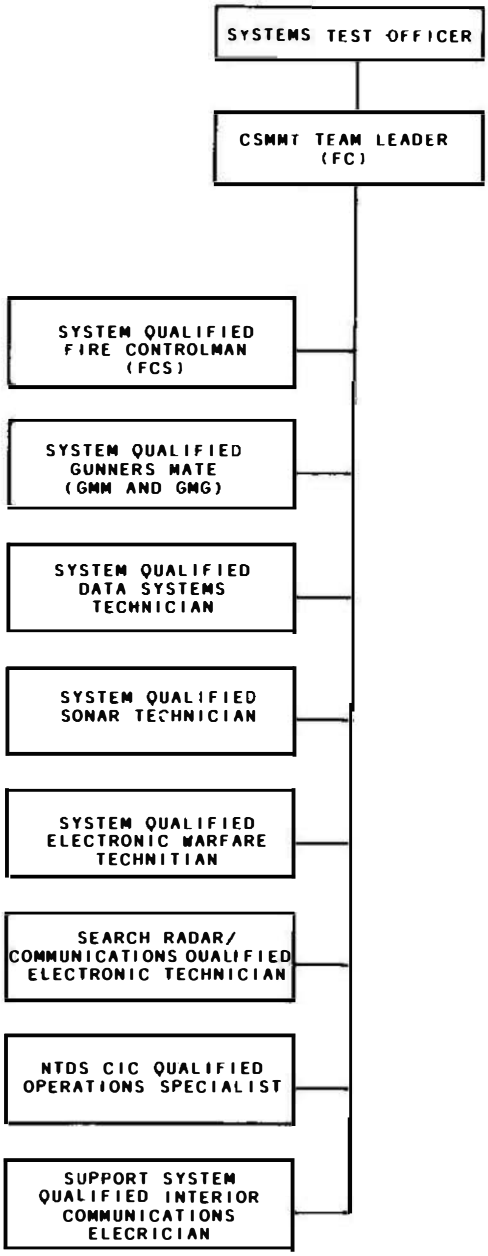
55. REPAIR ACTIVITY UIC — 56. WORK REQ. ROUTINE — 57. EST. MANDAYS — 58. EST. MANDAY COST $ — 59. EST. MATERIAL COSTS $

60. EST. TOTAL COST $ — 61. JOB ORDER NUMBER — 62. LEAD PBE CODE — 63. DATE OF EST. YR DAY

64. FINAL ACT. — 65. MHRS. EXPENDED — 66. DATE COMPLETED YR DAY — G. (Signature + Rate): R. J. Baker ET-2 — H. ACCEPTED BY (Signature + Rate/Rank): PJ Carlton ETCS

173.710

Figure 1-9.—Sample completed maintenance action.



173.711

Figure 1-10.—Combat system maintenance management team organization.

of material condition to maximize their sustained operational availability to the fleet commanders.

The second component, the fleet modernization program (FMP), is designed to update the ships as required to meet current and projected enemy threats and to incorporate safety, environmental, reliability, maintainability, and other improvements. While the maintenance and modernization programs are distinct, they are not independent and are tightly intertwined in their execution. The modernization program is not addressed in this chapter.

The Navy ship maintenance strategy is defined as the process of identifying and utilizing the applicable maintenance assets in a predetermined manner in keeping the materiel condition of Navy ships at the desired level. These assets include personnel, material, facilities, programs, and procedures. The 3-M manual provides the basic structure for maintaining all fleet units at the desired level of operating readiness. The maintenance plan is likely to differ among ship types and classes, but the overall goal is the same.

The Navy ship is an entity in which responsibility for the operation and maintenance of the ship rests with the ship itself. Other Navy organizations exist to support that entity. Integration of the support provided by three defined levels of maintenance into a coordinated system of maintenance and maintenance support throughout a ship's life cycle is a key feature of the Navy's ship maintenance strategy.

The three levels of maintenance are organizational-level (shipboard) maintenance, intermediate-level maintenance, and depot-level maintenance.

ORGANIZATIONAL-LEVEL (SHIPBOARD) MAINTENANCE

The first level of maintenance is the organizational level, which consists of the ship itself and the sailors on board the ship. Organizational-level maintenance is that corrective and preventive maintenance accomplished by the ship's crew. The work is a blend of equipment operation, condition monitoring, planned maintenance action, and repair ranging from simple equipment lubrication to component changeout and, in some cases, complete rework in place. The PMS topics addressed in this chapter thus far have applied to the conventional PMS system. But with the advent and evolvement of sophisticated combat systems, the conventional PMS system had to be expanded to provide PMS coverage for these combat systems; thus, the term *integrated maintenance* was derived.

Integrated Maintenance

Integrated maintenance procedures are intended to provide minimum preventive maintenance coverage of the combat system. The procedures are written to establish specific controlled conditions that challenge the functions under test. Combat system testing is conducted at three levels: combat system, subsystem, and equipment. A combat system test exercises the combat system as one entity. It is the highest level of testing that can be accomplished on board ship. A subsystem test exercises two or more pieces of equipment functionally contained within the same subsystem. An equipment-level test is generally directed toward power levels, frequencies, series tests, output functions, and other special features of individual equipments.

Combat System PMS Management

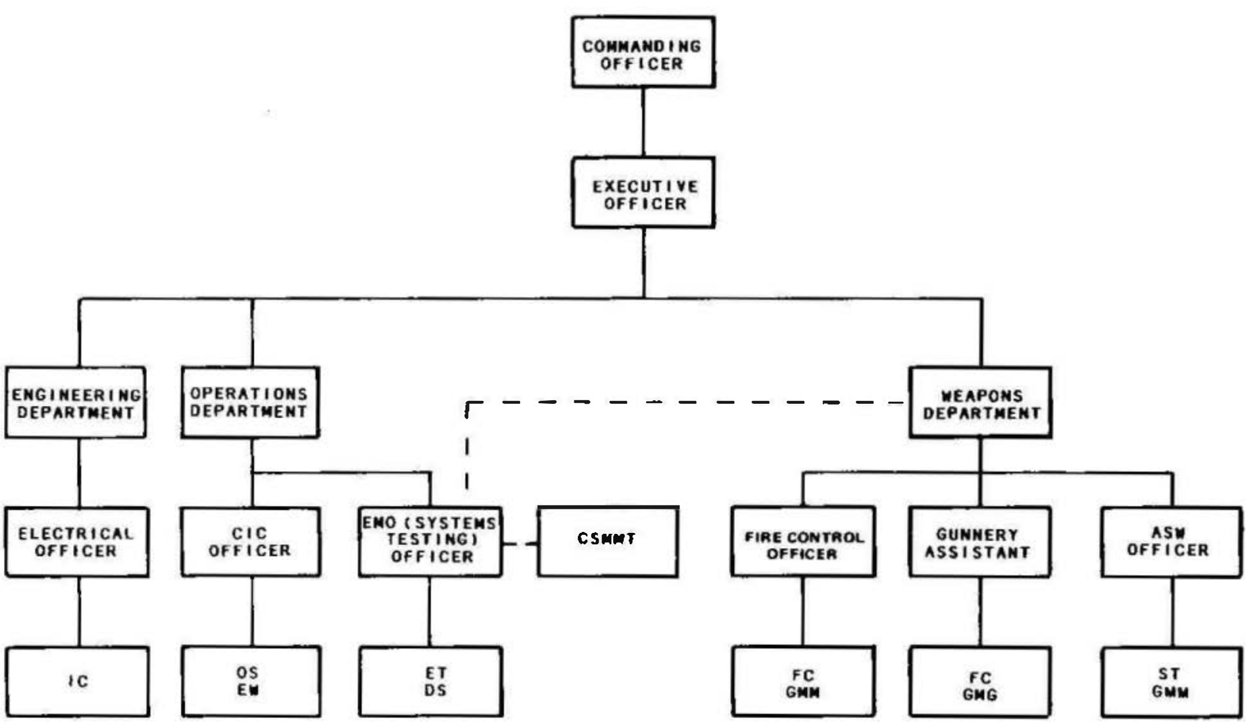
The PMS management includes supervision of actual maintenance actions and all forms of efforts required to plan and support maintenance events. Therefore, a management task involves controlling all combat system PMS activities, including PMS tasks for the combat systems, subsystems, and equipment. The PMS management is one of the major functions of the combat system maintenance management team (CSMMT) (on some ships, this organization is referred to as ship's electronic readiness team—SERT). The CSMMT organization (fig. 1-10) is selected from senior petty officers having extensive experience in subsystem and equipment maintenance. The CSMMT is an official part of the ship's organization and is assigned specific responsibilities that are primary rather than collateral duties. The CSMMT is administratively controlled by the systems test officer (STO). It is responsible to the STO for ensuring combat system maintenance management and providing a liaison with personnel of all subsystems.

Although the combat system does not encompass the entire ship nor include all departments, it does depend on other departments for certain vital support. Figure 1-11 shows the interdepartmental relationship of the CSMMT.

INTERMEDIATE-LEVEL MAINTENANCE

The intermediate level of maintenance is the second highest level of maintenance. This level of maintenance is normally performed by Navy and government civilian personnel on tenders, repair ships and aircraft carriers, fleet support bases, and shore intermediate maintenance activities (SIMAs). Work normally consists of calibration test; repair or replacement of damaged or unserviceable parts, components, or assemblies; the emergency manufacture of unavailable parts; and providing technical assistance.

In keeping with the Navy's maintenance strategy, intermediate maintenance activities (IMAs) accomplish ship maintenance beyond forces afloat capability to the maximum extent feasible consistent with the availability of material, funds, and skilled manpower.



173.712

Figure 1-11.—CSMMT interdepartmental relationship.

DEPOT-LEVEL MAINTENANCE

Depot-level maintenance is that type of maintenance generally requiring a greater industrial capability than possessed by either shipboard or intermediate-level activities. Work consists of maintenance performed by shipyards, either private or Navy, on equipment requiring major overhaul or complete rebuilding of parts, assemblies, subassemblies, and the complete manufacture of parts.

QUALITY ASSURANCE (QA)

The QA programs are established to ensure that materials meet specifications and that repairs are done correctly and documented. Ship's company and repair activity personnel will typically share the responsibility for ensuring that repairs are performed in accordance with QA program requirements. As a first class petty officer, you can expect to be involved in QA programs and have an essential part of any successful QA program.

DEFINITION OF TERMS

There are several terms that are frequently used in discussing QA requirements. You should be familiar with these terms.

Quality assurance. QA is a system that ensures that material, data, supplies, and services conform to technical requirements and that repaired equipment performs satisfactorily.

Quality control. Quality Control (QC) is a management function that controls defective repair products.

Specification. A specification is any technical or administrative directive, such as an instruction, technical manual, drawing, plan, or publication, that defines repair criteria.

In-process inspection. This type of inspection is performed during the manufacture and repair cycle to prevent production defects. It is also performed to identify production standards or material characteristics that are not detectable during a final inspection.

Technical repair standards. Engineering technical repair standards (TRS) are instructions that are developed for overhaul, repair, or restoration of selected equipment.

Levels of essentiality. Levels of essentiality are codes that indicate the degree a ship's system, subsystem, or components are necessary and indispensable in the performance of its mission and the impact their catastrophic failure would have on the ship's mission capability and personnel safety.

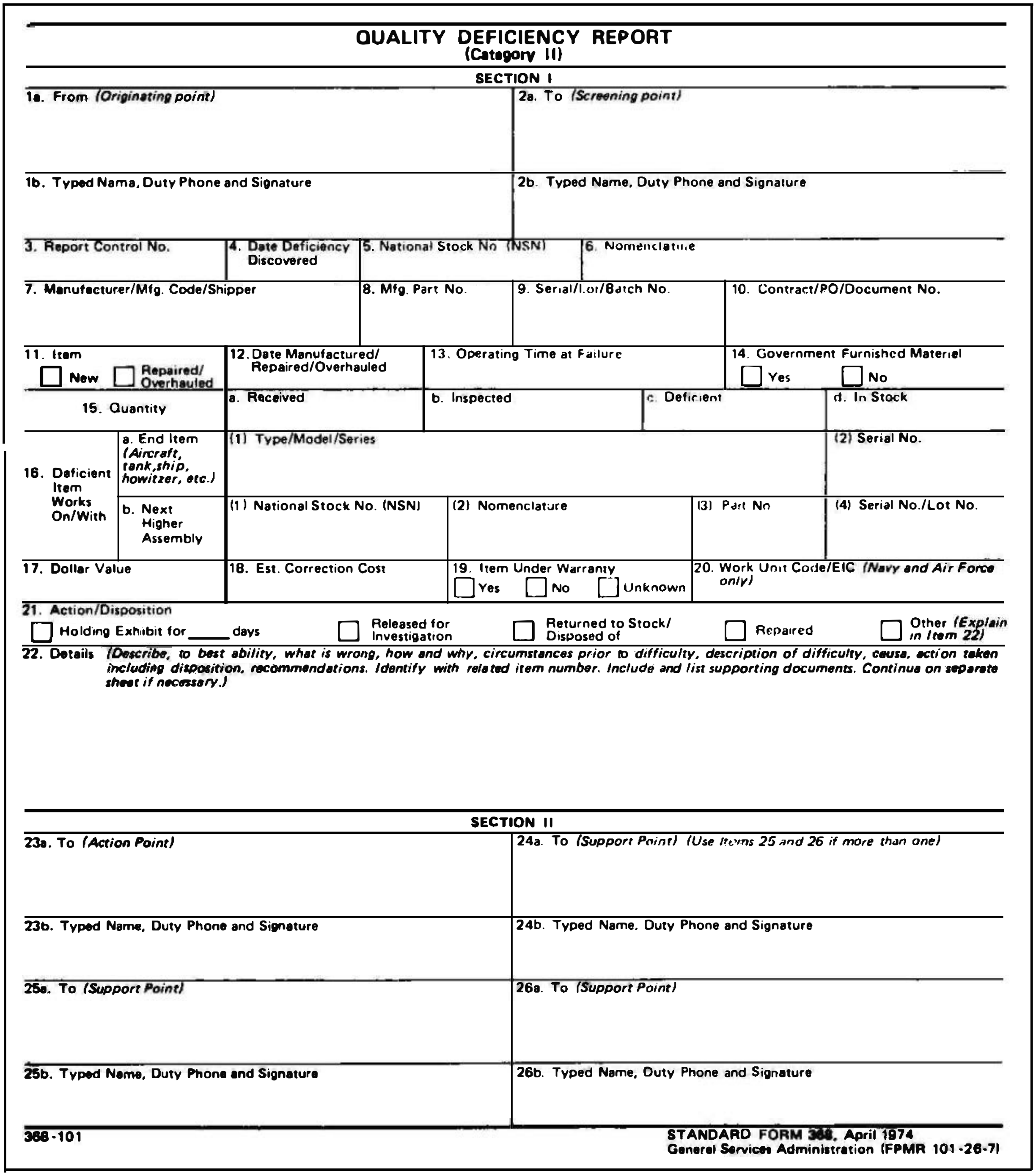
Levels of assurance. Levels of assurance reflect the quality of verification requirements of individual fabrication in-process or repair items. Here, verification refers to the sum total of quality control and test and inspection, etc. Levels of assurance may fall under one or more of the assurance categories (A, B, or C). Level A assurance provides for the most rigidly controlled verification techniques. This normally will require both quality control and test and inspection methods. Level B assurance provides for adequate or sufficient verification techniques. This normally will require limited quality controls and may or may not require test and inspection methods. Level C assurance provides for minimum or as necessary verification techniques. This normally will require very little quality control or test and inspection.

Levels of control. Levels of control are the degrees of control measures required to assure reliability of repairs made to a system/subsystem or component. Furthermore, levels of control (quality control techniques) are the means by which we achieve levels of assurance. Levels of control may fall under one or more of the previously mentioned assurance categories (A, B, or C). An additional category, level I, is reserved for systems that requires maximum confidence that the composition of installed material is correct. An example of where level I controls would apply is to the ship's steam system with a temperature greater than 775 °F. Levels of control requirements, other than those specified by higher technical authority, are decided and assigned by the repair activity only.

In summary of the ship/IMA relationship, the ship submits work requests to IMA indicating the desired QA level. (The QA level is entered in the first three positions of the CSMP summary, block 37 of OPNAV Form 4790/2K or 4790/2Q; for example, QAA, QAB, or QAC to indicate QA levels A, B, or C, respectively.) The intermediate maintenance activity responds to the ship's concerns and requirements by offering both repair quality and repair quality assurance.

To provide repair quality assurance, the quality assurance and repair departments work jointly to set up and use quality control (QA) procedures. By translating/transforming the ship's system essentiality requirements into a compatible level of assurance (A, B, C), the IMA can assign appropriate levels of control (A, B, C, I). Therefore, the IMA guarantees the ship's level of assurance with respect to repair quality by maintaining stringent levels of control.

If an item is defective on receipt from the supply system, it must be reported to the Fleet Material Support Office (FMSO), Mechanicsburg, Pennsylvania, by message and/or by Standard Form 368, Quality Deficiency Report (QDR) (fig. 1-12). Discrepancies in shipments attributable to



QUALITY DEFICIENCY REPORT
(Category II)

SECTION I

1a. From *(Originating point)*
2a. To *(Screening point)*
1b. Typed Name, Duty Phone and Signature
2b. Typed Name, Duty Phone and Signature
3. Report Control No.
4. Date Deficiency Discovered
5. National Stock No (NSN)
6. Nomenclature
7. Manufacturer/Mfg. Code/Shipper
8. Mfg. Part No.
9. Serial/Lot/Batch No.
10. Contract/PO/Document No.
11. Item ☐ New ☐ Repaired/Overhauled
12. Date Manufactured/Repaired/Overhauled
13. Operating Time at Failure
14. Government Furnished Materiel ☐ Yes ☐ No
15. Quantity — a. Received — b. Inspected — c. Deficient — d. In Stock
16. Deficient Item Works On/With — a. End Item *(Aircraft, tank, ship, howitzer, etc.)* — (1) Type/Model/Series — (2) Serial No.
b. Next Higher Assembly — (1) National Stock No. (NSN) — (2) Nomenclature — (3) Part No — (4) Serial No./Lot No.
17. Dollar Value
18. Est. Correction Cost
19. Item Under Warranty ☐ Yes ☐ No ☐ Unknown
20. Work Unit Code/EIC *(Navy and Air Force only)*
21. Action/Disposition
☐ Holding Exhibit for_____ days ☐ Released for Investigation ☐ Returned to Stock/Disposed of ☐ Repaired ☐ Other *(Explain in Item 22)*
22. Details *(Describe, to best ability, what is wrong, how and why, circumstances prior to difficulty, description of difficulty, cause, action taken including disposition, recommendations. Identify with related item number. Include and list supporting documents. Continue on separate sheet if necessary.)*

SECTION II

23a. To *(Action Point)*
24a. To *(Support Point) (Use items 25 and 26 if more than one)*
23b. Typed Name, Duty Phone and Signature
24b. Typed Name, Duty Phone and Signature
25a. To *(Support Point)*
26a. To *(Support Point)*
25b. Typed Name, Duty Phone and Signature
26b. Typed Name, Duty Phone and Signature

368-101

STANDARD FORM 368, April 1974
General Services Administration (FPMR 101-26-7)

173.713

Figure 1-12.—Sample Quality Deficiency Report, SF 368.

REPORT OF DISCREPANCY (ROD)

[X] SHIPPING [ ] PACKAGING

1. DATE OF PREPARATION	80JUL01
2. REPORT NUMBER	005/80
3. TO *(Name and address, include ZIP Code)*	Naval Supply Center N00244 NDZ San Diego, CA 92132
4. FROM *(Name and address, include ZIP Code)*	Commanding Officer USS JOHN PAUL JONES (DDG-32) FPO San Francisco 96669
5a. SHIPPER'S NAME	Same as #3
5b. NUMBER AND DATE OF INVOICE	25 JUN 80
6. TRANSPORTATION DOCUMENT NUMBER *(GBL, Waybill, TCN, etc.)*	
7a. SHIPPER'S NUMBER *(Purchase Order/Shipment, Contract, etc.)*	
7b. OFFICE ADMINISTERING CONTRACT	
8. REQUISITIONER'S NUMBER *(Requisition, Purchase Request, etc.)*	R52192-0160-2435

9. SHIPMENT, BILLING, AND RECEIPT DATA				10. DISCREPANCY DATA				11.
NSN/PART NUMBER AND NOMENCLATURE (a)	UNIT OF ISSUE (b)	QUANTITY SHIPPED/BILLED (c)	QUANTITY RECEIVED (d)	QUANTITY (a)	UNIT PRICE (b)	TOTAL COST (c)	CODE[1] (d)	ACTION CODE[2]
9N 5960-00-806-0292	EA	2	1	1	74.06	74.06	S1	1G

12. REMARKS *(Continue on separate sheet of paper if necessary)*

Shortage has been verified as not being transportation related.

[1] DISCREPANCY CODES

CONDITION OF MATERIAL
- C1 — In condition other than that indicated on release/receipt document
- C2 — Expired shelf life
- C3 — Damaged parcel post shipment

SUPPLY DOCUMENTATION
- O1 — Not received
- D2 — Illegible or mutilated
- O3 — Incomplete improper or without authority *(Only when receipt cannot be properly processed)*

MISDIRECTED MATERIAL
- M1 — Addressed to wrong activity

OVERAGE/DUPLICATE SHIPMENTS
- O1 — Quantity in excess of that on receipt document
- O2 — Quantity in excess of that requested *(Other than unit of issue pack)*
- O3 — Quantity duplicates shipment

PACKING DISCREPANCY
- P1 — Improper preservation
- P2 — Improper packing
- P3 — Improper marking
- P4 — Improper unitization

PRODUCT QUALITY DEFICIENCIES
- Q1 — Deficient material *(Applicable to Grant Aid and FMS shipments only)*

SHORTAGE OF MATERIAL
- S1 — Quantity less than that on receipt document
- S2 — Quantity less that that requested *(Other than unit of issue pack)*
- S3 — Non-receipt of parcel post shipments

ITEM TECHNICAL DATA MARKINGS *(i.e., Name Plates, Log Books, Operating Handbooks, Special Instructions, etc.)*
- T1 — Missing
- T2 — Illegible or mutilated
- T3 — Precautionary operational markings missing
- T4 — Inspection data missing or incomplete
- T5 — Serviceability operating data missing or incomplete
- T6 — Warranty data missing

WRONG ITEM *(Identify requested item as a separate copy in Item 9 above)*
- W1 — Incorrect item received
- W2 — Unacceptable substitute

OTHER DISCREPANCIES
- Z1 — See remarks

[2] ACTION CODES
- 1A — Disposition instructions requested *(Reply on reverse)*
- 1B — Material being retained *(See remarks)*
- 1C — Supporting supply documentation requested
- 1D — Material still required expedite shipment *(Not applicable to (FMS)*
- 1E — Local purchase material to be returned at supplier's expense unless disposition instructions to the contrary are received within 15 days *(Reply on reverse)* *(Not applicable to FMS)*
- 1F — Replacement shipment requested *(Not applicable to FMS)*
- 1G — Reshipment not required. Item to be re-requisitioned.
- 1H — No action required. Information only
- 1Z — Other action requested *(See remarks)*

13. FUNDING AND ACCOUNTING DATA

14a. TYPED OR PRINTED NAME, TITLE, AND PHONE NUMBER OF PREPARING OFFICIAL	14b. SIGNATURE
R. BURGESS, LCDR, SC, USN AV Operator 958-0111 (ask for ship supply officer)	R Burgess

15. DISTRIBUTION ADDRESSEES FOR COPIES

364-101 7540-00-159-4442 *(Previous edition is obsolete.)* STANDARD FORM 364 (REV. 2-80) Prescribed by GSA FPMR 101-26.8

173.714

Figure 1-13.—Sample Report of Deficiency, SF 364.

the shipping activity require the submission of a Report of Discrepancy (ROD), SF 364, (fig. 1-13). Included in this category are shortages, unacceptable substitutes, material shipped in error, and shipment of the wrong item. Detailed procedures on the use, preparation, and submission of these forms are contained in NAVSUP Publication 485 (paragraphs 4274 and 4270 respectively).

SHIP'S FORCE QUALITY ASSURANCE PROGRAM

During private shipyard overhauls or major restricted availabilities, ship's force personnel will be assigned as members of the ship's force quality assurance organization. The ship's force quality assurance organization works jointly with the supervisor of shipbuilding (SUPSHIP) organization to monitor work done on the ship and make sure that QA program requirements are met. Personnel will be assigned to the organization by the commanding officer, and their responsibilities will be explicitly identified in a memorandum of understanding or some other document executed by the SUPSHIP and commanding officer. The personnel assigned are usually E-5 or above, knowledgeable in the rating, mature, and, if possible, are on board for the entire availability. They receive detailed training from SUPSHIP before performing any QA functions. The primary loyalty of ship's force personnel is to their ship, and they keep the commanding officer informed of all matters on the QA of ship equipment repair.

TEST EQUIPMENT

Fire Controlmen use a wide variety of test equipment to perform the day-to-day maintenance on their equipment. This requires not only the proper use of the test equipment, but also knowledge as to whether or not the test equipment is functioning properly. As an FC1, you must be able to supervise and train maintenance personnel in the proper use of test equipment. You should also be familiar with the administration procedures and programs required to repair and keep that test equipment in calibration.

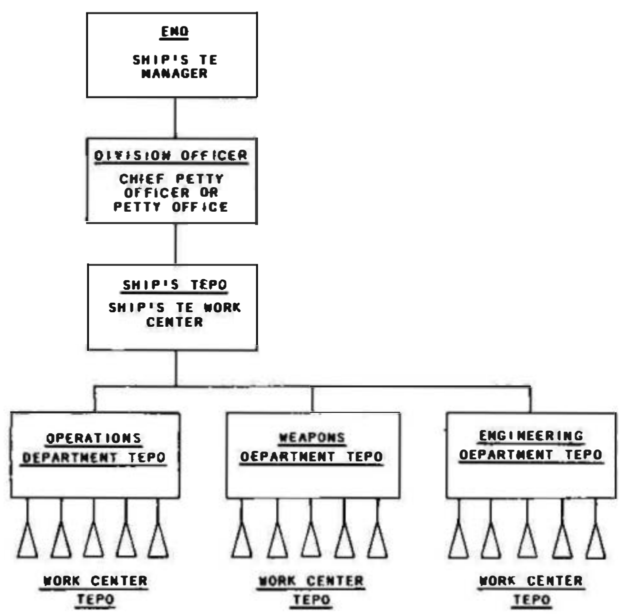
TEST EQUIPMENT ADMINISTRATION

The electronics material officer (EMO) is usually the officer assigned overall responsibility for all electrical and electronic test and monitoring systems (TAMS) assigned to the ship. Shipboard organizations for onboard test equipment management will vary from ship to ship. Typically, the EMO will have a designated ship's test equipment petty officer (TEPO) as the principal assistant. First class petty officers from all technical rates, including Fire Controlmen, are likely candidates for the job. Figure 1-14 shows a typical test equipment chain-of-command organization. The ship's TEPO will be expected to be knowledgeable of the various programs involving shipboard test equipment.

The ship's TEPO is the focal point for all matters pertaining to TAMS on board the ship. All test equipment should be documented through one specifically designated work center with the ship's TEPO, who is usually the work center supervisor. In this way a complete and composite status of your test equipment can be obtained at any time through the TEPO.

The administration of the test equipment program involves several areas including inventory, procurement, disposal, calibration and repair, and storage and handling. As a FC1, you should be familiar with these programs.

The inventory of assigned test equipment is directly related to the ship's equipment configuration accounting system (SECAS). A properly maintained SECAS will show the complete inventory of test equipment on board by quantity, serial number, and location. You can then compare this document to the ship's allowance of portable



173.715

Figure 1-14.—Typical shipboard test equipment organization.

test equipment to determine deficiencies or excesses.

The allowance of test equipment is contained in the ship's portable electrical/electronic test equipment list (SPETERL). The SPETERL (fig. 1-15) identifies the latest known requirements for portable electrical/electronic test equipment (PEETE). New SPETERLs are forwarded to the ship before the start of any shipyard overhaul and before the start of any availability in which major electronic changeouts will occur.

SUBCATEGORY (SCAT) CODES

SCAT codes are normally used where references are made to test equipment. The SCAT code is a four-digit, numeric, subcategory code used to identify a range of measurements by functional category. Test equipment is assigned SCAT codes in the 4000 to 4999 series of numbers. These SCAT codes may be found in the PEETE index and in the SPETERL.

The PEETE index (fig. 1-16) is a guide that fleet personnel use to identify portable electrical/electronic test equipment required for support of prime electronic, electrical, interior communications, weapons, and reactor instrumentation systems. This test equipment index does not, in any way, supersede or modify the SPETERL, nor does it authorize procurement of, or requisition of, items listed in the SPETERL.

The ship's portable electrical/electronic test equipment requirements list (SPETERL) is your allowance list for PEETE. The quantity of each SCAT is based upon support requirements of a ship's configuration of prime electronic, electrical, interior communications, weapons, and reactor instrumentation equipment and systems. The SCAT quantity is also dependent upon the following factors:

- Location of prime equipments and systems

SHIPS PORTABLE ELECTRICAL/ELECTRONIC TEST EQUIPMENT REQUIREMENTS LIST
S P E T E R L
TEST EQUIPMENT QUANTITIES BASED
USS (Ship's name) (Ship type & no.) ON WSP DATA OF 11/04/85

SCAT FUNCTIONAL DESCRIPTION OF
CODE SCAT CODE REQUIREMENT

MPG SYM	FSCM	TEST EQUIPMENT MODEL NUMBER	PRIORITY	ALLOWANCE EQUIPAGE LIST NO.	ACC QTY	LTD QTY	OBS QTY	EXC QTY	DEF QTY	TOTAL RQD	P M S	EQUIPMENT / SYSTEM APPLICATION	PE QTY	PRIME EQUIP LOCATION SHIPALT	FOOT NOTE
4245 MULTIMETER															
	0-4KVDC, 0-1KVAC														
CSV	55026	260-6XPL	22	7-670052807EQ						1		ASROC FCS			
CSV	55026	260-6P	23	7-670052276EQ						1		BASIC POINT DEFENSE MISSILE SYS			
CSV	55026	260-6PRT	23	7-670052596EQ						1		DEGAUSSING SYS			
		AN/PSM-4B	23	7-670050129EQ	1					9		ELECTRONICS USE-AGFF, FF			
		AN/PSM-4D	23	7-670050136EQ						1		IC SYS GEN USE-AGFF/FF/FFG1--6			
		AN/PSM-4E	23	7-670050115EQ						1		MK 16 ASROC MLS			
		AN/PSM-4F	23	7-670050122EQ						2		MK 68 GUN FIRE CONTROL SYSTEM			
		AN/USM-311	23	7-670050848EQ	5							NC-2 MOD 2/2A PLOTTER			56
		ME-48B/U	23	7-670050220EQ						1		POWER GEN USE-AGFF/FF/FFG1--6			
		ME-48D/U	23	7-670052281EQ						4		SONAR AN/SQS ()-DEDICATED			
		ME-48E/U	23	7-670052282EQ											
		ME-48F/U	23												
CSV	55026	260-5	24	7-670051026EQ	5										
CSV	55026	260-5P	24	7-670050588EQ	1										
		AN/PSM-4C	24	7-670050143EQ											
		ME-48C	24	7-670050227EQ											
CSV	55026	260	25	7-670050150EQ											
CSV	55026	260-4	37	7-670050164EQ	2										
CSV	55026	270	37	7-670050591EQ											
CSV	55026	270-3	37	7-670052277EQ											
					14				7	21	SCAT	4245 TOTALS			
4261 FREQ, DEVIATION METER															
	100KHZ, 1,2,5 and 5 MHZ														
CDED	19397	527A	22	7-670051063EQ								AN/URQ-10	1	2-67-2-C	50
		AN/URM-115	23	7-670051062EQ											
											SCAT	4261 TOTALS			

173.716

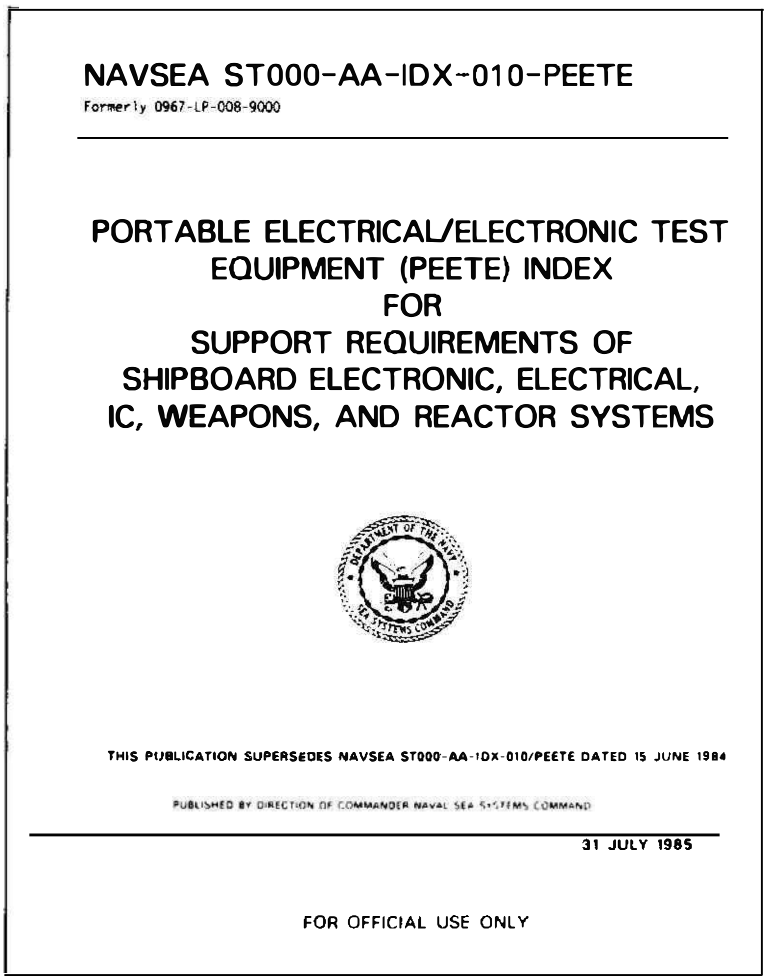
Figure 1-15.—Sample page of SPETERL.

- Number of these prime equipments and systems installed
- Portability of the test equipment
- Number of personnel that use the test equipment
- Frequency of test equipment usage
- Ability to share test equipment among different divisions

Several sources of information are combined to develop the SPETERL. First, cognizant activities provide information concerning prime equipments or systems and the PEETE required to support them. Next, NAVSEA adds this information to the data base used to prepare the SPETERL. The data base is then compared to the configuration of the ship, as reported by SECAS teams and other sources. Finally, from this comparison, the SPETERL is produced, showing allowances of PEETE, quantities on hand, and similar information.

CALIBRATION ACTIVITIES

Now that we have discussed the inventory of test equipment, we can turn our attention to the calibration of test equipment. Various echelons of calibration activities are established to meet the calibration requirements of test equipment. These echelons are integrated so that each level activity has traceable standards tied to the highest standards available for calibration. The calibration



NAVSEA ST000-AA-IDX-010-PEETE
Formerly 0967-LP-008-9000

PORTABLE ELECTRICAL/ELECTRONIC TEST EQUIPMENT (PEETE) INDEX FOR SUPPORT REQUIREMENTS OF SHIPBOARD ELECTRONIC, ELECTRICAL, IC, WEAPONS, AND REACTOR SYSTEMS

THIS PUBLICATION SUPERSEDES NAVSEA ST000-AA-IDX-010/PEETE DATED 15 JUNE 1984

PUBLISHED BY DIRECTION OF COMMANDER NAVAL SEA SYSTEMS COMMAND

31 JULY 1985

FOR OFFICIAL USE ONLY

173.717

Figure 1-16.—Cover of the PEETE index.

echelons (fig. 1-17) are discussed in the following paragraphs.

National Bureau of Standards

The National Bureau of Standards (NBS) is the chartered agency of the federal government having custody of the nation's basic physical standards (national standards). It provides the common reference for all measurements made within the scope of the Navy calibration program and certifies the Navy standards submitted by the type I Navy standards laboratories in accordance with an approved schedule.

Navy Standards Laboratory—Type I

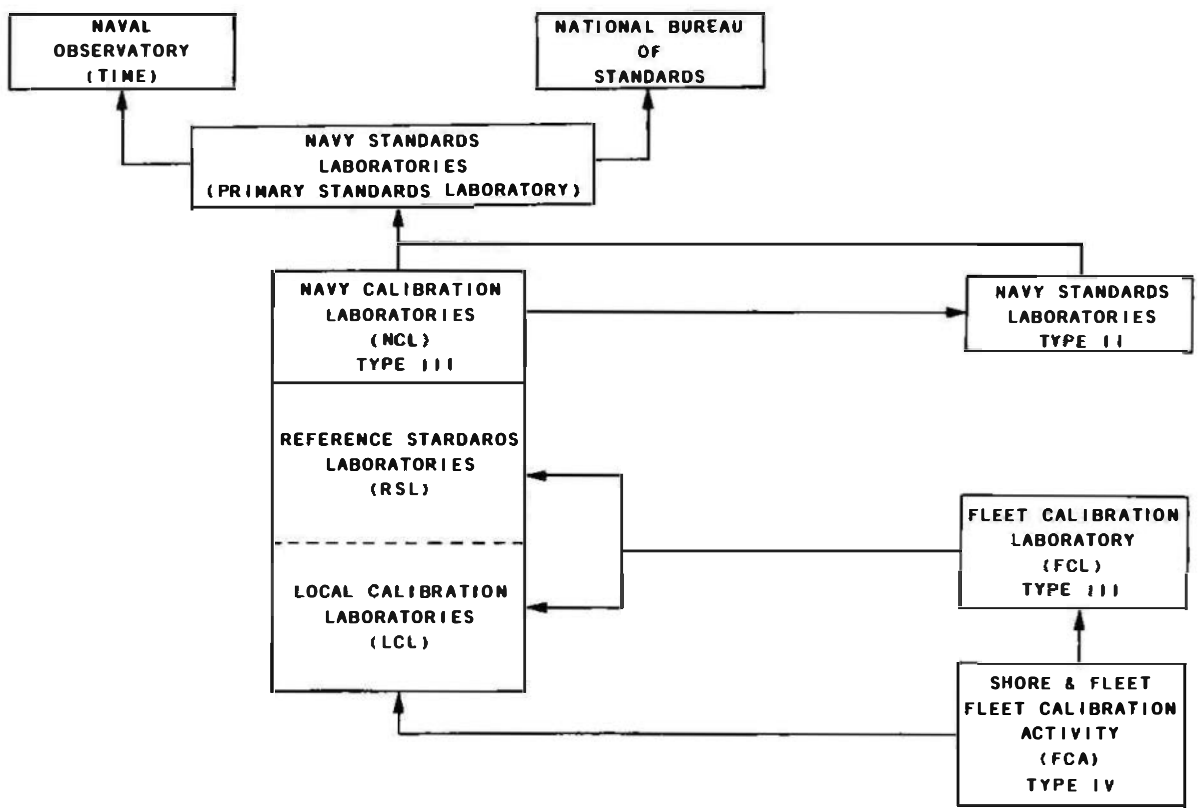
Type I laboratories maintain the highest standards within the Navy calibration program. They maintain and disseminate measurements of the highest accuracy within the program. They obtain calibration services from NBS and provide calibration of standards and associated measuring equipment received from type II standards laboratories and calibration laboratories.

Navy Standards Laboratories—Type II

Type II laboratories furnish the second highest calibration services to assigned geographic areas within the Naval Establishment. They obtain standard calibration services from the cogizant type I Navy standards laboratory, which are received from lower echelon laboratories.

Navy Calibration Laboratory—Type III

Navy calibration laboratories (NCLs) are located in shipyards, ship repair facilities, and at various field activities. An NCL is usually made up of a reference standards laboratory (RSL) and one or more local standards laboratories (LSLs). The RSL is a type II laboratory. The LSL normally receives calibration services from the RSL.



173.718

Figure 1-17.—METCAL program structure.

Fleet Calibration Laboratory—Type IV

Fleet calibration laboratories (FCLs) are established aboard tenders and repair ships and at selected shore activities. They provide calibration for fleet-held and selected shore-based activities' test equipment. Calibration services provided to ships will be funded by the shore activity or its sponsor.

Field Calibration Activity

The field calibration activity (FCA) segment of the Navy calibration program was established to extend calibration-support capability to selected ships and shore activities to ensure the accuracy and reliability of electronic test and measuring equipment. It also permits users to calibrate certain items of their own low-accuracy, high-volume electronic test equipment.

A complete FCA consists of suitable working spaces, field calibration package(s), trained personnel, and necessary support documentation, such as the metrology requirements list (METRL) and instrument calibration procedures (ICPs).

CALIBRATION SERVICES

The preceding section explained the calibration echelons established for calibration of test equipment. Now let's take a look at an important automated data processing (ADP) system called the metrology automated system for uniform recall and reporting (MEASURE) program.

The MEASURE program is an ADP system designed to provide a standardized system for the recall and scheduling of test equipment into calibration facilities. It was developed to support the Navy's metrology and calibration (METCAL) program in an effort to ensure that all equipment requiring calibration and repair is submitted to a calibration activity on a timely basis and, thus, is maintained to specified accuracy tolerances. In addition, the system provides documentation of actions performed by the calibration activity.

The initial cycle of MEASURE begins with the completion of the inventory for equipment held on board (fig. 1-18). These forms are forwarded to the cognizant MEASURE data processing facility (DPF) to establish the data base.

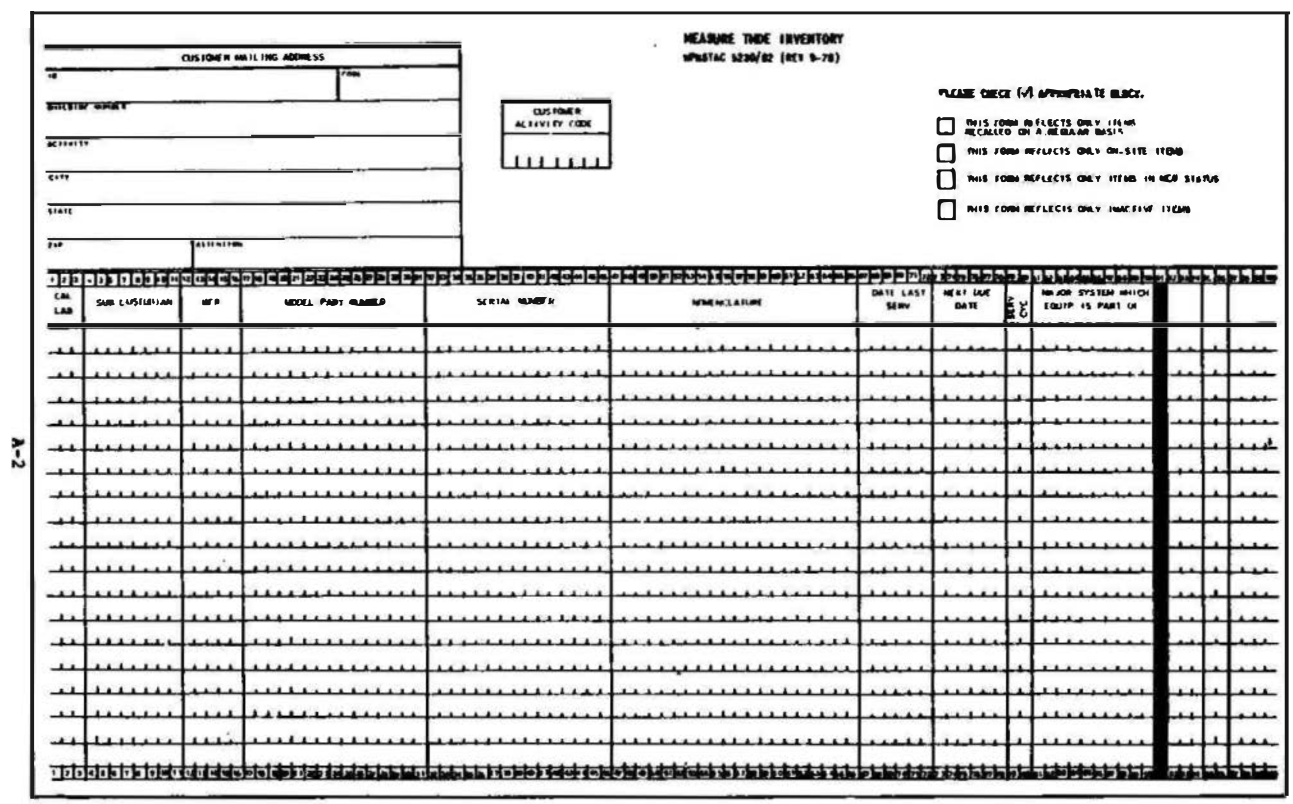


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Figure 1-18.—MEASURE TMDE inventory report form.

The activity holding the test equipment is then provided a printed inventory and a set of preprinted metrology equipment recall and report (METER) cards (fig. 1-19). The MEASURE cycle is completed when the cognizant METCAL representative provides recall schedules to the activity holding the test equipment and to the calibration activities. As equipment is gained or lost, more inventory forms and METER cards are processed or deleted, the data base is kept current, and the system continues to cycle. If you are assigned as the ships TEPO, you will be expected to make sure that this cycle operates smoothly from start to finish.

CALIBRATION STATUS

The Navy calibration program has a series of distinctive labels and tags for indicating the calibration or repair status of all Navy test and measuring equipment. All calibration personnel and equipment users should be familiar with each label and tag and its meaning. Labels of different nomenclature, color combinations, and shapes have been designed to help users identify the calibration status. These labels and tags are used by all participants in the Navy METCAL program and are affixed to all Navy standards and test and measuring equipment.

Calibrated

This label (black lettering, white background) comes in three different sizes and is the most commonly used label in the Navy METCAL program. It indicates that the instrument is completely within its applicable tolerances. If it is not, then one of the labels discussed in the following paragraphs should be used.

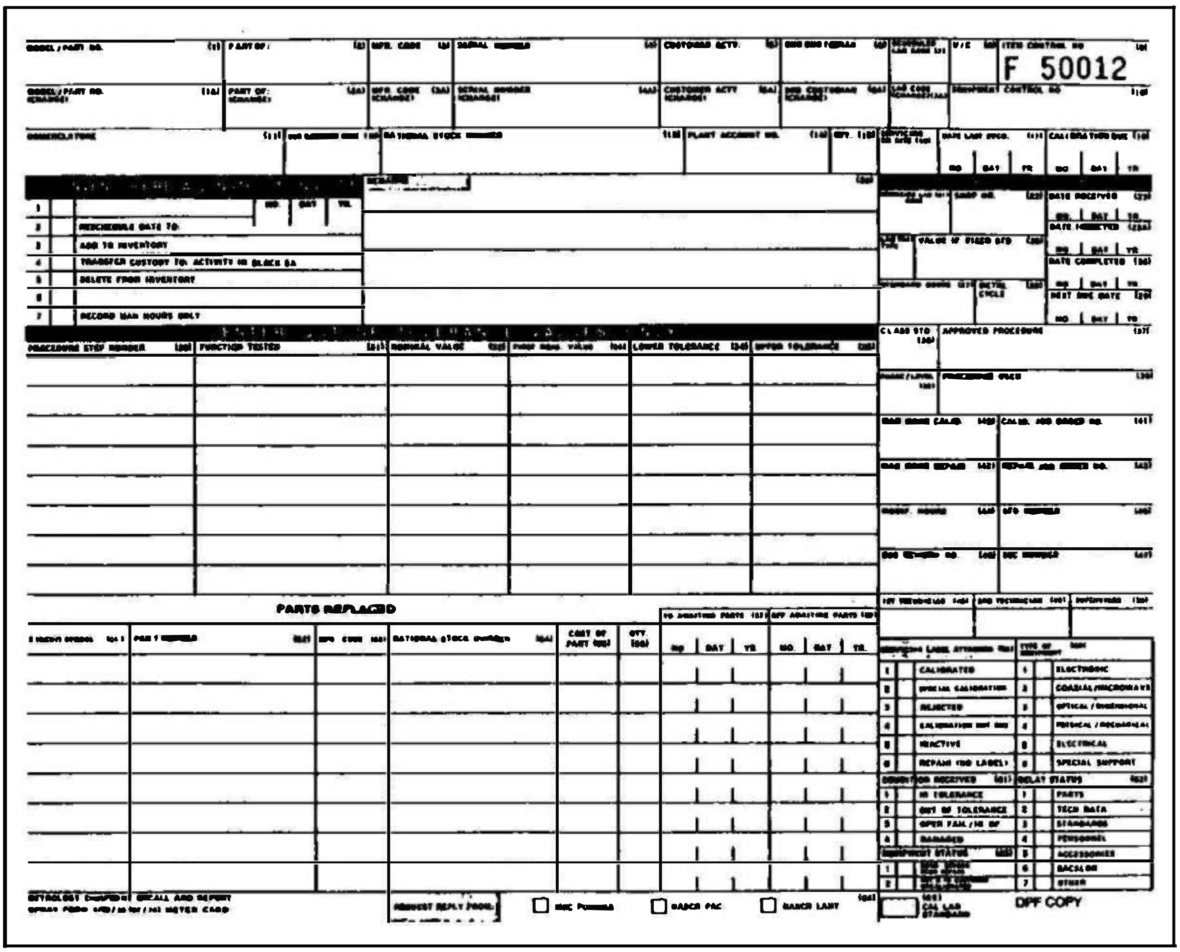

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Figure 1-19.—MEASURE meter card, OPNAV Form 4790/58.

Special Calibration

There are two special calibration labels (black lettering, yellow background), differing in size and content. There is also a special calibration tag, which is used whenever there is some unusual or special condition in the calibration that should be drawn to the attention of the user and/or calibrator. The special condition requiring the special calibration should appear on the large label when there is sufficient space, or on the tag when the small label is used. An item of test equipment cannot be specially calibrated without the consent of the user (subcustodian).

DEVIATION FROM SPECIFICATIONS.— In cases where test/measurements do not require full instrument capability, the calibration could be performed to reduced tolerances or cover less than all ranges and scales. This method is often used when the instrument does not meet full calibration tolerances on certain ranges or scales but can still meet use requirements.

MULTIPLE CALIBRATION INTERVALS.—Some instruments have components that require calibration less frequently than the rest of the instrument. For example, the attenuator in a signal generator may require calibration every 12 months, while the rest of the components should be calibrated every 4 months. Since the attenuator calibration is time consuming and may require unavailable standards, this calibration method can save considerable man-hours as well as permit the more frequent calibration to be performed at a lower level laboratory. When a multiple calibration instrument has multiple interval written on the special calibration label, the type of calibration performed (partial 1 of 2, 2 of 2, complete calibration, etc.) is indicated. The calibration due date is the date the next partial or complete calibration is due.

CALIBRATED ON SITE.—Some instruments should be calibrated on site. Information written on the special calibration label or tag will alert both user and calibrator of this fact.

User Calibration

Some test measuring diagnostic equipment (TMDE) should be calibrated by the user rather than sending it to a calibration facility. Other instruments are calibrated as part of daily or weekly check-out procedures with test data recorded in maintenance logs. The various requirements for user calibration and calibration intervals (each use, daily, every 100 hours, etc.) are indicated in the METRL. The user calibration label (black lettering, white background) is attached when the calibration is to be performed by the user; however, this label is not replaced at each calibration. When it is first attached to the instrument, the appropriate calibration interval is written on the label. Calibrations performed at times other than each time of use should be recorded by normal maintenance practices; for example, maintenance log or maintenance action form.

Inactive Label

Instruments due for recalibration that are not to be used for some time in the future may have an inactive label (green lettering, white background) attached. The inactive label remains on the instrument until it is recalibrated. The instrument is not to be used while bearing the inactive label.

Calibration Not Required

Standards and TMDE instruments/equipment not requiring calibration are classified as NCR in the METRL. The calibration not required label (orange letter, white background) is affixed and should remain on the instrument indefinitely unless its calibration requirements change. The calibration not required label may be affixed for any of the following reasons:

- Equipment does not make quantitative measurement nor provide quantified outputs.

- The equipment is fail safe, in that operation beyond specified tolerance will be apparent to the user.

- All measurement circuits are monitored during use by calibrated instruments.

When determining that an instrument falls into the calibration not required category, the label should state the authority for the decision such as METRL, technical manual, or letter or message from higher authority. When this label is used on instruments that normally require periodic calibration but it is not used to perform quantitative measurements, it should be stated, "Not used for quantitative measurements."

Rejected

In the event an instrument fails to meet the acceptance criteria during calibration and cannot be adequately repaired, a rejected label or tag, giving the reason for rejection and other information as required, is attached to the instrument. The rejected label or tag remains on the instrument until it is repaired and recalibrated. The instrument is not to be used while bearing a rejected label.

Calibration Void If Seal Broken

This label (black letters, white background) is placed over readily accessible (usually exterior) adjustments to prevent any tampering by the user that could affect calibration. It may also be used to prevent removal and/or interchange of plug-ins, modules, or subassemblies when such removal or interchange will affect the calibration.

Calibration Standard

This label (black letters, blue background) comes in two sizes and is used to identify Navy METCAL program calibration standards. The calibration standard label is attached to all equipment specifically designated for use as Navy standards by calibration activities.

SUMMARY

This chapter discussed a few of the administrative procedures that you, as an FC1, will routinely encounter. The 3-M System is composed of two systems; the PMS system and the MDS system. Some of the objectives of the 3-M System are as follows:

- Establish uniform maintenance procedures
- Reduce paperwork
- Reduce cost
- Increase efficiency
- Document equipment performance

The basic ship report for the 3-M System is OPNAV Form 4790/2K.

All maintenance falls under one of three categories: organizational-level maintenance, intermediate-level maintenance, or depot-level maintenance. Fire Controlmen are primarily involved with organizational-level (shipboard) maintenance, and secondarily with intermediate- and depot-level maintenance.

The QA program is a system of checks, controls, and inspections that ensure that materials and services conform to technical requirements and that repaired equipment performs satisfactorily.

The test equipment that you use in performing PMS requires periodic calibration. This calibration is part of the MEASURE program. The MEASURE program provides for automatic scheduling and recall of test equipment. The calibration program aboard ship is usually run by the Electronic Technicians (ETs). Your job is to take care of the equipment in your charge and see that it is delivered to them in a timely manner when due.

CHAPTER 2

EQUIPMENT-LEVEL MAINTENANCE

Fire control systems are complex because of the interrelationships that exist between electrical, electronic, and mechanical equipment and the small tolerances within which this equipment must work to solve the fire control problem. Design complexities and critical tolerances create both preventive and corrective maintenance problems.

In relation to ordnance, the highest major level of maintenance is combat system testing and repair. Below this level is the maintenance performed on the fire control system. The final level is equipment-level maintenance, which entails radar, computer, and director maintenance as separate equipment. This chapter will discuss some of the aspects, procedures, and maintenance aids to assist you, as a Fire Controlman first class, in meeting the responsibilities of performing equipment level maintenance.

RADAR MAINTENANCE

The typical radar system can be reduced to the following functional components: synchronizer, transmitter, antenna, receiver, and indicator. Because power supplies differ so greatly in different radar sets, they will not be considered in this general discussion. While the complexity of each of the above components may vary considerably, depending on the use for which a particular radar equipment was designed (search, navigation, fire control, etc.), the function of each type of unit is basically identical in all radars. It is not the purpose of this discussion to describe any specific radar set, but rather to deal with the functional requirements of each unit necessary for the efficient overall performance of any radar facility.

FREQUENCY MEASUREMENT

The following subjects are pertinent to the measurement of radar frequencies: standards, coupling methods, typical test equipment, and accuracy limitations. Table 2-1 shows typical bands of radar operation and their respective frequencies.

Frequency Testing Standards

Frequency testing instruments are not designed to be coupled directly into the radar equipment, since the high-power transmitter pulse develops very high voltage within resonant circuits associated with the instruments, and arcing would

Table 2-1.—Frequency and Letter Designations for Microwave Bands

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              +----------+----------+---+---+-----+---+----+---+----+--------+
              |          |          |   |   |     |   |    |   |    |        |
PREVIOUS      |          |          |   |   |     |   |    |   |    |        |
FREQUENCY     |   VHF    |   UHF    | L | S |  C  | X | Ku | K | Ka | MILLI- |
DESIGNATIONS  |          |          |   |   |     |   |    |   |    | METER  |
              |          |          |   |   |     |   |    |   |    |        |
              +--+---+---+---+--+---+-+-+-+-+-+-+-+-+-+--+-+-+---+-+--+-+--+-+
              |  |   |   |   |  |   | | | | | | | | | |  | |  |   | |  | |  |
           0.1|  |   |   |0.5|  |   | |2| | | |6| | |  | 20 |   | | |60| |
FREQUENCY     |0.15  |   |   |0.75|  | | |3| | |8.0| |  | |  30  | | |  75|
  (GHz)       |  |  0.2  |   |  |   | | | |4| | | |10|  | |  |   40|  | |100
              |  |   |0.3|   |  |   |1.5| | |5| | | | 15  |  |   | |50| | |
              +--+---+-++---+--+---+-+-+-+-+-+-+-+-+-+--+-+-+---+-+--+-+--+-+
              |        |      |     |   | | |   | | |    |     |   |   |    |
CURRENT       |        |      |     |   | | |   | | |    |     |   |   |    |
FREQUENCY     |   A    |  B   |  C  | D |E|F| G |H|I| J  |     K   | L | M  |
DESIGNATIONS  |        |      |     |   | | |   | | |    |         |   |    |
              |        |      |     |   | | |   | | |    |         |   |    |
              +--------+------+-----+---+-+-+---+-+-+----+---------+---+----+
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result. Therefore, satisfactory methods of frequency coupling are required.

Frequency Testing Equipments

The two test equipments that are satisfactorily used in the measurement of microwave frequencies are the resonant-coaxial-line frequency meter and the resonant-cavity frequency meter. Both of these test instruments depend upon a condition of resonance to provide an accurate test indication.

RESONANT-COAXIAL-LINE FREQUENCY METER.—Coaxial-line frequency meters may be connected to operate as either transmission-type or reaction-type indicators. When used as the transmission type, energy is fed into one coupling loop, and the indication device is connected to the other loop. When the circuit is resonant, the greatest energy transfer takes place, and the indicator shows the greatest output signal. When used as the reaction type, the resonant circuit functions as an absorption device, so that at resonance the indicator shows a dip in the reading.

RESONANT-CAVITY FREQUENCY METER.—A common type of resonant-cavity frequency meter consists essentially of a hollow metal cylinder coupled to a waveguide by means of a small hole or coupling loop and coaxial connector. The cavity within the cylinder is resonant by virtue of its dimensions. Two end plates may be thought of as the capacitance elements and the adjoining walls as the inductance. Frequency is varied by adjusting the position of one of the end plates with a micrometer screw calibrated to indicate frequency. The degree of accuracy obtained with this type of meter is greater than that obtained with the resonant-coaxial-line frequency meter.

Spectrum Analyzers and Frequency Counters

Both of these equipments provide a high degree of accuracy but require additional care to prevent excessive power from being applied to the input circuit.

SPECTRUM ANALYZER.—The spectrum analyzer provides a visual indication of frequencies and peak power levels present at the testing point. The high impedence input of the spectrum analyzer causes very little loading effect and can thus be used on rf sources having a very small output.

FREQUENCY COUNTER.—Frequency counters, in general, do not have the sensitivity or high impedence of the spectrum analyzer. Therefore, they should be used to measure continuous frequencies rather than pulsed rf because of the harmonics that are generated. Frequency counters are available to measure up to 40 gigahertz.

Frequency Measurement Accuracy

The accuracy of a microwave frequency measurement is expressed in terms of maximum error in megahertz, and may be either absolute or relative. Absolute accuracy states how much error with respect to a standard is involved in a single frequency measurement, whereas relative accuracy indicates how much error is involved in the difference in frequency (or increment) between two microwave signals. For example, assume a measurement accuracy of ±4 MHz absolute and ±1 MHz relative; if the frequency of a certain transmitter measures 9300 MHz and the local oscillator frequency is 9330 MHz, the following conclusions can be reached:

- The transmitter frequency is somewhere between 9304 MHz and 9296 MHz (or 9300 MHz ±4 MHz absolute); or
- The local-oscillator frequency is somewhere between 9334 MHz and 9326 MHz (or 9330 MHz ±4 MHz absolute); or
- The local-oscillator frequency is 29 MHz to 31 MHz above the transmitter frequency (9330 MHz minus 9300 MHz or 30 ±1 MHz relative). Thus, it can be seen

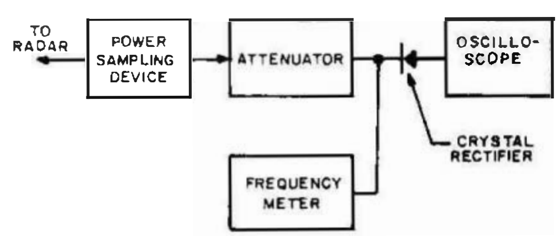

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Figure 2-1.—Frequency measurement, reaction type.

that the difference between two measured values is much more accurate than the measured values themselves.

ACCURACY.—In receiver frequency testing, an absolute accuracy of ±4 MHz is not considered good enough. To obtain required accuracy, manufacturers of frequency testing equipments carefully calibrate, by hand, that part of the test equipment that concerns frequency testing, with the result that these equipments have an absolute accuracy better than ± 1 MHz in the X-band.

METER TUNING.—Most of the early frequency meters were tuned by means of a micrometer screw, and the readings were converted into frequency with the aid of a calibration chart. Some of the newer type of meters make use of a dial, geared to the screw, which indicates frequency directly. Thus, dial readings are greatly simplified, but the gear mechanism associated with the dial introduces a certain amount of backlash that affects the accuracy of the indication. The backlash effect may be minimized by always approaching the final dial setting from the same direction. This direction should be the same as that used during factory calibration, and should be specified in the instructional literature accompanying the test equipment.

Reaction-type Method

This method of frequency measurement is shown in figure 2-1. The meter absorbs power from the crystal detector at resonance; thus, a reaction-type indication is obtained. Figure 2-2 shows the appearance of the rf envelope as the frequency-meter tuning is varied. Resonance is obtained when the center of the pulse reaches its lowest point, indicating maximum reaction. If desired, a microammeter may be used instead of the oscilloscope. In that case, the frequency meter is adjusted for a dip in the current reading.

Transmission-type Method

Figure 2-3 shows a widely used test method for frequency measurement, using the transmission-type indication. The procedure for this method is as follows:

1. The equipment is connected, as shown in figure 2-3, and the power sample is coupled into the frequency meter.
2. The measurement starts with maximum attenuation, and the frequency meter is then tuned through the frequency range.
3. If no indication is observed, the attenuation is reduced about 10 dB, and the frequency control is again tuned through the frequency range. The process is repeated until a reading is observed.
4. The frequency dial is set for maximum reading with sufficient attenuation to keep the reading below full-scale value.
5. Ordinarily, it is necessary to convert the dial reading to frequency.

Combination Power and Frequency Testing

In modern power-testing equipment, a frequency meter is often included as an integral part

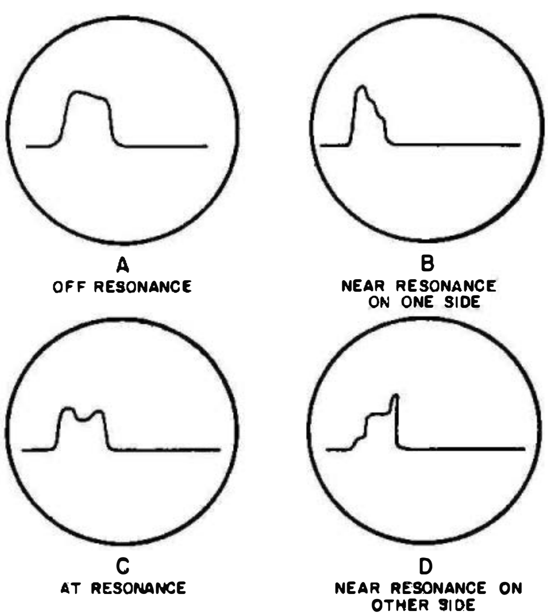

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Figure 2-2.—Change of waveform observed during frequency measurement.

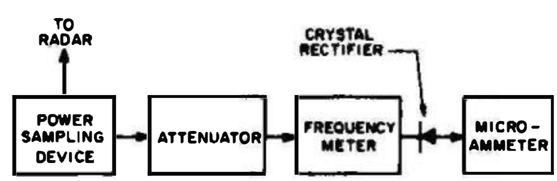

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Figure 2-3.—Frequency measurement, transmission-type indication.

of such equipment. The frequency meter is usually connected as shown in figure 2-4. For power testing, the frequency meter must be tuned off-resonance so as not to affect the accuracy of the power measurement. The test procedure is very simple and is usually performed directly after a power measurement. Frequency measurement is performed as follows:

1. A 1 mW reading is established, as will be discussed in the power-testing procedure.
2. The frequency meter is tuned for a minimum meter reading. (The meter must be tuned slowly or the resonance point may be passed before the thermistor can respond.)
3. Ordinarily, it is necessary to convert the dial reading to a frequency.

LOCAL-OSCILLATOR FREQUENCY MEASUREMENT.—The local-oscillator frequency can be measured by feeding the output of the local oscillator (directly, if possible) to the frequency meter and then making the test previously described. If desired, the local oscillator may be set to some predetermined frequency by setting the frequency meter above or below (as specified in instructional or maintenance literature) the frequency to be received by an amount equal to the intermediate frequency. The local oscillator is then tuned for the required indication. This method is especially useful for a radar system employing afc, which requires that the local-oscillator frequency be set on a certain side of the signal frequency.

The measurement of frequencies employed in radar operation falls into two general categories: transmitter frequency and receiver frequency.

TRANSMITTER FREQUENCY MEASUREMENT.—Radar transmitters may be either fixed frequency or tunable. If the frequency of a fixed-frequency transmitter is measured and found to be outside the operating band, the magnetron, or the defective component of the magnetron assembly, must be replaced. Tunable transmitters may be adjusted throughout the operating band; this is a desirable feature when several radars are in use in a limited area because the radar may be tuned to a particular frequency to prevent or avoid interference. In addition, when jamming signals are present, a change in radar frequency may be effective in eliminating or reducing their effect. Since the operating bands are fairly wide, however, transmitter frequency tests do not require extreme accuracy.

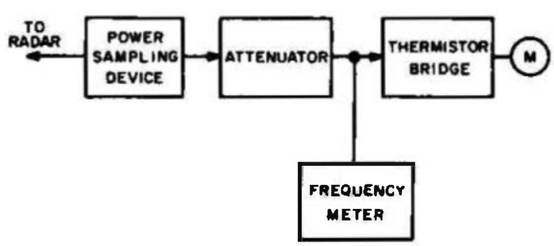

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Figure 2-4.—Combination power and frequency measurement.

RECEIVER FREQUENCY MEASUREMENT.—Testing the radar receiver frequency consists of measuring the frequency at which the receiver operates most efficiently, or of measuring the local-oscillator frequency. For radar reception, a knowledge of the receiver frequency is not important so long as the receiver is carefully tuned to the transmitter frequency. In receivers using automatic frequency control (AFC), the local oscillator must be operated either above or below the signal frequency in accordance with the design specifications. Here again, a knowledge of the exact frequency is not very important, but receiver bandwidth is an important factor and should be checked.

POWER SAMPLING

The testing of radar power always requires some method of removing or inserting the power to be measured. Three principal devices are used to accomplish this. They are the test antenna, the rf probe, and the directional coupler.

Test Antenna

The test or pickup antenna consists of a directional antenna array, which is broadly tuned to the radar band to be used. This antenna is placed in the radiation field of the radar antenna, and picks up a certain percentage of the radiated signal. The test antenna may be made portable by mounting it on a tripod frame, or it may be fixed by means of a bracket installed as a part of the radar system. It is common practice to locate the pickup antenna at least one diameter of the radar reflector away from the radar antenna, as shown in figure 2-5, view A, and to orient the two antennas for maximum pickup. With this procedure, the space attenuation is approximately

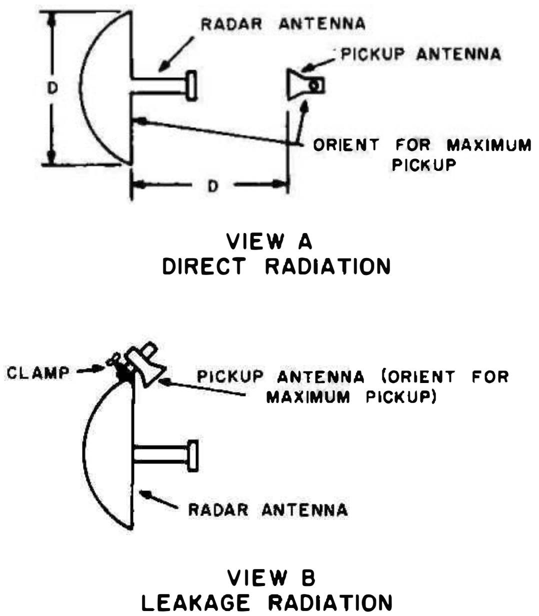

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Figure 2-5.—Placement of pickup antenna.

30 dB. The exact loss will be given for the particular installation or it must be measured. Any subsequent testing should be done with exactly the same antenna spacing.

Another placement method is to clamp the pickup antenna to the edge of the radar reflector in such a manner that the pickup is directed toward the radar antenna feed array. This method is shown in figure 2-5, view B. With the pickup in this position, antenna leakage power is used in the test rather than direct radiation. This procedure has the advantage of allowing operation of the test equipment at various radar antenna positions, and the radar antenna does not require careful orientation. The use of a pickup antenna has the important advantage of testing the entire radar system (including the radome) if the pickup antenna is placed outside the radome. This enables the testing to show operating efficiency, with all controllable factors included.

Four primary disadvantages are associated with the pickup antenna method of sampling power: (1) the placement of the antenna is critical; (2) antennas are sensitive to frequency changes; (3) it is difficult to make tests during radar scanning; and (4) nearby objects can modify the signal picked up by the antenna. Nearby objects, or propagation from other sources, can cause reflections and result in large errors in signal pickup. The presence of these reflections can be detected in the following manner: While observing the signal picked up by the antenna, carefully move the pickup antenna closer to the radar antenna. A smooth increase in signal strength should be noted and, if the pickup antenna is moved away, a smooth decrease in signal strength should be noted. Any sudden or erratic variations or minimum points indicate that nearby objects are influencing the pickup, and another pickup position must be chosen. The test antenna method is used primarily by shipyards and antenna research facilities.

Rf Probe

The rf probe consists of a small capacitive probe inserted into the electrostatic field in the rf transmission line. The greater the penetration of the probe, the greater the power pickup. The penetration of most rf probes is sufficient to provide 20 dB or more attenuation between the main line and the probe output. The probe is fitted with a coaxial connector to facilitate connection to test equipment. In older radar facilities, the rf probe was used extensively, but it is now considered obsolete since the development of the directional coupler. The rf probe allows normal radar operation during test, but it has some disadvantages. Reflections from nearby objects in the rf line have a great effect on the attenuation figure, and probe penetration is very critical. The probe is quite sensitive to frequency, and the attenuation figure depends upon the load connected to the probe.

RECEIVER PERFORMANCE TESTING

The performance of a radar receiver is determined by a number of factors, most of which are involved and established in the design engineering of the equipment. In the test to follow, only those factors concerned with maintenance will be considered. The most important factors, which will be discussed in detail, are receiver sensitivity, which includes noise figure determination and minimum-discernible-signal (MDS) measurement; TR recovery time; receiver recovery time; and receiver bandwidth.

Many radar installations include circuits that serve a special function. Four of these special circuits commonly encountered are (1) moving target indication (MTI); (2) instantaneous automatic gain control (IAGC); (3) sensitivity time control (STC); and (4) fast time constant (FTC). These circuits may be found in combination or singly, depending upon the purpose of the radar. In the test methods and procedures about to be described, the special functions should be disabled. If an automatic frequency control (AFC) circuit is included in the radar equipment, it may be permitted to operate during receiver tests. A good check on AFC is to make the tests specified for manual tuning, then switch to AFC. If the AFC circuit is normal, the signal indications should not change.

Receiver Sensitivity

Inefficient range performance of a radar set can result from troubles in the radar receiver. Loss of receiver sensitivity has the same effect on range as a decrease of transmitter power. For example, a 6-dB loss of receiver sensitivity shortens the effective range of a radar just as much as a 6-dB decrease in transmitter power. Such a drop in transmitter power is very evident in meter indications and, therefore, is easy to detect. On the other hand, a loss in receiver sensitivity, which can easily result from a slight misadjustment in the receiver, is very difficult to detect unless accurate measurements are made. The sensitivity of the receiver determines the ability of the radar set to pick up weak signals. Greater sensitivity, then, indicates that the receiver can pick up weaker signals. Sensitivity of a radar receiver is measured by determining the power level of the minimum discernible signal (MDS). The MDS is defined as the weakest signal that produces a visible receiver (scope) output, and its value is determined by the receiver output noise level, which tends to obscure weak signals. It follows, therefore, that an MDS measurement is dependent upon the receiver noise level, and that measuring either one of these quantities will provide an indication of receiver sensitivity. The input to the IF amplifier does not go through an rf amplifier as in HF receivers. Radars in the UHF and above range couple the received signal into a mixer to reduce noise normally generated in the rf head. Figure 2-6 shows a typical mixer and AFC circuits.

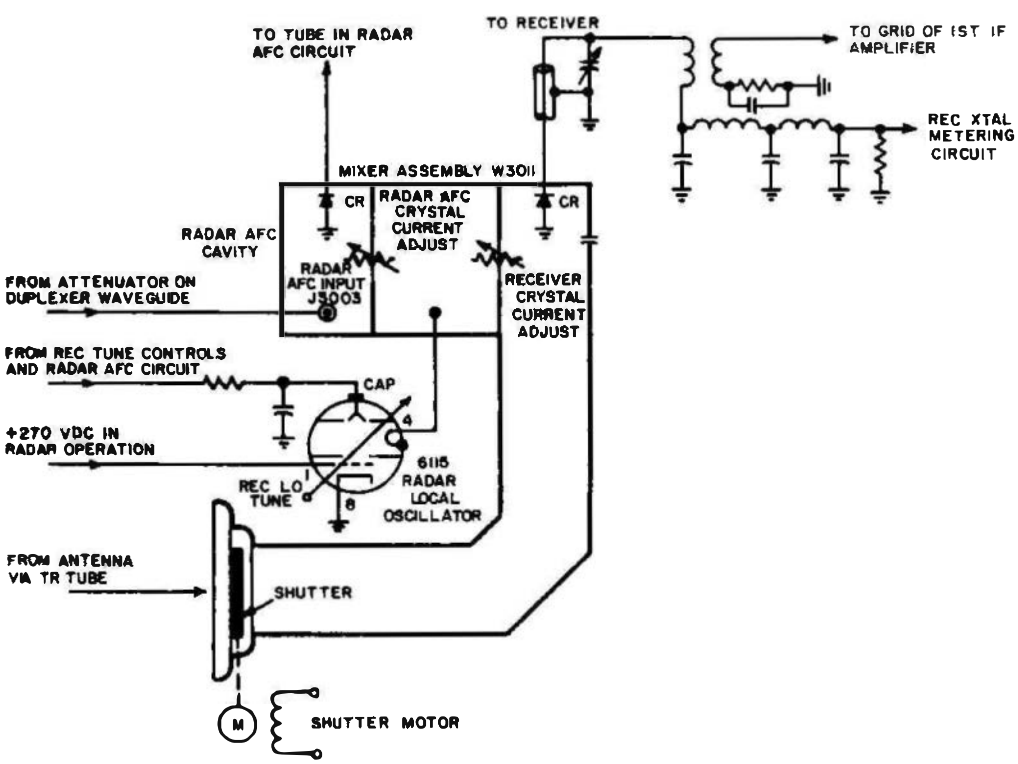

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Figure 2-6.—Typical radar mixer and AFC circuits.

Noise Analysis

In any conductor there is a certain amount of random electron motion resulting from thermal agitation. This motion produces a voltage within the conductor that varies in a random manner. Since this voltage is a pure noise voltage, it produces signals that contain frequencies randomly distributed throughout the rf spectrum. The signals that occur in the portion of the rf spectrum covered by a given receiver are picked up and appear at the receiver as noise.

THERMAL AGITATION.—Thermal agitation noise is determined by bandwidth and temperature. The constant merely serves to convert the noise units into units of power. A decrease of temperature causes less random electron motion, and, at absolute zero, all motion and noise theoretically cease.

Since noise covers all frequencies, it is apparent that a greater bandwidth encompasses a greater range of signals, which means more noise power. In a theoretically perfect receiver, this noise could be considered as a voltage across the antenna terminals, and the power represented could be calculated on the basis of temperature and bandwidth. In practice, however, the actual noise developed in a receiver is greater than the calculated value because of the generation of other types of noise within the receiver circuits. For example, a carbon-type resistor, which is comprised of fine particles of carbon, generates a noise signal when current flows through the resistor because of small changes in the contact area of the particles. Various resistors have widely varying noise levels, and those that are used in the input circuits of a radar receiver must be chosen so as to have as low a noise level as possible. Electron tubes also generate noise signals because of random variations in electron emission from the cathode and random variations in the current division between the plate and screen grid. Since electron tubes produce noise in proportion to the number of electrodes employed, it follows that triode tubes are generally used where noise limitation is an important consideration.

NOISE FIGURE DETERMINATION.—The term *noise figure* (nf), as applied to a radar receiver, indicates the amount of noise that is to be expected. Thus, nf is defined as the ratio of measured noise to calculated noise, and it may be expressed as a power ratio or in dB. Therefore, nf can be said to be the input signal-to-noise ratio in comparison to the output signal-to-noise ratio. Since the input ratio is larger than the output ratio, nf is always greater than 1. The input should be at a temperature of 290° Kelvin. In the microwave range of operation, virtually all of the noise originates within the receiver. Atmospheric and man-made noise or static is normally too small to be considered. The three main sources of noise in a radar receiver are the crystal mixer, the IF preamplifier (usually the first two IF stages), and the local oscillator.

Conversion loss and noise figures are functions of the rectified crystal current and are determined by the local oscillator signal level. Noise figure increases and conversion loss decreases as the rectified crystal current increases. These crystal characteristics have been correlated to the front-to-back resistance ratio of the crystal and the back crystal current at 1 volt. Therefore, a measurement of this ratio and of the back current becomes an indication of the crystal condition.

In most cases, the most expedient and successful check of a mixer crystal is to replace it with a new or known good one. Note that the output noise of a reflex klystron is much greater than normal when the tube is tuned off the center of a mode. Early radar receivers had noise figures in excess of 20 dB, while modern receivers have noise figures of only 0.5 to 18 dB. In general, lower receiver frequencies result in lower noise figures. The noise figure of a radar receiver can be determined by the use of either a noise generator or a CW signal generator.

TEST METHOD USING A NOISE GENERATOR.—A noise generator produces a random noise signal that covers a frequency range in excess of the radar bandwidth. One such instrument uses a temperature-limited diode, operated at saturation, as the noise-signal source. When a diode is operated under these conditions, the noise produced is proportional to the dc current, the generator frequency range must be adequate, and the diode cannot be used for over 1000 MHz. Therefore, the dc input power can easily be converted to obtain the true noise power.

TEST METHOD USING A CW SIGNAL GENERATOR.—The continuous wave (cw) method of measuring the noise figure uses a calibrated signal generator in the same manner as the noise generator. This method is not as accurate as the noise-generator method because the detector characteristics of the receiver under test may affect the ratio of signal power to noise power.

MINIMUM DISCERNIBLE SIGNAL MEASUREMENT.—The measurement of a minimum discernible signal (MDS) consists of measuring the power of a pulse whose level is just sufficient to produce a visible receiver (scope) output. It follows that if a radar receiver has the specified MDS level, the noise figure should be correct also. Therefore, measurement of the MDS is a satisfactory substitute for a noise-figure determination, and it is less complicated. The correct pulse length must be used. When readings are taken periodically for comparison purposes, the identical pulse length must be used each time.

In the measurement of MDS, a very high degree of attenuation (approximately 98 dB for the average radar) and a very low power level (about one pico watt) are involved. Because of these factors, very little rf leakage from the signal generator can be tolerated, or the amount of leakage signal picked up by the receiver will be appreciable, compared to the signal fed through the attenuator. Since leakage signals are independent of attenuator setting, inaccurate MDS readings can be obtained when leakage is present. If the leakage signal reaches the receiver in phase with the signal through the attenuator, the MDS reading will be low, and thus it will indicate that the receiver sensitivity is much better than it actually is. In such a case there is a good possibility that a defective receiver may appear to be normal. On the other hand, if the leakage signal reaches the receiver out of phase with the signal through the attenuator, the MDS reading will be high, and thus it will indicate that the receiver sensitivity is worse that it actually is.

In the construction of a signal generator, special attention is given to the problem of minimizing rf leakage. The rf oscillator is carefully shielded, and then it and the attenuator assembly are enclosed in a second shield, which serves as the case of the instrument. In addition, all connection cables and couplings are provided with shields and close-fitting connectors. In spite of these precautions, however, a small amount of rf leakage exists, even in the most modern equipment.

The presence of leakage makes it imperative to locate all equipment associated with the MDS test outside the radar antenna radiation field. In addition, the equipment should never be operated outside its case or with loose cable connections. Also, on early types of signal generators where a door is provided on the front panel for access to the oscillator adjustments, the door must be kept closed during measurements. These precautions must be observed; otherwise, erroneous measurements will be obtained.

The presence of rf leakage is detected by the following method. Determine the MDS level; then move the test set to another position and determine the MDS level at that point. Observe whether the first MDS reading differs from the second; if it does, rf leakage is present in one of the two positions. When leakage is found to be present, locate the test set as far from the radar antenna and receiver as practicable. Find that position where movement of the test set does not affect the MDS. In general, if rotation of the test set does not change the MDS level, the rf leakage can be considered negligible.

Testing Receiver Bandwidth

Receiver bandwidth is defined as the frequency spread between the half-power points on the receiver response curve. Receiver bandwidth is specified for each radar, although wide variations are often tolerated. If either the bandwidth or the shape of the receiver response curve is not correct, a considerable change in the value of circuit components is required to alter the response materially. The receiver response should be checked after an extensive repair to any IF amplifier. Figure 2-7 shows a typical response of a radar receiver. The half-power points are shown as 3 dB below maximum (mid-frequency) response. Since the curve is plotted in terms of voltage, these points are also represented by the 70.7 percent voltage points (1/2 = 0.707, as shown in the figure).

INTEGRATED METHOD.—The bandwidth test procedure given is used when the receiver is operating as an integral part of the radar facility and can very easily be reformed after checking

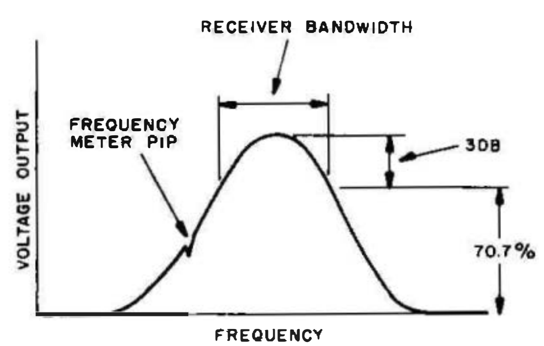

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Figure 2-7.—Receiver response curve.

the MDS. When the radar receiver is to be tested as an individual component, another test procedure is used, which will be described immediately following this method. The integrated receiver method, which is considered superior to other methods, makes use of the test setup for measuring MDS, using a sweep signal generator.

PREFERRED METHOD.—This method is employed when the radar receiver is to be tested as an individual component rather than an integral part of the radar equipment. Figure 2-8 shows the test setup for checking a receiver that is detached from the radar facility. A sweep generator produces a variable-frequency signal that is fed into the receiver IF input.

> NOTE
>
> The sweep width and the center frequency of any fm signal generator is adjustable to cover standard radar intermediate frequency.

The receiver video output is fed to the vertical-deflection circuit of an oscilloscope. In addition, a sync voltage is supplied by the sweep generator to maintain horizontal motion of the electron beam in synchronism with the frequency sweep. The oscilloscope, therefore, indicates frequency horizontally and receiver output vertically. A second signal generator, called the marker oscillator and is internal to the sweep generator, produces an accurately calibrated cw signal, which is mixed with the sweep generator output. When the varying sweep passes the marker-oscillator frequency, a beat signal results that produces a marker pip on the response curve, as shown in figure 2-9. The marker-oscillator dial indicates the frequency at which the pip occurs.

To check receiver bandwidth using the test arrangement discussed above, the marker pip is positioned until it rests at the 70.7-percent point on the curve, and the frequency dial is read. The frequency at the other half-power point is determined in the same manner. The spread between these two points, expressed in frequency, is the measured bandwidth. In most cases, the radar receiver does not need to be removed and cable connections can be made to the input and output of the receiver. The principal of bandwidth testing can be applied to any part of a radar that has a bandpass or bandstop system. By using the sweep generator to supply a broad source of rf energy and an oscilloscope to monitor the system response, adjustments can be made or repairs facilitated. When rf signals are being passed through nonamplifying circuits, such as passive preselectors or filters, a spectrum analyzer should be used.

TR Recovery Time

The time required to permit tr recovery is determined by the time it takes the tr switch to deionize after each transmitter pulse. It is usually defined as the time required for the receiver to return to within 6 dB of normal sensitivity after the end of the transmitter pulse. However, some manufacturers use the time required for the sensitivity to return to within 3 dB of normal or to full sensitivity. The tr recovery

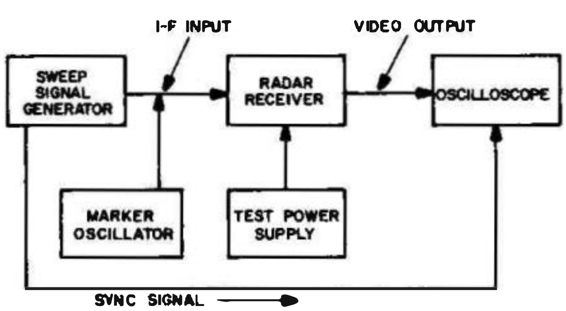

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Figure 2-8.—Test setup for checking receiver response.

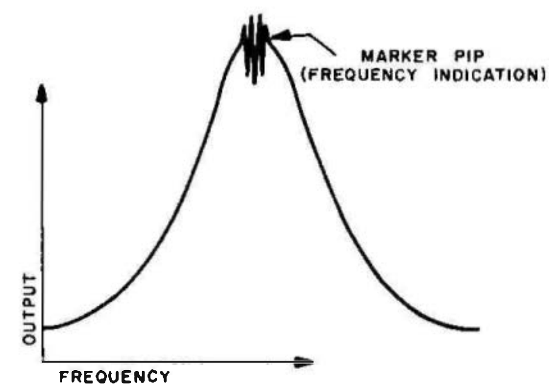

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Figure 2-9.—Response curve showing marker pip at mid-frequency point.

time is one of the factors that limits the minimum range of a radar because the radar receiver is unable to receive signals until the tr switch deionizes. The recovery time may vary from about 0.3 to 20 microseconds, depending upon the particular radar set.

TR FUNCTION.—The primary function of the tr section is to protect the crystal detector from the powerful transmitter pulse. Even the best tr switches allow some power to leak through, but when the switch is functioning properly, the leakage power is so small that it does not damage the crystal. It has been found however, that the useful life of a tr tube is limited because the amount of leakage and the recovery time increase with use. To ensure efficient performance, some technicians make it a policy to replace the tube after a given number of hours. A better practice is to measure the tr recovery time at frequent intervals, as called for in preventive maintenance procedures, and make a graph or chart, which will immediately disclose any change in performance. In practice, the tr tube is replaced when any sharp increases in recovery time become apparent. Ambient temperature also has a effect on recovery time. The colder a tr tube, the greater its recovery time. For example, tube type 721A recovers in about 7 microseconds at 28°C; however, at −186°C, the recovery time is about 100 microseconds, and at −20°C, the recovery time is about 14 microseconds. When tests are conducted under widely varying temperature conditions, this effect must be considered.

CURRENT AND VOLTAGE CHECKS.—One method used in testing a tr tube is to measure the keep-alive current. This current maintains the tr tube partially ionized to make the firing more reliable, and thus helps protect the crystal. The current is usually about 100 microamperes, and it falls off as the end of the tr tube life approaches. Another method is to measure the keep-alive voltage between the plate and ground of the tr tube when the voltage is known to be good and to record this voltage for use as reference for future checks. However, these checks are not as reliable as a recovery-time test.

RECEIVER RECOVERY TIME.—Radar-receiver recovery time is defined as the time required for the receiver sensitivity to return to normal after a saturation echo is received. This time is determined in the original radar design and is of very short duration. Receiver recovery is not discussed in terms of minimum range since tr recovery is much longer. The receiver recovers from a transmitter pulse long before the tr tube recovers. Figure 2-10 illustrates the effect of receiver recovery. Note that immediately following the echo pulse, the noise is at reduced amplitude, and the recovery time is the period of reduced noise level. No absolute measurement of receiver recovery is necessary. A noticeable time interval, however, usually indicates trouble. From that point, the AGC and STC circuits should be checked for proper operation if they cannot be disabled during testing.

TRANSMITTER PERFORMANCE TESTING

The performance of a radar transmitter is determined by several factors, most of which are established in the design engineering of the equipment. In the test to follow, only those factors involving maintenance will be considered. The most important factors that will be discussed are the magnetic field of the magnetron magnet, pulse repetition rate measurements, pulse duration measurement, and the measurement of the modulator pulse.

Magnetron Performance

The magnetron is a high-power transmitting tube used in microwave radars. As a source of high-power microwaves, the multicavity magnetron represents an advance over both conventional space-charge and velocity-modulated or medium-power, klystron-type tubes. Magnetrons produce pulse power on the order of hundreds of kilowatts at frequencies as high as 24,000 MHz. These tubes are basically self-excited oscillators

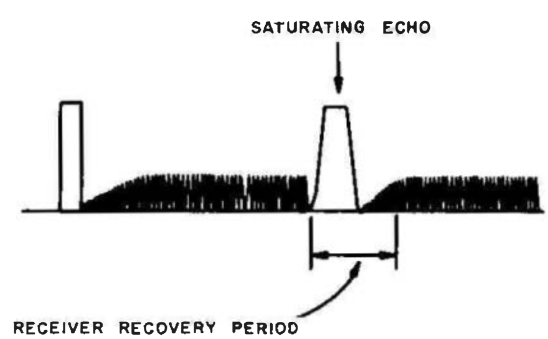

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Figure 2-10.—Receiver recovery time.

whose purpose is to convert dc input power into rf output power. Magnetrons are generally constructed so that they are inserted between the pole pieces of a permanent magnet or electromagnet.

CAUTION

Certain precautions should always be taken when handling magnetron magnets. The field strength of these magnets is greatly reduced if they are jarred or hit even lightly. The magnetic field is very strong and if magnetic tools are used when working close to the magnet, the strong field may pull them sharply against the magnet.

NONMAGNETIC TOOLS.—A test was made to determine the effect of allowing tools to strike a magnet, and it was found that only one touch with a steel screwdriver reduced the main magnetic field by 50 gausses. Since the magnetron used with this particular magnet was designed to operated properly within limits of 50 gausses above or below its rated 2500 gausses, two or three such light taps on the magnet would seriously affect its performance. This difficulty can be avoided by the use of nonmagnetic tools. A nonmagnetic screwdriver is essential. If magnetic tools must be used, special precautions must be taken to prevent them from jumping toward the magnet. A nonmagnetic cover, such as cloth or tape, wrapped around the pole pieces to a depth of three-sixteenths of an inch reduces the effect of touching a screwdriver to the magnet to about one-tenth of what it would be without the cover. In general, iron, nickel, and other magnetic objects should not be brought near the magnet. When drilling or filing in the vicinity of the magnetron assembly, cover it completely so as to prevent any metal filing from becoming attached to the magnet. During storage, care should be taken to prevent the interaction of the fields of two or more magnets. A safe rule is to allow not less than 6 inches between them. In addition, always store a magnet with the keeper in position.

MATERIAL STORAGE.—All material having a strong magnetic field should be stowed away from cables carrying heavy current. Such cables, in themselves, produce a strong magnetic field and can induce or remove magnetic properties in nearby ferrous metals.

Pulse Repetition Rate Measurements

Pulse repetition rate (prr), also termed *pulse repetition* (prf), is an important factor in radar performance. The pulse rate is a direct function of average transmitter power, and it also serves to set the upper limit or maximum range of the radar equipment. Short-range radars (fire-control or ground-controlled approach radars) have a high prf, while long-range (search) radars have much slower rates, since the required rest time is considerably longer for the greater ranges. Pulse recurrence frequencies of 200 to 400 pulses per second are typical for radar equipments operating at 250- or 300-mile ranges. Fire-control and ground-approach radars have pulse repetition rates that are as high as several thousand pulses per second. Regardless of the type of pulse radar, the prf is often in the low audio frequency range.

NOTE: Some fire control radars have a prf that is so high it cannot be heard by the human ear. This poses a serious safety hazard that has resulted in death and serious injury.

FREQUENCY COUNTER.—Two methods for measuring prf employ a frequency counter and an oscilloscope. The frequency counter can be used to measure the prf in terms of frequency. The accuracy of this method is far superior to any other method.

OSCILLOSCOPE.—The oscilloscope method requires two main triggers to be displayed. The time separation must be interpolated from the display screen. Calculations are then performed if the prf in frequency, rather than time, is to be determined. Small changes in prf may go undetected because of the small display or to large pulse-repetition time. Procedures for determining the pulse repetition frequency are as follows:

1. Connect the trigger or sample of the transmitter output to the vertical input of the oscilloscope.

2. Adjust the sweep frequency until at least two pulses appear on the time trace.

3. Using the sweep calibration, determine the time elapsed between either the leading or trailing edges of two successive pulses.

4. Using the following formula, calculate the pulse repetition rate.

$$\text{prf} = \frac{1}{\text{pulse repetition time}}$$

NOTE: To calculate pulse repetition time, use the formula $\frac{1}{\text{prf}}$.

Pulse Width Measurements

Pulse width can be measured by means of a frequency counter, using the time-internal function. The frequency counter's timing circuits are started on the leading edge of the pulse and then stopped on the trailing edge. The time is displayed on the readout. The oscilloscope method of measurement requires one pulse to be displayed and then expanded either by delayed intensity function or simple time-base expansion. An interpolation from the display is made from the 70.7 percent points of the leading and trailing edges, as shown in figure 2-11.

MODULATOR PULSE MEASUREMENT.—Since modulator pulses in the order of thousands of volts are common in radar equipment, several different pieces of test apparatus have been developed so that these high-voltage pulses may be viewed on an oscilloscope. These pieces of apparatus all perform the basic function of dividing the modulator pulse so that a small portion of the pulse voltage, which is proportional to both the magnitude and the shape of the pulse, can be applied to the oscilloscope at a voltage low enough to be within the operational range of the oscilloscope.

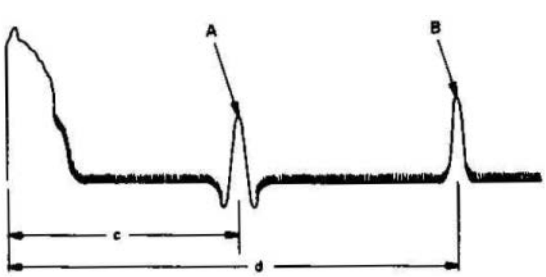

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Figure 2-11.—Double-echo range scope presentation.

RESISTIVE LOAD.—The *resistive* load is a form of dummy load capable of providing a termination for making overall performance tests on radar modulators. The termination is comprised of high-voltage resistors in the form of a voltage divider of a known ratio for the purpose of measuring and viewing the output pulse of the modulator with an oscilloscope.

A dummy load typical of a 50-ohm termination consists essentially of two resistive elements made up of one 49-ohm resistive element and a 1-ohm element connected in series, thus providing a 50-to-1 ratio voltage divider. A tap or coaxial connector, with a nomenclature such as MEASURE PULSE, is connected across the 1-ohm resistor. The electrical connection from the divider to the modulator is made with the high-voltage pulse cable of the radar set. The modulator is operated in accordance with the standard instructions of the radar set before any measurements are made; the modulator must be operative long enough to heat the load thoroughly (often 10 minutes). This is important because the values of the resistances are generally unstable, decreasing with temperature. The total resistance and divider ratio is determined with the resistors thoroughly heated. To measure the modulator pulse, connect an oscilloscope, capable of displaying video pulses, to the MEASURE PULSE terminal video jack. Observe the shape and measure the pulse voltage. The voltage is determined by means of the oscilloscope and a calibrating voltage. Measure the pulse by taking the voltage indicated by the oscilloscope and multiply it by the ratio factor or the resistance load (50 in the case illustrated).

VOLTAGE DIVIDER.—The voltage divider (in this application) is a complete portable test equipment used to measure, in conjunction with an oscilloscope, video pulses from about 200 volts to 200,000 volts (or higher in high-impedance circuits). The voltage divider differs from the resistive load basically in that the pulse voltage division is accomplished by capacitors, rather than by resistors.

Timing-Circuit Testing

Although pulsed radar was developed primarily for detecting and range finding of various objects, certain specialized requirements have come into later applications. Radar equipments are classified as to the particular use for which they are designed.

RANGE ACCURACY.—Since the range of a target is determined by the time interval between the transmitted pulse and the echo return to that point, all time delays introduced by the radar components will add to the range indication. Thus, the range indicated will be in error by an amount equivalent to the time delays that have been introduced.

In every radar installation, time delays occur within the equipment between the time the radar trigger is initiated and the time the echo pulse arrives at the indicator. The causes of these time delays are as follows: (1) The modulator output pulse occurs a short time after the trigger input pulse; (2) the rf output from the transmitter takes time to increase to the proper amplitude after application of the modulator pulse; (3) time is required for the transmitted rf energy to travel to the antenna, for the reflected rf energy to travel from the antenna, and for the reflected rf energy to travel from the antenna to the receiver; (4) time is required for the rf pulse to travel through the receiver; and (5) time measurement errors are caused by incorrect scale factors in the ranging circuits; for example, the oscillator frequency that determines the range mark position may not be correct, or the linear sawtooth slope that generates timing delay may slope too much or too little. Therefore, this is called a slope or rate error. Nonlinearity of the ranging circuits is caused by nonlinearity of the linear sawtooth waveform, and there is also a small delay in starting the range circuit. The latter, however, is a negative or compensating delay, as it subtracts from the other delays.

ZERO RANGE ERROR.—The difference between real range and indicated range is termed *zero range error*. A certain amount of range error may be due to the target distance being measured on one radar set and then measured on another set, which may be separated from the first by up to 100 yards; therefore, an error of 100 yards exists that cannot be compensated for. An even greater problem exists if the farther radar is being used for gunfire control in which the gun mount may be another 20 yards away and, therefore, a total of 120 yards of error. During shipyard availability periods, the delay (the range error) inherent in the transmission line from the transmitter to the antenna, plus equipment reaction time, will delay the transmitted wave with respect to the zero range trigger. These delay periods are carefully measured and tested so that corrections can be applied to the zero range trigger to give an accurate range reading on the ppi.

Fixed-target Method.—The fixed-target method of zero-error determination is the most reliable method in common use. This method involves the use of a fixed target at some accurately known distance. A natural target may be used, but a portable reflector gives more reliable results. The target range indicated by the radar is carefully read and compared with the known range. The range indicated by the radar should be greater than the known distance; the difference is the zero error.

Double-echo Method.—The double-echo method of range correction is normally associated with fire-control radar equipments, but any radar set that is capable of receiving two echoes from the same target during one sweep on the range scope is capable of determining range accuracy by the double-echo method. An example of how the double-echo method is used is given below.

1. The radar antenna is trained on a target at a range of between 1,000 and 3,000 yards. A transmitted radar pulse strikes the target, is reflected, and returns to the point of transmission. A small portion of this returned radar pulse is accepted by the radar antenna and presented as target A (fig. 2-11) on the indicator of the radar equipment. The remainder of the returned pulse is re-radiated and directed back toward the target for the second time. There the pulse is again reradiated back to the point where the radar antenna accepts the pulse and presents it as target B on the scope.

2. The time elapsed between the reception of target pulse A and target pulse B indicates the true range of the target from the radar set; provided, of course, that both pulses were received during the time of one sweep of the range scope. By placing the ranging device (step, notch, or marker) at target B and noting range d and then moving the ranging device to target A, and noting range c, the correct range may be computed. Subtract the range recorded for target A from the range recorded for target B (d minus c). This resultant figure should equal the range recorded for target A. If it does not, then, with the ranging device set at target A, the range correction control is adjusted, or the range counter mechanically disengaged and "slipped" until the counters indicate the correct range. This procedure of noting the ranges and altering the counters is repeated as many times as necessary to obtain accurate ranging. The following note of caution should be observed: The measurement of ranges c and d is

made as quickly as practicable, to prevent the possibility of the target range varying by any appreciable amount during the time interval between two range measurements.

Standing-wave-ratio Measurement

In a radar installation a low SWR is maintained principally for the following reasons: (1) Reflections occurring in the rf line cause magnetron *pulling*, and can result in faulty pulsing (this effect is more pronounced when the line is long, as compared to a wavelength); (2) arc-over may occur in the rf line at maximum-voltage points; (3) mechanical breakdown in the line may sometimes occur because of the development of hot spots, and (4) reflection of power causes excessive heating heating of the transmitting device (the SWR should be less than 1.5 to 1), which represents a reflection of less than 5 percent of the incident power. In the maintenance of radar, SWR measurements are useful in two ways. First, defective rf line components can be located by checking the SWR of each component or by substitution. Second, radars having rf tuning adjustments can be adjusted with the aid of SWR test equipment.

SLOTTED-LINE METHOD.—The slotted-line method of measuring SWR can be used with the aid of an rf probe and a slotted line. The slotted line is a coaxial or waveguide section of transmission line with a longitudinal slot cut into its outer conductor that permits insertion of the rf probe. The slot is constructed at least a wavelength long, but is not wide enough to cause appreciable loss by radiation. To explore the voltage field existing in the line, the probe is placed in the electrostatic field, through the slot, and then moved back and forth. The probe feeds an rf detector, and the rectified output operates a meter that indicates the SWR. Many radars have slotted-line test sections that are integral parts of the rf section. In such cases, a removable protective plate usually covers the slot. For those facilities not having built-in slotted sections, a series of slotted-line sections to fit any radar set have been devised. In some cases the section is inserted into the radar set by means of coupling sections, or a test setup is developed whereby the radar units may be tested. The SWR is measured by performing the steps given below:

1. If the radar facility does not have a line, insert a slotted section into the radar transmission line (with the adapters provided) as close to the magnetron as possible.
2. Connect the rf probe to an amplifier, and adjust the probe for a penetration of a few thousandths of an inch.
3. Operate the radar transmitter and probe to a maximum point.
4. Set the probe penetration to provide a scale meter reading of 1.
5. Move the probe to a minimum point, and read the SWR on meter.
6. If the SWR is too high (1.5 to 1 or higher) and the radar has tuning stubs, adjust the stubs for an SWR of as near 1:1 as possible. The latter adjustment is made with the antenna pointing at free space.

NOTE: When the slotted-line test sections are not an integral part of the equipment, special equipment from an intermediate maintenance activity (MOTU or NAVSEA) must be obtained to perform the SWR measurement.

DIRECTIONAL COUPLER METHOD.— The directional coupler method of determining the SWR is frequently used in the field. To determine the SWR of an assembly, the coupler is inserted into the transmission line and the incident power is measured. The coupler is then reversed, and the reflected power is measured. The SWR can then be calculated. This method is not very accurate if the coupler directivity is low. For example, if a given coupler has a nominal loss of 20 dB and a directivity of 20 dB, the SWR obtained as a result of its use is 1.6 to 1; however, the actual SWR may be any value from 1.4:1 to 1.8:1. It is seen that the greater the directivity, the greater the accuracy. The above method has been largely superseded by the use of the bidirectional coupler, which greatly simplifies the application. This coupler, which consists of two directional couplers mounted on the same line but coupling in opposite directions, has been developed to a point where the accuracy of the method is quite good. The bidirectional coupler does not require reversing, is easier to use than the slotted line, is more rapid in operation, and can be made a permanent part of a pressurized rf assembly. In addition, the coupler can be used in connection with power and frequency testing and spectrum analysis, which is discussed in detail later in this chapter.

BIDIRECTIONAL COUPLER METHOD.—In many equipments, a bidirectional coupler is included in the transmission line. The operation of this coupler for use in waveguides was discussed previously. Only the method for using the coupler for measurement of SWR is given here. Bidirectional couplers are also designed for use in coaxial transmission lines. The value of the SWR is given by the ratio of the voltage at a maximum point to that at a minimum point; that is

$$SWR = \frac{E_{max}}{E_{min}}.$$

Since E_{max} is the sum of the incident voltage E_I and the reflected voltage E_r and E_{min} is the difference of these two voltages, the equation above can be rewritten as

$$SWR = \frac{E_I + E_r}{E_I - E_r}.$$

Figure 2-12 is a plot of the equation for common values of incident and reflected

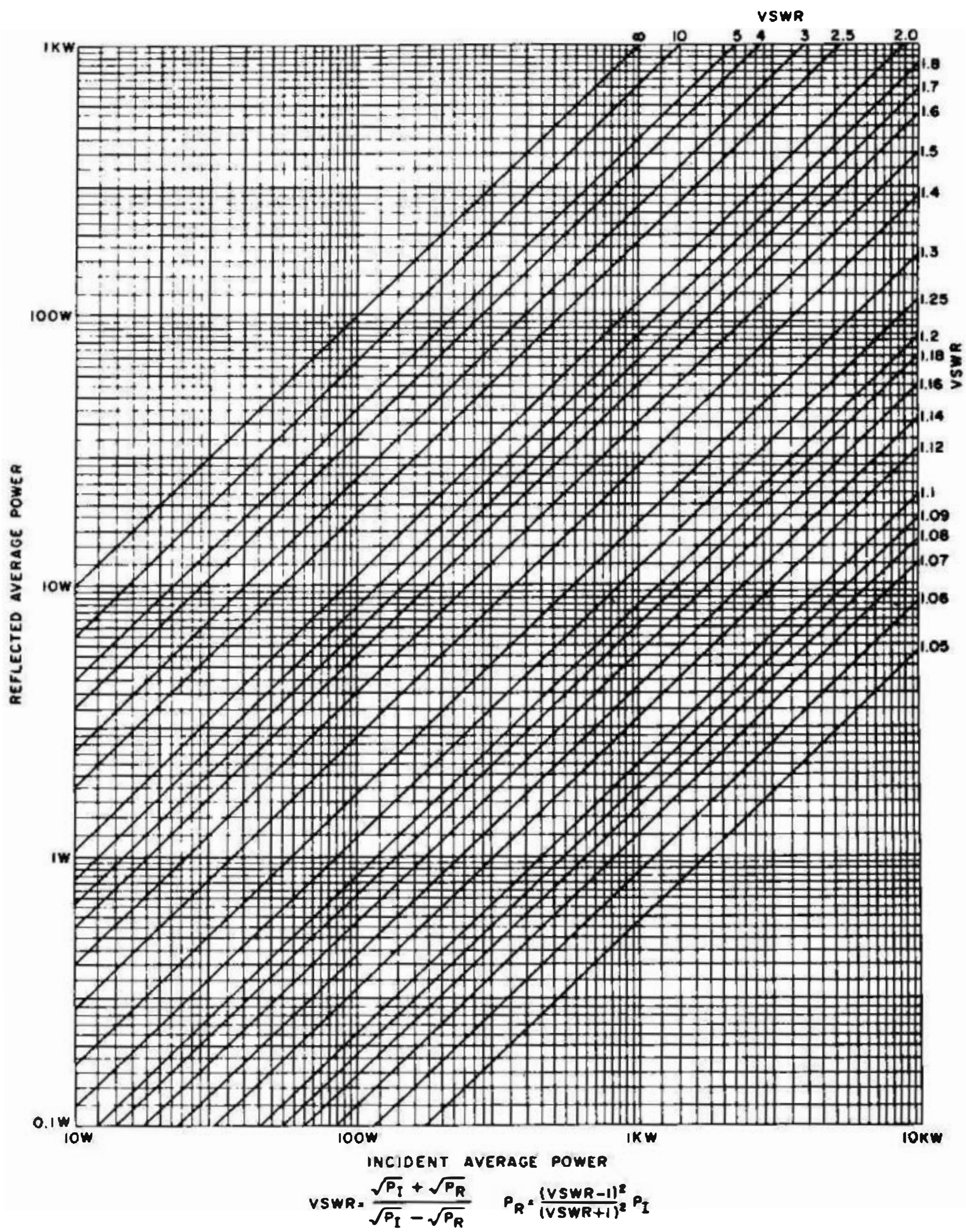

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Figure 2-12.—Graph of relation between incident power, reflected power, and SWR.

power. An important item in using this method for finding the SWR is that the power meter used with the bidirectional coupler will not, in general, directly provide actual values of incident and reflected power. The total attenuation in the coupling to the meter must be taken into account when calculating incident and reflected power. These values are then used to determine the SWR using the figure.

CAUSE OF STANDING WAVES.—Any discontinuous change along an rf line, such as might be introduced by a change in dimensions, or a change in geometry introduced by a sharp bend, dent, or an obstacle in the line, produces reflections. Some of the most common causes of an excessively high standing-wave ratio are (1) dirt or moisture in the rf line, (2) a dented or bent line, (3) burrs or poorly soldered joints, (4) defective coupling joints, (5) defective rotating joint, and (6) a mismatched antenna.

Locating Discontinuities.—If an increase is noted in the standing-wave ratio, check the rf transmission lines for the common causes listed above, as well as for any other damage that may result from battle, storms, or normal wear. Check the antenna also, since any bending of the reflector or dipoles changes its impedance and results in an increased SWR. Many rf transmission-line faults are visible and easily located; however, in some cases the trouble may be of such a nature that the defective part can be found only by making special tests, such as a time-domain reflectometer, or terminating the transmission line by sections to locate the defective section.

Dummy Rf Load Method.—A dummy rf load is a resistive section of transmission line that absorbs rf power without causing appreciable reflection. A typical waveguide, filled with a mixture of sand and colloidal graphite, serves as a resistance to absorb power. To minimize reflections, the front surface of the resistive elements is constructed so as to present an oblique surface to the incident rf power. The exterior of the dummy load is fitted with cooling fins and is painted a dull black for greater heat transfer. A typical X-band dummy load gives an SWR of less than 1.05 to 1, and absorbs 150 watts of power (average). If necessary, the power rating of dummy rf loads is increased by the use of forced air or water cooling. Coaxial dummy rf loads are similar in operation to the waveguide-type loads. The resistive mixture forms a tapered contact between the inner and outer conductors. Two distinct advantages are gained by the use of dummy rf loads in radar maintenance: (1) When military security prohibits rf radiation, maintenance can still be carried out with the aid of the loads; and (2) the load can be used to absorb power without reflections, regardless of surroundings. It may also be used for measurement of power output.

When the SWR of an rf transmission line becomes excessive, the causes of the standing waves may be located with the aid of a dummy rf load by performing the following steps:

1. Remove the antenna feed, and substitute a dummy rf load. If the substitution corrects the condition, the trouble may possibly be in the antenna, or it may be the result of reflections from nearby objects.
2. If the SWR is still too high, change the antenna scanning position and recheck the SWR. If the SWR changes, a defective rotating joint is sometimes indicated. In some cases, the SWR may not change, even though a rotating joint is defective. Therefore, this test will not eliminate the possibility of a defective joint, but it will locate faults caused by its rotation.
3. If the rotating joints are not defective, remove the section of the line next to the antenna feed section, and replace the dummy load at the open end of the rf assembly. Recheck the SWR. If the section removed is defective, the SWR will improve. Continue the process of removing sections until the offending section is located. The SWR should be checked again after the trouble is corrected and the rf components are reassembled.

Equipment using rigid coax as a transmission line may use a time-domain reflectometer to measure discontinuities along the transmission line, as well as measurements on any other type of cable. A display of length versus impedance is provided, as shown in figure 2-13. Each

173.734

Figure 2-13.—Time-domain measurement of line length versus impedance.

connector or joint can be located through the use of the length unit and a multiplier.

Spectrum Analysis

It is possible, by means of a spectrum analyzer, to observe a selected portion of the electromagnetic spectrum on the screen of a cathode-ray tube. The display consists of vertical pulses distributed along the horizontal axis; the position of each pulse indicates the frequency of a particular signal, while the relative height of each pulse indicates the relative strength of the signal. In other words, the display viewed on the cathode-ray-tube screen is, in effect, a graph of energy plotted against frequency. By analyzing the spectrum of a radar transmitter, a great deal of information is obtained regarding the condition of the radar. The spectrum analyzer can show the presence or absence of frequency modulation, and can also indicate the presence or absence of amplitude modulation in the signal. By means of a frequency meter, which is normally an integral part of the spectrum analyzer, it is possible to determine the bandwidth necessary to transmit each condition; only a limited number of harmonics are involved in the usual square wave. However, in actual practice a good square wave may contain frequencies up to the one-hundredth harmonic.

When a transmitter is modulated by short rectangular pulses occuring at the prf (pulse repetition frequency) of the radar, two distinct modulating components are present. One component consists of the prf and its associated harmonics; the other consists of the fundamental and odd-harmonic frequencies that comprise the rectangular pulse, as was previously discussed. Figure 2-14 shows an ideal display of that part of the spectrum covered when an rf carrier is pulse modulated. The vertical lines in the figure represent the modulation frequencies produced by the prf and its associated harmonics, while the lobes represent the modulation frequencies produced by the pulse frequency and its associated harmonics. The vertical lines are separated by a frequency equal to the prf. The amplitude of the main lobe falls off on either side of the carrier until it is zero at the points corresponding to the second harmonic of the fundamental pulse frequency. The first side lobe is produced by the third harmonic of the pulse frequency and the second zero point by the fourth harmonic. In the ideal spectral display, each frequency above the carrier has a counterpart frequency equally spaced below the carrier so that the pattern is symmetrical about the carrier. The amplitude of the side lobes is considered important, because in the ideal spectral display, the first side lobe represents 4.5 percent of the carrier amplitude, and the second side lobe represents 1.6 percent of the carrier amplitude. The main lobe carries the major portion of the transmitted energy.

TRANSMITTER OUTPUT VERSUS RECEIVER RESPONSE.—The importance of the transmitter output characteristics as compared with the receiver response becomes readily apparent by inspection of figure 2-15, which shows an optimum receiver response curve superimposed upon an ideal pulse spectral display. The receiver bandwidth is broad enough to include all the energy between the first zero points. Note that the receiver also responds to the first side lobes but at a reduced level. Any rf energy that exists outside the limits of the receiver response is, of course, lost, and the effect is the same as if the

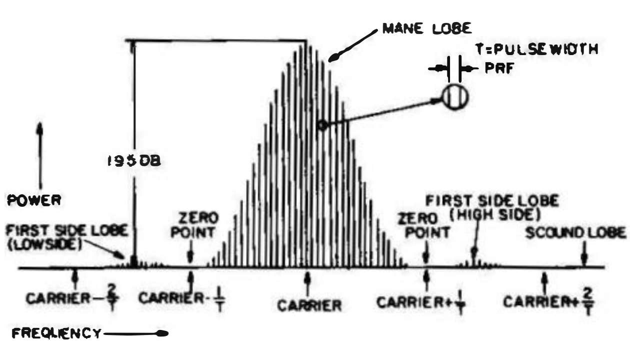

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Figure 2-14.—Ideal spectral display of a modulated rf carrier.

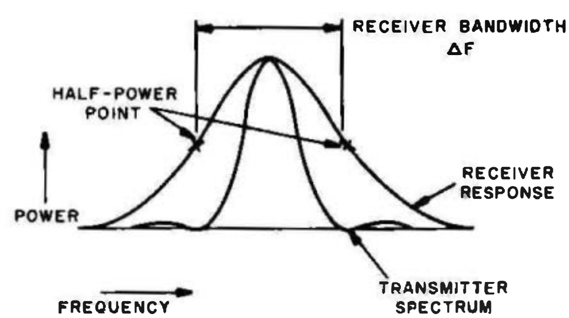

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Figure 2-15.—Transmitter spectral display compared with receiver response curve.

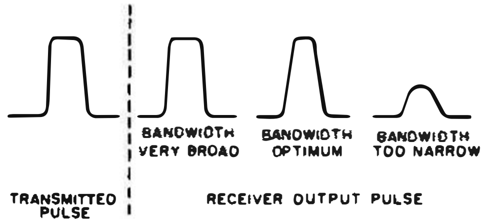

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Figure 2-16.—Effect of receiver bandwidth upon pulse shape.

transmitter power were reduced. Since practically all of the transmitted energy is within the limits of the receiver response, as shown in figure 2-15, further broadening of the receiver bandwidth results in little increase in energy pickup. It is apparent, however, that a decrease in bandwidth causes a definite reduction in energy pickup.

The spectrum side lobes contribute very little in terms of pulse amplitude, but contribute to the steepness of the edges on the output pulses, as shown in figure 2-16. From this cursory examination, it can be seen that an ideal receiver has sufficient bandwidth to include a great many side lobes to reproduce the transmitted pulse with a high degree of accuracy. However, if the above condition is obtained, the increased bandwidth allows the receiver to respond to more than the normal amount of noise and limits its sensitivity. A reduction of bandwidth, within limits, does not lessen the pulse amplitude, but it reduces noise response. Too great a reduction of bandwidth results in decreased pulse amplitude, as shown in figure 2-16, because of the loss of some energy in the main lobe. Optimum bandwidth results in the greatest receiver sensitivity, but it causes a slight distortion of pulse shape. Since accurate pulse shape is important in precision ranging and tracking operations, certain radar systems designed for this type of service have a receiver bandwidth that is broader than optimum to provide a sharp leading edge on the pulse.

MODULATION DISTORTION.—In a properly functioning transmitter, the period of the transmission interval is as specified, the oscillations during the transmission interval are of constant frequency and amplitude, and the time required for oscillation to start and stop is approximately zero. Any deviation from these conditions produces distortion that is visible on the spectral display in the form of either pulse amplitude distortion or frequency modulation (FM), or both. Figure 2-17 shows the spectral display when FM is present. The zero points are lost, thus indicating the presence of new frequencies in the spectral display. This has the effect of placing more of the transmitted power in the sidebands, which results in the loss of energy

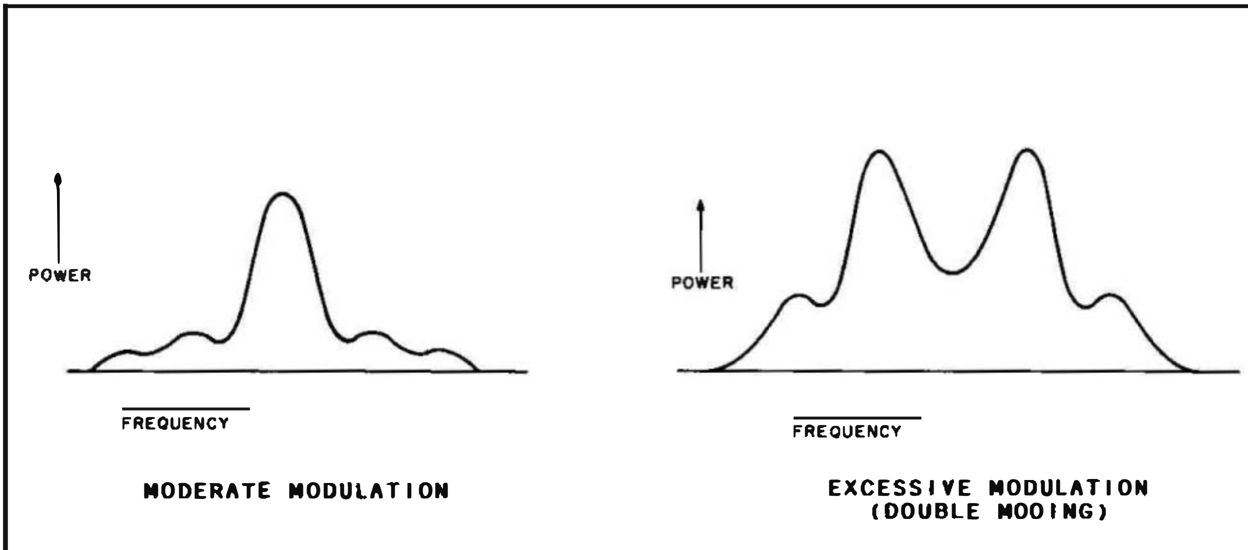

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Figure 2-17.—Transmitter spectral displays showing distortion resulting from frequency modulation.

outside the receiver passband. The same figure shows the spectral display when the amount of frequency modulation is excessive. When the frequency modulation is excessive, the magnetron is operating at two distinct frequencies (double moding), and the receiver, if tuned throughout its range, would thus have two tuning points. When the above condition prevails, more than half of the transmitted power is wasted. The presence of pulse amplitude distortion in the transmitted output has the effect of producing dissymmetry in the display, as shown in figure 2-18. The zero points are still clearly defined, but the lobes on one side of the carrier are much larger than normal. In general, distortion resulting from frequency modulation is far more undesirable than distortion from amplitude modulation. Figure 2-19 shows a combination of both types of distortion, which results in a very poor quality spectral display.

The troubles that give rise to a poor transmitter spectral display are sometimes difficult to locate. Trouble may arise from the following causes: (1) a defective magnetron, (2) a defective magnet, (3) mismatch in the rf section (pulling), (4) improper pulse shape or amplitude (pushing), and (5) reflections from nearby objects (pulling). There are two methods of obtaining a graph or display of the spectrum. The first method requires that a graph of power verses frequency be plotted. The method is relatively slow and demands considerable experience on the part of the technician. The second method is simplified by the use of a spectrum analyzer, which provides, as was mentioned earlier, a display on the screen of a cathode-ray tube corresponding to the graph plotted in the first method. The circuit of a typical spectrum analyzer is discussed briefly. Some spectral displays are examined and interpreted, and a method for frequency measurement is described.

FREQUENCY METER METHOD.—The use of a frequency meter is a rather simple method of obtaining readings to plot a spectral graph. A high-Q, transmission-type, resonant cavity meter, such as is found in most echo boxes, is used together with a rectifier-meter indicator. The test arrangement is shown in figure 2-3. Readings are taken at frequent intervals throughout the frequency range of the transmitter, and a graph is made to indicate meter readings vertically and frequency-meter indications horizontally. If the graph is very carefully plotted, a rough outline of the spectrum is obtained. A good idea of the spectrum is gained by noting how the meter reading varies as the frequency meter is tuned through resonance. All spectral readings must be obtained by rotating the frequency-meter dial in one direction only. If the dial is rocked into position, backlash in the dial drive mechanism will cause an appreciable error. The usual procedure is to approach each reading from the low-frequency side.

SPECTRUM ANALYZER METHOD.—The spectrum analyzer, which is a form of panoramic receiver, provides a simplified method of analyzing spectral phenomena. A small portion of the transmitter output is coupled into the signal input circuit of the spectrum analyzer. Care must be taken to keep the input low enough to prevent burnout of the attenuator. A directional coupler provides an ideal coupling system, but a pickup antenna may also be used.

In the spectrum analyzer, a narrow-band receiver is electrically tuned through a range of frequencies. The output, in terms of power, is displayed vertically on an oscilloscope, whose horizontal sweep is synchronized with the frequency sweep of the receiver. A block diagram of a typical spectrum analyzer is

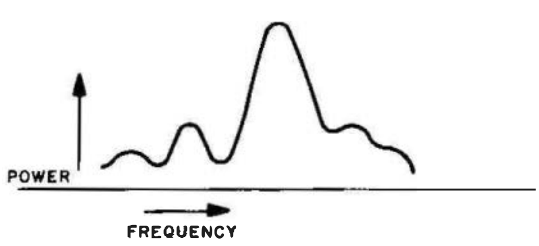

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Figure 2-18.—Transmitter spectral display showing distortion resulting from amplitude modulation.

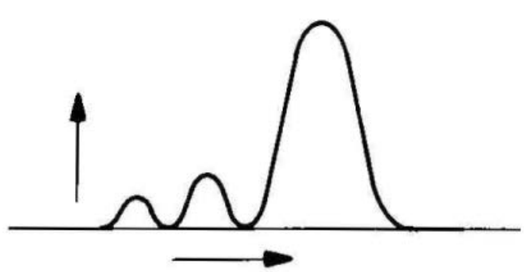

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Figure 2-19.—Transmitter spectral display showing distortion resulting from combined frequency and amplitude distortion.

shown in figure 2-20. The receiver employed is a superheterodyne type. The input, which usually consists of a coaxial-line termination, a broadband attenuator, and a crystal mixer is untuned; therefore, it responds equally well to all signals within the operating band. The local oscillator is usually a reflex-klystron type. The IF amplifier is a high-gain, narrow-band (50 kHz or less) amplifier, usually operated above 20 MHz. In some cases, double or even triple superheterodyne action is used to obtain the narrow bandwidth required. The IF section is followed by a detector and amplifier, which feed the vertical plates of a cathode-ray tube. The sweep generator produces a variable-frequency sawtooth voltage that sweeps the local-oscillator repeller and, therefore, the receiver frequency and the horizontal deflection plates simultaneously. A reaction-type frequency meter is included that is designed to absorb local-oscillator power at resonance, thereby indicating the local-oscillator frequency.

On the front panel of the analyzer is a function switch, usually labeled MIXER-SPECTRUM. In the SPECTRUM position, the indicator displays the output of the receiver. In the MIXER position, the indicator displays the crystal-mixer current, which is a function of the reflex-klystron, local-oscillator output. Figure 2-21 shows a typical reflex-klystron chart. Note that the tube will oscillate only at certain voltages, and as the voltage is varied, the power output varies. Each separate voltage range of oscillation is called a *mode*. The modes are relatively flat on top, and each succeeding mode encountered becomes stronger as the repeller is made more negative. Within any given mode, the frequency is proportional to the negative voltage on the repeller. A frequency range of 60 MHz is common in X-band tubes. However, the frequency at the top of each mode is determined by the size of the resonant cavity in the tube; therefore, all of the modes have the same center frequency. The sweep generator produces a sawtooth voltage. The sawtooth amplitude control, usually called the spectrum width control, has sufficient range to cover at least one mode, and quite often, two. The average voltage control of the sawtooth, usually called the spectrum center control, allows the choice of any desired klystron mode or the use of any range within a particular mode. In normal use, only a limited section of one mode is employed.

The spectrum analyzer can be used as a klystron tube tester. When the function switch is in the MIXER position, the presentation is similar to that shown in figure 2-22, which illustrates one complete klystron mode and part of another. The pip shown in the center of each mode is the frequency indication introduced by the reaction-type frequency meter. The mixer function of the analyzer allows the condition of the local oscillator to be checked; if desired, the oscillator frequency can be set to any specified value. The klystron to be tested is substituted for the local oscillator in the spectrum analyzer and the mode

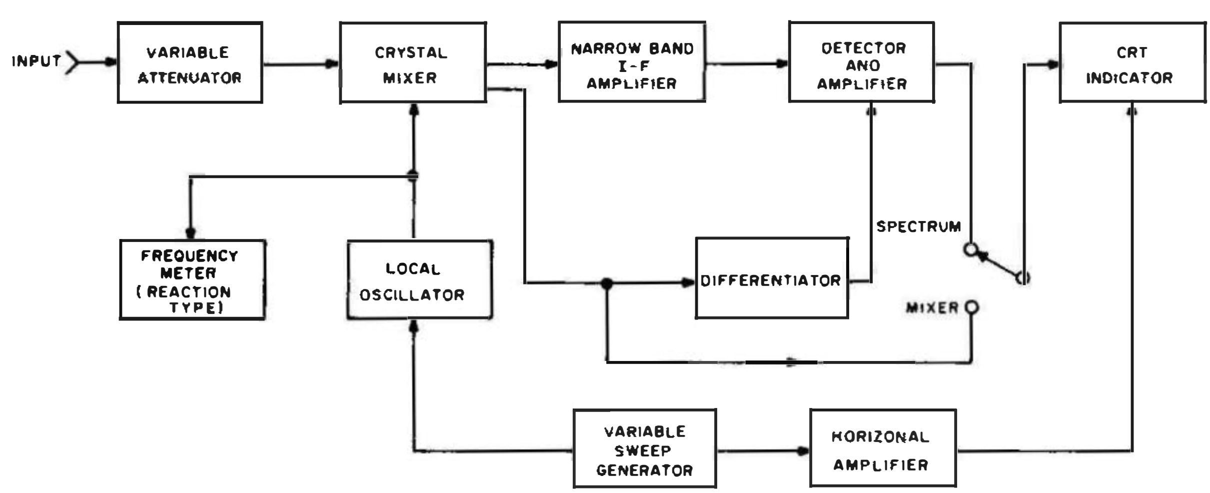

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Figure 2-20.—Typical spectrum analyzer, block diagram.

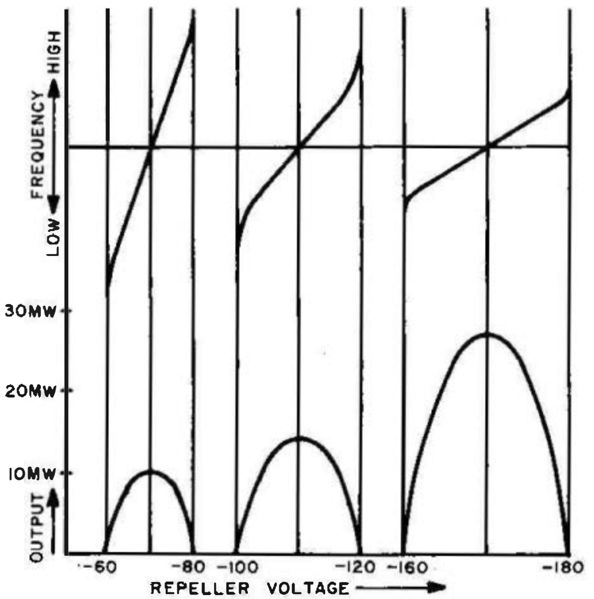

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Figure 2-21.—Typical reflex klystron chart.

pattern observed. The amplitude of the mode indicates power relative to that of the regular oscillator. The tuning range is examined and any irregularities noted. Each mode should present a smooth regular curve. If desired, the tube under test is pretuned to the approximate frequency before insertion into the radar to simplify radar tune-up.

As the spectrum analyzer frequency is swept, the spectral display appears upon the cathode-ray tube indicator in the form of a series of vertical pulses. These pulses are not to be confused with the vertical lines shown in figure 2-14, which are separated by a frequency equal to the prf. If the spectrum analyzer has a bandwidth of 50 kHz, a large number of prf lines are included in each

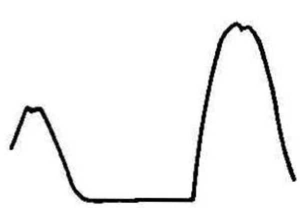

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Figure 2-22.—Klystron modes as presented on spectrum analyzer.

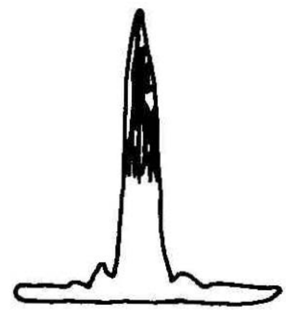

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Figure 2-23.—Typical magnetron spectral display.

pulse because the analyzer samples a 50-kHz segment of the spectrum each time the transmitter fires. Thus, each pulse in the display represents the energy contained in a 50-kHz band at the frequency of the analyzer at that instant. If the radar prf is 200 pulses per second and the analyzer sweep rate is 10 Hz, the display consists of 20 pulses across the screen of the cathode-ray tube. Figure 2-23 shows a typical magnetron spectral display. These pulses indicate only the general outline of the display, and are much too coarse to reveal the internal structure. Figure 2-24 shows the same conditions with the spectrum width control advanced to produce a greater spread.

FREQUENCY MEASUREMENT.—The measurement of frequency is greatly facilitated by the use of a differentiator. A portion of the crystal-mixer current is applied to a differentiator, and the differentiated waveform is applied to the amplifier section of the spectrum analyzer.

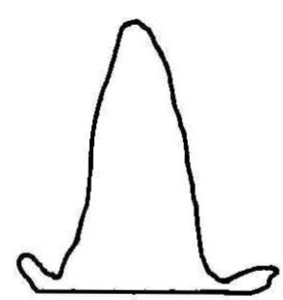

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Figure 2-24.—Typical magnetron spectral display, analyzer width control advanced.

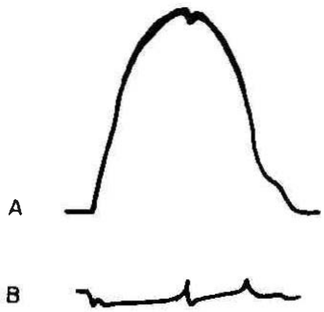

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Figure 2-25.—Effect of differentiator on mixer output.

Figure 2-25 shows the result of differentiating and amplifying the mixer signal. View A of the figure shows the display with the function switch in the MIXER position; and View B is the display with the switch in the SPECTRUM position. Note that the frequency-meter pip now appears as an S curve, and that the mode ends are marked by pips. This signal is combined with the spectral display, and appears superimposed on the base line of the pattern, as shown in figure 2-26. The exact frequency is taken at the center of the S curve, where it crosses the base line. The pips marking the mode-end limits should never be seen on the display, since no spectral indication may be obtained outside the mode limits.

INSTALLATION TESTING.—The spectrum analyzer can also be used for some installation tests. In this case, both the transmitter and local-oscillator signals can be conveniently sampled by means of a small pickup antenna placed near the base of the local-oscillator socket. In this position, the pickup antenna is the rf leakage field, and the intensities of the two signals are approximately equal because of the proximity of the pickup antenna to the weaker source. Because the rf section of the analyzer is untuned, image signals are also received. Thus, the signal picked up appears at two points on the analyzer tuning scale. In practice, however, an image is just as useful as the real frequency and is often used in measurements even though the frequency scale is reversed.

Since the analyzer frequency meter is designed to indicate its local-oscillator frequency rather than the input-signal frequency, the most accurate frequency-measurement method is to measure the analyzer's local-oscillator when the oscillator is tuned above the input signal, and then measure it when the oscillator is tuned below the signal. The signal frequency is then halfway between the two readings. The signal frequency meter also is tuned for maximum absorption of the input signal to obtain a direct indication of the input-signal frequency. Resonance is indicated by a slight reduction in the amplitude of the signal; however, this is difficult to observe.

Figure 2-27 shows an overall spectral representation of a transmitter and local-oscillator of a particular radar installation. In this figure, it is assumed that the intermediate frequency of the spectrum analyzer is 25 MHz, the radar-transmitter frequency is 9375 MHz, and the radar local-oscillator frequency is 9405 MHz. This produces a radar intermediate frequency of 30 MHz. If the spectrum analyzer were capable of showing the entire range of frequencies, the transmitter display would be recorded at 9350 MHz and 9400 MHz, and the local-oscillator display, which appears as a single frequency, would be recorded

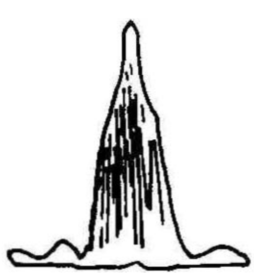

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Figure 2-26.—Typical spectral display, showing frequency-meter pip.

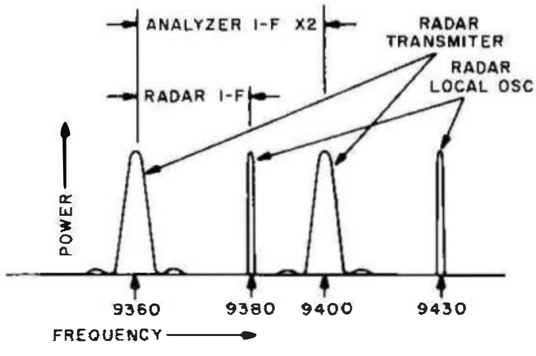

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Figure 2-27.—Spectral display of transmitter and local-oscillator output.

at 9380 MHz and 9430 MHz. (Note that the frequencies shown represent the local-oscillator frequency of the spectrum analyzer, and not the signal frequency.) Most spectrum analyzers, however, cannot show the entire range of frequencies given in figure 2-27. A typical X-band analyzer, for example, is able to present a continuous range of only 50 to 60 MHz. To examine various portions of the entire range, the analyzer turning dial is turned to vary the range of frequencies being covered. In this way, the entire band (8500 MHz to 9600 MHz) may be covered by one instrument.

COMPUTER MAINTENANCE

For a refamiliarization of analog computers and digital computers used in fire control, refer to chapters 2 and 3 of *Fire Controlman Second Class*, NAVEDTRA 10277. This section will focus on maintenance procedures rather than the basic operating principles of these computers.

ANALOG COMPUTER MAINTENANCE

Fire control computers are almost fully automatic in all modes of operation. The computer replaces human judgment by mechanical reaction. Therefore, the computer's solution must be reliable and valid. By reliable we mean that identical values in the computer always produce an identical solution. Valid refers to the correctness of the solution. Validity can be measured only by comparison with an external criterion.

Each computer has specially designed tests to indicate if the computer is performing properly. We are not concerned here with the step-by-step procedures of the various tests; procedures are covered in the applicable OPs. We are primarily concerned with the use of these tests for troubleshooting.

We can divide computer tests into three general classifications: PRELIMINARY, ROUTINE, and UNIT. Preliminary tests are operational checks; they are performed first. Routine tests simulate actual tracking conditions and problems. These tests are for checking the overall operation of the computer. Unit tests are checks of the individual computer elements or sections. In these tests the interrelationship between elements is broken, and the unit under test is checked as an independent component.

Preliminary Power Test

The preliminary power test indicates whether the computer is being supplied with the proper voltages. These voltages are used in the computer for the generation of displays, switching signals, and transmission of data. Computations performed in the computer are based on scale factor. These voltages are the basis of the scale factor. Obviously, voltage potentials, dc polarities, and ac phase relationships are critical in all modes of computer operation.

Supply voltages are checked by specially designed test circuits and installed meters. Normally, a check of the computer's control setup and meter readings of the monitored power supply voltages is all that's necessary before proceeding to the routine tests. If computer operations are generally erratic or sluggish, a further check of the power supplies is indicated.

Power supply circuits are extensive. Consequently, the first step is to localize the casualty to a particular supply. Study the computer's operation and note the symptoms of any malfunction. This should indicate the sections or elements affected by the casualty. Determine from this information the wiring diagrams to study. Logic will tell you that if a particular supply is common to all the malfunctioning elements, but not used by elements operating normally, it is the cause of the malfunctioning. The next step is to locate the casualty by a point-to-point check of the suspected circuit. Troubleshooting procedures in the OP will tell you the correct reading, tolerances, and type of meter to be used. Remember, test readings can be misleading and erroneous when the effect of the meter on the circuit being checked is not considered. Be sure of your test equipment, and use the test points indicated in the troubleshooting chart.

Routine Tests

Routine tests are normally held daily. A record of the test results is kept in a special log issued as a NAVSEA form. The theoretical answers, determined mathematically, and the computer's answers, both past and present, furnish a basis for evaluating the overall operation of the computer. Routine tests can be divided into two general classes—static and dynamic.

STATIC TESTS.—In static tests, sometimes referred to as A tests, we stop a normal problem at a fixed point. Thus, the input test quantities have a constant value, and the problem has fixed answers that do not change with time. As noted previously, some computers receive relative rates from the director. In these computers a static test does not check the determination of the rates. The rates are known inputs to the test. But any computation performed in the computer on these rates is checked. Dual ballistic computers solve separate prediction problems for weapons of different ballistics. These computers have separate answers to the tests for the different ballistics. The test values are inserted manually, and usually require switching from the normal mode to a test mode. Upon completion of the test, be sure that all switches are returned to normal mode.

DYNAMIC TESTS.—Dynamic tests are a check of the target tracking loop in the computer. Since there are variations between tracking systems, there are variations between dynamic tests. First we will consider linear rate computers. In this type of computer, the rates are calculated in the computer, and time, represented by shaft rotation, is present in the generating section. This means the test values of the relative rates can be established by the computer, and the problem run for a given time interval. This is an ideal test situation. The test answer is the amount generated of the quantity or quantities under test. When the tracking loop is completed by the director, special dials in the computer are used to read the amount generated. The relative rates remain fixed throughout the test. This type of dynamic test is called B test. Each of the generated quantities (range, bearing, and elevation) has a separate set of tests. When the computer is regenerative, that is, the tracking loop is complete within the computer, a different type of dynamic test is used. In this type, called a C test, the generated changes feed back into the present position quantities. Consequently, the rates are continuously changing. The test answer is the amount of the quantity or quantities under test being generated. All the generated quantities are checked in a single test.

Rate control, as you've learned, is the process of correcting the relative rates in linear rate computers. The rate control test is a check of the time required by the rate control system to reduce a known rate error by a given percent. This type of test is run on computers that are not regenerative.

Dynamic tests are run on some angular rate computers by using a special test set. The test set is substituted for the director and completes the tracking loop. The tester generates a problem that simulates a target's flight and introduces sudden variations in target range, bearing, and elevation. The computer performs as it does for an actual problem. The computer's solution is transmitted to the tester, where it is compared with the correct solution. Errors are monitored by indicating lamps, which light up when the error exceeds the allowable value. To obtain a detailed analysis, the indicator lamps are bypassed and the error voltages are transmitted to an error recorder.

UNIT TESTS.—Unit tests are checks of individual computing elements or related groups of elements. Some unit tests are performed periodically and could come under the heading of routine tests. If a computer section is not checked by routine test, a set of unit tests is performed for that section. An example is the deck-tilt corrector in some angular rate computers. The A test input quantities are in the horizontal plane, and the deck-tilt corrector is bypassed. A unit test is performed at regular intervals to check this section.

The majority of unit tests are used during analysis of routine test errors. The unit tests reveal malfunctioning or adjustment errors of an individual section or element of the computer. Since many variable functions contribute to the solution of a fire control problem, an error introduced anywhere in the computing process could produce an excessive error in the final solution. This makes it impractical to resort to unit tests as soon as an error is detected. Instead, a complete set of static tests is performed. A static test is indicative of only one fixed condition of a problem, which, in its normal state is dynamic. To obtain all the relevant circumstances surrounding the error, we should observe the problem from as many viewpoints as possible. By running a complete set of tests, the effects of modifying factors on the quantity in error can be noted under varied conditions. The values of the input quantities in the static tests are changed so that the effect of each modifying factor varies between tests. We can think of the test as a series problem in that the modification or generation of a quantity is done in steps. The correctness of each step is dependent on the previous operation to the quantity. However, some modifying factors affect more than one final quantity. Hence, the modifying quantities perform separate operations simultaneously on more than one final quantity. The modifying factors are called intermediate quantities. The input and the intermediate quantities make up the final quantity. The deviation of a final quantity is referred to as its "family tree."

Let's take the quantity gun train order, Bdg', and use it as an example to show a family tree, as shown in figure 2-28. At the same time, we analyze an A test error.

Assume that, on examination of the A test results, you find that the errors in Bdg' are greater than the allowable values. Bdg' is equal to director train (Bd'), plus the total deflection in the deck plane, (Ld'). Furthermore, Ld' is the addition of trunnion tilt correction (Lz), and sight deflection (Ls).

To analyze the A test errors in Bdg', you must consider the intermediate quantities one at a time. The first thing to check is the Bd' input. From your study of the fire control problem you know that Bd' is a basic quantity that affects all other deflection quantities. Consequently, an error in Bd' will result in an error in Ls. The relationship between the two quantities is considered by comparing the test readings. Unit tests are run on the Bd' followup, and on any other element that has Bd' as an input. The procedures for running the unit tests are given in the OP. Next, after assuring yourself that Bd' is not the cause, check the test readings of Ls and Lz. The trouble will necessarily have to be in one of these two. Let's say it is in Lz, and that the Lz followup is working satisfactorily. Then, of course, you have the error localized to the trunnion tilt corrector. To locate the exact source of the error, it is necessary to run the trunnion tilt corrector tests and unit tests on its individual components. These tests will show what adjustment is necessary.

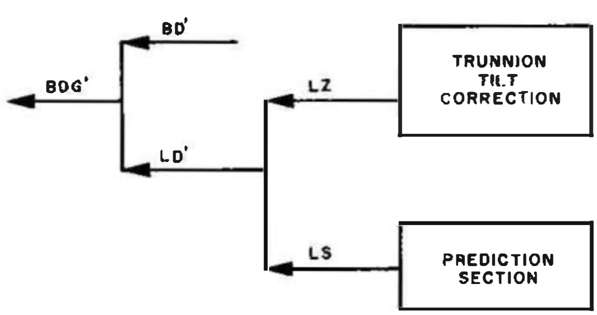

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Figure 2-28.—Analog family tree.

Troubleshooting

The computer test results and operation are well within the allowable values when the computer is installed aboard ship. An excessive test error indicates a deviation from the original condition. Past test results will indicate whether the deviation is the result of a gradual, cumulative change or of sudden defect or failure.

MECHANICAL TROUBLESHOOTING.— Computer operation causes wear in mechanical parts. The wear is cumulative and results in lost motion. Lost motion is particularly critical in low tolerance computer gearing. As lost motion increases, computer reliability decreases. Lost motion causes random computational errors. You can see this effect at its worst if you first set the test values from one direction and record the results, then reset them from the opposite direction and record the results. The difference in the results is the effect of lost motion. The accumulated lost motion in gear train can be felt by holding the gear at one end stationary and turning the gear at the opposite end of the line slowly back and forth. Lost motion between any two points on a shaft line can be checked in the same manner.

The mechanical lines are subject to sticking or jamming caused by dirty or damaged gears or bearings, bent shaft, or improper gear mesh. Sticking means that one or more parts move sluggishly throughout their normal travel, or resist moving past certain points. A sticking part may jam eventually if the cause is not eliminated. Jamming means that one or more parts that should move cannot be moved by normal force, usually hand pressure. The amount of force necessary to move a line is determined by the load on the line, and you must judge each line accordingly. Never force a jammed or sticking line to turn. Use the lost motion check to locate the source of trouble in a particular shaft assembly or gear mesh. In a jammed or sticking line, the farther a gear mesh is from the point of the trouble, the more accumulated lost motion can be felt in it.

Slipping, or failure of all the assemblies in a shaft line to turn together, may be caused by loose hangers, stripped gear teeth, loose clamps, or missing or sheared taper pins. To locate a particular assembly that is slipping, follow a procedure similar to that used to check lost motion.

ELECTRICAL TROUBLESHOOTING.— The electrical and electronic circuits in computers are usually complex and extensive. Circuit voltages and currents are critical; therefore, the circuit components have low tolerances. But normal electrical troubleshooting procedures for shorts, opens, and grounds can be followed. Troubleshooting charts or diagrams give a systematic procedure to follow, along with the correct readings. The troubleshooting chart usually includes possible causes of an improper reading at the checkpoints. Most electronic assemblies are checked as a unit by a special test set. If an assembly proves faulty, make a point-to-point check.

High voltages, capable of causing death, are used in computers. Dangerous potentials may exist in capacitors after power shutdown.

Computer Adjustments

Adjustments are provided to establish the proper relationship between components. This relationship is checked by computer tests. Therefore, you will be adjusting in the blind without tests. When running a test, take care to make precise input settings. Before analyzing the results of routine or unit tests, recheck the computer setup, recalculate the error, and rerun the test. Before you rerun the test, recheck the computer control switches and power supply indicators. These preliminary steps will eliminate unnecessary troubleshooting, and, in the long run, save you time and needless worry.

After the source of trouble has been localized to an individual component, the experienced technician will stop and study the computation of the quantity in error and reexamine the test run. Before making an adjustment, he will study the computing network to see exactly what effect the adjustment will have on the network, keeping in mind that the adjustment may affect other components and quantities. After the technician is satisfied that he knows exactly how to make the adjustment, and what the effect of the adjustment will be, he will be ready to start adjusting.

Adjustment procedures are outlined in detail in the computer's OP. Broadly speaking, the adjustment procedure considers the component's input, function, and outputs. The inputs are set at a test value. The component modifies the input values by its designed function. Thus, the outputs have a definite relationship to the inputs. The adjustment is made so that the output values have the correct relationship to the input values. After the adjustment is made, rerun the component's unit tests.

On the other hand, an adjustment in a computing network may offset the correct relationship between components. For example, you may have adjusted a component with an output connected to a limit stop, which controls the operational values of the output quantity. But this quantity is related to the component's input, which you have adjusted. Therefore, the limit stop must be checked and possibly adjusted. This holds true of all the components that could possible be affected by the adjustment.

DIGITAL COMPUTER MAINTENANCE

To meet reliability requirements and provide efficient troubleshooting procedures, special maintenance techniques have been developed for large digital computers. Maintenance program tests provide loop circulation of a simulated data pattern. The type of testing will determine whether the test signal becomes distorted in the circulation process and whether the control circuits in the loop allow passage of the entire succession of signals. Marginal checking circuits are included in some computers to detect aging of the circuit parts before a failure occurs. In addition to these special techniques, normal signal-tracing methods are used to locate the specific circuits in which malfunctions exist. Basic measurements are used to detect faulty parts.

Computers can be given an overall check by means of maintenance programs. A maintenance program provides a thorough and rapid method of detecting failure in a special portion of a computer. This type of overall maintenance check is very flexible and efficient. These programs use the same type of tape, memory, computing, and drum circuits as the operational programs. A program can be changed when the computer or auxiliary components are changed, and the program can be constantly improved. No extra test equipment is required since the computer circuits are themselves used to perform the test. Testing by means of maintenance programs also results in the computer circuits being used in a more normal manner than during signal-tracing procedures. When a program has been checked and accepted as a good maintenance tool, it is not subject to deterioration. In contrast, test equipment may be checked and accepted only to become unreliable shortly after being placed in actual use.

Maintenance programs are divided into three main classes: reliability, diagnostic, and utility programs. Maintenance programs employed to detect the existence of errors are called reliability programs. Reliability programs should be designed to check as many computer circuits as possible. Maintenance programs employed to locate the circuits in which computer malfunctions originate are called diagnostic programs. An effective diagnostic program should locate the source of trouble as precisely as possible. Actually, in many cases, reliability programs have diagnostic features, and diagnostic programs have reliability features. For convenience, a program is called either a reliability or diagnostic program depending on its intended emphasis. In general, programs that check rather than diagnose are shorter and simpler.

To write a satisfactory maintenance program, it is necessary to have a thorough knowledge of the instructions that can be used. This includes execution time, the overall purpose of the instruction, when the instruction may be used, and the state of the computer after the instruction has been carried out. In addition, the programmer must know whether the instruction can be indexed and what internal conditions must be satisfied before it can be executed.

Reliability Programs

Reliability programs are used in both preventive and corrective maintenance tests to detect circuit failures rapidly and to discover failures that may occur only under particular operating conditions. Examples of troubles that are not evident at all times are failures that appear at specific repetition rates or for certain combinations of bits. To detect such failures, it is necessary to use reliability programs that check logical operation, paths of information flow, timing, ability of the computer to perform all functions, and execution of instructions.

Reliability programs check either the logical functioning of an entire computer section or the logic functioning of individual circuit groups within a section. Whichever method is used, it is assumed that associated circuits that are not directly checked by the program are in satisfactory operating condition. Thus, these programs can be considered to fall into two categories: first order, and second order. First-order reliability programs check the operation of an entire computer section, whereas second-order programs check the operation of assemblies or circuit groups such as registers, counters, etc. In most cases, first-order programs are merely a combination of several second-order programs.

A reliability program provides a good or bad indication regarding the ability of the tested computer section or circuit to perform its designed operating functions. For example, consider a reliability program that checks the switching time of relays with a specific section of a computer. As long as the switching time of the relays is within normal limits, the reliability program will indicate satisfactory operation. If switching time is excessive, however, there is an indication that maintenance is required. If the program runs successfully, there are no failures within the checked area. In event of a failure indication, the failure may be in the area being checked or in another area that has been assumed free of trouble. Diagnostic maintenance programs should then be used to pinpoint the source of trouble.

Diagnostic Programs

To be efficient, maintenance programs for diagnostic applications must narrow the area of a failure down to the smallest possible number of circuits. This can be accomplished by employing increasing-area, decreasing-area, overlapping-area, and large-area checks. The most effective method will depend on the particular type of computer being tested.

INCREASING-AREA CHECK PROGRAM.—A program using the increasing-area check initially tests a small number of circuits. If a check indicates that all tested circuits are operating properly, successive checks are run in which progressively greater numbers of circuits are added. By this method, circuits that are found to be operating correctly are used to check other circuits. This process is continued until all circuits that can be checked by a maintenance program have been tested.

DECREASING-AREA CHECK.—When this method is used to find the source of a trouble, a large number of circuits are initially checked by the maintenance program. If trouble is detected in a large area, additional checks are made of successively smaller portions of the equipment until the stages affected by the failure are not included in the test area. It should then be possible to determine which stages are defective. If the check of a single large area reveals no error, the remaining large areas of the equipment are checked until the trouble is detected. In many cases, trouble can be located more rapidly by this procedure than by the increasing-area method.

OVERLAPPING-AREA CHECK.—Another efficient method of narrowing trouble detection, to within a small section of the equipment, is the overlapping-area check. The routines of this type of maintenance program overlap each other. Thus, a failure will be located at the overlapping portions of those routines indicating the presence of trouble.

LARGE-AREA CHECK.—It may not prove feasible to program an effective maintenance test for certain small sections of a computer. A maintenance program is useful only to detect the general area in which the malfunction occurs. When the general area is located, conventional troubleshooting will be necessary to find the circuit in which a failure has occurred.

Utility Programs

Utility programs are used as aids for both operation and maintenance programming procedures. This type of program is used to print out information from magnetic cores or other storage devices within the computer memory section. It is also used to transfer maintenance programs from punched cards or magnetic tape into the computer memory section. Utility tracing programs provide a printed record of the contents of various computer registers to enable followup on maintenance program operations.

MARGINAL CHECKING.—Marginal checking is a preventive maintenance technique used for some Navy and commercial computer equipment to detect the decrease in reliability of circuit parts due to aging. Aging circuit parts almost invariably change in value, current-handling capabilities, or in voltage limitations. Generally, the changes brought about by aging are gradual and without alarming variation in the normal operation of the equipment. For maximum equipment reliability, parts that are

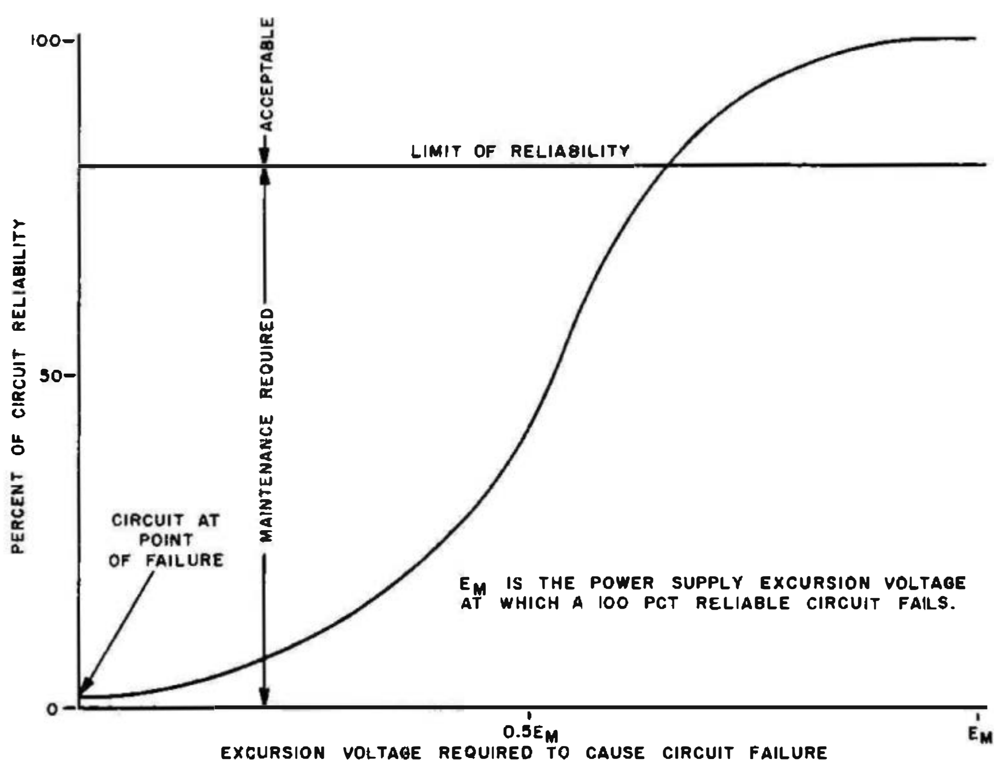

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Figure 2-29.—Circuit reliability versus excursion voltage required to cause circuit failure.

beginning to deteriorate must be detected and replaced before a failure occurs. Marginal checking is usually controlled by a maintenance program. The program directs the computer to perform the normal computer operations of addition, subtraction, etc., while the program varies certain circuit parameters about their normal values. In this way, the computer is made to perform normal functions under adverse operating conditions. To accomplish marginal checking, certain operating conditions are changed from their normal values. Since circuit-part values normally change with age, the variations that can be introduced before a failure occurs become less as the actual parts age. The amount of variation from the normal value that can be introduced before equipment failure occurs is called the "margin of reliability" of the circuit or group of circuits being tested.

Dc Supply Voltage Variation.—The most versatile method of marginal checking is by variation (excursion) of the dc supply voltage for one or more circuits. Causing an excursion of a circuit's dc supply voltage will simulate the changes that normally result from the aging of circuit parts. Gradually increasing the excursion of the supply voltage to a circuit will eventually result in a circuit failure regardless of the circuit's age. Figure 2-29 shows the relationship between circuit reliability and the excursion voltage required to cause a circuit failure. The magnitude of the voltage excursion necessary to cause a failure is called the "margin of the voltage" on the circuit. This margin becomes smaller as the circuit ages. When the circuit fails at the normal operating voltage, the margin is zero. As long as the possibility of circuit failure is low, the circuit is considered satisfactory. For the example shown in figure 2-29, the circuit reliability of 80 percent is acceptable. When the voltage excursion necessary to cause a circuit failure decrease such that the circuit reliability is below the 90-percent value, maintenance must be performed to replace parts or an entire plug-in assembly. The level at which the circuit reliability is acceptable must be determined for each circuit or circuit group that is tested by marginal-checking methods.

Circuit-Part Value Variation.—Failure of circuit parts can be anticipated by periodically simulating the aging of the parts. Figure 2-30 represents a circuit that can be selected by a maintenance program for marginal checking. The operation of this circuit is such that successive pulses place a 1 in FF1, transfer it to FF2, and clear both flip-flop stages. During the marginal checking operation, an excursion is applied to the supply voltage line of FF1. Assume that at some voltage value, the computer senses that a 1 was not transferred to FF2. The excursion is stopped and the margin noted. To determine which stage has failed, voltage and resistance checks can be made of the circuit parts of FF1. If this check indicates that FF1 is functioning correctly, it is possible that the output pulse from gate AG1 is so small that a slight change in the supply voltage applied to FF1 causes the circuit to fail. It is also possible that gate AG2 has aged to the point where any decrease in the

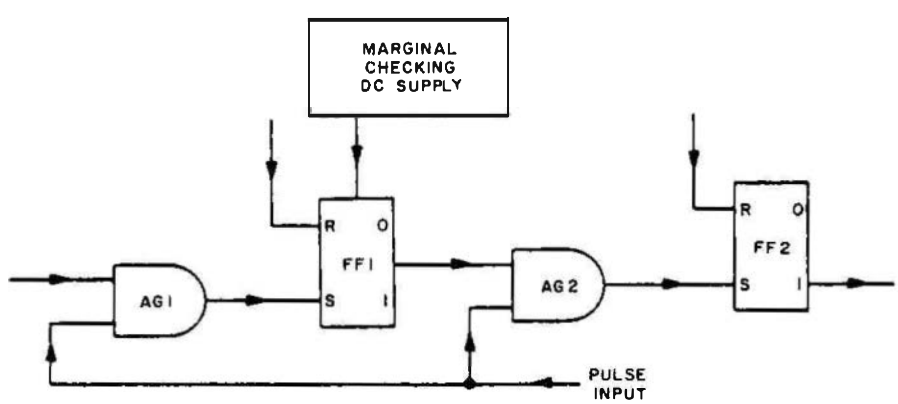

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Figure 2-30.—Typical circuit selected for marginal checking, logic diagram.

signal output level of FF1 will result in failure of the pulse to be transferred to F2.

BITE TESTING.—Most of the modern Navy computers use a maintenance system termed *built-in test equipment* (BITE). This program periodically checks the condition of the computer. Some of the parameters that can be tested are circuit response time, component use time, component full time, pulse duration, checksum, and pulse amplitude. View A of figure 2-31 shows a typical pulse that can be measured by a BITE program. Detail A_1 in the figure shows the circuit's response time; for example, the speed with which the circuit in question turns on and off. The computer program will open up a "window" during which the circuit must respond before the "window" closes. As a circuit ages, its response time will normally decrease to a point where the circuit will fail the test. Component use and full time is the interval the circuit requires to change its logic state. Pulse duration is a measure of pulse width at the half-power points. Pulse amplitude serves as a check of the pulse voltage level. If he circuit has deteriorated, the computer may not be able to recognize the pulse. If the pulse is supposed to be a logic 1, the computer may recognize the pulse as a logic 0 because of insufficient voltage level. View B of figure 2-31 illustrates the checksum process. If the BITE

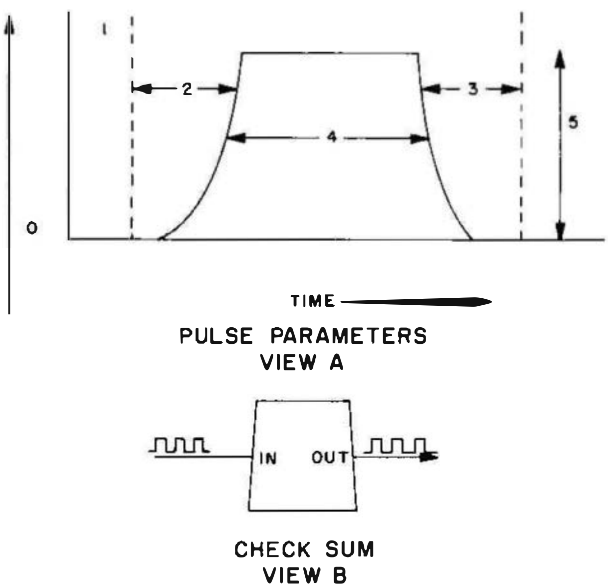

Figure 2-31.—BITE parameters.

program puts 3 pulses into a circuit, it should get 3 pulses out. The test is repeated frequently in the course of testing the computer circuits.

Alignment

Circuit adjustments may be necessary when input or output units are either connected or disconnected from a computer. These adjustments may vary the gain of amplifier stages, the frequency of a timing circuit, or the voltage furnished by a power supply. The need for other adjustments will be indicated by preventive maintenance checks. Power-supply outputs must be adjusted to furnish the correct current to magnetic cores and the correct voltage to amplifier and oscillator stages. The speed of tape devices must be adjusted to provide computer signals having the correct pulse width and timing.

Core-memory circuits may require realignment because of changes in operating currents due to the aging parts; replacement of plug-in units, such as digit plane drivers, memory gate generators, or timing stages; or accidental changes of the original potentiometer settings. The procedures for adjusting a core memory require checks of the memory timing cycle, the digit-plane-driver current, the read current, and the write current. The memory-timing cycle can be measured with an oscilloscope calibrated to measure time. The time between the clear-memory, start-memory, set-read, clear-read, set-inhibit, set-write, clear-write, and clear-inhibit pulses must be checked. If a discrepancy exists in the timing of any of these pulses, an adjustment must be made. In some memory units this is done by changing the taps on the memory clock delay line. An oscilloscope calibrated to indicate voltage can be used to determine the digit-plane-driver, read, and write currents. Maintenance programs can be used to inject the proper computer signals into the memory-coil arrays. You can then calculate the current through each drive line after measuring the voltage drop across the terminating resistor for each set of windings. Potentiometers located in the memory units are used to set the voltage to the correct amplitude. Recheck and, if necessary, readjust the read and write currents after the first adjustments are completed. This readjustment may be necessary because of interaction between the two circuits. After the read and write currents have been adjusted, you can check the balance by means of an oscilloscope and, if necessary, make a fine adjustment. Connect the oscilloscope probe to the read-write drive line.

Run a maintenance program to apply synchronized bursts of read and write pulses to the drive line. If the read and write currents are equal, the oscilloscope display should be similar to that shown in view A of figure 2-32. If any unbalance is present, the oscilloscope display will resemble the display shown in view B or C of the figure. Either the read or write current potentionmeter should be adjusted slightly to provide a balance.

Preventive Maintenance

Preventive maintenance for computer equipment is basically the same as for other electrical equipment; it consists of inspection, cleaning, preservation, lubrication, and performance checks. However, a unique feature of computer preventive maintenance is that the reliability programs can be used to quickly determine whether a computer is operating properly. In some computers marginal checks can be controlled by the reliability program, or performed manually to detect deterioration of computer parts before a failure occurs. Because of the extensive amount of wiring in large computers, wiring and cabling should be carefully inspected. Check the wires for loose or broken lacing and frayed insulation. Check the cables and connectors for improper placement that might subject them to strains or kinks. Inspect the connectors and wires for burned or charred parts, dirt, cracks, and breaks. Inspect switches for loose mountings and connections. Examine the contacts for dirt, pitting, and corrosion. Test the action of the switches and see that they operate without binding. In gang and wafer switches, see that the movable blade makes good contact with the stationary member. Makes sure that the stationary contact leaves spread as a movable blade slides into them. Some switches have contacts that are impossible to reach without damaging the switch assembly. Check these switches for defective mechanical action and looseness of mountings and connections.

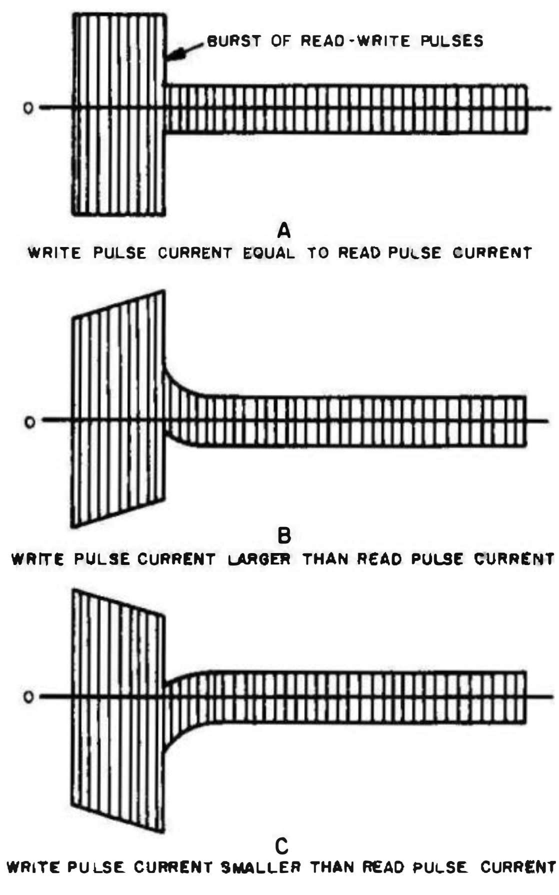

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Figure 2-32.—Magnetic core read and write current balance check waveforms.

Many digital computers include tape-handling equipment. This equipment must be cleaned, lubricated, and periodically checked to ensure proper operation. Daily maintenance includes cleaning the head assembly at the beginning of each day's operation and running a short reliability maintenance program, if the computer has this feature. Weekly maintenance may include the cleaning of items such as the friction drive clutch and the air filters. Check the machine's forward and reverse transfer time, the high-speed rewind, creeping of the tape reel, and the tape brake circuitry. Check the ability of the equipment to reproduce test pulses, to measure the tape speed, and to measure the moving coil and erase coil currents. A more comprehensive reliability maintenance program than is used for the daily check can then be run to determine whether error-free operation can be achieved for a period of 15 minutes.

Troubleshooting

Computer circuits, such as multivibrators, clock oscillators, and gates, can be tested in the same manner as similar circuits in radar, radio, and multiplex carrier equipment. Test equipment, such as oscilloscopes, voltmeters, ohmmeters, frequency meters, tube testers, and transistor testers, can be used to determine which parts are actually defective and, if possible, which has caused the failure. However, large computers have such enormous numbers of circuits that efficient troubleshooting to locate defective circuits can be accomplished only with the aid of maintenance programs, built-in test equipment, and special test sets designed to be used with specific computers. In computers that feature maintenance programs, reliability checks may be used to determine the area of a computer in which a failure has occurred. Diagnostic programs can be run to localize the trouble to a group or circuits or plug-in units. For example, if trouble appears to be in a plug-in matrix assembly, the suspected matrix assembly can be replaced by a unit known to be operating correctly. If this results in proper computer operation, test the defective matrix assembly with the aid of a matrix test set to locate the defective parts. If a special matrix test set is not furnished for the computer, the assembly must be tested with general-purpose test equipment to find the defective parts. Test equipment, such as test-pattern generators, trouble indicators, and memory units, are furnished with some computers as built-in equipment. Test-pattern generators can be used for signal-tracing applications or to provide a simulated signal for maintenance purposes. Visual and audible alarms are provided to indicate errors in calculations or the existence of conditions that might cause damage to the computer. Light-emitting diode LED indicators are often connected to flip-flop stages to indicate the status of registers. By observing the indicators and alarms, the technician can often decide what action should be taken to correct a malfunction.

MEMORY UNITS.—Trouble within a memory unit can usually be located by means of diagnostic maintenance programs. An example of a troubleshooting procedure is as follows:

1. Apply power to the computer and prepare the computer for test mode operation.
2. Check the supply voltages to the memory units; if they are not set properly, adjust them to their correct values.
3. Determine which memory unit is faulty by analyzing the computer error indication, program error, or error printout.
4. Run a diagnostic maintenance program. When an error printout occurs, check the computer condition indicators to determine in which routine the failure occurred.
5. Set the maintenance memory unit to repeat the routine that produced the first error. Run this routine to make sure that the error will occur when the routine is run separately. If the test routine does not produce the error when run separately, set the maintenance program to the previous routing so that the program operation will switch to the first error printout.
6. If the trouble is intermittent, use the marginal-check version of the program to apply prescribed margins to the memory unit. If the original memory failure is detected under marginal-check conditions, verify the failure margin by applying a manually controlled voltage excursion to the tested marginal unit while running the routine.
7. Check the memory unit for the remaining errors that were detected by the maintenance program. This is accomplished in the same manner as in steps 5 and 6.
8. Analyze the error printouts to determine whether the error is a bit failure or a selection failure. If the error is a bit failure, determine which bit is causing the failure, and check the associated sense amplifier or digit plane drive. If the error is a selection failure, further analyze the printout to determine which selection line or lines are causing the failure, and check the associated driver stage.
9. Refer to the equipment technical manual troubleshooting guides to determine which circuits should be tested. Rerun the maintenance routine, and observe the action of the suspected memory circuits.

Diagnostic Test.—Troubleshooting of computer magnetic tape units can also be accomplished by means of diagnostic maintenance programs. Such a program may use the control units, memory units, line printer, and marginal check equipment to test the tape units.

REPAIR PROCEDURES.—When the cause of a computer failure has been found by troubleshooting procedures, corrective action, such as adjustment, alignment, tuning, cleaning, and replacement of parts, will normally be performed. The replacement of computer parts involves the same basic procedures as are used for radio, radar, and carrier equipment. When replacing parts with many wire connections, such as switches, relays, connectors, and transformers, each wire should be tagged and identified. The wires may then be detached from the defective part and the replacement made without inducing an error in the wiring. Many computer circuits are contained in modules, which may be either plug-in units or soldered to the equipments.

The extent of repair for module units will depend on what is considered to be economically practicable. The units may be repaired in field maintenance shops or sent to depots. Appropriate soldering techniques must be used when repairing computers that use semiconductors, miniature circuits parts, and printed circuits to avoid overheating the parts. The voltages used in ohmmeter measurements of semiconductor circuits must be limited to safe values.

RADOME AND DIRECTOR MAINTENANCE

Repair of radomes and antennas is, in all but a few cases, performed at the depot level and should not be attempted by shipboard personnel.

Preservation, on the other hand, is a responsibility of shipboard personnel. For each separate antenna or radome, the equipment technical manual should be used as a reference for specific procedures used in preservation. As an example the procedures for preservation of the antenna and radome for the AN/SPG-55B, the Terrier missile fire control radar, will be discussed. An illustration of the antenna and radome is shown in figures 2-33 and 2-34 respectively.

REFINISHING OF A RADOME

In the event that the olive-drab finish on the radome surface is damaged, refinish affected areas as follows:

1. Lightly sand the area of the radome to be refinished with 100 grit sandpaper. Do not penetrate so deeply into the surface as to expose the internal fibers in the radome.

WARNING

Clean radome surface in a well-ventilated area.

2. Wipe the sanded surface free of residue with a lint-free cloth soaked in a low-flash naphtha (Aliphatic Naphtha Fed. Spec. TT-N-95 Type II). The cloth should be rinsed frequently and the excess should be squeezed out before wiping the surface.

NOTE

Total minimum thickness of primer shall be 0.001 inch.

3. Apply one coat of Adhesive Products Corporation Adweld No. 3880 primer by spraying. Allow the primer to air dry 24 hours at 68°F (20°C) before applying a second primer coat. Air dry the second primer coat 24 hours at 68°F (20°C).

NOTE

In lieu of Adweld No. 3880 primer, use Sherwin Williams Co. Kemak Primer Surfacer, White D65WA7 with Kemak Catalyst V66VA33 in the proportion of 1 pint Kemak catalyst to 1 gallon Kemak primer surfacer, white, mixing thoroughly. Reduce the catalyzed mixture 1:1 with xylene (Fed. Spec. TT-X916) to proper spraying consistency.

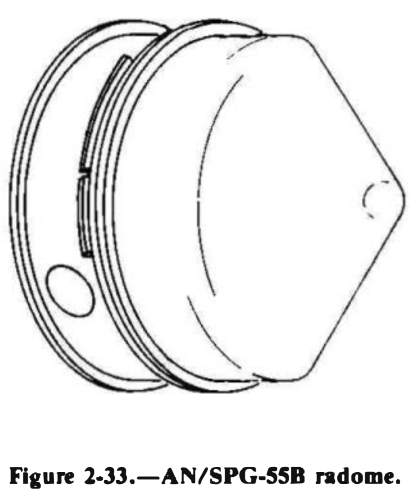

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Figure 2-33.—AN/SPG-55B radome.

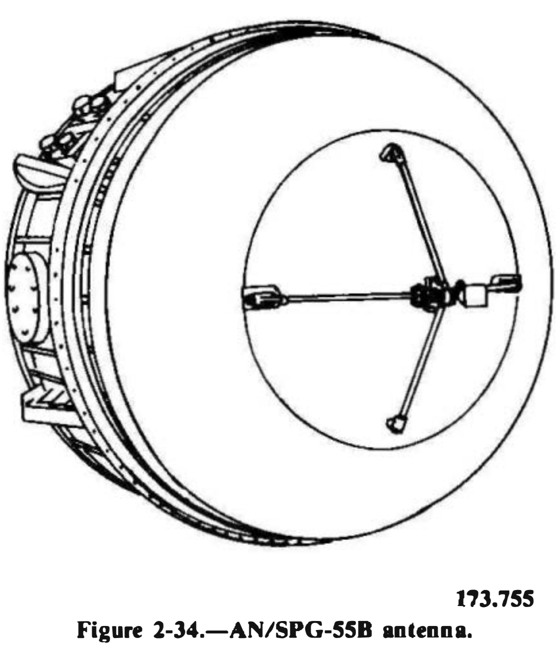

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Figure 2-34.—AN/SPG-55B antenna.

4. Apply a coat of olive-drab radome coating, by spraying, to the area to be refinished. Air dry 30 minutes at 68 °F (20 °C). The olive-drab radome coating No. 1896C, obtainable from the Goodyear Tire and Rubber Company, Aviation Products Division, should conform to MIL-P-9503 (USAF), Federal Standard No. 595 and No. 34087. Prepare the rubber base paint for spraying by thinning three parts by volume of paint with one part by volume of toluene (Fed. Spec. TT-T-548).

NOTE

The total thickness of the coats shall not exceed 0.004 inch.

5. Apply two more coats of olive-drab radome coating. Air dry 30 minutes at 68 °F (20 °C) after the second coat. For the final coat, allow it to dry a minimum of 72 hours at 68 °F (20 °C).

NOTE

Steps 6, 7, 8, and 9 are followed only to refurbish a radome surface that has an undamaged olive-drab finish.

6. Scrub the entire radome (including the non-stick surface) with a soft-bristle brush using a detergent-type cleaner. Rise with clean, fresh water.

7. Rough up all shiny paint surfaces with a fine sandpaper (approximately 100 grit).

CAUTION

Care must be taken not to remove primer or break through to the bare cloth fiber of the radome structure. Moisture getting into the radome fiber material will alter the electronic characteristics of the radome. The same holds true for unshielded radar antennas.

8. Perform step 2.

9. Perform steps 4 and 5, applying only one light coat of paint.

DIRECTOR TOPSIDE MAINTENANCE

Fire control directors of various systems perform basically the same function; that is, to establish the line of sight from the ship to the target. One example is the Mk 68 director, which is part of the Mk 68 gun fire control system.

Maintenance of fire control directors is relatively simple at the equipment maintenance level. Most of the maintenance procedures are contained in the director's maintenance requirement cards (MRCs), while the remainder of the maintenance is contained in the equipment's technical manuals.

The exterior components of the Mk 68 director are shown in figure 2-35. Topside maintenance consists of lubrication, cleaning, preservation, and weatherization.

Lubrication

Lubrication should be performed in accordance with the equipments MRCs. Attention should always be given to cleaning the grease fittings *before* and *after* greasing.

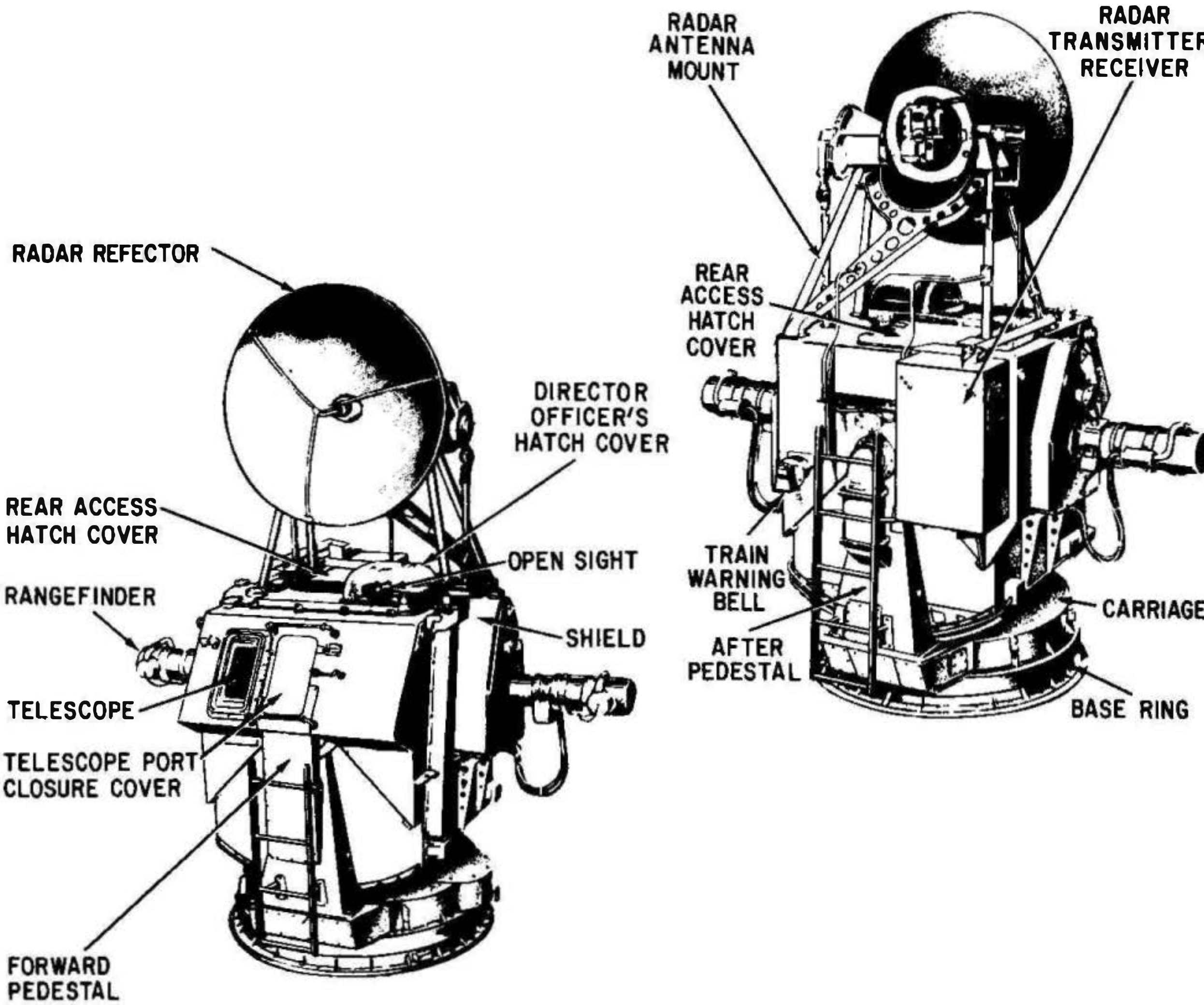
The plastic grease caps should also be installed after the application of grease to a particular fitting to protect that fitting from foreign particles. The location of every grease fitting to be lubricated during a given period of time (for example M-1, Q-2) is clearly illustrated on the MRC.

Cleaning

Exterior cleaning can be initiated either with salt water or fresh water. But, prior to applying a mild detergent, the director should be thoroughly rinsed with fresh water to remove the salt. Then, with the use of a scrub brush, the director can be cleaned to remove dirt and the oxidized paint. Waxing is not recommended because of the chemical action of the wax on the paint.

Preservation

When old paint has to be removed, the section or sections should be chipped down to bare metal. The exposed metal and the surrounding painted areas are to be *feathered* with sandpaper or a wire brush to present a smooth surface. Primer paint should be applied as soon as possible to minimize the occurence of new corrosion. Then, a fresh coat of paint can be applied in the final stage of preservation. When paint removal is not necessary for repainting, all surfaces should be sanded or wire-brushed



170.211

Figure 2-35.—Gun Detector Mk 68.

to a rough finish. Now, a new coat of paint can be applied without the use of a primer.

Weatherization

Weatherization consists of preventing moisture from entering support tubes (stuffing tubes) that have cables running through them. Electrical connectors on the director's exterior should be wrapped with weatherizing tape to ensure that no moisture enters the connectors or their associated plugs. This tape must have an adhesive on both sides.

OPTICAL EQUIPMENT

Optical equipment, such as pointing telescopes, range finders, and camera lens housings must be kept clean to ensure optimum clarity. The lenses and glass covers are cleaned with isopropyl alcohol and a lint-free cloth. Care must be taken not to scratch these surfaces, or visual distortion may occur.

Periodical *regassing* of optics is required to maintain a moisture-free environment in the internal housing of the equipment. Nitrogen gas is used in all optics and is applied under pressure. One characteristic of nitrogen gas is that it absorbs moisture; hence, the requirement to replace the old nitrogen with new nitrogen. As shown in figure 2-36, the old gas is purged through the air outlet. The new gas is pumped into an inlet on the left (hidden) side of the telescope. Range finders and camera lens housings are regassed in a similar manner.

NOTE: Regassing of optical equipment should only be accomplished with the assistance of qualified technicians from an intermediate maintenance activity (IMA).

POWER DRIVES

Power drives are comprised of the components that actually move the director. They contain electronic amplifiers, amplidynes or silicon-controlled rectifiers, dc drive motors, and gear trains. For a review, chapter 1 of *Fire Controlman Second Class*, NAVEDTRA 10277, can be used as a reference. A typical power drive is shown in figure 2-37.

Commutators and Carbon Brushes

Commutators are segments of conductive metal, usually copper, on a rotary drum separated by insulating strips, usually mica. The metal portion of the commutator must be kept clean and shiny for optimum electrical conductivity. This can be accomplished by using the eraser of a pencil to clean the commutator while the dc motor is running. One other item of attention in a motor is the carbon brush. The brushes should not be allowed to reach minimum length, or grave damage could occur to the commutator. Minimum allowable brush length is given in the MRC. This is usually one-quarter inch in length.

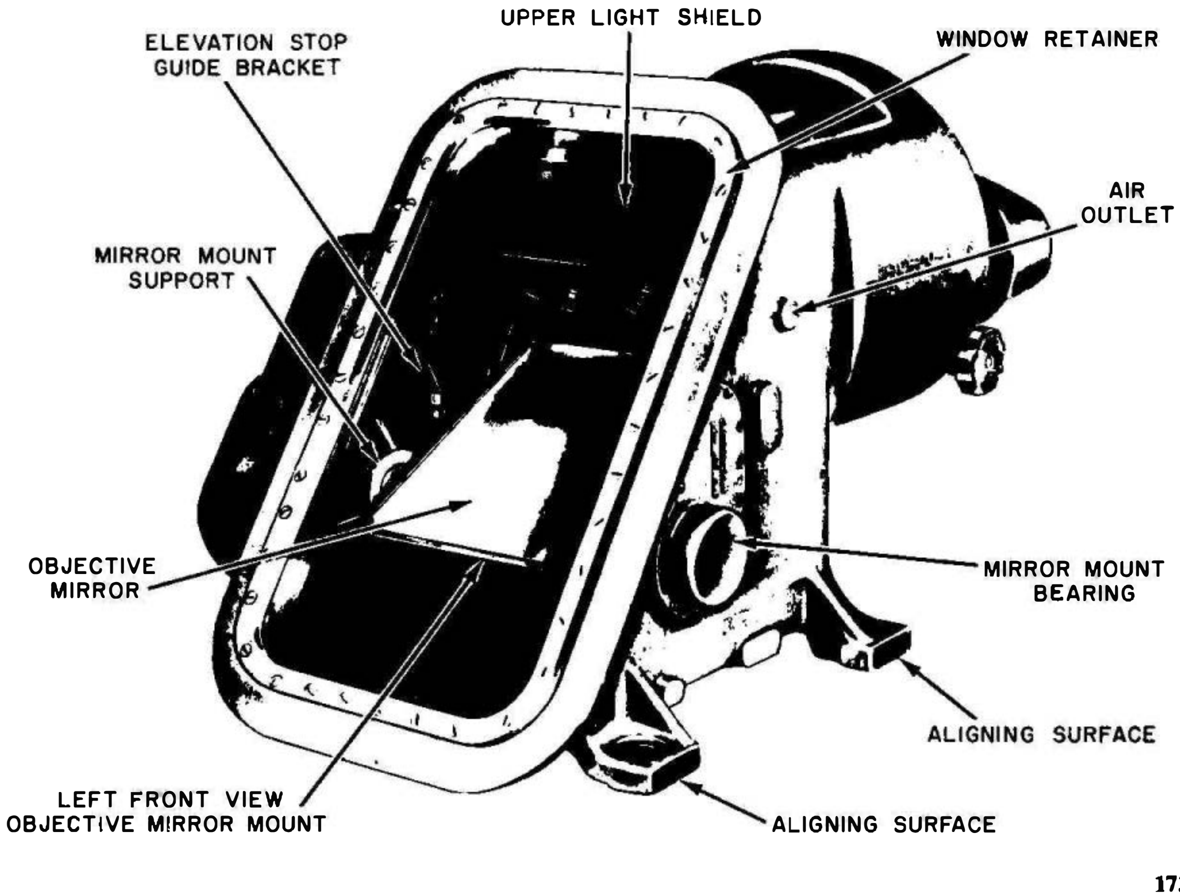


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Figure 2-36.—Telescope Mk 100.

Lubrication

On the motors themselves, one grease cup is located at each end of the motor. These cups should be kept full as specified in the applicable MRC. The only other areas to be lubricated are the drive gearboxes and gear assemblies, with oil and grease respectively. The proper lubricants for these units are also listed in the MRCs.

SLIP RING ASSEMBLIES

Slip rings are devices that allow continuous rotation of a piece of equipment without the restraints of limit stops and cable twists.

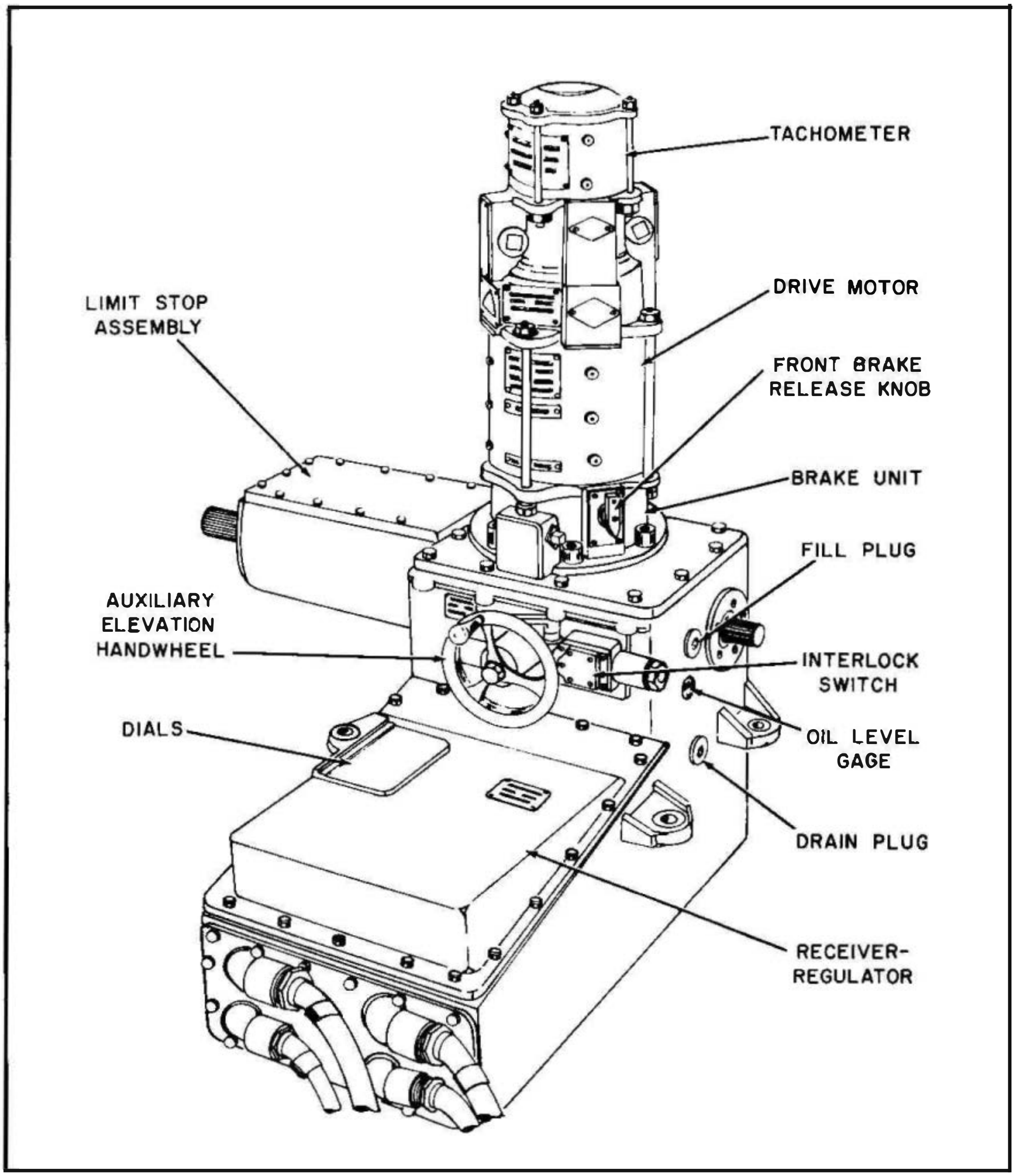

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Figure 2-37.—Elevation Power Drive Mk 49.

The two major components are the slip ring drum and brush block assembly. These components are shown in figure 2-38 and figure 2-39 respectively.

Periodic inspection is required to ensure there is no dirt in the slip ring assembly and all the brushes are making good electrical contact with the drums. When arcing is discovered on a drum or brush, an available spare brush and slip ring combination must be selected. Repair of slip rings is only performed at intermediate or depot maintenance level.

Slip rings, just like commutators on a motor, should present a bright and shiny appearance. When they become discolored, the slip rings will appear to look chocolate-brown. Again, as with a commutator, the eraser on a pencil can be used to clean the slip rings.

NOTE: Emery cloth should *never* be used to clean electrical equipment because emery is an electrical conductor and can cause a short circuit.

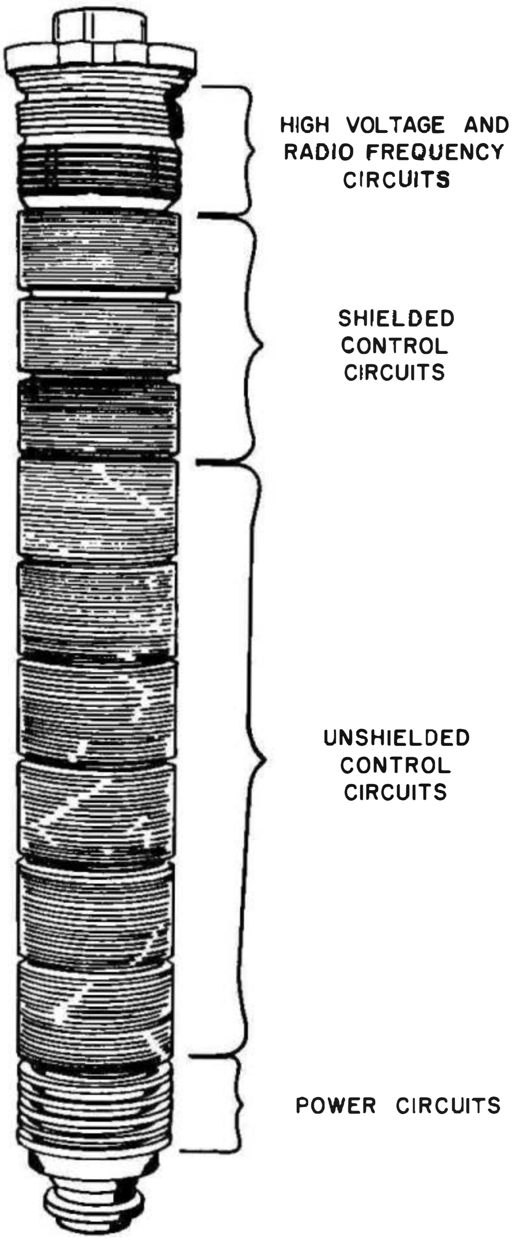

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Figure 2-38.—Slip ring drum assemblies.

SUMMARY

Equipment-level maintenance is the type of maintenance performed on individual pieces of equipment to maintain optimum performance of that particular equipment. All the individual equipments, when functioning properly, enhance optimum performance of a system; in this case, a fire control system. System level maintenance will be discussed in the next chapter. This level of maintenance consists of tests on the fire control system itself, and testing the interface of the fire control system into the overall combat system.

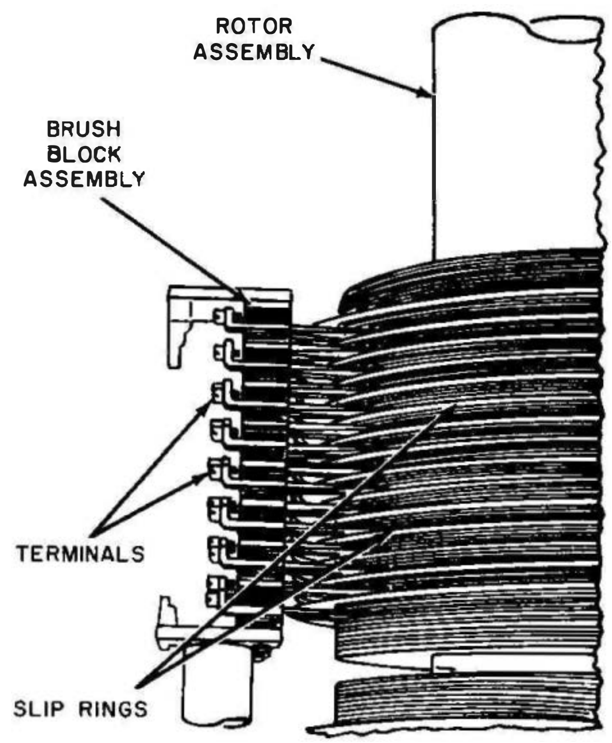

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Figure 2-39.—Brush block assembly.

CHAPTER 3

SYSTEM-LEVEL MAINTENANCE

System-level maintenance covers the combined operation of separate pieces of equipment or the combined operation of separate subsystems that function together as a system. An example would be a computer, radar, and director operating as a fire control system, or a fire control system, gun mount, and weapons direction system functioning as part of the total ship's combat system.

You, as a Fire Controlman first class, will be responsible for supervising subordinates in conducting various system-level tests. Two of the tests you will be conducting are (1) the overall combat system operability test (OCSOT) and (2) the daily system operability test (DSOT). The overall combat system operability test (OCSOT) tests the combined operation of all or at least most of the subsystems in a ship's combat system. The daily system operability test (DSOT) tests the combined operation of all or at least most of the equipment in a fire control system.

SYSTEM OPERABILITY TESTING

The combat system tests are the highest level of tests that can be performed to verify the ship's combat system readiness. These tests are normally performed on a weekly basis, but the periodicity of any PMS testing may vary depending on the ship's class. Typical combat system and PMS testing hierarchies are shown in figure 3-1. The overall combat system operability test (OCSOT) is normally performed weekly and assesses the detection to engagement (DTE) sequence of selected combat system functions. The daily system operability test (DSOT) is performed daily and tests the operation of the individual subsystem, such as the fire control system.

OVERALL COMBAT SYSTEM OPERABILITY TEST (OCSOT)

The overall combat system operability test (OCSOT) is the detection to engagement (DTE) assessment of selected major warfare capabilities and modes of the entire ship's combat system. The DTE assessment entails processing a target from initial detection through identification, classification, threat evaluation, weapon assignment, weapon firing, and kill evaluation. In this process all elements of the combat system required for a selected engagement (hardware, software, and personnel) are involved.

While the intent of OCSOT is not the evaluation of the operator's proficiency, the operators must be included as they perform a major function in the interoperability of hardware and software subsystems and functions. For these reasons, OCSOT requires trained operators to man consoles and weapons control stations. This is a departure from normal PMS procedures.

The minimum selected major warfare capabilities or modes tested by OCSOT will include, if applicable, ASW using ASROC and torpedo tubes; AAW using the MFCS and the CIWS; ASU using the GFCS and HARPOON; EW using ESM and SRBOC; and if suitable support services are available, AIC and ASAC capabilities. Failures in any portion of the OCSOT are noted and the problems are taken for action by the ship's electronic readiness team (SERT).

Examples of other level 1 PMS used in OCSOT problems resolution are the combat system operability test (CSOT), the combat system alignment test (CSAT), and the combat system interface test (CSIT).

The daily system operability test (DSOT) checks the operation associated with fire control equipment as a subsystem or fire control system (FCS). Since DSOTs for all fire control systems are contained on maintenance requirement cards (MRCs), the subject will be covered lightly here. DSOT varies greatly depending on the type of system and the class of ship. Two prime examples are the DSOTs for the Mk 86 gunfire control system and the Mk 76 guided missile fire control system.

Mk 86 Gunfire Control System DSOT

The DSOT for the Mk 86 gunfire control system is an extensive test of most of the fire control system and gun mount. The system generates and displays test surface targets on the plan position indicator scope (PPI). These targets are acquired and tracked with one target for each of the four tracking channels. Then the tracking data are checked and analyzed, and console control functions and data readouts are checked. This ensures that the interface between the control console and the computer is correct.

The last part of the test checks the data transmission to and from the gun mount. Gun train, elevation, and fuze orders are sent to the gun mount. When the gun mount shifts to remote and moves to match up with the gun orders, feedback signals are sent back to the computer for evaluation. The TV-sighting system, B-scan displays, digital read-out displays, firing circuits, and so forth, are all tested daily.

Mk 76 Missile Fire Control System DSOT

The DSOT for the TERRIER Mk 76 missile fire control system is a test of the AN/SPG 55B

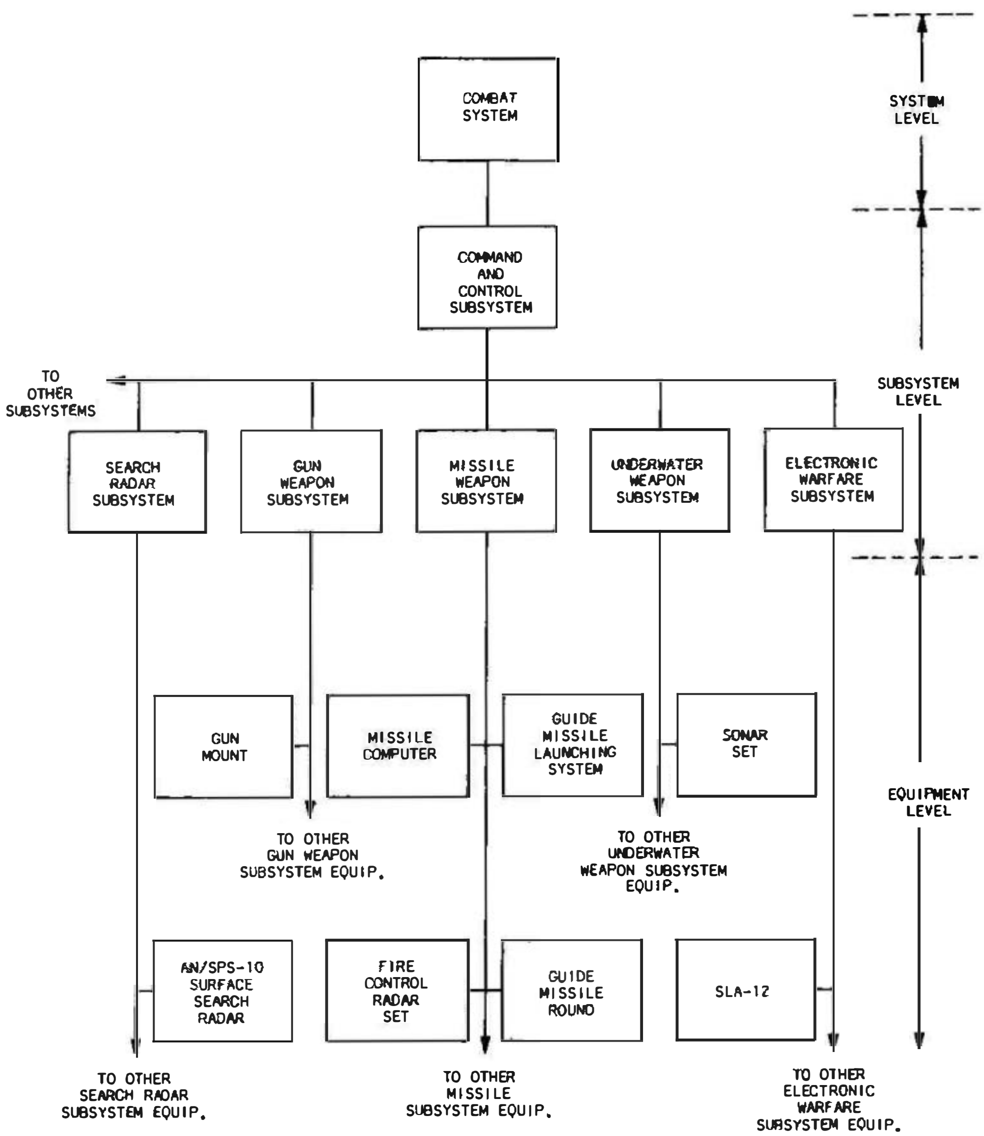

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Figure 3-1.—Typical combat system hierarchy.

radar by the fire control computer. The computer generates targets that are tracked by both the pulse and Doppler radar tracking circuits in the AN/SPG 55B. The test evaluates the radar receivers, director servos, control functions, and data readouts. The missile fire control system to launcher interface is checked on a weekly basis but is not part of the DSOT. The DSOT also checks the radar's electronic countermeasure capabilities and the uplink data transmitted by the AN/SPG 55B for the SM-2 TERRIER missile.

DIRECTION AND DESIGNATION TEST

For a fire control system to quickly and efficiently acquire a fast moving target, the weapon direction system (WDS) must be functioning properly and accurately. An air target must be acquired, tracked, and engaged before it gets within its estimated weapon release range (EWRR).

Major components of the WDS are the launching system module console (LSMC), the target designation transmitters (TDTs), and the casualty weapon direction panel (CWDP). In addition to the preceding dedicated hardware, the WDS shares hardware with other systems. Since the active WDS operational program resides in the primary missile fire control computer (MFCC), this computer and its signal data converter (SDC) are, functionally, part of the weapons direction system. The SDC provides conversion channels used only in WDS-related operations. Many functions performed by the computer program can be directly related to the control of a major hardware element, such as a missile director or a display console. For these hardware control functions to operate in unison, support functions are also required. The executive and coordination control function (ECC) provides the input/output data interface with the tactical data system (TDS) during normal operation and with the WDS consoles during casualty mode operations.

The designation source for designation to the fire control system (FCS) by the WDS is selected on a priority basis. The priorities are classified; therefore, the priority sequences are referenced in the appropriate technical manual.

CONTROL AND STATUS TESTS

Control and status tests function to verify that all relays and indicators, for a given stage of system operation, energize and light up to show that the system or equipment is properly engaged in a particular stage of system operation.

Relay Logic

Electronic relays often function in a series, depending on the mode of operation selected for the equipment. One example is a fire control director being assigned to acquire an air target. A certain series of relays are energized to send the director out to a designated bearing, elevation angle, and range. Another series of relays is energized to put the director into a search mode until radar lock-on is achieved. Then, once the radar is locked on the target, other relays are energized to put the director, radar, and the computer into the track mode. Relay malfunctions can be detected by improper performance during the designation and acquisition phase through improper displays on dials and indicators.

Indicator Logic

Using the same example of director designation, as the WDS assigns a target to the director, indicators light to display the status and position of the director, radar, and the WDS during the transition from designation to track. Indicators must show when the director has accepted designation, when the radar has locked on the target, and when the weapons delivery equipment is placed in *remote*. The proper functioning of indicators is paramount so that an equipment problem can be identified as a casualty instead of a burned-out light bulb.

INTERFACE TESTS

These tests serve to verify computer intercommunication between two or more digital systems in a combat system. The two interface tests to be discussed are the programmed operational functional analysis (POFA) and the end-around test (EAT). Both tests provide a computer printout for test analysis. Analysis of these printouts will be discussed further in this chapter.

Programmed Operational Functional Analysis (POFA)

POFAs enable the technicians to verify intercomputer operational capabilities between the Naval Tactical Data Systems (NTDS) computer complex and the fire control computer. The test is run by a special computer program, which is loaded into the NTDS computer. The POFA test is initiated from the NTDS computer complex. This test will check the following interface capabilities:

- Transfer of data over intercomputer data lines
- Transmission of input acknowledge signals and recognition of resume signals
- Transmission of ready signals and recognition of data input signals
- Transmission of external function signals and recognition of external interrupt signals
- Recognition of faulty output channels by interrupt signals using the special time-out interrupt

End-Around Test (EAT)

This type of test uses the fire control switchboard to connect, or end-around a computer output channel back to the computer on an input channel. The test routine compares the output with the resultant input, for a given channel, as the outputs are incremented over their full range. This routine counts the number of times a comparison difference exceeds the test tolerance and saves the maximum difference for printout. The test also computes and prints out the root-mean-square (rms) error for each subchannel on the basis of a set number of samples. The test can be performed with all outputs in unison or offset by operator inputs. Operator inputs, via the initial data display, also select one of two printouts—summary or detailed.

TEST RESULTS

After a test is run, the final condition of the equipment must be determined. Test results, in the form of dial readings, status of indicator lights, chart graphs, and computer printouts provide the technician with the information.

ANALYSIS OF TEST RESULTS

Without being able to interpret test results to verify proper equipment or to plan a troubleshooting sequence, system readiness could be assessed as vague at the very best. As a Fire Controlman, you must be able to use these test results to determine trends so that an equipment problem can be identified before the equipment actually malfunctions.

Analyzing Analog Tests

Before 1938, the transmission and follow-up systems of guns and directors were tested only for alignment with all the units of the system at rest. The director and guns are always in motion when a moving target is being followed, and it is important that they be aligned not only when stationary but when responding to a dynamic signal as well. Thus, it became necessary to determine the accuracy with which a director and/or gun responds to a continually changing signal, such as generated bearing or gun orders. The dynamic tester and error recorder were developed for this purpose; they provide a means of transmitting an automatic signal to a computer, gun, or director and simultaneously measuring the amount that the unit is in error. These tests are called dynamic accuracy tests. A computer can be tested alone, in combination with a gun mount or director, or both (fig. 3-2). The resulting gun and fuze orders (repeat-back) are sent to the tester for comparison with the transmitted quantities. Any errors are then sent to the error recorder for a permanent record.

Before each test run, the recorder operation should be checked and each channel recalibrated, if necessary. Each channel must be calibrated separately. The procedure used is the same for all three and requires using an ac voltmeter. The gun elevation channel calibration will serve as an example of the steps involved.

On the error recorder, ensure the pen element is aligned to the zero line of the chart; if not, use zero, adjust the lever to align, then set the MAIN POWER, LOCAL RECORD, and PAPER DRIVE switches to ON, the PHASE SHIFT switch at NORMAL, and the individual chart drive switches at OFF. These settings enable the error recorder to operate remotely from the dynamic tester. Insert the test probes of the voltmeter in the gun elevation SIGNAL jacks. At the Mk 47 computer, position the gun elevation servo to obtain a null voltage (minimum) reading on the voltmeter. When the null is obtained, remove the probes and position the gun elevation channel paper drive to ON. The trace should be made on the center line of the chart. If not, the BALANCE control should be adjusted. Now offset the gun elevation order on the computer by plus and minus 20 minutes, and adjust the GAIN and ZERO ADJUST to obtain equal deflection on each side of the chart center line. Turn the paper drive OFF. The calibration of this channel is now complete.

The gun train and fuze channels are calibrated in the same manner. The gun train order should be calibrated using 20-minute deflection, and the fuze setting order should be done using .15-second deflection.

After calibration is completed, set the LOCAL RECORD switch to OFF and the individual paper drive to ON. Ensure that all of the computer controls are returned to the automatic positions.

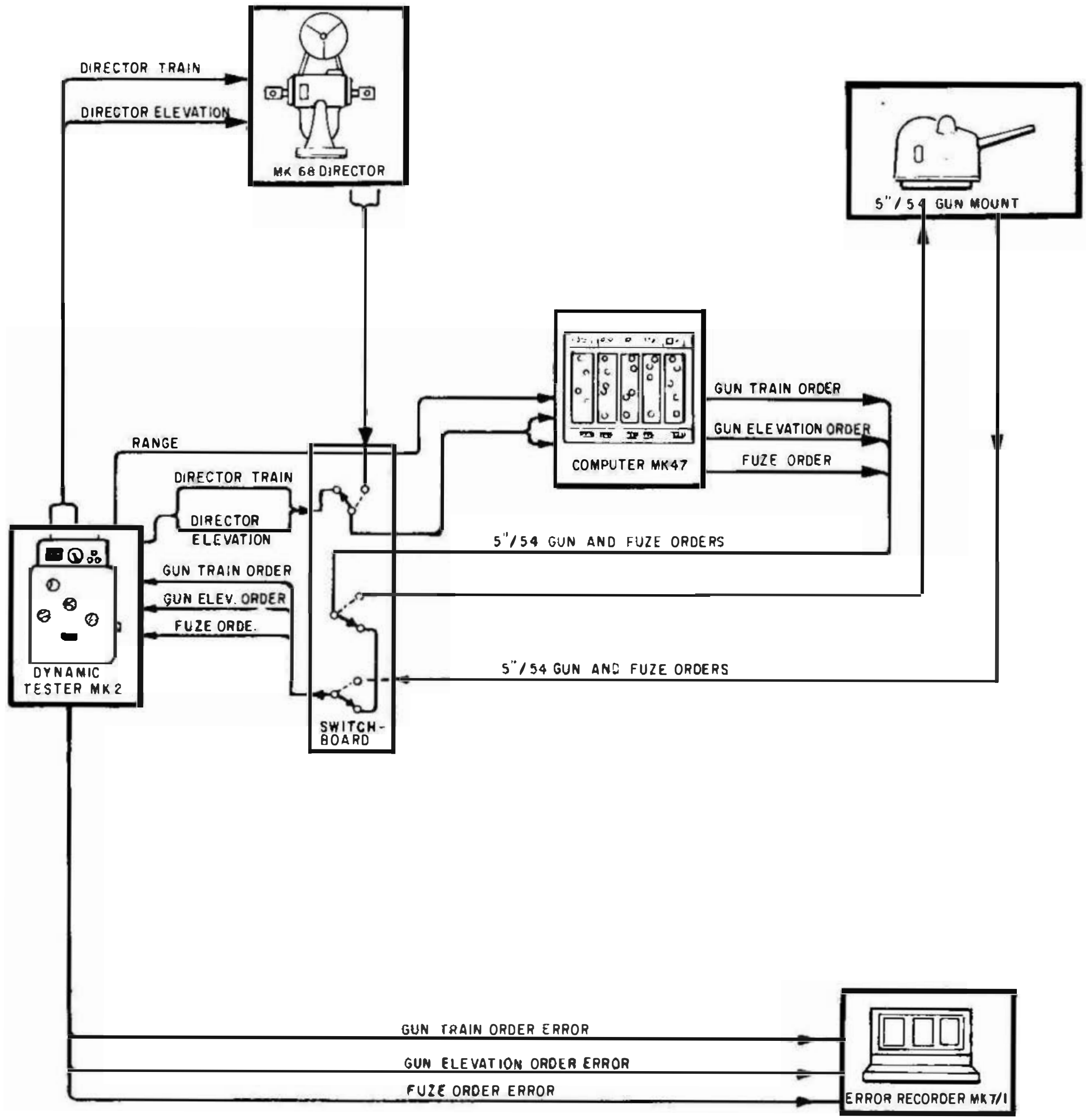

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Figure 3-2.—Dynamic tester and error recorder system connections.

Three coincident traces in figure 3-3 show the error characteristics of a typical Mk 47 computer. Refer to the fuze trace portion of figure 3-3. The square wave on the first 4 inches indicates meter response to calibration signals and is not pertinent to the test. The abrupt change in the trace indicates the start of the problem and the time lag of the computer solution. Traces within plus or minus .15 second show that the computer has an acceptable solution. The abrupt movement out of the limits of plus or minus .15 second is the crossover point and indicates that the target is at the closest range.

Analyzing Digital Tests

Many different tests are run on digital fire control systems that give test printouts. Since it is beyond the scope of this chapter to include all of them, only one test will be covered, which is a detailed EAT printout for a syncro-to-digital channel (table 3-1).

The EAT test routine prints out the first 25 output, input, and error data for a selected channel. This data represents the input and output for which the difference exceeded the test tolerance in the indicated channels.

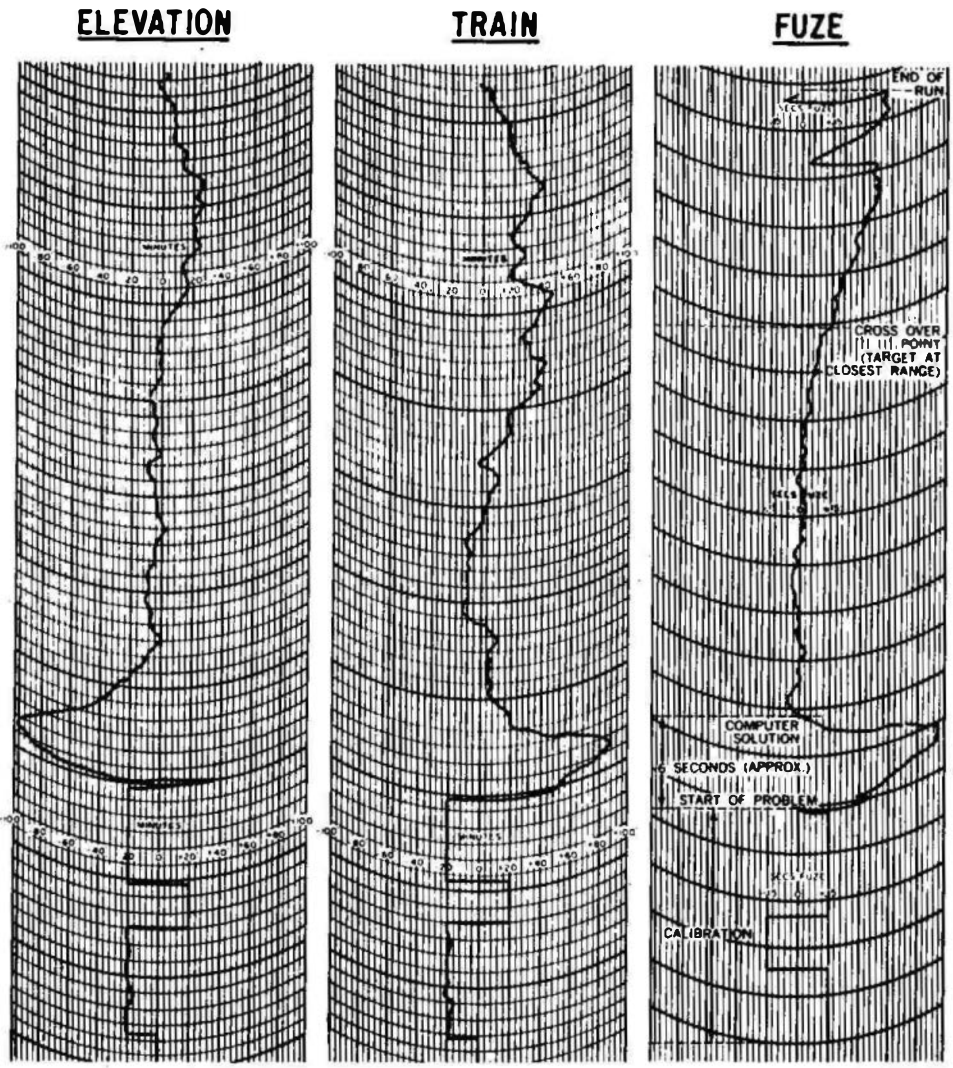

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Figure 3-3.—Examples of a charted test run.

Table 3-1.—Detailed EAT Printout of an S/D Channel Fault Example

S/D CHAN 0013		
OUTPUT	INPUT	ERROR
043005	002000	001005
043006	002001	001005
043007	002001	001006
043010	002004	001004
043011	002005	001004
043012	002006	001004
043013	002006	001005
043015	002010	001005
043016	002011	001006
043017	002012	001005
043020	002012	001006
043021	002015	001004
043022	002016	001004
043023	002016	001005
043024	002021	001003
043025	002021	001004
043026	002022	001004
043027	002024	001003
043030	002024	001004
043031	002024	001005
043032	002026	001004
043033	002030	001003
043034	002030	001004
043035	002031	001004
043036	002031	001005

END OF CHANNEL - SELECT NEXT CHANNEL

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Table 3-1 is an example of the detailed, single-channel printouts for faulty CHAN S/D 13. The printout provides the D/S output, S/D input, and the error between them in octal form for the first 25 sample errors. In the OUTPUT column, the first two digits represent the output address. Even though the detailed printouts are not mentioned in every test analysis paragraph, they should still be used to help localize the fault. However, the CHAN S/D 13 does provide additional insight into the problem. In this case, the S/D input is following the wrong S/D output. This type of failure indication is due to a fault in the channel address decoder.

ANNOTATION OF TEST RESULTS

Once test results are obtained, some manner of recording these results must be used. To detect trends in system degradation, keep successive tests on record so they may be compared to detect those trends.

As a general rule, if a system test meets all the requirements of a maintenance requirement card (MRC), the system that is being tested is considered to be functioning properly. But unless test results are kept as a record, system performance, over a period of time, cannot be monitored.

One method of recording test results is to retain the work center copy of the Nonexpendable Equipment Status Log, NAVSEA Form 4855/2. Although it is intended as a rough log, as much information as deemed necessary by the technician may be entered into this log. For more information on the NAVSEA Form 4855/2, refer to chapter 10 of *Fire Controlman Third Class* (NAVEDTRA 10276).

Another way of documenting tests is by retaining copies of computer printouts. Through the proper interpretation of the digital data on the printouts, the technician can detect the slightest change in system performance long before a problem occurs, thereby preventing degradation of combat capability.

Equipment logbooks are yet another record-keeping aid. An example is the Mk 1A computer logbook for the Mk 37 GFCS. This log lists, in fine detail, every dial reading and computed error recorded from the computer tests. Through careful study of this log, slippage of shaft couplings and gearing can be detected in time to make the proper adjustments required to maintain optimum computer accuracy.

SUMMARY

In this chapter you have been introduced to the level of maintenance required to maintain your fire control system as an integral part of the ship's combat system. The tests mainly associated with this level of maintenance are the overall combat system operability test (OCSOT) and the daily system operability test (DSOT). Other tests, which are equally important to verify optimum combat system performance, are the direction and designation test, control and status test, and the interface test. The results of these tests must be interpreted properly to verify system performance so the technician can determine if there is a need for corrective maintenance. The documentation of those test results is important so system degradation can be detected before an equipment casualty.

In the next chapter, you will be introduced to spotting and naval gunfire support. You will be exposed to terminology and some procedures involved in these fields to acquaint you with the integration of the gunfire control system (GFCS) and mission requirements.

CHAPTER 4

SPOTTING AND NAVAL GUNFIRE SUPPORT

As a Fire Controlman on a ship possessing a major gun-weapon system, you may be required to operate, maintain, and stand watches on the various components of the fire control system, and, as a result, you will be part of the naval gunfire support team. This chapter will acquaint you with the various aspects of spotting and naval gunfire support and how to apply that knowledge to your fire control system.

Naval gunfire support (NGFS) is, in some cases, conducted in support of an amphibious operation. NGFS can also be used to engage existing shore targets, to harass enemy troops, or to provide tactical support fire for friendly ground force operations. Without naval gunfire support, many previous land battles would have resulted in heavy casualties being inflicted among friendly troops.

The advantage of sea-based gunfire are mobility and the capability of carrying large amounts of ammunition. The mobility asset allows the ship to move rapidly from one area to another and to maneuver evasively, thereby dodging enemy gunfire. The large ammunition capacity enables the ship to remain in the fire support area for extended periods of time.

In most cases it is unlikely that the initial salvo from a gun battery will register a direct hit because of various factors such as battery alignment errors, shifts in weather parameters affecting ballistics, and so forth. The process of bringing the shell burst to where the target is located requires a correction (spot) to the aiming point being applied to the ballistic solution. This holds true when shooting at surface targets as well as conducting shore bombardment, also known as naval gunfire support.

Spotting is defined as the estimating of corrections in range, elevation, and deflection necessary to hit a target. A spotter observes the fall of shot and estimates the corrections required to bring the shot on target. Spotting is an integral part of fire control; therefore, it is necessary that you, as a Fire Controlman, understand the procedures governing it.

Spotting procedures apply principally to surface and shore targets. Spotting on air targets is not satisfactory because of the speed of the aircraft and the short time of the engagement. All spotting must be done quickly and accurately if a target is to be hit.

Naval gunfire support (NGFS) is a special evolution where a ship's guns are used against shore targets. Frequently, the targets cannot be seen by the radar or optical equipment of the fire control system. Therefore, the gunfire control system (GFCS) has to be operated manually, instead of automatically as with air or surface targets. This calls for skilled and competent GFCS operators.

Before proceeding, let us consider the following terms that relate to gunfire and spotting.

- SLOW FIRE. In slow fire, firing is deliberately delayed to allow the application of spots or the conservation of ammunition.

- SALVO. A salvo consists of one or more shots fired simultaneously by all or part of the guns in a battery.

- SLOW SALVO FIRE. In slow salvo fire, the guns are loaded on command and fired together at a fairly slow rate.

- RAPID SALVO FIRE. In rapid salvo fire, the guns are loaded on command and fired together at a rapid rate.

- RAPID AND CONTINUOUS FIRE. Rapid and continuous fire is the fastest firing method for naval guns. The gun's firing key is locked in the closed position, and the rate of fire depends only on the loading speed.

- DISPERSION. Dispersion is the scattering of rounds when a salvo is fired. Theoretically, all rounds fired in a salvo should land in the same spot, but this is not usually the case. Normally, there is some separation.

Dispersion is caused by errors that are inherent in the firing of guns under normal operating conditions. These errors are due to such variations as minor differences in the weight and temperature of the powder, irregularity in the operation of the gun recoil system, or the misalignment of the guns. Because of these errors, some dispersion can always be expected in the points of fall of the projectiles from guns fired in a salvo under normal operating conditions. This must be taken into account when a spotter makes corrections to bring the fall of shots onto the target.

- HITTING SPACE. Hitting space for a target (usually measured only in range) is the distance behind the target (measured along the line of fire) that a shot through the top of the target will strike the horizontal plane through the base of the target (fig. 4-1). It includes the projection of the target's vertical height upon the plane of the water, plus the target's horizontal dimension in the line of fire (or depth). Hitting space in deflection is the angle subtended by the target.

- DANGER SPACE. The danger space for a target is the distance in front of the target, measured parallel to the line of fire, that the target could be moved toward the firing point; therefore, a shot striking the base of the target in its original position would also strike the top of the target in its new position (fig. 4-1). At most, danger space is virtually equal to hitting space for a given trajectory.

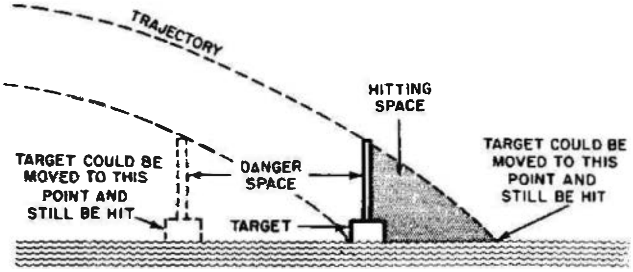

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Figure 4-1.—Hitting space and danger space in range.

- MEAN POINT OF IMPACT (MPI). The point whose coordinates are the arithmetic means of the coordinates of the separate points of impact of a number of projectiles fired at the same aiming point under a given set of conditions.

- STRADDLE. A straddle is obtained from a salvo in range (or deflection) when, excluding wild shots, some of the shots of that salvo fall or detonate short of the target, and others fall beyond it (or right and left, respectively, for deflection).

SPOTTING

Now that you are familiar with some of the terms relating to spotting and gunfire support, we will discuss some of the problems encountered in spotting.

UNPREDICTABLE ERRORS

Since dispersion of individual shots is caused by unpredictable errors, it is logical to assume that no two salvos are exactly alike. Hence, the fall of the shots of a given salvo can be expected to differ in location from the fall of shots of other salvos.

The MPI shift between successive falls of shot is usually so small that it is difficult for the spotter to estimate the difference. Therefore, the spotter should not be too quick to spot when only one or two salvos seem to wander off the target during a string; which, in general, is satisfactory.

CONTROL ERRORS

The only accidental errors considered so far have been those that affect the individual guns of a battery. These are known as gun errors and should be distinguished from another class of errors that affects the battery as a whole. These are known as control errors and include computational errors; transmission errors; and, in director controlled fire, director pointing errors. They are not reflected in increased pattern sizes (increased dispersion among the guns), but they are characterized by increased dispersion or error in the MPI's themselves.

There are three general control inaccuracies that may cause fall-of-shot errors. They are listed below in the order of probable frequency of occurrence and magnitude of effect.

1. The computer is set up with incorrect values.
2. The ballistic corrections are based on incorrect values (IV, wind, air density, and so forth).
3. The battery is not properly aligned with the director.

Incorrect Computer Setup

Target course and speed are determined by radar and plotted by personnel in the combat information center (CIC) or by rate controlling. The correct values of these two variables are difficult to determine. Therefore, they are the chief cause of incorrect computer setup, and hence, the chief source of error in the fall of shot.

Present range to target is valid only so far as its measurement is accurate. An error in basic range measurement directly causes an error in the fall of shot. Usually, measurement of own ship's course and speed is reasonably accurate, but any inaccuracies result in an error in the fall of shot.

Inaccurate Ballistic Corrections

The computer determines corrections for variations from standard conditions. Determination of these corrections based on incorrect ballistic quantities (wind, IV, air density, and so forth) gives a total ballistic correction that results in a corresponding error in the fall of shot.

Poor Battery Alignment

An error in the fall of shot can be caused by misalignment between the controlling director and the gun battery. All directors and gun batteries are required to be aligned to a common reference element. An error in the fall of shot can be caused by misalignment between the controlling director and gun battery. Frequent alignment checks can assist in the elimination of this cause of error.

METHODS OF SPOTTING

There are two methods of spotting—visual spotting and radar spotting. For surface targets, spotting consists of range spots and deflection spots. For shore targets, spotting consists of range spots, deflection spots, and height spots. Before discussing visual and radar spotting, let us discuss some peculiarities about spotting in deflection and range.

Spotting in Deflection

Because it is simpler to make range spots when there is no deflection error (particularly at long ranges), the spotter customarily calls deflection spots first. The angular mil unit is used in deflection spotting.

THE MIL AND ITS USE.—You should already be acquainted with the angular mil. There are about 6,400 mils to a circle, and 1 mil is about .056 degree, or 3.37 minutes of arc. The reason for using the mil as an angular unit in measuring deflection, rather than using degrees or minutes, is that it has a very useful property. If a distant object appears to an observer to have an angular width of 1 mil, then the actual width of the object is 1/1000 of the range. For example, 1 mil is equal to 1 yard at 1,000 yards; 2 yards at 2,000 yards; and so forth.

Telescopes, binoculars, and other optical devices for naval use often have reticles with mil scales etched on them. If you were to use such binoculars to look at a 30-foot boat broadside at a range of 1,000 yards, the image you would see in the binoculars would have an angular width of 10 mils. Figure 4-2 shows additional graphic

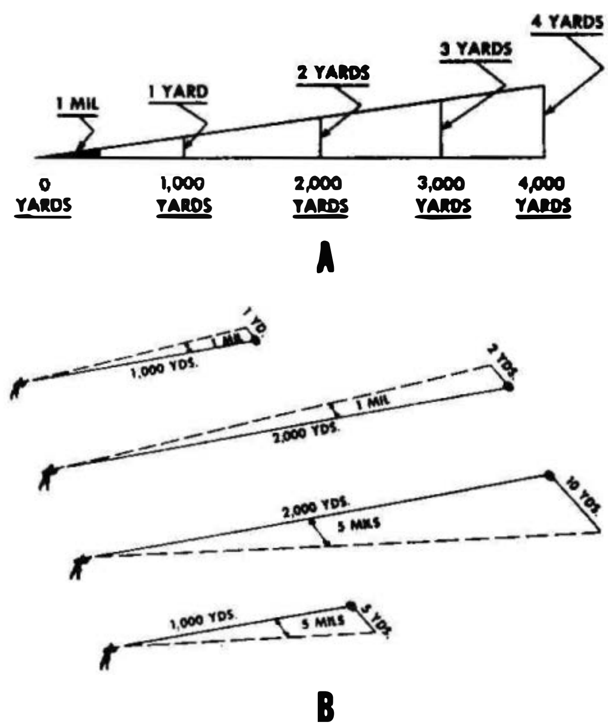

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Figure 4-2.—The angular mil and how it is used.

examples of the relationship between mils and range. Part A of the figure shows how 1 mil subtends different linear distances at different ranges, and part B shows several other examples of the relationship. To bring the use of mils down to a more practical level, look at figure 4-3. What is the linear size in deflection of salvo A's pattern?

At a range of about 11,500 yards, salvo A subtends 5 mils. One-thousandth of the range is 11.5 yards; multiplying by 5 (mils) gives an actual pattern width in deflection of 57.5 yards. As a practical matter, it is absurd to specify a pattern width down to half a yard; rounding off, the answer would be about 58 yards. In estimating deflection spots, you should use target width in mils as a guide.

ALLOWING FOR SPLASHES.—With a high-speed surface target, the spotter should bear in mind that the fall of shot in deflection should be held behind the point of aim to allow for target travel while the splashes are forming. Do not assume that full splashes form instantaneously at the impact of a salvo. Although the time lag is only a few seconds at most, it is sufficient to allow considerable movement of a fast target.

Spotting In Range

Spotting in range is more difficult than spotting in deflection. There is no convenient angular measure that is uniformly applicable at all ranges, such as the almost foolproof mil.

Figure 4-3 is adapted from a typical spotting diagram. It shows schematically how different ranges look to an observer from 100 feet above the water surface. The lateral broken lines represent ranges in increments of 1,000 yards; the diagonal broken lines represent angular mils; and the curved solid line at the right shows the

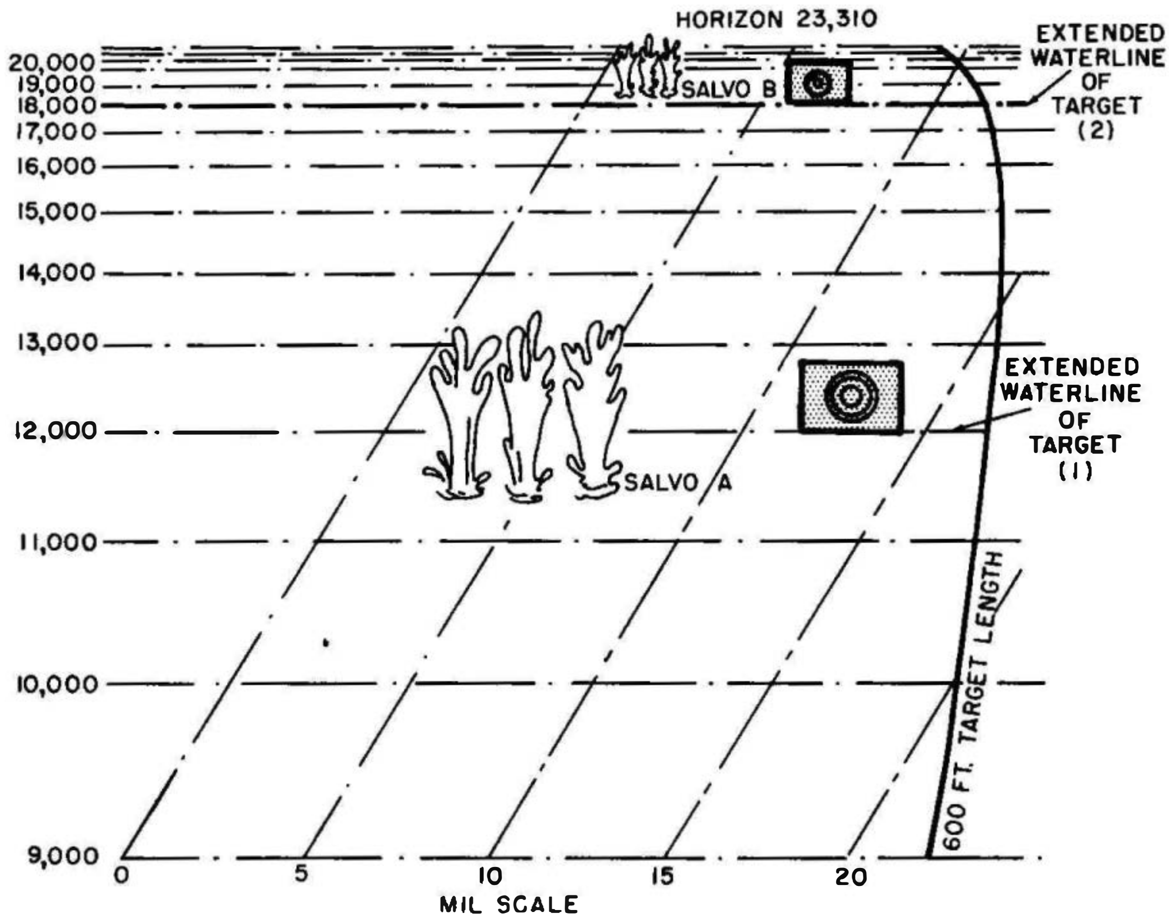

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Figure 4-3.—A spotting diagram.

apparent length in mils of a 600-foot broadside target at various ranges. Unfortunately, the natural seascape is not marked with these handy reference lines; but the diagram is a helpful guide in learning how to estimate ranges. It is used with such training aids as miniature spotting boards and with observation during target practice.

The range lines in figure 4-3 represent the angular distance below the horizon at which any object would appear from a height of 100 feet, if observed on the corresponding range lines. The distances between the range lines represent the apparent range differences as viewed by an observer at the height (in this case 100 feet) for which the diagram was constructed.

A study of figure 4-3 shows that salvo A is clearly short, by about 500 yards, of the imaginary extension of the waterline of a target at 12,000 yards. However, the error of salvo B, fired at a target at 19,000 yards, is not so apparent. The 500-yard error of salvo B is difficult to see when compared with the extended waterline of the target. Thus, for shipboard spotting at such a range, the splashes must be in line with some portion of the target before the spotter can reasonably tell whether the salvo is long or short, to say nothing of estimating the amount of error.

In addition to its use for estimating range and range errors, the spotting diagram shows the number of mils a given target length will subtend at any given range. For example, in figure 4-3, a 600-foot (200 yards) target will subtend 20 mils at a 10,000-yard range.

One of the most common mistakes made by the untrained spotter is to underestimate the amount of range error at long ranges, because a given range error will subtend a much smaller angle at long ranges than it does at short ranges. However, with good visibility and from a height of 120 feet or more, the error in the fall of shot can usually be estimated with reasonable accuracy at ranges up to 15,000 yards by observing the position of the bases of the splashes relative to the target's waterline.

Visual Spotting

The three methods of visual spotting are as follows:

- The direct method
- The bracket-and-halving method
- The ladder method

The method used depends on the type of battery firing, the type of target, the visibility, and the range.

DIRECT METHOD.—Spotting by the direct method is, as its name implies, the spotting of salvos (splashes) directly to the target. This is the most desirable procedure, but its use is limited to short ranges and good visibility conditions. For reasonably accurate visual spotting at a range of 15,000 yards, a spotting height of 120 feet is required. The splash must be relatively close to the target and the computer setup fairly accurate.

A thoughtful analysis of the problem, with reference to the spotting diagram in figure 4-3, reveals that the greatest limitation of the direct method in visual spotting is in range. Deflection spots can be made with equal accuracy at any visible distance. If air observation is available and the plane spots in range with the ship spotting in deflection, the direct method can be used by the battery at any range at which a portion of the splash is visible to the shipboard spotter. Air spotters cannot spot accurately in deflection unless they have a line of sight containing the firing ship and the target.

Spotting the fall of shot at very short ranges differs from other spotting problems in that range errors are not difficult to judge. However, in determining deflection errors at short ranges, consideration must be given to the travel of the target and the spotter's position relative to the projectile's line of flight. For example, with the firing ship and target on opposite courses, target to starboard, a shot fired with correct deflection, but long in range, will appear to the spotter to be in error to the left of the target. Special short-range splash diagrams aid the spotter in this type of firing.

BRACKET-AND-HALVING METHOD.—The bracket-and-halving method is used at long ranges when no air or radar spot is available, and the range is estimated. At great distances, it is impossible to tell if a splash is short of or over a target, unless the two are in line. If the splash and target are not in line, the first spot is made in deflection only. When the target and splashes are in line in deflection, a range spot is made in such a direction and amount as to cross the target definitely. The direction of the next spot is reversed, and the size of the spot is cut in half. This halving is continued until a straddle is obtained, at which time it may be appropriate to shift to rapid partial salvo or to rapid continuous fire.

LADDER METHOD.—When ranging is difficult and visibility poor because of fog, smoke, or darkness, the ladder technique is valuable. There are many variations of this technique, but the basic procedure is along the following guidelines:

1. Fire is deliberately opened short of the target.
2. Succeeding salvos are fired to approach the target.
3. As soon as the target is crossed, the steps are reversed and halved until the target has again been crossed.

After the target is straddled, a rocking ladder may be used with slow timed fire, or with rapid and partial salvo or continuous fire. In a rocking ladder, the pattern is shifted back and forth across the target by small arbitrary successive spots (such as +500, −750, +375, and −100) introduced at the computer. Its effect is to increase the pattern size, which may be valuable when firing against a target capable of rapid maneuvering. The rocking ladder can be used with air or radar spotting, so long as the spotter is kept informed that this technique is being used. Ladders are not particularly adaptable to fast-moving targets.

Radar Spotting

Radar spotting has proven to be both accurate and reliable within the range of surface batteries. Radar provides a means of spotting that is independent of conditions of visibility, so that blind spotting is possible with blind firing.

Shell splashes appear on the scope as fluctuating echoes that last for several seconds, depending on the size of the projectile and the range. The large column of water thrown up by the projectile produces the echo. Salvos produce larger or multiple echoes on the scope.

If the projectile stays within the vertical limits of the radar beam, its flight to the point of impact can be followed on the main sweep scope. The projectile produces a small, weak, moving echo that begins at the edge of the scope and moves out in range toward the target. At the point of impact, the echo stops and grows larger as the splash builds. Echoes from direct hits or near misses are lost in the target echo, while salvos that straddle the target may envelop the target echo in the midst of the splash echoes on the scope, thereby making it impossible to distinguish individual splashes. Range errors can usually be estimated with greater accuracy by radar than by optical spotting, but deflection spotting with radar is sometimes difficult, especially when the error is small. Near misses sometimes merge with and are indistinguishable from the target pip. Consequently, repeated salvos can land with a 2- to 5-mil error that is not separately distinguishable, but they may not be hits. Target practice is used to determine the minimum deflection error that can be detected on a particular radar. When radar is the only means available for deflection spotting, a deflection rocking ladder should be used. The order of preference in spotting surface fire is usually accomplished in the following manner: RANGE—radar, air, and visual; and DEFLECTION—visual, radar, and air. In night action, or action under reduced visibility, radar normally spots for both range and deflection.

SPOTTING TERMINOLOGY AND MESSAGE PRACTICE

As in other operational communications, there is a prescribed terminology and message sequence for spotting. These are published in fleet operational directives. The examples described in this section show the general practice at the present time.

Surface Fire

For surface fire, only range and deflection are spotted. The correction necessary to bring the fall of shot on target is given in the following terminology sequence:

1. Deflection correction—"RIGHT" or "LEFT," in mils
2. Range correction—"ADD" or "DROP," in yards

When no correction in deflection is necessary, only a range spot is made. When no range spot is necessary (regardless of whether a deflection spot is required), the phrase "NO CHANGE" is used. Typical examples of spot transmission by telephone are as follows: "RIGHT 10, ADD 1,000; LEFT 5, DROP 500; LEFT 10, NO CHANGE; NO CHANGE".

Antiaircraft (AA) Fire

For air targets, corrections to bring the burst on the target are needed in three dimensions. Even well-trained personnel find it almost impossible to estimate errors rapidly in three dimensions. Therefore, AA spotting is generally limited to correcting for obvious constant system errors. At the present time only the digital fire control system has the capability to conduct AA spotting.

The proper terminology for spotting in AA fire is as follows:

1. Deflection correction—"RIGHT" or "LEFT," in mils
2. Range correction—"ADD" or "DROP," in yards
3. Height-of-burst correction—"UP" or "DOWN," in mils

NOTE: Antiaircraft spotting should not be attempted while shooting. Spot only after a run is completed.

Shore Bombardment

In shore bombardment, spots in three dimensions may be necessary. When naval guns are used to support landing operations, joint forces are involved. The Navy, Army, Marine Corps, and Air Force have a standardized spotting terminology for joint operations that differs from the preceding information in that all corrections for indirect fire are spotted in meters. Deflection and elevation spots may have to be converted to angular units before being applied to the computer.

Spots in three dimensions are made in the following order:

1. Deflection—"RIGHT" or "LEFT"
2. Range—"ADD" or "DROP"
3. Height of burst—"UP" or "DOWN"

NAVAL GUNFIRE SUPPORT

During World War II, naval task forces frequently carried out bombardments of enemy installations on shore. After ineffective results were noted during the Tarawa operation in November 1943, shore bombardment techniques were gradually improved through successive landings during the remainder of the Pacific campaign. Later, the Korean War and the Vietnam conflict gave frequent opportunities for refinement of the techniques learned in World War II.

An opposed amphibious landing is one of the most hazardous types of military operation. Until World War II, many military authorities believed that such an operation was too hazardous to be attempted. This belief was, in part, based on the Allied failure in the amphibious Dardanelles (Gallipoli) campaign during World War I. That failure has been attributed, at least partially, to inadequate naval preparation before the campaign.

To be successful, naval gunfire support for amphibious operations must be carefully planned in advance. In addition, it must be executed with skill and dispatch. Support is especially important in the period after the troops have landed. This support is vital until adequate artillery can be brought into action to protect them. Its full exploitation can be achieved only if ground, naval, and air personnel understand the organization, basic techniques, capabilities, and limitations of naval gunfire support, and follow the standard procedures that have been agreed upon by the joint services and outlined by the appropriate fleet commanders.

Naval gunfire is delivered from a ship's batteries in support of troop operations and to support related naval and air operations such as mine warfare and air-sea rescue; reconnaissance and demolition; flak suppression during air strikes; and interdiction of coastal roads, railroads, airfields, and troop assembly areas. All these activities rest on the same basic principles as the naval gunfire support of amphibious operations.

The basic task of naval gunfire support units in an amphibious operation is to support the seizure of the objective by destroying or neutralizing the following:

- Shore installations that oppose the approach of ships and aircraft to the objective
- Defenses that may oppose the landing
- Defenses that may oppose the post-landing advance of troops

These tasks are carried out in the preparation of the objective for the landing, the support of the landing, and in support of troop advance after the landing.

MILITARY GRID REFERENCE SYSTEM

A rapid and accurate means for designating the location of targets is important in shore bombardment. Particularly in naval gunfire support of troop operations, the troop unit supported and the supporting ship must use a common chart, although the charts need not be of the same scale.

Like other techniques of naval gunfire support, the development of a system of target location designations has passed through several stages, generally following a grid-system method. In this method, the land and sea areas are divided into squares by north-south and east-west lines, which are numbered. These lines are called grid lines.

The military grid reference system (fig. 4-4) imposes vertical and horizontal reference lines over a projection of the earth's surface. Its purpose is to simplify and to increase the accuracy of reporting and plotting in military operations. This grid reference system is based on two projections—the Universal Transverse Mercator (UTM) and the Universal Polar Stereographic (UPS). The UTM is used in the area between 80° south latitude and 80° north latitude; the UPS is used in the polar regions of the earth south and north of these limits. The UTM system divides its area of the earth into a grid pattern with each rectangle in the grid 6° from east to west and 8° from north to south. (Because the grid is rectangular and the earth's surface is not flat, there is some distortion in maps based on the grid; however, in any single rectangle this distortion is negligible.) Each rectangle is called a grid zone, and is designated by a number and a letter (for example, 52S). The grid zones are broken down into squares of 100,000 meters on a side and are designated by letters only. Further division down to the smallest

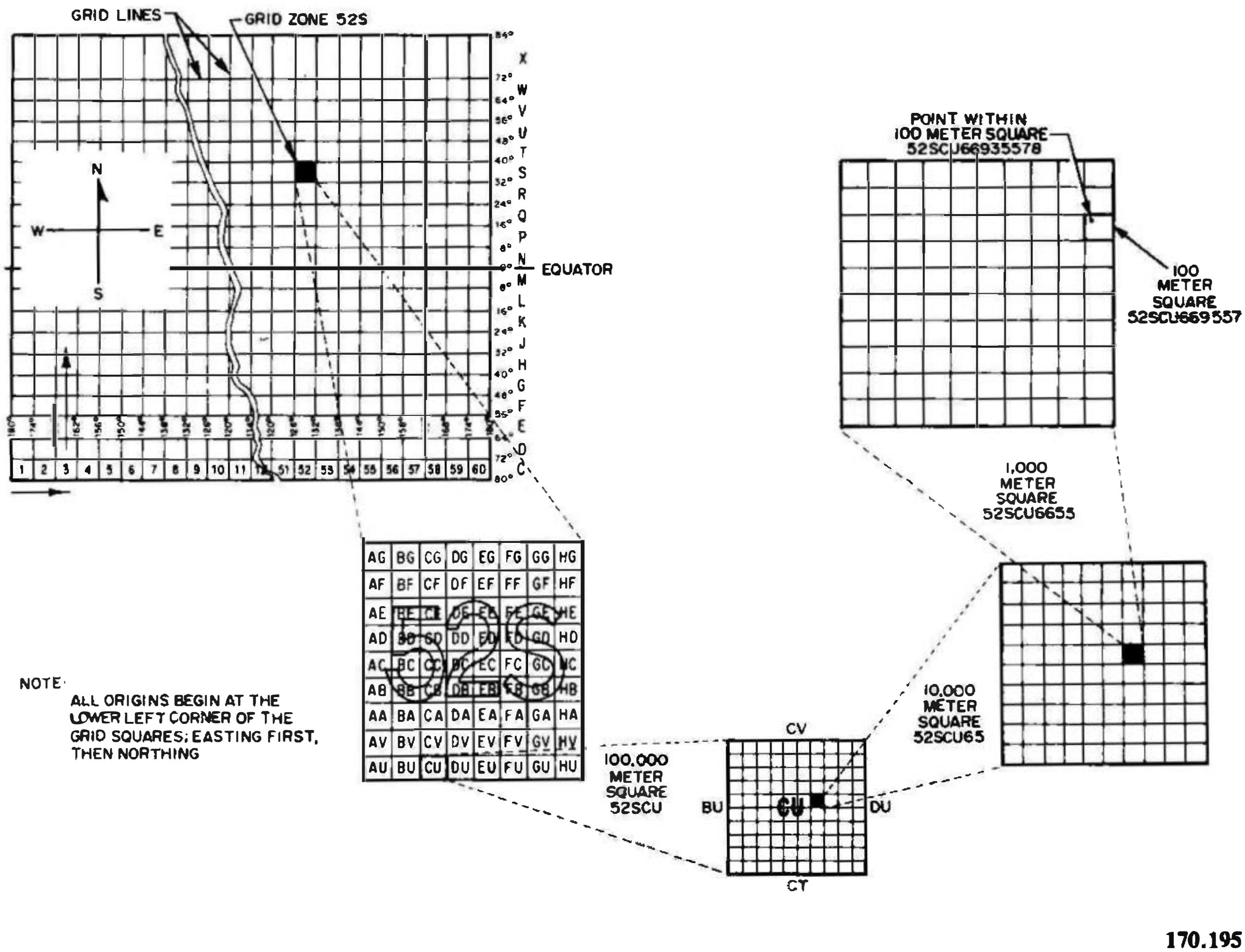

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Figure 4-4.—Military grid reference system.

practical subdivision (a 100-meter square) is possible. These divisions are designated by numbers only. In theory, any 100-meter square spot on earth can be located by its number-letter code. In the examples below and in figure 4-4, 52S identifies the grid zone, and CU identifies the 100,000-meter square subdivision where an objective is located. The military grid reference, which consists of a group of numbers and letters, indicates (1) the grid zone designation, (2) the 100,000-meter square identification within that zone, and (3) the grid coordinates; that is, the numerical reference of the objective expressed to the desired accuracy.

The determination of the numerical part of the grid reference follows standard naval practice of reading to the right and up. Once the 100,000-meter square has been located, you find the nearest vertical grid line to the left of the objective and read the figure(s). You must then estimate to the closest tenth the distance between this line and the objective point itself.

The reading of the horizontal line is done in a similar manner, finding the nearest horizontal line below the objective and estimating in tenths to the objective point. In figure 4-4, the 10,000-meter square is located in area 52SCU by the number 65. This same process is repeated to find the 1000-meter square and the 100-meter square. Examples of this process are as follows:

52S	Grid zone designation on the earth's surface (52 = 126° to 132° east longitude S = 32° to 40° north latitude).
52SCU	Locating a 100,000-meter square within grid zone 52S.
52SCU65	Locating a 10,000-meter square within the 100,000-meter square 52SCU. The 65 locates a square east 60,000 meters; north 50,000 meters.
52SCU6655	Locates a 1,000-meter square within the 10,000-meter square 52SCU65. The 6655 locates a square east 66,000 meters; north 55,000 meters.
52SCU663558	Locates a point, 100 meters square, within the 1,000-meter square 52SCU6655. The 663558 locates a square east 66,300 meters; north 55,800 meters.

NOTE: East 66,300 meters and north 55,800 meters are referenced to the lower left corner of the 100,000-meter square grid chart.

As a matter of practical use in a shore bombardment problem, both the grid zone designation and the 100,000-meter square identification are generally omitted. The UPS system, in similar fashion, permits location and identification of any 100-meter square on the earth's surface near the poles.

Fire support ships are provided with approach charts and bombardment charts for use on their dead reckoning tracers (DRT) and fire control computers. These charts are complete in hydrographic as well as topographic detail, and both have a grid system overprinted on them. These charts are of particular use in indirect fire.

SPOTTING IN SHORE BOMBARDMENT

The basic principles of spotting apply in shore bombardment spotting; however, procedures are different when spots are made by a fire control party ashore.

A spotter ashore must be located where he can best observe the fall of shot. Usually, this requires the spotter to be as close as possible to the target; this can put him in considerable danger. The spotter also has an alignment problem. Spots made by an observer aboard the firing ship are naturally oriented to the line between the firing ship and target (gun-target line). Spots made from aircraft can be readily oriented to the gun-target line, since both the gun and the target are normally within the aircraft observer's field of vision. But spotters ashore are frequently unable to see the firing ship, and if they are required to make their reports in relation to the gun-target line (GTL), the value of the information sent by the spotter to the ship is limited.

To simplify this problem for the spotter, the target-grid system for use in spotting the fall of shot on land is used. The target-grid system is part of the standard spotting and general shore bombardment procedure for use within the naval service.

The system permits the observer to spot the fall of shot just as he sees it along his own line of sight to the target (called the observer-target line), irrespective of the position of the firing ship and of the gun-target line. The procedure is briefly outlined as follows (fig. 4-5):

1. The observer, in calling for fire, must give the bearing from himself to the target (direction OT in the illustration).

2. The observer makes all observations and corrections with respect to the observer-target line (OTL).

3. The CIC or plotting room crew converts the corrections of the observer to corrections with respect to the gun-target line (GTL).

4. The plotting room crew introduces into the rangekeeper (computer) the spots corrected to the gun-target line.

APPLICATION OF THE TARGET-GRID SYSTEM

As we have already said, the target-grid system permits the ground observer to call spots with respect to his own line of sight (OTL in fig. 4-5), while spots introduced into the ship's fire control system are stated with

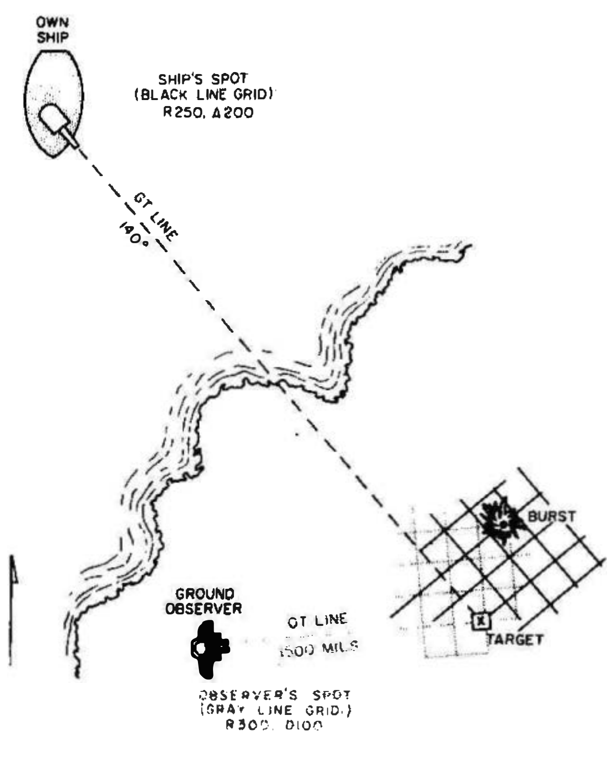

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Figure 4-5.—Target-grid spotting problem.

respect to the ship's line of fire. The practical application of the target-grid system depends on quick, accurate conversion from spots in terms of the observer's line of sight (OTL) to spots in terms of the line from gun to target (GTL). This is done graphically by the grid spot converter, which superimposes a set of coordinates based on OTL upon a set based on GTL.

The converter (fig. 4-6) consists of a transparent, circular, plastic disc secured by a pivot (as its center) to a rectangular, white, plastic piece. Each is printed with a square grid pattern. The squares on both pieces are of equal size; the words *LEFT* and *RIGHT* are on either side, and the words *ADD* and *DROP* are on the upper and lower parts. The grid lines on both pieces are numbered, with each square representing an increment of 100 yards.

The grid pattern on the white, plastic piece is printed in a dark shade and inscribed in a circle graduated counterclockwise in degrees; this represents the reference grid for own ship. On the 0- to 180-degree line of this pattern is a darkly shaded arrow. At the top of the own-ship pattern appears an additional degree of calibration for introducing magnetic variation correction.

The transparent pivoted disc has its grid pattern printed in a light shade; the circumference of its circle (which is concentric with that of the own-ship pattern) is graduated counterclockwise in mils. A lightly shaded arrow is on the 0- to 3200-mil line. This is the reference grid for the observer.

The problem is illustrated in figure 4-5. Figure 4-6 shows the converter setup with the part of the grid pattern that relates to the observer's spots in a light shade; the darkly shaded grid pattern relates to own-ship line of fire. Magnetic variation is assumed to be zero. The procedure is as follows:

1. The converter operator obtains the true azimuth of the GT line in degrees by reading the true target bearing from the computer. He makes a mark with a grease pencil at this azimuth on the lower (darkly shaded) disc, obtains the azimuth of the OT line in mils from the observer (spotter) via CIC, and then makes a mark at this azimuth on the upper (lightly shaded) disc.

2. The operator then rotates the upper disc until the two pencil marks match. (In fig. 4-6, GTL is 140°, and OTL is 1,500 mils.) The light and dark arrows now indicate the

angular relationship of the observer's line of sight and the ship's line of fire.

3. When a spot is received, the operator starts at the center of the upper disc (light shade), which represents the burst,and plots the observer's spot, "RIGHT 300, DROP 100" on the observer's reference grid (light shade), with each square representing 100 yards. The point plotted then represents the target, which is marked with grease pencil.

4. The operator now goes back to the burst (center) and counts off the squares to the target

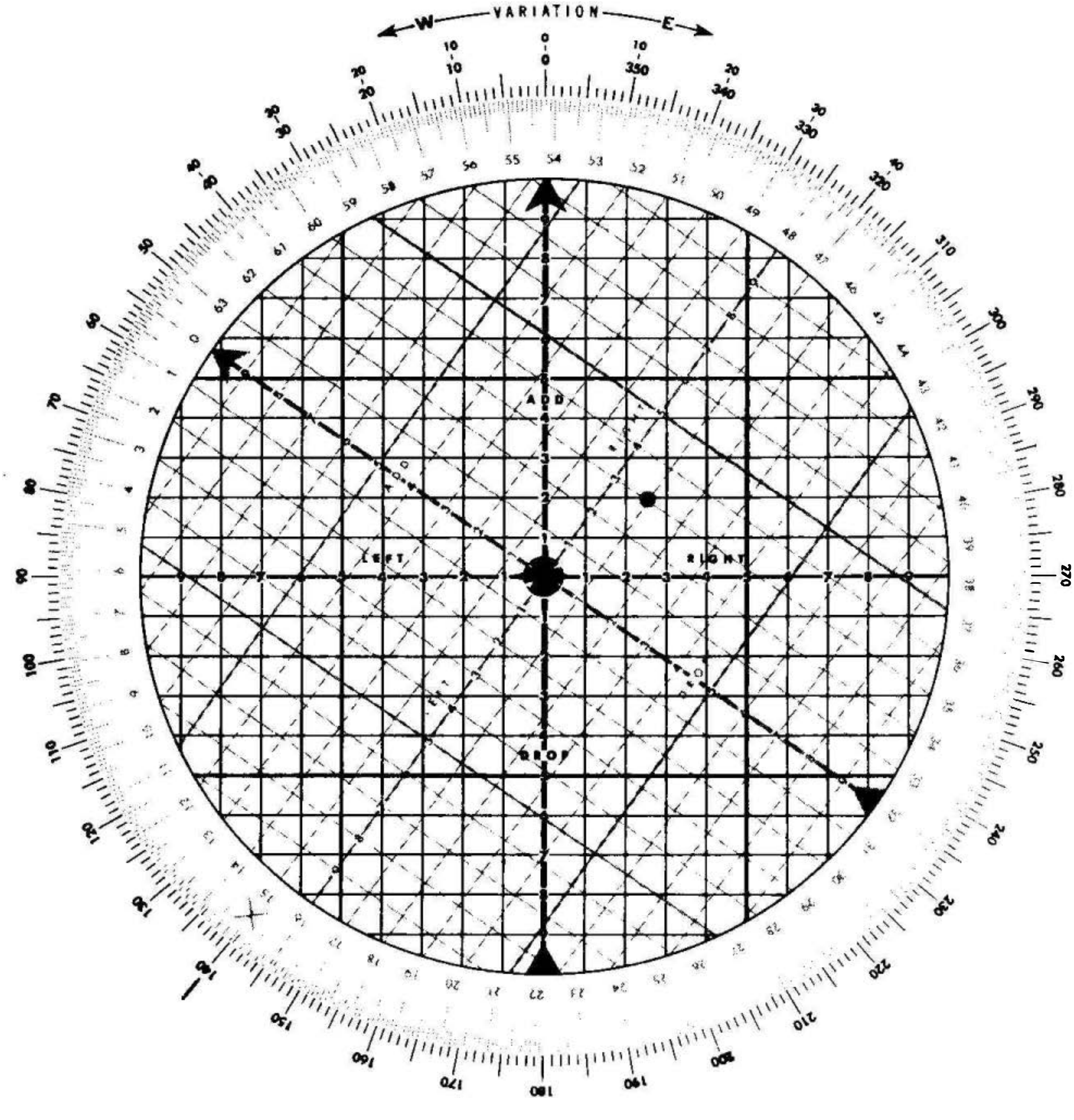

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Figure 4-6.—Grid spot converter.

point as projected onto the lower disc (own-ship reference grid). This gives a spot with reference to the ship's line of fire of "RIGHT 250, ADD 200." This is the spot that is applied to the computer. (R250 is in yards and must be converted to mils before it can be applied.)

Rectangular coordinate computers, such as Mk 47 and Mk 48, operate on the X/Y coordinate principle. Spots are applied as north (Y) or south (– Y) and east (X) or west (– X) values. Instead of the gun target line, the Y axis is used as the reference. This requires that the grid

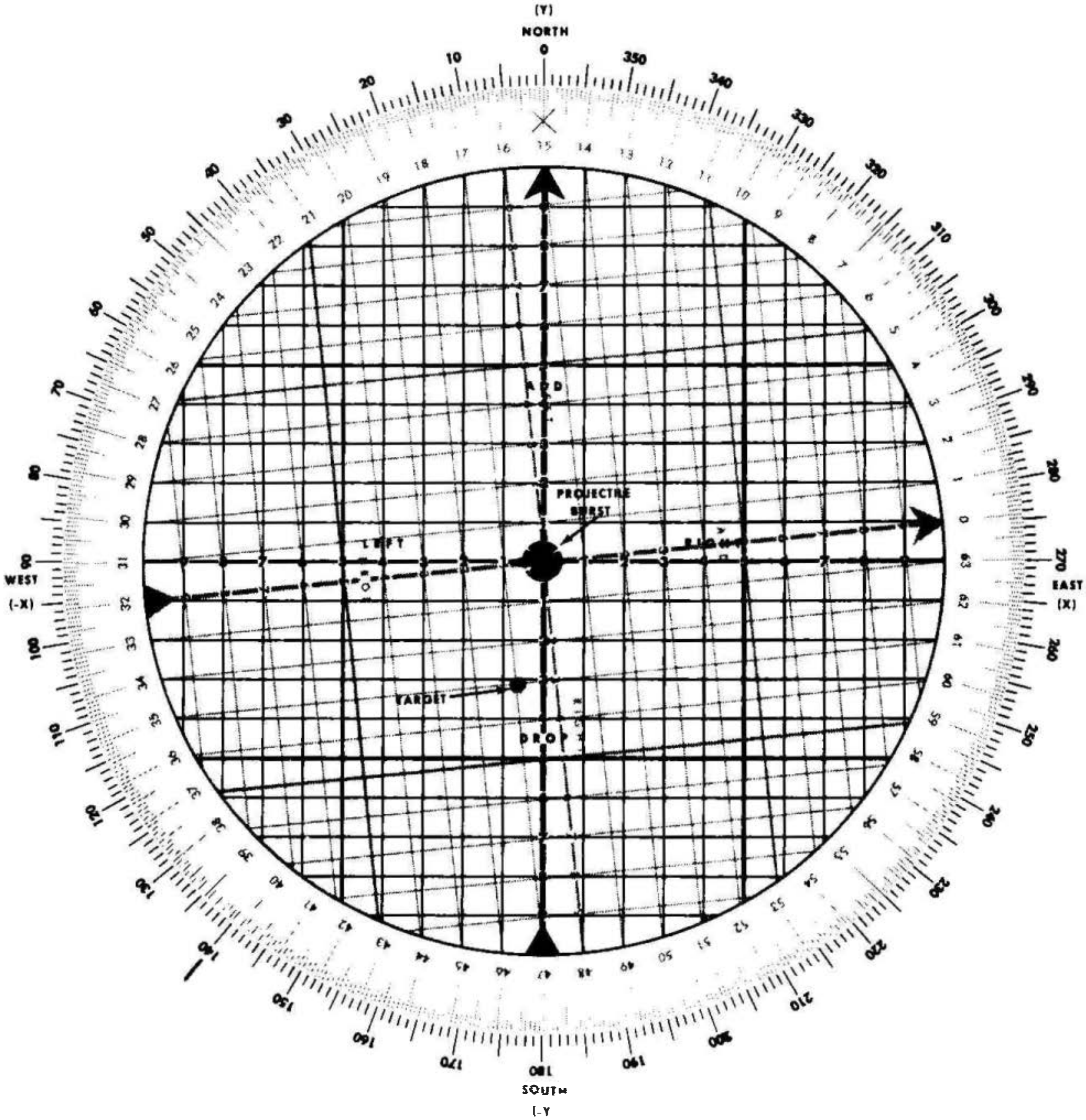

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Figure 4-7.—X/Y coordinate grid spot converter.

spot converter be changed as shown in figure 4-7. Along the Y axis, 0° is labeled as north and 180° as south; along the X axis, 090° is labeled as west and 270° as east.

The following are procedures for using the X/Y coordinate grid spot converter:

1. Using the same problem as before, mark OTL at 1,500 mils on the upper (lightly shaded) disc (fig. 4-7).
2. Rotate the upper disc until the OTL (1,500-mil mark) is aligned with the Y axis (north or 0).
3. Plot the received correction on the upper (lightly shaded) disc as right 300, drop 100.
4. Read converted correction from lower (darkly shaded) disc as west 75, south 300.

In a digital GFCS (such as the Mk 86) the OTL, in mils grid received by CIC, is converted to degrees true and entered into the computer via the gun/weapon control console. From that point, all spots are entered as received, and the computer does the conversion of the spots to the GTL.

CONVERSION SCALE (SPOT) MK 2

The conversion scale is designed to convert a linear value (yards, feet) to an angular value (mils, degrees, minutes). This conversion is necessary in gunfire support, since spotters transmit their corrections (spots) in linear values, but computer or rangekeeper bearing and elevation corrections must be introduced as angular values. Figure 4-8 shows the Conversion Scale (Spot) Mk 2. The conversion scale consists of two discs made of metal or plastic with the inner disc pivoted in the center so that it will rotate on top of the outer disc. The outer disc has numbers around the edge representing the size of a spot. The inner disc is divided into range from 1,000 to 50,000 yards. Various arrows show to what point on the outer disc the different conversion factors are read.

The operation of the scale is very easy. Referring to figure 4-8, assume that you received a spot in deflection of 190 yards, and the present range on the computer is 6,000 yards. Rotate the inner disc until the 6 representing 6,000 yards is lined up beneath the 190, representing the spot on the outer disc, thus converting from yards to mils. Look at the arrow that represents this

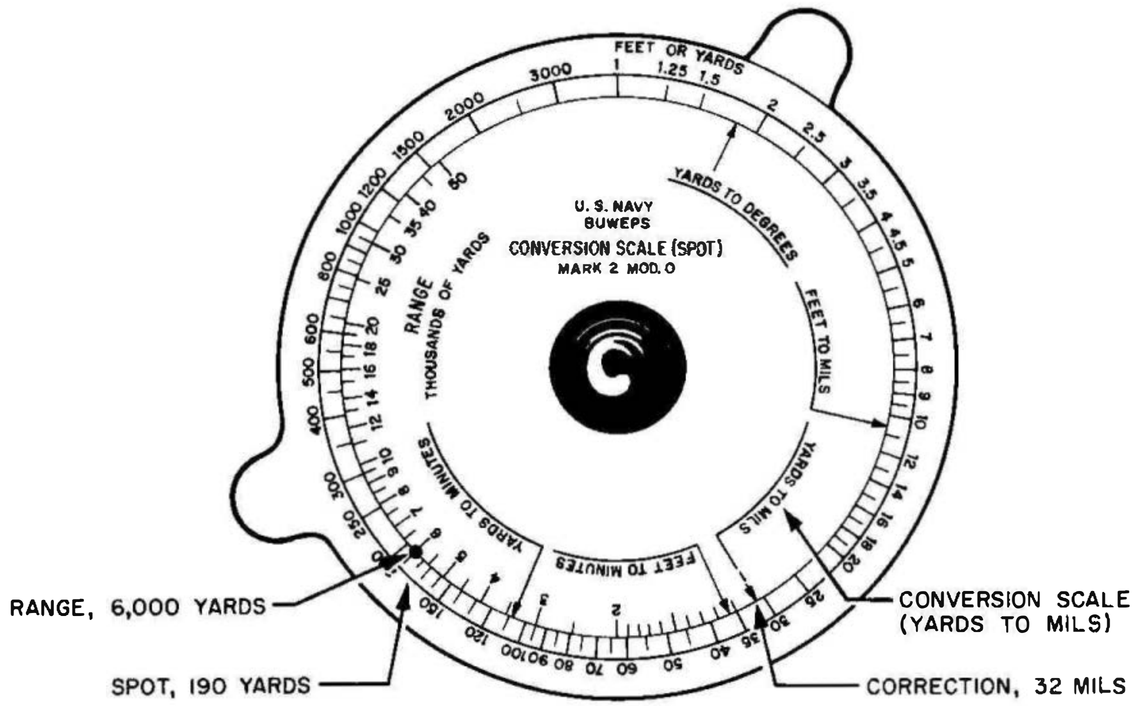

Figure 4-8.—Conversion Scale (Spot) Mk 2.

conversion and find a correction of 32 mils. The spot must have a direction of right or left, but it is not necessary to know this to use the conversion scale. Assuming the spot was RIGHT 190, the correction you put in the computer will be RIGHT 32 mils.

NOTE: When spots are received in meters, mental multiplication by 1.1 is required for conversion to yards.

It is important that you constantly correct the range on the conversion scale to agree with the present range on the computer. If you don't, any correction you set into the computer will be in error.

GUNFIRE SUPPORT

Gunfire support is the delivery of naval gunfire against shore targets to assist the supported unit (normally an infantry company) in accomplishing its mission. These targets may be prearranged by an operational order, as a target of opportunity by the ship itself, or identified to the ship through direct radio communication with a shore fire control spotter (call for fire mission). Targets threatening the ship (counter-batteries) are also considered in the broad term *gunfire support*.

Prearranged Targets and Targets of Opportunity

Prearranged targets are engaged according to the existing operational order, which outlines the target location, ammunition requirements, time restraints (time to open fire, time to cease fire, etc.), and follow-up report requirements. Beyond the restraints and requirements of the operational order, conduct of the mission is in accordance with the ship's gunnery doctrine and current fleet directives. Targets of opportunity will be taken under fire within the guidelines of current directives and will be conducted in accordance with the ship's gunnery doctrine.

To explain the procedures of gunfire support, we will discuss a general call for fire mission. The first requirement for a firing mission is preparation. The basic preparation necessary for reporting on station for call for fire can be divided into four general categories.

1. All personnel involved must be thoroughly familiar with the elements of a call for fire mission, including the procedures for incorporating those elements into their particular fire control system.
2. The equipment involved must meet current operational standards (PMS, alignment, etc.).
3. The necessary ballistic information (IV, wind, etc.) must be properly computed and entered into the fire control computer.
4. The position of own ship must be determined and its direction and motion, including the effects of current set and drift, must be accounted for in the fire control computer. This is accomplished either by tracking a known point with the fire control radar (offset method, direct method, NAVREF or BEACON method) and allowing it to establish the ship's position/motion in relation to that point or by manually plotting navigational fixes (local control/dead reckon) and computing the quantities needed for entry.

Once preparations have been completed and the ship has reported on station to the spotter, the fire mission will be received in three segments containing seven elements. A general outline of the fire mission is shown below:

1. FIRING ALERT
   a. Spotter identification
   b. Warning order
   c. Target numbers
2. TARGET LOCATION
3. ATTACK DATA
   a. Target description
   b. Method of engagement
   c. Method of fire
   d. Method of control

FIRING ALERT.—The following elements are involved in the firing alert:

- <u>Spotter identification</u> tells the ship who is calling. The spotter and the ship will use call signs that change daily and are of the letter, number, or letter form; for example, C6D, X9A.

- <u>Warning order</u> informs the ship that a call for fire mission is being sent. It consists of the words "FIRE MISSION." The words "FIRE MISSION" set up a precedence of IMMEDIATE on the circuit and allow call signs between the ship and spotter to be dropped for the remainder of the mission.

● Target numbers are assigned to each target so the gun liaison officer (GLO), who is monitoring the call for fire, and the ship can keep track of each location being fired upon. The spotter will use the previously assigned number if the target is a planned target. If the target is a target of opportunity, the spotter will assign it a number in numerical sequence from the block of target numbers allocated by the GLO.

TARGET LOCATION.—Target location must be transmitted in a manner that is understood by both the ship and the spotter. Five methods of target location in use are *grid, polar, shift from a known point, refire, and fresh target shift and new target* (Mk 86 GFCS only).

The term *direction* in NGFS is an angular measurement from a reference north to an imaginary line that passes through the observing-target line. It is along this line that the spotter will make corrections to the fall of shot. It may be measured in mils or degrees, and the reference north may be true, grid, or magnetic. Unless stated in the transmission, the direction will be understood as mils grid.

Grid Coordinates.—When the spotter desires to use the UTM GRID system for target location, the first word of the second part of the call for fire will be "GRID."

Example:

"FIRE MISSION TARGET NUMBER 01, OVER" (first part)

"GRID 576342, ______ ______ ______ ______" (second part)

The spotter, when using this method for target location, must estimate the target's location within a particular 1,000-meter square. The degree of accuracy in defining the target's location within this 1,000-meter square is dependent upon the quantity of grid numbers given by the spotter.

If the location were given using four digits such as 5734, the target would be defined within a 1,000-meter square. However, if the location were given as 576342, the target would be defined to within a 100-meter square. Accuracy could be further increased by sending 8 digits (10-meter square) or even 10 digits (1-meter square). The coordinates 576342 would be interpreted as 57,600 meters easting and 34,200 meters northing with respect to the lower left corner of a 100,000-meter square UTM grid chart. Target altitude is transmitted immediately following the target's grid location, and is understood to be measured in meters unless otherwise specified.

Polar Plot.—When the spotter desires to use the polar plot method of target location, the first word of the second part of the call for fire will be "DIRECTION."

Example:

"FIRE MISSION TARGET NUMBER 01, OVER" (first part)

"DIRECTION 1600, ______ ______ ______ ______" (second part)

This method does not require the spotter to use a chart to locate a target. However, the spotter must give his position to the ship before using this method. The spotter's location is plotted by the CIC NGFS team on the appropriate chart. The spotter will also give an altitude for his position. Target location is given by the spotter as a direction and distance from his position. Altitude differences will also be given.

Example:

"DIRECTION 1600"

"DISTANCE 2000"

"UP 30"

The first step would be to convert the spotter's direction (OTL) into a true bearing using the grid spot converter. The direction 1600 from the example above converts to an OTL of 090°T. A bearing line of 090°T would be drawn on the chart from the spotter's position.

The distance is given in meters. A point, 2,000 meters on the bearing line, from the spotter's location would be marked on the chart. This would be target location.

Shift from a Known Point.—When the spotter desires to use the shift from a known point method of target location, the first word of the second part of the call for fire will be "FROM."

Example:

"FIRE MISSION TARGET NUMBER 01, OVER" (first part)

"FROM REFERENCE POINT NUMBER 3 ______ ______ ______" (second part)

This method of target location can only be used if both the spotter and the ship know the locations and altitude of the known point. The known point can be provided by the spotter to the ship, stated on an operational order, or it can be a previously fixed target whose location was recorded by the firing ship.

Example:

"FROM REFERENCE POINT NUMBER 7"

"DIRECTION 090° TRUE"

"LEFT 500"

"ADD 500"

"DOWN 30"

The location of the target using this method is quite similar to the direction method except the bearing line and distance are plotted from the known point instead of from the spotter's position.

Refire and Fresh Target Shift.—These methods are variations of the methods already explained.

New Target.—This method of target location is used when taking two separate targets under fire simultaneously.

ATTACK DATA.—After the ship knows where the target is, it must be told what the target is and how the spotter intends to attack it. This information is given in the attack data segment.

- Target description. Target description gives a brief description of the target. Three items are generally considered in target description: type of target, size of target, and degree of protection.

Type of target. What the target is and what it is doing (i.e., troops digging in, truck convoy, tanks attacking).

Size. The number of elements in the target, or its physical dimensions; i.e., 5 trucks, 500 troops, 100 × 100 meters.

Degree of protection. Does the target have protection (i.e., in open, in foxholes, in bunkers with overhead cover)?

- Method of engagement. Detailed information on the method of attacking the target, which includes the following:

Danger close. When friendly troops are within 750 meters of the target.

Trajectory. Whether full charge or reduced charge is desired due to terrain around the target. If not specified, full charge is assumed.

Ammunition. Type of projectile required. Three types are available: high explosive (HE), illumination (ILLUM), and smoke (white phosphorous—WP). HE is assumed if not otherwise specified.

- Method of fire. Detailed information on the type of fire desired. This would include the number of guns and any special instructions such as the interval of fire, sustained fire, time on target, coordinated illumination, or continuous illumination. The spotter specifies the number of guns to be used and the type of fire desired.

Interval. The time in seconds between salvos. For example, 2 guns, 10 salvos, interval 30 seconds.

Sustained fire. Continuous fire over a prolonged period of time. For example, sustained fire, 20 salvos, 5 minutes or 4 rounds per minute for 5 minutes.

Time on target (TOT). The required time of impact of the salvos on the target; for example, TOT at 0715, or TOT 15 minutes from now.

Coordinated illumination. The technique used to fire both illumination and high explosives at the same target.

Continuous illumination. Provides constant illumination on a target.

- Methods of control. The four methods of controlling the adjustment of fire are as follows:

Spotter adjust. Fire is adjusted by the spotter.

Ship adjust. Fire is adjusted by the ship.

Cannot observe. Neither the spotter nor the ship can see the target; therefore, no adjustment can be made.

Fire for effect. The fire is on target, and additional salvos are desired to neutralize the target. There are no adjustments during this firing.

"AT MY COMMAND" is a phrase used when the spotter desires to control the time of firing of each round. The order "FIRE" is given after the ship has reported "READY" and when the spotter wishes the ship to fire. This can be used with any of the methods of control previously listed. A basic call for fire mission using a UTM grid would sound similar to the conversational pattern shown in figure 4-9.

SHIP	SPOTTER
"D4L THIS IS R4P. ON STATION AND READY FOR CALL FOR FIRE, OVER"	
	"R4P THIS IS D4L, FIRE MISSION TARGET NUMBER 01, OVER."
"FIRE MISSION TARGET NUMBER 01, OUT"	

(Notice call signs are dropped after the receipt of the firing alert.)

SHIP	SPOTTER
	"GRID 796540, ALTITUDE 40, DIRECTION 1600, TROOPS IN THE OPEN, I GUN SPOTTER ADJUST, OVER."
"GRID 796540, ALTITUDE 40, DIRECTION 1600, TROOPS IN THE OPEN, I GUN SPOTTER ADJUST, OUT"	

(Remember, in this CALL FOR FIRE mission, the method of target location being used is grid. The altitude is assumed to be 40 meters and the direction is assumed to be 1600 mils grid, since the units were not specified. We can also assume HE, FUZE QUICK ammunition because it was omitted from the CALL FOR FIRE.)

SHIP	SPOTTER
"GUN TARGET LINE 076 DEGREES TRUE, READY 12, OVER"	
	"GUN TARGET LINE 076 DEGREES TRUE, READY 12, FIRE, OVER."
"FIRE, OUT"	

(Gun target line is the bearing of the gun, indicated in degrees true. Ready indicates the time of flight.)

SHIP	SPOTTER
"SHOT * * * * * * * * SPLASH, OUT"	

(Shot given at time of fire. Splash given 5 seconds before impact.)

SHIP	SPOTTER
	"RIGHT 200, ADD 400, UP 20, OVER."
"RIGHT 200, ADD 400, UP 20, OUT"	

(Spots are normally given in meters. Since most fire control systems require yards, conversion must be made before the entries are made.)

SHIP	SPOTTER
"SHOT * * * * * * * * SPLASH, OUT"	
	"FUZE TIME, 1 GUN, 6 SALVOS, FIRE FOR EFFECT, OVER."
"FUZE TIME, 1 GUN, 6 SALVOS, FIRE FOR EFFECT, OUT"	

(Notice the change of fuze order. The spotter desires an air burst at this time. Also notice the change in control to Fire for Effect, indicating that the impact is within the desired area.)

SHIP	SPOTTER
"SHOT * * * * * * * * SPLASH, BREAK. ROUNDS COMPLETE, OVER"	
	"ROUNDS COMPLETE, END OF MISSION, TROOPS DISPERSED, OVER."
"END OF MISSION, TROOPS DISPERSED, OUT"	

(The spotter has ended the mission. The damage assessment is given to the ship. The ship will CEASE FIRE and prepare for the next mission.)

Figure 4-9.—Example of communication in a call for fire mission.

Classification of Naval Gunfire Support

Fire control techniques discussed so far have taken into account only own ship and the target, and the location and velocity of the target with respect to own ship. This is necessary because the featureless seascape provides no reference points. On land, however, there are reference points that can be used to assist in laying the guns on the target and in preventing fire on friendly troops, vehicles, and installations. In addition, terrain features complicate corrections of the fall of shot. Since computer solutions assume the point of fall to be in the horizontal plane, the elevation of the target above sea level must be considered in the solution. Figure 4-10 shows the errors resulting when the range of the land target is taken from a chart and the target's elevation is not considered. Terrain features also affect the size of the pattern in range; a forward slope decreases the dispersion and a reverse slope increases the dispersion. Figure 4-11 shows these effects. Gunfire support nearly always involves the use of maps and charts to an extent rarely required in other types of naval engagements.

Naval gunfire against land targets may be classified in various ways. The classifications are interrelated; terms from several types of classifications must be used for a full description. These classifications are based on the effects sought, tactical use, technique of delivery, and type of fire.

- Effect sought

DESTRUCTION—Deliberate and accurate fire, usually delivered at short range, for the purpose of destroying a target, usually a material object.

NEUTRALIZATION—Rapid, fairly accurate fire delivered for the purpose of hampering, interrupting, or preventing enemy fire, movement, or action. Destruction of weapons and personnel is secondary. The effect of neutralization is comparatively temporary, and such fire may have to be repeated.

HARASSMENT—Sporadic fire delivered during otherwise quiet periods to prevent enemy rest, recuperation, or movement; and, in general, to lower enemy morale and combat efficiency.

INTERDICTION—Fire designed to prevent or curtail the use of an area, bridge, airfield, or route of communication by the enemy.

ILLUMINATION—Gunfire employing illuminating projectiles (star shells) to illuminate the enemy, to detect their movements, to aid our own observation, or to aid our own troop movements.

- Tactical use

CLOSE SUPPORTING FIRE—Gunfire delivered on enemy targets that, because of their proximity, present an immediate and serious threat to the supported unit. (Close supporting fire may be as close to friendly troops as 300 meters enfiladed or 600 meters

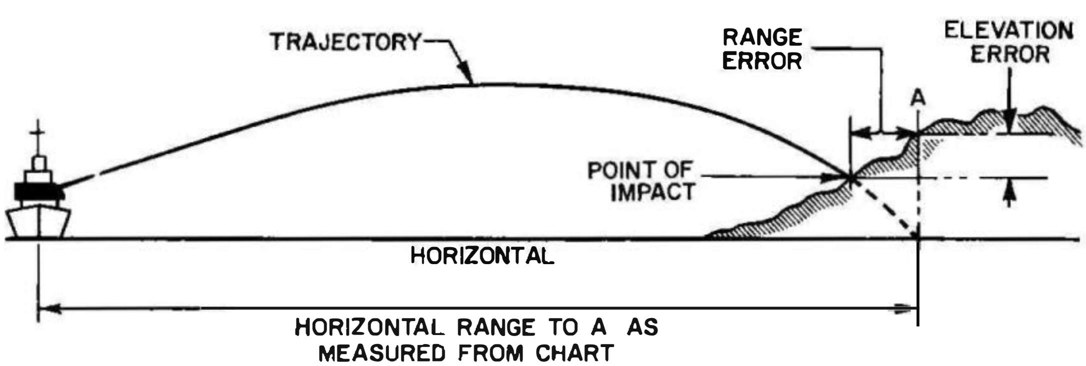

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Figure 4-10.—Errors resulting from failure to compensate for target elevation.

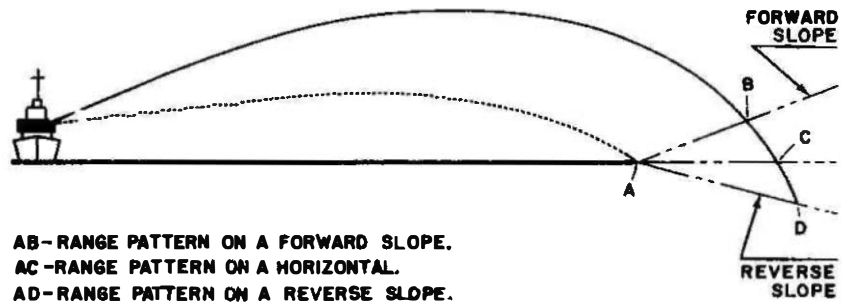

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Figure 4-11.—Effects of the terrain slope on the range pattern produced by a ship's gun.

when the target axis is not parallel to the line of fire.)

DEEP SUPPORTING FIRE—Gunfire delivered on objectives not in the immediate vicinity of friendly forces to neutralize or destroy enemy reserves and weapons and interfere with enemy command, supply communications, and observation.

PREPARATION FIRE—A heavy volume of prearranged neutralization fire, delivered just before a landing or a ground attack by friendly forces on enemy positions.

COUNTERBATTERY FIRE—Gunfire delivered against active enemy guns and fire control stations for the purpose of silencing the guns before they can damage the firing ship.

PREARRANGED OR SCHEDULED FIRE—Gunfire formally planned and executed against targets of known location. Such fire is usually planned well in advance and executed at a predetermined time.

CALL FIRE—Gunfire delivered at the request of troop units ashore or a spotting agency. Call-fire missions must not be interrupted without permission of the unit requesting the fire, except in case of emergencies such as equipment failure or counterbattery.

OPPORTUNITY FIRE—Gunfire delivered without formal planning or troop request on newly discovered targets, or upon transitory targets. Targets of opportunity may present themselves to the firing ship at any time, but fire must be delivered only with due regard for safety of friendly troops. Ships delivering fire on targets of opportunity close to their own troops require approval of the troop echelon concerned before opening fire. Ships executing deep support missions must assure that the target of opportunity is within their assigned sector of responsibility.

RECONNAISSANCE FIRE—Gunfire delivered in areas where camouflaged positions are suspected or in vital areas where natural cover prevents observation and/or gathering of photo intelligence.

FLAK SUPPRESSION FIRE—Gunfire used to suppress AA fire immediately before and during an air attack on enemy positions.

- Technique of delivery

DIRECT FIRE—Gunfire delivered on a target by using the target itself as a point of aim for laying the guns or director. Direct fire is usually used on targets that can be seen (by optics or radar) from the firing ship.

INDIRECT FIRE—Gunfire delivered on a target that is not itself used as a point of aim for laying the guns or director. Indirect fire is always used on targets not visible from the ship. This fire is spotted by air spotters or shore fire control party spotters assigned for this specific purpose.

- Type of fire

AREA FIRE—Gunfire delivered in a prescribed area. Area fire is generally neutralization fire.

POINT FIRE—Gunfire directed at a definite material target in order to destroy that particular target.

ENFILADE FIRE—Gunfire delivered on a target in such a manner that the range pattern of the fall of shot coincides with the long axis of the target (fig. 4-12, view A).

DEFILADE FIRE (REVERSE-SLOPE FIRE)—Gunfire delivered on targets located behind some terrain feature, such as a hill or ridge, that masks the target (fig. 4-12, view B). This type of fire requires a very steep terminal trajectory.

Definitions of Terms

Many terms that may be unfamiliar to you are used in shore bombardment. A brief definition of each of the more common terms is given here.

FIRE FOR EFFECT—A volume of fire of a specified number of rounds delivered on a target after the fall of shot has been placed on the target.

CANCEL AT MY COMMAND—Cancels "AT MY COMMAND."

SHOOT—Command to fire.

SHOT and SPLASH—SHOT is given when the round is fired; SPLASH is given 5 seconds before the round is to land.

GUN-TARGET LINE (GTL)—An imaginary line connecting gun and target. GTL is reported to the spotter when requested before delivery of the first round and after the last round or salvo has been fired.

READY—Indicates to the spotter that the ship is ready to fire.

ROUNDS COMPLETE—Sent by the ship to indicate that all rounds requested in the FIRE FOR EFFECT have been delivered.

DELAY—Used by the ship to indicate that the ship will be unable to provide fire as requested. The amount of delay is indicated in figures understood to be minutes, as "DELAY 10."

WILL NOT FIRE—Used to indicate the ship is unable to deliver fire as requested.

CORRECTION—To correct an error made by the transmitting agency.

WRONG—Your last transmission was incorrect. The correct version is . . .

LOST—The round was not observed. The round may have been a dud or out of the spotter's field of vision.

CHECK FIRING—Temporary interruption. Stop firing immediately but continue generating solution.

CANCEL CHECK FIRING—Cancels check fire and is the only term to do so.

FRESH TARGET—A procedure requested by the spotter to the firing ship to indicate

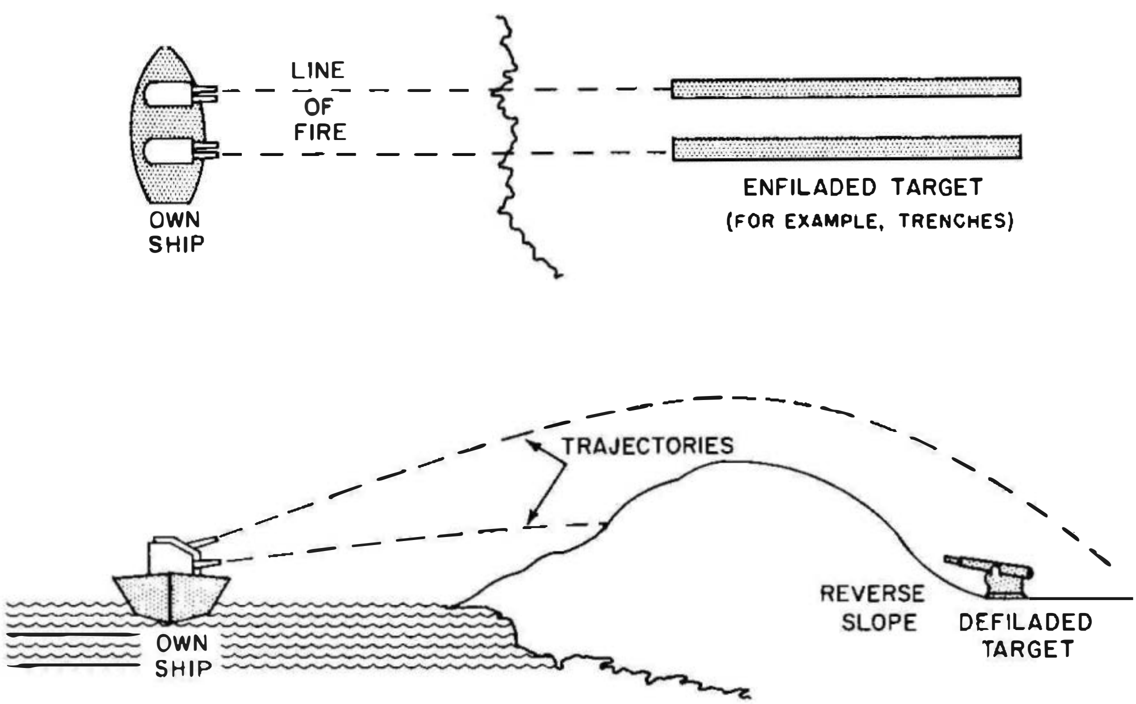

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Figure 4-12.—Types of targets.

that fire will be shifted from the last round fired (on the old target) to a new target by corrections applied to the computer solution being generated.

RECORD AS TARGET—Read the gun-target line, range, target height, and accumulated spots.

SPOTTING SEQUENCE—Deflection, range, and elevation are all understood to be in meters, unless otherwise specified. Each may be omitted except the range spot. If no change is wanted in range, the command is "NO CHANGE."

NOTE: The word "REPEAT" should *never* be spoken over a radio telephone network (RT net) as a signal to request retransmitting a message.

END OF MISSION—An order given to terminate firing at a specific target.

NEGLECT—Term used to indicate the last salvo was fired with incorrect data.

DANGER—No longer used.

DANGER CLOSE—Whenever friendly troops are within 750 meters of the target. It will be followed by a cardinal or intercardinal direction giving the location of the friendly troops in relation to the target. The spotter's responsibilities include the placement of the initial round and subsequent adjusted salvos. The ship's responsibilities are the safe firing of the guns and to advise the spotter of any potentially unsafe situation.

Types of Fuzes

Spotters must also be knowledgeable of the various types of fuzes and the ammunition with which they are associated. Such things as when a fuze is activated and the conditions that cause activation are considerations that contribute to effective spotter performance. The following is a list of fuzes and the ammunition they are used with:

- Quick—Point detonating fuze (PDF), detonate on impact (HE and smoke HE/MTPD)

NOTE: *Fuze quick* is implied unless otherwise specified.

- Time—Mechanical time fuze (MTF), airburst, (AAC, SMOKE, ILLUM, HE/MTPD)

- Delay—Base detonating fuze (BDF), approximately .02-second delay in detonation (HC).

- Controlled variable time (CVT)—Burst occurs between 60 and 75 feet in height when fired against ground targets. A mechanical time fuze delays the activation of the transceiver for the safety of friendly troops and aircraft.

Control of Fire

Another factor in the accomplishment of effective spotting is for the spotter to be knowledgeable of established methods for controlling fire. Remember that the actual methods of control are a matter of doctrine. You should refer to the appropriate gunnery publications to determine actual procedures. The following methods are, for the most part, acceptable.

- <u>Spotter adjust</u>—The spotter controls the fire and is responsible for the adjustment. The ship is responsible for the following: (1) Report READY and TIME OF FLIGHT before firing the first round; (2) fire succeeding rounds upon the receipt and application of spots; and (3) send SHOT and SPLASH to the spotter on all indirect fire missions.

- <u>Ship adjust</u>—The ship can see the target and direct the fire mission. The spotter will play no part in the adjustment of the mission.

- <u>Will observe</u>. Not used.

- <u>Cannot observe</u>—The spotter has information on an important target that cannot be seen. The spotter will (1) send to the ship the best available information as to target location, and (2) call for a certain number of rounds of fire for effect.

- <u>At my command</u>—Spotter will regulate the time of firing of each round or salvo. The following is required:

  1. Ship will report READY for each salvo.
  2. Ship will fire on FIRE order from the spotter.
  3. At my command remains in effect until cancelled by the commands "CANCEL AT MY COMMAND" or END OF MISSION."

METHODS OF FIRING

In conventional gunfire control (antiair warfare [AAW] and surface fire), the target is visible from the ship, either by radar or optical equipment. As mentioned earlier, this is not always true of shore targets. Much of the firing done by ships in gunfire support missions will be at targets that no one on the ship can see. Fire at a visible target is called *direct fire*; fire at an unseen target is called *indirect fire.*

Direct Fire

Targets visible from the firing ship offer the simplest fire control problem to the ship,and their destruction is easier than targets that require indirect fire. Such visible targets include point targets, counterbattery targets, targets of opportunity, and area targets. When the target can be seen, the director can furnish accurate target bearing and elevation. These, with a present range that can be measured, ensure an accurate fire control setup that should result in early hits. Direct fire is controlled as it would be for fire against enemy ships except that when the ship is providing call-fire support, the spotter will locate the target, order the firing of the first round, and assist the ship in spotting when necessary. The ship will make its own corrections if visibility is good, and it will end the mission. For a target that is acquired by the ship, control and spotting will be done entirely by the ship.

Indirect Fire

Indirect fire is employed against targets that cannot be seen by the firing ship. Given an accurate chart and knowing the exact position of own ship, it is possible to measure range and bearing to any land target that has been designated in advance and to hit that target without using radar or optics.

POINT OSCAR METHOD.—This method of indirect fire was devised primarily for ships with fire control systems incapable of correctly generating range and bearing to a designated grid point. Its use, however, even by the newest ships, is advantageous under certain conditions, such as when no shore spotter or air spotter is available for observing the fall of shot. The method requires a visible point of aim—designated Point Oscar—near the target, as well as the accurate location of the target and Point Oscar on a map.

In practice, the director line of sight is kept continuously trained and ranged on the point of aim (Point Oscar) to give a continuous range and bearing solution to this point. Salvos are initially fired at Point Oscar as a check on the gun ballistic. As soon as the point of impact has been spotted to hit, range and deflection spots necessary to hit the invisible targets are applied.

Since the motion of the firing ship continuously changes the values of the offsets from the point of aim, frequent changes in these offset spots must be made to ensure hitting the target. This problem is shown in figure 4-13. One way to continuously determine correct range and deflection spots is to use a small transparent overlay. Inscribed on the overlay are 100-yard squares drawn to the same scale as the chart. With the center of the grid overlay on Point Oscar and the grid lines oriented to the direction of the line of sight from the ship, range and deflection spots to hit the designated target may be read directly from the grid overlay.

RADAR BEACON.—The radar beacon is a portable transmitter-receiver. Set up by the shore fire control party, it is capable of emitting a characteristic signal when keyed by the transmitted pulse of the ship's fire control radar. This signal is different in frequency from the transmitted pulse to eliminate the normal echo returns from the shore. The signal is received by the fire control radar when the radar receiver has been tuned to receive the beacon frequency. Extremely accurate ranges and bearing to the beacon may be obtained. It can be tracked manually or in automatic radar control. The radar beacon is used primarily to aid in the delivery of accurate naval gunfire under all conditions of visibility and to eliminate the errors of normal navigational

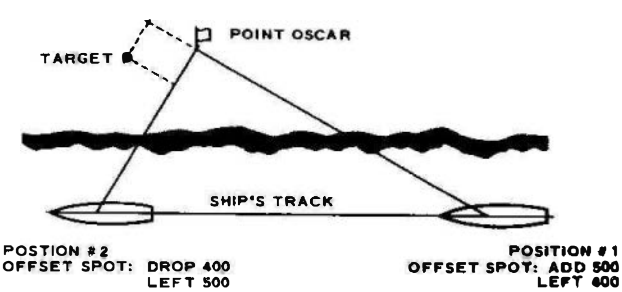

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Figure 4-13.—Point Oscar method of indirect fire, showing necessity for continuous changes in offset spots to hit the target.

plotting by using landmarks and other visual navigational aids.

DEFILADED TARGETS.—Targets that are located on the far slope of a hill or ridge between the firing ship and the target present a particularly difficult problem to the flat trajectory of naval gunfire. The projectile must clear the crest of the hill and fall steeply enough to hit the target beyond. In this situation (defiladed target), an angle of fall must be chosen that is greater than the angle of the reverse slope. Two solutions are then available. The ship may either increase the range or it may use reduced-velocity charges at a shorter range to obtain this selected angle of fall. Figure 4-14 shows this problem and its solutions. Line A is the trajectory produced by standard service charges and is too flat; line B is the trajectory that can be obtained by using reduced-velocity charges; and line C is the trajectory that can be obtained with standard service charges by increasing the range.

If the ship must fire over friendly troops on an elevated position between the firing ship and the target, it is necessary to determine target elevation, the elevation of the troop position, and the difference between the two.

CIC Team

During NGFS and especially during indirect fire, the CIC team is of major importance to the successful completion of an NGFS mission. The CIC team usually consists of the GLO (gun liaison officer), assistant GLO, CIC supervisor, navigation plotter, target plotter, navigation recorder, RT talker, and RT recorder. However, this team could change depending on ship's doctrine and the applicable operational orders in effect at the time. The usual team duties are as follows:

GLO. GLO is the officer in charge of the NGFS team. As such, this person is responsible to the commanding officer for the proper and safe conduct of NGFS. The GLO should have a thorough knowledge of all team members' assigned duties and be familiar with the operation, capabilities, and limitations of the GFCS and gun batteries installed aboard the ship. The GLO must also have a thorough knowledge of ALLIED spotting procedures as stated in ATP-4. The GLO must maintain sound-powered communications with plot and must provide plot with all necessary ship's information such as course, speed, target course and speed, wind direction, and wind speed. Upon receipt of a fire mission, the GLO relays all necessary data to plot and conducts computer checks with plot until plot reports "PLOT SET, GTL __, RANGE __ CHECK SIGHT CLEAR."

ASSISTANT GLO. The assistant GLO must be familiar with the duties of the GLO and assist the GLO as needed. The assistant GLO maintains sound-powered phone communication with the bridge, converts all spots, utilizing the grid spot converter (as a double check for GLO), and assists GLO by ensuring that all information GLO passes to plot is correct.

CIC SUPERVISOR. The CIC supervisor must be thoroughly versed in NGFS and ALLIED spotting procedures. He closely supervises all team members, lending assistance when needed, and correcting procedural errors, when and if necessary; and assists GLO by verifying computer checks to ensure accuracy.

NAVIGATION PLOTTER. The navigation plotter plots own ship's position every 2 minutes. He works closely with the target plotter to determine ship's course and speed made good. He maintains an advance track of 6-10 minutes and informs GLO of any changes in target course and speed.

TARGET PLOTTER. The target plotter plots the target location as given by the spotter, double checks the altitude of the plotted target against the altitude given by the spotter, and informs GLO of any major differences. He must check the charts for any interesting terrain feature between the target and the ship, advising GLO of the need to fire reduced charge if the terrain warrants. The target plotter must be familiar with all the duties of the navigation plotter and will assist the navigation plotter in conducting computer checks, marking the fall of shot, and in any other way deemed necessary.

NAVIGATION RECORDER. The navigation recorder mans the JW sound-powered phone circuit and records all visual and/or radar bearings for predesignated navigation points

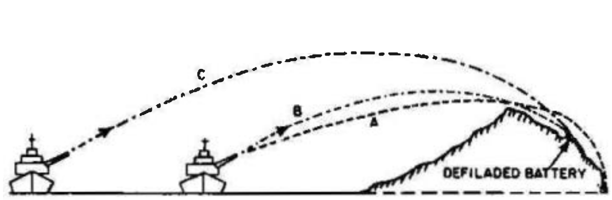

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Figure 4-14.—Problem of hitting a defiladed target.

every 2 minutes. He passes the navigation fix information to the navigation plotter.

RADIO-TELEPHONE (RT) TALKER. The RT talker must be thoroughly versed in all RT procedures in accordance with all applicable instructions and operational orders. He maintains the call for fire status board, ensuring all information received from the spotter is passed to GLO. The RT talker passes all information from GLO to the spotter.

RADIO-TELEPHONE (RT) RECORDER. The RT recorder must be thoroughly versed in all RT procedures in accordance with all applicable instructions and operational orders. He maintains the call for fire log, and immediately advises the RT talker of any communications or procedural errors that occur so the RT talker can correct whatever was transmitted in error. The RT recorder assists the RT talker in recording all necessary data, as required, when "RECORD AS TARGET" is desired by the spotter.

NOTE: The specific responsibilities of the CIC team members may vary slightly, depending on ship's doctrine and the fire control system installed.

NGFS with an Analog Computer

Before beginning an NGFS mission, there are certain general actions that must be taken in plot before reporting to GLO that "PLOT IS READY FOR CALL FOR FIRE." Of primary importance is the initial setup of the computer. The plotting room officer (PRO) must ensure that all knobs and switches are in the correct position and that any predetermined values are set into the computer.

The PRO receives the manned and ready report from the gun mount and passes it along with plot's manning report to GLO. The PRO is also responsible for ensuring that initial velocities are computed using the projectile and fuze combinations desired by the spotter. He also ensures that own ship's information is entered correctly and reports "PLOT READY FOR CALL FOR FIRE" when entries have been completed. The GLO will pass the call for fire data to plot. He will also send computer check data to the PRO. The north/south (N/S) range is entered by the assistant computer operator using N/S generated range handcranks and N/S range dials. The east/west (E/W) range is entered by the computer operator by using the E/W generated range handcrank and E/W range dials.

After the initial values are entered, the operators stand by for a "MARK" from GLO. The time motor is turned on when GLO gives the "MARK." The computer operators then stand by for comparison checks of the generated values of target position against the CIC chart values of these positions. The comparison procedure is repeated at 15-second intervals until the computer values are within 50 yards/meters and 1/2 degree of the CIC values. A typical computer check would sound like this: "ON MY MARK, THE TARGET WILL BEAR NORTH—SIX FIVE FOUR ZERO ZERO, EAST—TWO ZERO FIVE ZERO ZERO, STANDBY . . . MARK."

A minimum of three computer checks should be taken to determine if they are satisfactory. If on each of the three successive computer checks the values are within tolerance, the computer and assistant computer operators give a THUMBS UP indication to the PRO. Once computer checks are satisfactory, the PRO gives the order to the mount captain to "GO TO REMOTE." When the mount matches the ordered signal, the "MOUNT IN REMOTE, IN SYNC" report is given to the PRO. The mount safety observer checks the *check sight*, and if he sees anything to inhibit firing, he reports "CHECK SIGHT FOULED"; if not, he reports "CHECK SIGHT CLEAR, TIME OF FLIGHT ____ ____ ____." After having received the THUMBS UP from all computer operators and the report "MOUNT IN REMOTE, IN SYNC, CHECK SIGHT CLEAR" is received, the PRO reports to the GLO "PLOT SET, GUN TARGET LINE ______ ______ ______ RANGE, ___ ___ ___ ___ CHECK SIGHT CLEAR, TIME OF FLIGHT ______ ______ ______." The GTL and range are sent to CIC for verification of a correct computer solution.

When plot receives a *shoot command*, the order to the gun mount is "MOUNT ______ ONE ROUND, LOAD AND SHOOT." The JP sound-powered phone talker then closes the firing key and keeps it closed until the mount fires. The mount reports "BORE CLEAR, ONE ROUND EXPENDED, NO APPARENT CASUALTIES" to plot. The PRO relays this report to the GLO in the CIC. If the mount reports "BORE FOUL," misfire procedures are carried out in accordance with ship's doctrine.

The spots received in plot are converted from meters to yards and applied to the appropriate generated range handcrank; that is, N/S to the N/S handcrank and E/W to the E/W handcrank. Elevation spots are converted from meters to yards and then to feet and applied as up/down at the height control knob.

A quick way of converting from meters to yards is to add 10% of the spot given. For example:

100 meters = 110 yards

100 + 10% of 100 = 100 + 10 = 110 yards

When spots are applied, the procedures for fire are similar to those for the initial fire. When "END OF MISSION" is received, the mount is given a "CEASE FIRE" order. The mount then gives a bore report, a total number of rounds fired report, and a mount status report that is relayed to GLO.

Example:

"MT51, BORE CLEAR, 22 ROUNDS EXPENDED, NO APPARENT CASUALTIES." The mount is then given a "READY SURFACE" command, shifts to local control, and returns to its centerline bearing.

NGFS with a Digital System

The outcome of NGFS with a digital system is the same as that with an analog system. The methods of arriving at the outcome are different in several ways.

The CIC NGFS team is basically the same as with the analog system. The functions of all members are the same, but there are some differences in communication between GLO and the control officer console (COC) operator if the Mk 86 GFCS is in use.

The GLO provides to the COC all the necessary information pertaining to the target and the conduct of the mission. The information entered into a digital system includes the following:

- Current set and drift (used only in dead reckoning mode).
- Ship's latitude in degrees and tenths of a degree.
- Grid variation E/W in minutes (east—positive value; west—negative value).
- True wind speed and direction.
- If in GRID-NAVREF or GRID-BEACON modes, the reference point grid coordinates east and north.

If the fire control system is in NAVREF or BEACON mode, GLO compares the coordinates generated by the computer against the navigation plotter's track. The navigation plot is matched to the computer track once the reference point has been verified.

Computer checks are conducted after 1 minute, and every 15 seconds thereafter; for example,

"ON MY MARK, SHIP'S GRIDS WILL BE EAST 55600, NORTH 06350, STANDBY . . . MARK."

The coordinates are entered into the computer via the gun/weapon control console (GCC/WCC), and on the "MARK," the dead reckon button is pressed to GREEN. This starts the computer solution of the track. Additional checks are taken by retrieving ship's grid EAST-WEST or ship's grid NORTH-SOUTH on the data readouts. In most cases where all GCCs/WCCs are entering the same data, the E/W coordinate can be taken at one console and the N/S coordinate at another. Computer checks are continued until they are within ±50 meters of the navigation plot (easting and northing).

Once preparations are complete, the GLO will direct the RT talker to report "ON STATION AND READY FOR CALL FOR FIRE" to the spotter. The COC operator will normally monitor the RT net and read the call for fire information to GLO for verification. Examples of basic call for fire missions are as follows:

- Example:

  "FIRE MISSION—TARGET NUMBER AB 2301"

  "GRID—57890635"

  "ALTITUDE—10 METERS"

  "DIRECTION—073° MAGNETIC"

  "DESCRIPTION—TANK"

  "1 GUN"

  "SPOTTER ADJUST"

- Example:

  "FIRE MISSION—TARGET NUMBER AB 2302"

  "DIRECTION—3250 MILS GRID—DISTANCE 2000 DOWN 30"

  "DESCRIPTION—FUEL FARM"

  "1 GUN"

  "SPOTTER ADJUST"

- Example:

  "FIRE MISSION—TARGET NUMBER AB 2303"

  "FROM REFERENCE POINT NUMBER 4"

  "DIRECTION 1600 MILS/GRID"

  "RIGHT 400 DROP 800 UP 40"
  (Spots are in meters.)

  "BUNKER"

  "1 GUN"

  "SPOTTER ADJUST"

Upon receipt of the fire mission from the spotter, the COC operator passes the grid coordinates and altitude to the GCC/WCC. Once this is entered and a solution is obtained, he reports to GLO "PLOT SET, GTL _____, RANGE _______, CHECKSIGHT _______, TIME OF FLIGHT _______."

When "BATTERIES RELEASED" is received from the commanding officer, the GLO directs the RT talker to report "READY _______" (time of flight) to the spotter. The spotter then orders "FIRE," and the GLO directs the COC to "SHOOT."

Before spots can be entered, the OTL must be converted to degrees true by the assistant GLO using the grid spot converter. The GLO passes the OTL to the COC, who passes it to the GCCs/WCCs, who enters it into the computer after the first round has impacted. Spots can now be entered without further conversion. Spots are received in meters, but mental conversion is required to enter the spots into the gun/weapon control consoles in yards. The fire mission continues, repeating as necessary, until "END OF MISSION" is directed by the spotter.

SUMMARY

The fundamentals of spotting that have been presented in this chapter should give you some understanding of spotting as accomplished in naval gunfire. Also, it should point out the fact that practice is necessary for you to keep and advance your proficiency in this area.

SPOTTING ERRORS. Spotting errors are either unpredictable errors or they are control errors. The unpredictable errors are usually small and require no corrections. However, the control errors are correctable by taking care when setting in computer values; correctly computing IV, wind, air density, and so forth; and ensuring the battery is correctly aligned.

METHODS OF SPOTTING. The two methods of spotting are visual and radar spotting. Radar spotting is limited to range and deflection spots while visual spotting can add height spots. Three methods are used with visual spotting—direct, bracket-and-halving, and the ladder method. Radar spotting has the advantage where visibility is poor, but it cannot be used against shore targets. Spotting terminology consists of the following simple commands to correct the fall of shot:

"RIGHT" or "LEFT"—deflection spot
"ADD" or "DROP"—range spot
"UP" or "DOWN"—for height of burst

NAVAL GUNFIRE SUPPORT. The purposes of NGFS are destruction, neutralization, harassment, interdiction, illumination, close support, deep support, preparation, counterbattery, prearranged, call opportunity, reconnaissance, and flak suppression fire. Most of these can be either direct or indirect (not visible) delivery. NGFS can be area, point, enfilade, and defilade types of fire.

SPOTTING IN GUNFIRE SUPPORT. For spotting, a fire control party ashore uses the target grid system with spots oriented to the observer target line (OTL). These spots must be corrected to the gun target line (GTL) aboard ship before firing.

Naval gunfire support is a very large field and has been touched upon very briefly in this chapter. The knowledge that you have acquired, plus the publications that are available on the subject, should help you to know and to understand the requirements that are necessary for a complete and reliable gunfire support team on any ship on which you may be serving. In the next chapter we will discuss the importance of the Navy's training program. This chapter includes the various types of training, training sources, and the administration methods used to keep the training program running smoothly and effectively.

CHAPTER 5

TRAINING

Modern naval warships and aircraft are equipped with elaborate devices for detecting, engaging, and destroying the enemy to carry out the Navy's mission. These complicated machines must be manned by highly trained personnel to reach their designed effectiveness. The ultimate purpose of naval training is to educate and train Navy personnel in a manner that will ensure efficient employment of modern naval material and principles.

The immediate objective of training is to enhance knowledge and practical abilities so personnel can better perform their duties. Continuing personnel shortages, rapid turnover of personnel, and heavy demands placed on the time of shipboard personnel are recognized obstacles that must be overcome in establishing and managing a successful shipboard training program. Shipboard training and material maintenance are two of the major factors contributing to battle readiness. Neither requirement is more important than the other. Training is a prerequisite to proper maintenance. In the absence of a vigorous and continuing shipboard training program, sustained combat readiness is impossible.

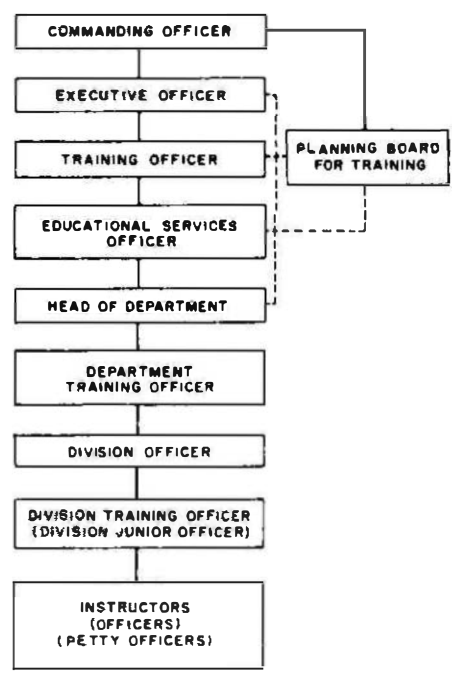
The basis of all training is the development of skills in the individual. The individual is trained to successfully fill a billet aboard ship, to prepare for advancement in rating, and for more responsibilities. Group training, or training of a ship's complement, can only be accomplished with a successful individual training program as a base.

You, as a first class petty officer, have the responsibility of training personnel in certain basic fire control training categories, in addition to assuring that the personnel in the division are trained in all professional military categories. A portion of this training should be performed as a part of the orientation and indoctrination of all new personnel reporting aboard. Other parts may be accomplished by on-the-job training. However, some subjects lend themselves to more formal training.

SHIPBOARD TRAINING ORGANIZATION

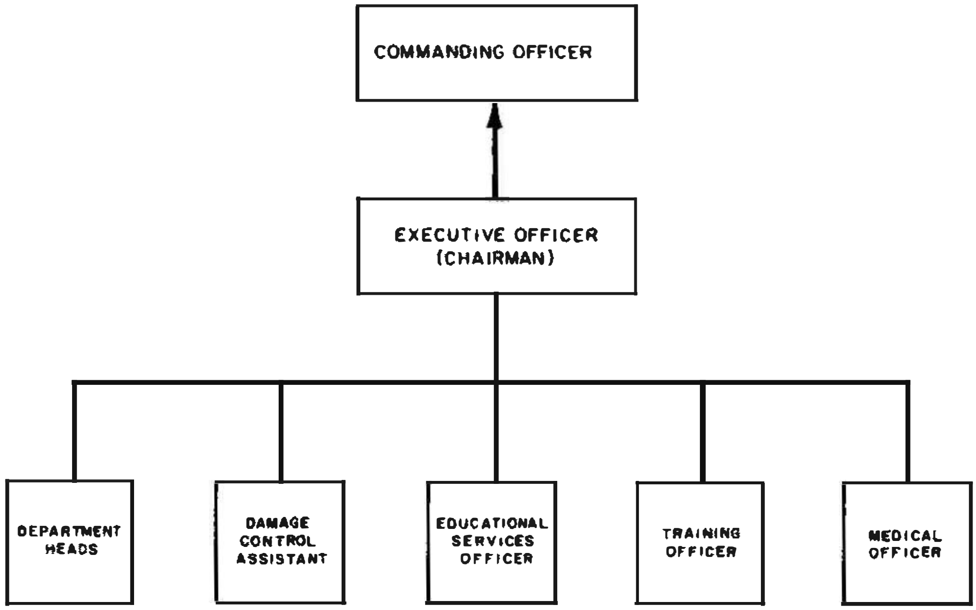
Basic policies for the administration and conduct of shipboard training are set forth in *U.S. Navy Regulations* and in *Standard Organization and Regulations of the U.S. Navy*, OPNAVINST 3120.32A. However, close attention must be given to the training requirements of the individual ship. Training methods vary from ship to ship, depending on the size, design, and personnel allowance. Each ship's training time must be carefully balanced with the time allotted for maintenance. Once a balance is established, programs for training and maintenance should be carefully planned, executed, and controlled.

Figure 5-1 shows a typical shipboard training organization. On small ships the executive officer



114.28

Figure 5-1.—Shipboard training organization.



173.836

Figure 5-2.—Planning board for training.

may assume all the functions of the training officer, and the division officer or the senior petty officer may perform all the duties of the division training officer. The planning board for training is responsible to the commanding officer for developing a unit's training program with the ultimate goal of producing well-trained and qualified personnel. The planning board is comprised of the personnel shown in figure 5-2. The training board's duties are outlined in *Standard Organization and Regulations of the U.S. Navy*, OPNAVINST 3120.32A. The board will meet, as directed by the chairman, no less than once a month after the training program begins to function to evaluate progress, coordinate action, and propose changes as necessary. The personal knowledge of members, the reports of the educational officer, and the various control devices used all indicate points at which action should be taken to improve coordination.

Progress is the only true measure of the training program's efficiency and effectiveness. To simply state that a certain amount of training has been done means nothing. Quality training will improve morale and motivation as well as skills and knowledge.

Although the original program is designed with utmost care, the need for change can be caused by a number of variables.

The following items should be examined periodically to determine their possible effect on the training program:

- Change in nature or schedule of operation
- New or improved equipment
- Change in the technical knowledge or skill required for performance of duty in any rating
- Change in personnel
- Change in regulations or procedures under which the ship is operating
- Completion of any phase of the training program
- Unforeseen obstacles to coordination or completion of the program
- Increasing or decreasing facilities and availability of fleet and shore-based training establishments

It is apparent in these considerations that the responsibility of the planning board does not end with issuance of the training schedule. Every exercise or training program must be formally reviewed by the planning board. Division officers and petty officers should review the effectiveness of the training program daily so that the necessary data will be available to the board members for evaluation.

TRAINING SCHEDULES AND RECORDS

Scheduling of shipboard training requires the careful attention of the training officer, department heads, and division officers to minimize conflict in ship's activities and to ensure that the time allotted to training is used to the best advantage. The only justification for a record of training is that it provides continuity to the training program by indicating what training has been accomplished. Records should be kept to an absolute minimum consistent with needs. When possible, the same forms used to schedule planned training should be used to record completed training. Therefore, standard forms that provide considerable flexibility have been developed. The training records are as follows:

Long Range/Quarterly Training Plan (fig. 5-3), OPNAV Form 3120.1A

Monthly Training Plan (fig. 5-4), locally prepared

TYCOM Required Training Exercises, Trials, and Inspections (fig 5-5), General Record (Type I), OPNAV Form 1500.30

Division Drill and Instruction Schedule (figs. 5-6 and 5-7), General Record (Type III), OPNAV Form 1500-32

Additional forms not shown are Division Officer's Personnel Record Form, NAVPERS 1070/6, and Record of Qualifications at Battle Stations, General Record (Type II), OPNAV Form 1500-31.

The training officer normally prepares the long-range training schedule and the monthly training plan. Inputs to these two plans, as well as the responsibility for carrying out divisional training plans, are usually the division officer's responsibility.

The training requirements set forth by the type commander are a primary consideration of the planning board in establishing the training schedules. Ship exercises often require the services of other ships and aircraft or qualified observers from another command. Naturally, whenever external assistance is required, more emphasis must be placed on advance planning and scheduling.

The Long-Range Training Schedule

The long-range training schedule is the most important training outline aboard ship. When properly used, it is the basic instrument for making and recording the plans for all training, and for keeping ship's personnel informed of projected training aims and operating schedules. In general, this schedule should contain enough information to guarantee that the overall coordination and planning of the shipboard training effort will be effective. It should provide the framework for the preparation of the quarterly and monthly training plans. For purposes of clarity and easy comprehension, the long-range schedule should be kept free of minor details that might obscure its broad outlines.

Initially, this schedule is prepared at the beginning of a ship's overhaul period and covers the entire training cycle (period between regularly scheduled overhauls). Upon receipt of the quarterly operating schedules from the fleet or type commander, the training schedule is revised to reflect all significant changes in the previously planned employment of the ship. Copies of the current quarterly training schedule should be posted on the crew's bulletin board for general information and guidance of all hands. Figure 5-3 illustrates a typical page of a long-range training plan prepared on OPNAV Form 3120.1A.

Quarterly Training Plan

The quarterly training plan is an integral part of the long-range plan. It consists of one sheet of the long-range plan and is updated to reflect the latest information on the ship's employment, giving, in significant detail, the ship's training intentions for a given quarter.

LONG RANGE TRAINING PLAN

FIRST QUARTER AFTER REGULAR OVERHAUL JULY (CALENDAR YEAR) SEPTEMBER (CALENDAR YEAR)

CONFIDENTIAL (WHEN FILLED IN) PREPARED

	JULY					AUGUST				SEPTEMBER					OCT
	1 4	7	14	21	28	4	11	18	25	1	8	15	22	29	4 6
Employment	Regular Overhaul LBEACH			RFS		TYT WESTPAC (SOT)				REFRESHER TRAINING SDIEGO					
Major Maintenance Projects, Trials and Test	Paint portside Complete OVHL 1 SS GEN	Dock Trials on 8th	Sea Trials on 14th	(Note: Much of the information in this section of the Long Range Training Plan should be drawn from PMS schedule)											
Inspections and Examinations	P.O. load exam on 2nd	Lower Decks (complwork) on 11th		Pers insp on 26th		E-4 Exams on 5th E-5 on 7th	E-6 Exams on 12th E-7 on 14th	Dept Heads Submit to XO complete RFT Check-off	TRE by FTG						
Operational Readiness Excercises (Competes)							Z-24-G on 12th Z-21-G on 13th								
Team Training Ashore	ASW Team Training ASW School		AAW Team Training AAW School						RFT Scol week (see ship's RFT scol sked)						
School Training Ashore (Individual)	AIC (ENS & ROC) → ENG Off Scol (LTJG) →			← OOD Scol (2ENS) →					RFT Scol week (see ship's RFT scol sked)						
General and Operational Drills	CDO Conduct Z-27-D daily except Sunday with the Duty Section when in port.			Z-10-D & Z-11-D 25th, 29th & 31st		Z-21-G, Z-24-G, Z-29-G, Z-3-E, Z-5-E, Z-6-E, Z-22-E, Z-24-E, Z-28-E, Z-81-E, Z-82-E, Z-83-E, Z-10-D, Z-11-D, Z-12-E, Z-25-D, Z-26-D, Z-29-D Z-52-D, Z-7-N, Z-3-S, Z-5-S, Z-14-S, Z-29-S, Z-10-CC, Z-13-CC, Z-1-C, Z-2-C, Z-6-C, Z-7-C, Z-9-C, X-13-C, Z-1-ET, Z-2-ET, Z-5-ET, Z-7-ET, Z-14-ET					Drills and Exercises in accordance with FTG Weekly Schedule				
Professional Training	(Note: The details of this Section of the Long Range Training Plan should be completed by Department Division Officers from the Division or Department instruction schedule)														
OPS															
NAV															
WEPS															
SUP															
ENGR															
General Military Training	First Aid	General Safety	Physical Fitness	Veterans Benefits	UCMI	Safe Driving	Personal Health	VD Prevention							
Officer Training				Maneuver Board	Leadership Discussion	J.O Ship Handling	Piloting	Tactical Comm.							
Miscellaneous Activities				Load Stores 21st Load Ammo. 24th											
	1 4	7	14	21	28	4	11	18	25	1	8	15	22	29	4 6

SAMPLE PAGE---UNCLASSIFIED

CONFIDENTIAL (WHEN FILLED IN)

245.2

Figure 5-3.—Long range/quarterly training plan.

JULY MONTHLY TRAINING PLAN 198_

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
OPPORTUNE: Z-26-S (R) Z-28-S (O) Z-29-S Z-13-CC	1 G. Q. Z-10-D NBC LECTURE INTELLIGENCE BRIEFING UNREP: 3 DER	2 DIVISIONAL SCHOOL J. O. SCHOOL CRYPTO DRILL UNREP: 2 MSD	3 DIVISIONAL SCHOOL J. O. SCHOOL INREP: AN THOI	4 HAND GRENADE & SMALL ARMS TRAINING ALL DAY FOR DECK AND OPS	5 FIELD DAY	6 G. Q. BATTLE PROB. Z-6-D Z-11-S (R) Z-10-D Z-14-S Z-24-D Z-27-D Z-52-D Z-111-E (R)
7 ARRIVE SUBIC Z-27-D	8 Z-20-C (O) Z-27-D (SEC I)	9 GMT III DIVISIONAL SCHOOL J. O. SCHOOL CRYPTO DRILL Z-27-D (SEC II)	10 GMT III DIVISIONAL SCHOOL J. O. SCHOOL Z-27-D (SEC III)	11 LOOKOUTS LECTURE (STEAMING WATCHES) Z-27-D (SEC I) PAY DAY	12 0500 DEPART SUB G. Q. GUN SHOOT Z-20-S Z-14-CC (R) Z-1-AA(R) Z-1-N(R) Z-3-AA(O) Z-5-N(O) Z-29-G (R) Z-110-E (R) Z-21-S(O) Z-1-E(R)	13 SF-I, 6-M (R) FOR ALL DEPARTMENTS GQLT NBC LECTURE TRAINING BOARD Z-27-D (NIGHT)
14	15 MIL/LEAD EXAMS E-3 EXAMS	16 ARRIVE YOKO DIVISIONAL SCHOOL J. O. SCHOOL CRYPTO DRILL Z-27-D (SEC II)	17 DIVISIONAL SCHOOL J. O. SCHOOL BLOOD DONATIONS Z-27-D (SEC III)	18 Z-27-D (SEC I)	19 FIELD DAY Z-27-D (SEC II)	20 DEPART YOKO C. O. PERS INSP. C. O. ZONE INSP.
21	22 G. Q. BATTLE PROB. Z-6-D Z-10-D Z-24-D Z-27-D	23 DIVISIONAL SCHOOL J. O. SCHOOL CRYPTO DRILL	24 DIVISIONAL SCHOOL J. O. SCHOOL	25 TELEPHONE TALKER DRILL (GQ TALKERS) PAYDAY	26 FIELD DAY SF-2, 5-M (R) FOR ALL DEPARTMENTS	27 GQLT NBC LECTURE TRAINING BOARD Z-27-D (NIGHT)
28 ARRIVE PEARL Z-27-D (SEC III)	29 COMSERVPAC VISIT G. Q. Z-10-D NBC LECTURE Z-27-D (SEC I)	30 DEPART PEARL DC LECTURES DIVISIONAL SCHOOL J. O. SCHOOL CRYPTO DRILL	31 DC LECTURES DIVISIONAL SCHOOL J. O. SCHOOL	1 AUG HAND GRENADE & SMALL ARMS TRAINING FOR SUPPLY & ENGINEERING	2 AUG FIELD DAY	3 AUG C. O. ZONE INSP. C. O. PERS INSP. 5 AUG ARRIVE SFRAN

245.3

Figure 5-4.—Sample monthly training plan.

GENERAL RECORD (TYPE 1)
OPNAV FORM 1500-30 (10-60) PERIOD COVERED: JULY 1987

COMPETITIVE EXERCISES, DRILLS, AND TRIALS

COLUMN CAPTIONS	DATE SCHEDULED	DATE CONDUCTED	GRADE ADJ/NUM	DATE LTR	RPT SUB 3500-6
Z-27-D(Sec)	7-1	1	G/85	---	7
Z-20-C(O)	7-1	1	E/90	1	7
Z-27-D(Sec)	7-2	2	G/80	---	7
Z-27-D(Sec)	7-3	---	---	---	---
Z-20-S	7-5	5		---	7
Z-1-AA(R)	7-5				
Z-3-AA(O)	7-5				
Z-29-G(R)	7-5	5			7
Z-21-S(O)	7-5	1			7
Z-14-CC(R)	7-5				
Z-1-N(R)	7-5				
Z-5-N(O)	7-5				

(Sec) = IN-PORT DUTY DAMAGE CONTROL FIRE PARTY.

(R) = REQUIRED EXERCISE.

(O) = OUTSIDE OBSERVERS REQUIRED.

245.4

Figure 5-5.—TYCOM required training exercises, trials, and inspections.

GENERAL RECORD (TYPE III)
OPNAV FORM 1500-32 (10-60)

PERIOD COVERED: FROM 1 JULY 1987 TO 30 JUNE 1988

TITLE SECOND DIVISION DRILL / INSTRUCTION SCHEDULE

MONTH		JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE
DAY OF THE MONTH	1			SUN									
	2			HOL									
	3	BM1	SAT	BM21									
	4	HOL	SUN	I70									
	5												
	6	SAT											
	7	SUN		SAT									
	8			SUN									
	9	T50		BM18									
	10	I5	SAT	D3									
	11		SUN	D4									
	12												
	13	SAT											
	14	SUN		SAT									
	15			SUN									
	16	D10		B2									
	17	D52	SAT	I45									
	18	BM7	SUN										
	19			I86									
	20	SAT											
	21	SUN		SAT									
	22			SUN									
	23			T50									
	24	PF20	SAT	BM6									
	25	BM30	SUN	BM4									
	26	BM31											
	27	SAT											
	28	SUN		SAT									
	29	I9		SUN									
	30												
	31		SAT										
WEEKLY OR BI WEEKLY	1ST												
	2ND												
	3RD												
	4TH												
	5TH												
MONTHLY													
QUARTERLY													
SEMI-ANNUAL													
ANNUAL													

(SEE REVERSE FOR INSTRUCTIONS AND/OR EXPLANATION OF ENTRIES)

245.5

Figure 5-6.—Division training schedule.

DATE PREPARED OR PERIOD COVERED: FROM 1 JULY 1987 TO 30 JUNE 1988

TITLE Legend of Coded Drills/Instruction Periods

COLUMN CAPTIONS Type Drill/Instruction	Code	FXP or TYCOM No.	NAVPERS 18068 Rqmts & References, Films, etc.
Flashing Light Drill	SM7	Z-7-C	86014-18; FXP 3
Radar Tracking Drill	OS10	Z-10-CC	87310; FXP 3
Hoisting & Lowering Boats	BM1	Z-11-S	34067; Man Overboard Drill
Boat Crew Drill (in port)	B2		34067; BM 3 & 2
Telephone Talker Drill	T50		NAVPERS 14005A
Handling & Firing .45 cal	A13	50-G	905202; GM 3 & 2
Lighting-off Boiler	BT7		31159; Film MN-2356A
Inland Rules (lights)	QM31		87327; CG-169
IC Doctrine & Circuitry	IC21		28390; 44474; Battle Bill
PMS	FC11		OPNAV 4790.4 series
Tuning AN/URC-32		Z-5-C	0967-LP-066-7010
L.O. Transfer & Purification	MM6	Z-28-E	Plan: AF58-S4501-148405C
Fractures & Splints	F9	SF-9-M SF-10-M	HM
Gen. Mil. Training - Unit I	I1		OPNAVINST 1500.22 series
Physical Fitness (AEROBICS)	PF20		OPNAVINST 6110.1 series
DC Material Readiness	D10	Z-10-D	Battle Bill & DC Manual
NBC Decontamination	D52	Z-52-D	NBC Bill
Security Orientation	I5		OPNAVINST 5510.1 series
Career Counseling	I9		
UCMJ Apprehension/Restraint	U7		UCMJ Art. 7-14
Financial Planning, Part I	I13		Base Legal Officer (Cohen & Hanson) "Per Fin"
SGLI Conversion	I45		Prudential Life Ins.
Traffic Safety Presentation	I70		Calif. Highway Patrol
Narcotics Presentation	I86		SFRAN Police Dept.

245.6

Figure 5-7.—Division training schedule (reverse side).

The plan is prepared by filling in the details of the subsequent quarter of the long-range training plan. It is prepared by the training officer, who submits the schedule after consultation with the training board and commanding officer at the beginning of each quarter.

Monthly Training Plan

The monthly training plan (fig 5-4) provides a schedule of training, evolutions, and operations for a given month. It shows all shipwide training, evaluations, and operations scheduled by the quarterly training plan. On larger ships, the plan may be prepared at the departmental level.

On receipt of the monthly training plan, the division's training requirements should be penciled in for that month. As the divisional events are completed, the penciled entries should be changed to ink, thus providing a record of training at the divisional level.

TYCOM Required Training

The training officer should maintain a record of completed exercises, trials, and TYCOM required training. Automatic data processing printouts could be substituted for the Type I form.

Division Drill and Instruction Schedule

Each division officer, under the supervision of the department head, should keep a record of all operational bills, team training periods, and instruction periods peculiar to the division. Department heads (or department training officers) should ensure that drills for various divisions within a department are coordinated when necessary. The schedule and record of division and interdivision instruction periods assist in planning for and recording the accomplishment of formal lectures and demonstrations or the showing of training films to groups of technicians or officers. The division schedule may also be used to reserve periods of supervised self-study of advancement-in-rate training or correspondence courses. In connection with scheduling of instruction periods, it should be noted that heavy reliance cannot be placed on on-the-job training and individual study unless time is allowed for self-study, tutoring, and supervision of subordinates.

The division training schedule (figs. 5-6 and 5-7) should be kept on both sides of a Type III form (OPNAV Form 1500-32); each sheet covers a period of 1 full year. Because of space limitations, entries on the front side are necessarily abbreviated or coded. The reverse side is designed for entering information, instructions, or remarks that explain the data recorded on the front side.

Figure 5-7 is a sample of the reverse side of a Type III form, on which should be listed all the various drills, exercises, and instruction periods that apply to the division. Two-letter or three-letter abbreviations and serial numbers should be used to support short drill numbers for use on the quarterly and monthly schedules (for example, FC 11-PMS). One-letter codes are reserved for basic training subjects. Often there are no standard lesson plans provided for division training periods. In that event, the only required entries on the reverse side are the subjects of any lectures or demonstrations that will be conducted or have been conducted, together with a serial number for each subject. Applicable NAVPERS 18068 requirements, references, texts, manuals, and films should also be listed on the legend, as shown in figure 5-7.

Divisional training that appears on the completed schedule should be placed in the appropriate space on the monthly training plan. For example, a divisional damage control lecture could be scheduled the same day as a general quarters, (GQ). This is done by penciling in the scheduled drill on the monthly training plan.

Personnel Advancement Requirement (PAR)

The purpose of the Personnel Advancement Requirement (PAR) form is to (1) individualize advancement requirements for each rating and for rates within the rating; and (2) provide a consolidated checklist that individuals can use in preparing for advancement, and that commands can use in their evaluation of the individual in determining readiness for advancement. It can provide a record of progress toward advancement as well as a history of advancement. A PAR form is shown in figure 5-8.

PAR is designed as a checklist of the various minimum requirements for advancement. It is presented in three sections. Section I lists the various administrative requirements; section II lists formal schools and other training requirements (if any) and recommended training for improved performance in rating; section III lists occupational and military ability requirements. Section III is based on the current occupational standards as published in section I, *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068D.

Record of Qualifications at Battle Stations

This record shows the knowledge and skills required of personnel who man battle stations, such as gun mounts, CIC, and repair parties lockers. These crews assemble and are trained as a team only during periods of general quarters or condition watches. They are, in effect, organized groups only for the purpose of performing their assignment at general quarters.

The record is kept on a Type II form by the officer or petty officer in charge of the battle station. Provisions should be made to record items of desired knowledge, qualifications for the various duties at the battle stations, and proficiency in carrying out important machinery casualty procedures.

SHIPBOARD TRAINING

When new FC personnel report aboard, they should fill out a Division Officer's Personnel Record Form, NAVPERS 1070/6. This form is to be reviewed along with the individual's service record for background information covering formal education, professional experience, and performance evaluations; and it is to be used as a basis for a personal interview. From the information gained during the interview and consultation with the senior Fire Controlman, it can be determined where the individual may be placed within the division to most effectively use special abilities.

During the personal interview, the division officer is usually ready and eager to talk with any of the personnel about their problems, either professional or personal. These talks yield additional details about the fire control systems on board, how the division is working as a team, as well as how the individual is developing. These talks afford an opportunity to build toward teamwork by instilling positive attitudes.

Each individual should understand that before advancement can be considered, certain rate training manuals must be studied and certain nonresident career courses (NRCC) must be completed. Additionally, both the military and practical requirements (PARs) for advancement must be completed. Finally, the command recommendation must be given, and a Navywide competitive examination must be passed (except for E8 and E9). Study material may be found in the *Bibliography for Advancement Study*, NAVEDTRA 10052-AG.

Additionally, formal schooling must be completed if required. Completion of all of the above does not necessarily mean immediate advancement; openings in the next higher paygrade will occur according to quotas and complements established by the Naval Military Personnel Command (NMPC).

The division training petty officer is responsible for the effectiveness of the division training program, including what texts and training aids are available and which are most suitable. This information may be obtained from the following sources:

- Onboard equipment technical manuals
- Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA 172-XX-00-79
- NAVSUP Forms and Publications Catalog, NAVSUP 2002
- List of Training Manuals and Correspondence Courses, NAVEDRA 10061
- Electronic Information and Maintenance Book (EIMB), NAVEDTRA 0967-LP-001-XXXX
- Current Navy film catalogs
- Rate training manuals pertinent to the division
- Combat System Technical Operations Manual (CSTOM)

NAVPERS 1414/4 (FC)(3-85)
S/N 0106-LF-014-1421

PERSONNEL ADVANCEMENT REQUIREMENT (PAR)

FIRE CONTROLMAN (FC)

THIS PAR IS EFFECTIVE COMMENCING WITH THE JANUARY 1986 ADVANCEMENT CYCLE. THE ASSOCIATED OCCUPATIONAL STANDARDS WILL BE PUBLISHED APPROXIMATELY SEPTEMBER 1985.

Requirements for advancement to:

FIRE CONTROLMAN THIRD CLASS (FC3)

Section I. Administrative	Date	Initials
1. Time in Rate - 9 months		
2. Pass E-4 military leadership examination		

Requirements for advancement to:

FIRE CONTROLMAN SECOND CLASS (FC2)

Section I. Administrative	Date	Initials
1. Time in Rate - 12 months		
2. Pass E-5 military leadership examination		

Section II. Formal School and Training	Date	Initials
1. Study Guide for Fire Controlman (recommended)		

Requirements for advancement to:

FIRE CONTROLMAN FIRST CLASS (FC1)

Section I. Administrative	Date	Initials
1. Time in Rate - 3 years		

Section II. Formal School and Training	Date	Initials
1. Study Guide for Fire Controlman (recommended)		

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Figure 5-8.—Personnel Advancement Requirement form (PAR).

In planning the training program, the requirements of other shipboard training programs should be kept in mind. Cooperation with other divisions may make it possible for you to take advantage of their training programs for subjects such as damage control, personal hygiene, and first aid.

The major burden of instructing in a training program rests with the petty officers; therefore, each must become a well-qualified instructor to truly fulfill his/her role in the Navy. A natural tendency in the selection of an instructor for a particular subject is to choose the most qualified person on that subject. This may ensure the highest quality of instruction, but it tends to place the entire burden of instruction in the hands of a few senior petty officers, which may stifle the enthusiasm of the junior petty officers. To develop instructor ability at all division levels, make it a point to choose instructors from the ranks of the junior petty officers, and even the nonrated personnel.

To teach a subject, the instructor must be completely familiar with it; and, in the case of a junior petty officer, this will likely entail study that will benefit both the instructor and the group to be instructed. Provisions should be made in the training program for instruction in training techniques. Instructor training schools conduct courses of instruction in training techniques and should be used to form a nucleus of instructor-trained personnel. These personnel can be used as instructors for training the rest of the petty officers on board ship.

An important element of the training is the feedback from the trainees. One aspect of this includes instructor quality evaluation. A method of gaining this information from senior and junior trainees and supervisors is the critique sheet. Positive critical comments directed to the instructor will enable self-corrections to be made and training to improve.

Another aspect of training feedback is observed on-the-job performance by trainees. Is there evidence of poor technical performance on repair work, preventive maintenance, or any other activity for which the technician has been trained? The senior petty officers should be alert for signs of deficient knowledge levels when planning training.

Another method of determining the areas where training is needed is to conduct a survey of subject matters in which the technicians would like to receive training. Such a survey can provide valuable feedback for use in developing training plans. The results of advancement in rate examinations is another indication of areas where training might be needed. Very often these results are ignored even though weak areas of knowledge are pinpointed in the exam results that each person receives.

A training plan is easy to formulate considering the many available indicators of weaknesses. It is the proper execution of that training program that is the challenge. Your effectiveness will be readily seen in the skill level and morale of the people you have trained.

Types of Navy Technical Training

In carrying out training responsibilities, you should keep informed of the quotas and entrance requirements for naval schools that offer training in fire control. To motivate personnel to improve their general education, you should also be alert to programs and courses offered through the educational services office. Some of the types of technical training are listed in the following paragraphs.

SERVICE SCHOOL.—Navy schools fall into the three types:

- Enlisted service schools, class A, and class C schools, and other specific purpose schools
- Fleet schools at fleet shore-based training activities
- Short courses conducted by various type commanders and by mobile technical units (MOTUs)

Class A schools provide basic technical knowledge and skills required to prepare personnel for the lower petty officer rates. Class C schools train enlisted personnel in a skill that is usually related to a specific equipment or a special knowledge requirement.

FLEET TRAINING SCHOOLS.—Fleet training schools offer courses that provide training on equipment or training to increase the efficiency of a team (for example, naval gunfire support training). These course may also be used to provide strikers and petty officers with basic information in equipment operation.

SHORT COURSE.—Several type commanders conduct short courses of instruction in various electronic equipments. Training is given on a specific piece of equipment by a specialist in the field. The electronic equipment concerned is usually used for instruction providing real on-the-job training. The courses are short and the knowledge gained far outweighs the loss of time to the ship. The courses offered, their subject matter, and the frequency with which they are given, are governed by the requirements of the fleet. The information concerning courses is issued locally, and ships of a command are usually aware of them. When it is desired to have personnel instructed on a particular equipment for which a course does not presently exist, the need should be made known and a special course requested through the TYCOM. When in port, personal contact can be established by phone with training personnel at the TYCOM and at training facilities.

School is also conducted by mobile technical units (MOTU), both in classrooms ashore and OJT aboard ship. There is no catalog for these schools, but the type of school available can be determined from regular MOTU bulletins and by liaison with the local MOTU.

OBTAINING SCHOOL QUOTAS.—The *Catalog of Navy Training Courses* (CANTRAC), NAVEDTRA 10500, contains information on schools and courses under the purview of the Chief of Naval Education and Training and Amphibious Forces, Atlantic and Pacific, and other Navy training commands. OPNAVINST 1500.21B expanded Chief of Naval Education and Training's (CNET) responsibilities to provide for centralized production of CANTRAC to include all catalogs previously produced by separate commands.

The function of CANTRAC is to provide a consolidated, centrally produced and computerized catalog presenting courses in standardized form. CANTRAC is organized in three volumes (1, 2, and 3). Volume 1 is printed in hard copy, while volumes 2 and 3 are on 4 by 8 microfiche.

Volume 1—Introductory, General Information, and Quota Control Notes.—Volume 1 includes all general information not subject to frequent changes. Volume 1 is printed in hard copy and published annually. This volume is subdivided into three sections as follows:

Section I—Introduction; introductory comments; organization of CANTRAC; explanation of pertinent terms, headings, and course number breakdown.

Section II—General information on facilities. Lists such information as seasonal uniform changes, quarters availability, mess availability, and any other pertinent information relative to schools operated by the Navy. In some instances, information common to a single geographical area, schools command, or other training complex may be grouped under the activity to which it pertains.

Section III—Quota control notes. When sufficient information cannot be presented in the quota control segment of the course description, refer to this section of volume 1.

VOLUME 2—Cantrac Course Descriptions.—Format and revisions are as follows:

Catalog format. All courses are arranged in numerical sequence (disregarding the command identifier) by course identifying number (CIN).

Revision frequency. Volume 2 and volume 3 will normally be published every 3 months; however, the time between publications may be altered, contingent on the volume of changes received during that period.

VOLUME 3—Cantrac Convening Schedules.—A numerical index of CINs that gives course short title, short location, convening dates, and course data processing (CDP) number for each location. Some courses do not have regular convening dates, therefore none are given. In this case refer to the "Convening Information" segment within the course description. This volume is devoted to information subject to frequent change and will be published along with volume 2. This information is provided by the Navy Integrated Training Resources and Administration System (NITRAS).

KEYWORD INDEX.—The keyword index of course long titles is produced with each edition of the CANTRAC. Course titles are listed in alphabetical order by key words appearing in the title. Titles and related course numbers may appear five or six times in the index, depending on how many key words appear in the title. Course titles with identical key words are grouped together.

The following is a typical listing of logical steps that the division officer takes to support and obtain a school quota:

1. Determine the equipment on which personnel require training and where the school that can conduct the training required is located. Eliminate schools when personnel can be sufficiently trained by on-the-job or cross training.

2. Check and record training course information from the appropriate catalog. This listing should contain information on course scope, length, prerequisites, obligated service, location, convening dates, and security clearance required.

3. Plan school quota request well in advance of class convening dates.

4. List the ship's inport, yard, or availability periods. Correlate this list with the class convening dates to establish when personnel may be sent to the school with minimum loss of at-sea time.

5. Turn in to the operations officer these facts and the names of the personnel who will attend the schools, along with a request to TYCOM for school quotas. The request to TYCOM includes the following:

- Course number, location, desired convening date, and an alternate date

- Name, rate, social security number, NEC, SDCD (and/or PRD as appropriate) and EAOS, as extended, of candidate

- Present duty station of the candidate

The TYCOM provides funding for all equipment schools. Differences in the handling of the quota requests occur after TYCOM approval and are described in the following paragraphs.

The school quota request for an NMPC-controlled school is forwarded to the rating control section of NMPC. Providing there is a quota available, it will be returned by NMPC along with the type of quota, class convening date, and the authority for transfer. However, should the request be denied because of a fully assigned quota at the school at the time of request, the division officer should maintain liaison with the school to take advantage of any quota cancellations. If there has been a cancellation within 3 working days of the class convening date, NMPC will normally reassign the quota to be filled by the school. Further information on service schools is contained in the *Enlisted Transfer Manual*, NAVEDTRA 15909, and CANTRAC, NAVEDTRA 10500.

The division officer should verify the security clearance required for the school from CANTRAC, and ensure that the candidate's orders are annotated with the appropriate clearance.

Commander Training Command, U.S. Atlantic Fleet (COMTRALANT) quotas are filled by Fleet Training Center, Norfolk, Virginia, and Commander Training Command, U.S. Pacific Fleet (COMTRAPAC at San Diego, California (unless otherwise indicated).

As previously mentioned, school is also conducted by mobile technical units (MOTU). There is no catalog for these schools, but the type of school available can be determined by liaison with the local MOTU.

PERSONNEL QUALIFICATION STANDARDS (PQS).—PQS is a vital element of an overall unit training program for both afloat and aviation communities. As an element of training, PQS must be incorporated as the keystone program for unit watch station or work center qualification. To manage the PQS program effectively, the responsible officer should assign to each individual a specific qualification goal and the time frame expected for completion of the qualification. In this regard, the division officer and leading petty officer should conduct individual interviews with newly reported personnel to evaluate their past experience, qualifications (if any), and general background. After the PQS program has been explained, provide a PQS package and assign specific completion dates as to which fundamental, system, and qualification goals are to be accomplished. Also, give the individuals information as to how much time they should spend each week on training to accomplish the established goals. This procedure will permit the individuals to know *what* they are qualifying for and *when* they are required to have their qualification completed.

It should be emphasized, that after all the Navy service schools, fleet training schools, short courses, and correspondence courses, the Navy man or woman must still be PQS qualified to complete their training. This period of qualification in work center PMS, damage control, topside or below deck watches, and GQ or battle stations starts when reporting onboard and continues through enlisted surface warfare specialist (ESWS) and OOD in some cases.

A detailed description of PQS and its implementation may be found in the Personnel Qualification Standards (PQS) Manager's Guide, NAVEDTRA 43100-1.

NAVY CAMPUS PROGRAM AFLOAT.—The Navy campus voluntary education program for personnel assigned to a ship is called PACE (Program for Afloat College Education). Classes provided at sea are delivered under contract with civilian colleges and universities. The Navy campus contracts with universities, colleges, and junior colleges to provide academic and vocational courses to all fleet units. The educational services officer can find out what is available on your ship and when the courses will begin. If the ship is in port, the Navy campus education specialist can provide needed information.

THE NAVY CAMPUS FOR ACHIEVEMENT.—The Navy Campus for Achievement is an educational program designed to give every Navy person an opportunity for college education.

Under this program each person desiring a college degree has the opportunity of meeting with a professional education advisor to discuss academic background and ambitions and to develop an academic path or degree program designed especially to meet the individual's personal and professional goals. This program is used most when personnel are assigned ashore; however, yard periods often afford opportunities for on-campus instruction. Tuition aid and veterans assistance are often used to assist with tuition fees.

CORRESPONDENCE COURSE.—Correspondence courses are still another method of training. You should encourage all FCs to enroll in all applicable training courses. When they complete the required courses, they should be encouraged to take others that will help them when they take their examinations for promotion. Applications for correspondence courses are handled by the educational services officer.

Advancement of Enlisted Personnel

Practical experience gained from the performance of regular duties, and theoretical knowledge gained from instructional programs, manuals, and textbooks, gradually qualifies the enlisted person for higher levels of responsibility.

PERFORMANCE EVALUATION SYSTEM.—Divisional personnel should be recommended by the division officer for advancement in rate only if and when they are, in all respects, fully qualified to hold the higher rate. Advancements should not be made in the nature of rewards for faithful or extended service or simply because the minimum service requirements have been fulfilled. It is poor personnel administration to advance a person (or to recommend a person for a change in rating) to a position for which that person is not fully qualified.

Over the years, the Navy has endeavored to be selective in accepting personnel for enlistment. Therefore, the vast majority of enlisted personnel will be competent in the performance of their duties. The average Navy enlisted person is one whom any commanding officer would welcome into the command. To make the enlisted performance evaluation system successful, it is desirable to assume that each command has an average crew. The proportion of individuals who exceed or fall below the average in performance, then, would be about the same for all commands. For the overall good of the Navy, and in the interest of the great majority of enlisted personnel, the evaluation system should be related, in general, to the average crew concept.

One of the primary purposes of the evaluation system is to permit the commanding officer to influence positively the advancement opportunities of the individuals in the command. To make the performance factor in the final multiple for advancement effective, evaluations must differentiate between individuals so that credit is given according to demonstrated performance. Should all individuals be evaluated too highly, the ability to assist those individuals who are, in fact, outstanding will be reduced.

REPORT FORMS.—Another important purpose of the evaluation system is to provide specific factual information for use in selecting individuals for advancement, appointment to commissioned status, assignment to special duties, and for special education programs. NAVPERS Form 1616/24 (single sheet) is used to report performance evaluations on personnel E4 and below. NAVPERS Form 1616/24 (OCR set) is used to report the performance evaluation of enlisted personnel in paygrades E5 and above. Evaluations must be based objectively on the member's demonstrated performance and abilities as compared to the performance of that member's contemporaries. Therefore, it is of the utmost importance that enlisted evaluation reports be completely frank. Outstanding performance should be reported. Equally necessary is the thoroughly objective reporting of shortcomings, such as alcoholism, or other indications of unreliability. Knowledge of such shortcomings can be vital in the selection of personnel for duty assignment.

ENLISTED ADVANCEMENT EXAMINATIONS.—Servicewide examinations for advancement in rate are conducted on a semiannual basis for paygrades E4 through E6, and on an annual basis for paygrade E7. These examinations in each rating are developed by the Naval Education and Training Program Management Support Activity, Pensacola, Florida.

Military leadership examinations are standardized Navy wide, but are administered locally. Once this examination has been passed, the individual need not retake it, although he may have failed the rating examination or may not have passed the rating examination with a sufficient score to fill the quota allowance.

The *Manual of Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (with changes), is the basic reference regarding qualifications, along with other current instructions, notices, and publications.

COMBAT SYSTEM TRAINING

The complex interrelationships between combat system elements compounded by the normal attrition of personnel require development and continuous practice of combat system training programs at various levels to maintain a high state of personnel readiness.

Combat system personnel readiness is sustained through the frequent conduct of gunnery, missile, electronic warfare, and antisubmarine warfare exercises and a continuing program of individual and team training. The training support elements available for accomplishing these tasks are as follows:

- Ship and fleet operational training exercises. These cover all aspects of combat system training and personnel readiness evaluation.

- Training programs and simulators. These provide equipment operators with a controlled training and operational environment.

- Test programs and procedures. These provide training during conduct of high-level combat system and subsystem-level operability testing.

SHIP AND FLEET OPERATIONAL TRAINING EXERCISES

Ship and fleet operational training exercises are designed to meet a variety of training objectives. The most basic is the demonstration of ship personnel proficiency in detecting, tracking, and successfully engaging hostile threats. Instructions establishing specific training requirements are issued by a number of command activities and include training and evaluation procedures for the conduct of the following:

- Readiness and operational evaluations
- Composite training unit exercises
- Fleet exercise publication series
- Total Force Ship Training and Readiness Manual (TF STAR) exercises
- Electronic warfare exercises
- Second fleet exercises
- Battle readiness exercises and competition instructions

Readiness and Operational Evaluation Fleet

Fleet exercises are intended to provide the fleet with advanced training and to examine fleet capabilities and limitations in various aspects of warfare. Normally, the duration of the exercise is 8 to 10 days, with the first 3 or 4 days devoted to warm-up operations. The exercise scenario and emphasis on particular warfare areas are adjusted, as appropriate, to the number and type of participants and their state of training. Specific objectives of accomplishment in a given readiness and operational evaluation are published in the letter of instruction for that exercise. The broad objectives for all readiness and operational evaluation exercises are as follows:

- To train the fleet in various aspects of naval warfare, and confrontation at sea with emphasis on improving command and control

- To provide specialized predeployment training for anticipated operations while attached to the fleet

- To identify, measure, and analyze to a practicable extent fleet performance, capabilities, and limitations; and to develop recommended corrective action as appropriate

- To develop and test new tactics and doctrine

Composite Training Unit Exercises

The composite training unit exercise is an exercise intended to enhance the readiness of participating units, to provide predeployment training, to test and evaluate new doctrine and procedures, and to stimulate development of new concepts in naval warfare. Participants in composite training unit exercises must prepare in advance to effectively use the underway time. Exercise objectives are to be imaginatively pursued, and maximum time must be devoted to multiship operations. Time spent on fundamental evolutions is minimized. The objectives of a composite training unit exercise are as follows:

- To exercise participants in a multithreat environment to enhance their readiness

- To complete the maximum feasible TYCOM exercises required to achieve unit training readiness levels and special predeployment requirements

- To achieve unit familiarity and expertise in fleet report requirements and procedures required by higher authority

- To train in operations under the minimum radiation concept, radiating electronic and communication equipment only as necessary to accomplish a specific mission or task, or to ensure safety

- To train and increase proficiency in all aspects of operational security

Fleet Exercise Publications Series

The fleet exercise publications 1, 2, 3, and 3-2 series bring together in four publications the training prescribed for crews of all ship types. Fleet exercise publication 1 contains submarine and antisubmarine exercises; fleet exercise publication 2 contains air and antiair warfare (AAW) exercises; fleet exercise publication 3 contains ship exercises; and fleet exercise publication 3-2 contains a battle problem. Each publication contains safety precautions and exercise evaluation procedures. The force commander, unit commander, and commanding officers are encouraged to use these publications for the development of training programs designed to maintain maximum proficiency in the applicable mission of each ship as delineated in NWIP 11-20, *Missions and Characteristics of U.S. Navy Ships and Aircraft.*

FLEET EXERCISE PUBLICATION 1 (FXP-1).—This document contains exercises designed to familiarize antisubmarine warfare (ASW) personnel with basic doctrine, tactics, and weapons. The document also contains exercises designed to train air and surface units in coordinated operation against submarines, and to train air, surface, and submarine forces to operate under the direction of their shore-based headquarters.

FLEET EXERCISE PUBLICATION 2 (FXP-2).—This document contains exercises to train and evaluate gunnery personnel in detecting, tracking, and destroying antiair targets. In addition, the document provides exercises to train and evaluate missile weapon subsystem personnel in detecting, tracking, and destroying antiair targets and antiship missiles. The document also contains exercises for the evaluation of combat information center (CIC) personnel in intercept control and AAW operations.

FLEET EXERCISE PUBLICATION 3 (FXP-3).—This document contains exercises for training gunnery personnel in naval gunfire support, surface firing, and spotting. Antimine defense exercises and surface-to-surface missile training are included. In addition, exercises are provided for CIC personnel training and electronic warfare (EW) personnel training. This document also contains exercises for training in detecting and combating the antiship missile threat.

FLEET EXERCISE PUBLICATION 3-2 (FXP 3-2).—This document contains guidance in the preparation, conduct, and analysis of a battle problem. The document is part of the fleet exercise publication series because it is concerned with training. Fleet exercise publication 3-2 is more closely related to NWIP-50 because it is not accomplished in a step-by-step procedure as is the fleet exercise publication. The document provides a summary of factors that must be considered when setting up a battle problem. Included are details on making up the problem, selection of control personnel, methods of simulating realism, and evaluation procedures. The battle problem must be planned individually to fit the ship involved and to take into account the training state of the particular ship.

Figure 5-9 shows a sample of fleet exercises used to support naval gunfire support training. The figure lists the series exercise number, exercise title, and subsystems exercised, and it identifies the specific operational phase of the subsystem. The prefix Z indicates that the exercise is primarily designed for coordinated and surface ship exercises. The suffixes (in this case, G) signify the type of training the exercise is designed to provide. Other suffixes are AA, for antiair; ASCM Antiship cruise missile; CC, combat information; EW, electronic warfare; G, gunnery; GM, guided missile; SM, surface-to-surface; and U, for antisubmarine.

TRAINING PROGRAMS AND SIMULATORS

Various subsystems can employ computer training programs or simulators to provide

FXP series exercise	Title	Subsystem				Operational phase			
		Search radar	CDS	Gun weapon	Communication	Spot conversion	Computer solution and firing	Direct fire tracking	Star shell solutions and continuous illumination
Z-40-G	Counterbattery and Destructive			X	X		X	X	
Z-42-G[1]	Indirect Call Fire-SFCP or Air Spot			X	X	X	X		
Z-43-G[1]	Point Oscar and Offset Method of Fire			X	X	X	X		
Z-44-G[1]	Indirect Illuminating and Destructive Fire			X	X	X	X		X
Z-45-G[1]	Prearranged Indirect Area Fire			X	X	X	X		
Z-46-G[1]	D-Day Fires	X	X	X	X	X	X	X	
Z-48-G[1,2]	Combined Shore Bombardment/ Counterbattery/Surface AAW Exercise	X	X	X	X	X	X		
Z-49-G[1]	Naval Gunfire Support with Ship Maneuvering at High Speed in Restricted Area	X	X	X	X	X	X		
Z-51-G[1]	Emergency Indirect Call Fire-SFCP or Air Spot			X	X	X	X		
Z-52-G[1]	High-Speed (Hit and Run) Indirect Call Fire-SFCP or Air Spot			X		X	X	X	

Notes (services required):
[1]Shore fire control party or air spotter.
[2]One target drone, one surface drone unit.

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Figure 5-9.—Sample fleet exercises in support of training.

equipment operators with simulated operational environments for training purposes. The following paragraphs describe some of the available training capabilities (which are not applicable to all ships).

Video Signal Simulator (VSS)

The VSS is a search radar simulator that communicates with the command and control system (C&CS) operational program.

The VSS operates in conjunction with the C&CS data display group to provide CIC personnel with a realistic, controlled display of an operational environment for training of CIC console operator target entry and video tracking techniques. The training function of the C&CS operational program generates simulated track messages that control VSS generation of simulated radar video. Outputs from the VSS may be selected by console operators in the same manner as search radar outputs. The VSS produces the following outputs:

- Locally generated simulated video
- Mixed video (simulated and live radar video)
- Live radar video (routed through the VSS)
- Computer-controlled height data added to simulated video

The VSS may also provide an output to automatic detection and tracking (ADT) equipment to provide training for the ADT console operator.

C&CS Operational Program

The C&CS operational program contains a transient training module that can be used to control training exercises. The program operates in conjunction with the VSS to control the training exercises of own ship while conducting combat system operations using a simulated realistic training scenario. Software flexibility allows the training scenarios to be preprogrammed, controlled, and modified as desired by an operator functioning in the training supervisor mode. Specific training capabilities provided by the C&CS operational program include the following:

- Generation of air, surface, or subsurface simulated target positions. The behavior of the simulated targets is characteristic of operational air, surface, and subsurface targets.

- Record and playback capability for preplanned problems.

- Modifications of the speed, heading, or altitude/depth of the present parameters by the training supervisor or training input console operators (if on-line steering has been authorized).

- Transmission of simulated target position data to Link 11 participating units for force training.

- Receipt of simulated target position data from Link 11 net control station for force training.

AEGIS Combat Training System (ACTS)

The AEGIS combat training system is an integrated system designed to train a team of AEGIS combat system shipboard operators using on-line operator displays and controls. The combat system can be configured into a training mode that uses one bay of the AN/SPY-1A computer for a training program while sharing the AN/SPY-1A suite with a three-bay AN/SPY-1A computer program. Training is under control of the training supervisor. A training scenario, generated off ship, is recorded on tape and used aboard ship to provide a variety of AAW, ASW, and SUW warfare situations.

ACTS consists of scenario script generation, tactical team coordinated training (TTCT), and post-training analysis. TTCT is the on-line training configuration of the combat system that uses the scenario scripts. TTCT provides the training supervisor with the capability to centrally select and initiate the training scenarios for selected combat system operators and to control and monitor the entire training exercise. TTCT and tactical operations may occur concurrently within the combat system. Post-training analysis provides the capability to reduce training data recorded during TTCT operation and provides hard-copy output that is used by the training supervisor to evaluate operator team performance.

Guided Missile Simulators

On certain ships this simulator is referred to as training surface-to-air missile (TSAM); while on other ships, it is referred to as guided missile training round (GMTR). The guided missile simulator is used to train personnel in magazine loading, launcher operation, and missile launching. The guided missile simulator functionally checks the launcher and missile fire control system and the weapon direction system.

Radar Test Set

A radar test set generates video test targets that have characteristics of real targets. A test set contains displays and controls that operate with the missile fire control computer. This setup allows selection of test targets from either the test set or the fire control computer. Radar test sets have operator control features that allow the operator to manipulate the test target parameters, such as simulated jamming in a jamming environment.

Test Programs and Procedures

Many of the tests designed to verify operational capabilities of the combat system and individual subsystems provide operational training of equipment operators through the use of procedural instructions identical or similar to the actual tactical operating procedures. The degree of training provided for each subsystem varies as a function of the equipment used and the testing philosophy existing in each subsystem.

SUMMARY

If the Navy is to accomplish its missions as efficiently as possible, enlisted persons as well as officers must eagerly increase their progressional knowledge and willingly assume more important positions with the accompanying increased responsibilities.

The objective of a training program is to increase the ability of personnel to administer and operate the ship effectively under all foreseeable circumstances. *Standard Organization and Regulations of U.S. Navy* (OPNAVINST 3120.32) discusses various aspects of shipboard training programs, including organization, administration, scheduling, application, and evolution. It also lists several other publications of considerable training value.

Training on a divisional level may be divided into two phases: (1) the basic training, team training, and drills necessary to develop the teamwork of a crew, and (2) training in the form of assistance to enlisted personnel in their preparation for advancement. The first phase usually is well developed in the ship's training program and will, naturally, take more of the training time; however, the latter phase must not be ignored and left up to the individual person because there are a few who need extra motivation and varying degrees of supervision.

A good training program with good instructors and supervised by an enthusiastic officer or training PO eventually will build an outstanding division of which all concerned will be justly proud.

APPENDIX I

ACRONYMS AND ABBREVIATIONS

AA	Antiaircraft, air action
AAC	Antiair common
AAW	Antiair warfare
AC	Alternating current/air conditioning
ACTH	Arbitrary correction to hit
A/D	Analog-to-digital conversion
ADCU	Audio directional coupler unit
AER	Alteration equivalent to a repair
AEW	Airborne early warning
AFT	After
AIC	Airborne intercept controller
AIMS MK XII	Air Traffic Control Radar Beacon System, Identification Friend or Foe Mk XII System
AIR CNTRL (AIC)	Air controller
AIR COND	Air-conditioner
AIR DET-TKR	Air detector-tracker
AM	Amplitude modulation
AMR	Assign missile radar
AMS	Alteration Management System
AMT	Amalgamated Military and Technical Improvement Plan
AMW	Amphibious warfare
ANLC	Automatic noise limiting control

ANT	Antenna
AOA	Angle of arrival
APP	Antipersonnel projectile
ASAC	Antisubmarine air controller
ASCM	Antiship cruise missile
ASMD	Antiship missile defense
ASPECT	Acoustic short pulse echo classification technique
ASROC	Antisubmarine rocket
ASU	Antisurface warfare
ASW	Antisubmarine warfare
ASWO	Antisubmarine warfare officer
ATDS	Airborne Tactical Data System
ATN	Auto track number
ATP	Allied tactical publication
AVAP	Audio visual alarm panel
BAT	Battle
BCD	Binary coded decimal
BD	Base detonating
BIT	Built-in test
BITE	Built-in test equipment
BOL	Bearing-only-launch
BT	Bathythermograph
BVP	Beacon video processor
C152	Digital Computer Mk 152
CA	Control amplifier
CAP	Combat air patrol
CBCU	Casualty battery control unit

CCC	Command, control, and communication
CFAR	Constant false alarm rate
CFM	Cubic feet per minute
CFR	Course frequency receiver
CHAN	Channel
CHT	Chemical holding tank
CIC	Combat Information Center
CIGARS	Console internally generated and refreshed symbols
CIWS	Close-In Weapons System
CL	Centerline
CMPTR	Computer
COC	Control officer console
COH	Complex overhaul
COM	Common
COMM	Communication
CONREP	Connected replenishment
CONT	Control
COSRO	Conical scan on receive only
CP	Control processor
CPA	Closest point of approach
CPM	Centrally procured material
CPU	Central processor unit
CPV	Clutter predict voltage
CR	Clutter reject
CRO	Cathode-ray tube readout
CRT	Cathrode-ray tube
CSCM	Cease-fire contact maker

CSFID	Combat system functional interface diagram
CSITT	Combat system interface test tool
CSL	Console
CSMMT	Combat system maintenance management team
CSMP	Current ship maintenance project
CSO	Combat system officer
CSOD	Combat system operational design
CSTOM	*Combat System Technical Operations Manual*
CTS	Communication tracking set
CTSL	Common track stores locators
CU	Control unit
CVT	Controlled variable time
CW	Continuous wave
CWDP	Casualty weapon direction panel
CWI	Continuous wave illumination
CWI XMTR	Continuous wave illumination transmitter
CZ	Convergence zone
D/A	Digital-to-analog conversion
DC	Direct current/damage control
DCC	Display and control console
DCU	Data conversion unit, digital control unit
DDG-TDS	Guided missile destroyer—tactical data system
DDI	Digital display indicator
DDR	Digital data recorder
DEGUSG	Degaussing
DET-TKR MON	Detector-tracker monitor
DK	Dicke fix

DFC	Direction frequency correlator
DFR	Direction-finding receiver
DIO	Digital input/output
DIR	Director
DISCH	Discharge
DLRP	Data link reference point
DME	Distance measuring equipment
DOA	Direction of arrival
DPC	Data processor computer
DPU	Digital processor unit; data processor unit
DRAI	Dead reckoning analyzer indicator
DRT	Dead reckoning tracer
D/S	Digital-to-synchro conversion
DS	Display module; data systems
DSOT	Daily system operability test
DTRM	Dual-thrust rocket motor
DTU	Digital tracking unit
EAT	End around test
EC	Engagement controller
ECC	Executive and coordination control
ECCM	Electronic counter-countermeasures
ECM	Electronic countermeasures
EF	External function
EFC	Electronic frequency converter
EHI	Engage HARPOON immediately
EHO	Engage HARPOON order
ELSCAN	Elevation scan
EMC	Electromagnetic compatibility

EMCON	Emission control
EMI	Electromagnetic interference
EMO	Engage missile order; electronics material officer
EOC	Engineering operating cycle
EQPT	Equipment
ES	Equipment scheduling
ESM	Electronic support measures
ESO	Engage STANDARD order
EW	Electronic warfare
EW SUP	Electronic warfare supervisor
EWRR	Estimated weapon release range
EX	Executive module
EXCOMM	External communications
EXS	Executed scheduler
FAB	Fixed action button
FAC	FCS assignment control
FANFARE	Torpedo Countermeasure System
FAS	Fuel-at-sea
FCS	Fire control system
FCSC	Fire control system coordinator
FFT	Fast fourier transform
FLD	Fault logic diagrams
FLMB	Flammable
FM	Frequency modulation
FMP	Fleet modernization program
FO	Fuel oil
FR	Frame

FR/FL	Fault recognition/fault location
FSO	Fleet support operations
FTC	Fast time constant
FWC	Force weapon coordinator
FWD	Forward
FXP	Fleet exercise publication
GCC	Gun control console
GFC SWBD	Gun fire control switchboard
GFCC	Gun fire control computer
GFCS	Gun fire control system
GLO	Gun liaison officer
GMFCS	Guided Missile Fire Control System
GMLS	Guided Missile launching system
GMT	Greenwich mean time
GMTR	Guided missile training round
GPETE	General-purpose electronic test equipment
GRR	Graphic range recorder
GTL	Gun target line
GWS	Gun weapons system
HAW	Home all the way
HC	High capacity
HCC	HARPOON control console
HE	High explosive
HE/MTPD	High explosive/mechanical time point detonating combination projectile
HERF	Hazards of electromagnetic radiation to flammable materials
HERO	Hazards of electromagnetic radiation to ordnance

HERP	Hazards of electromagnetic radiation to personnel
HF	High frequency
HFCS	HARPOON fire control system
HNDLG	Handling
HOJ	Home on jamming
HRT	HARPOON relay transmitter
HRTE	Harbor radio telephone exchange
HS	Horizon search
HSCLCS	HARPOON ship command launch control set
HT/SZ	Height/size
HVPS	High-voltage power supply
HWCIP	HARPOON weapon control indicator panel
HWS	HARPOON weapon system
Hz	Hertz
I	Intercommunication
IADT	Integrated automatic detection and tracking
IAGC	Instantaneous automatic gain control
IC	Interior communications
IDD	Interdirector designation
IF	Intermediate frequency
IFF	Identification friend or foe
IFM	Instantaneous frequency measurement
ILLUM	Illuminating (Starshell)
ILS	Integrated logistic support
IMA	Intermediate maintenance activities
INT/INTEL	Intelligence
I/O	Input/output

IOA	Input/output adapter
IOC	Input/output controller/console
I/O CSL	Input/output console
I/OSP	Input/output signal processing
IR	Infrared
ISA	Ignition and separation assembly
ISD	Intrasystem designation
ITL	Intent to launch
IV	Initial velocity
KEYSET	Digital data introducer
kW	Kilowatt
LAMPS	Light Airborne Multipurpose System
LAMS	Launcher and missile simulator
LCCP	Launcher captain's control panel
LCHR	Launcher
LED	Light-emitting Diode
LET	Leading edge tracking
LF	Low frequency
LFDM	Low-flyer detection mode
LIPS	Line independent power supply
LIQ	Liquid
LO	Lubricating oil, local oscillator
LOF	Line of fire
LOP	Line of position
LOS	Launch on search
los	Line of sight
LPD	Launch platform detected

LRM	Long-range mode
LS	Launching system
LSB	Least significant bit
LSM	Launching system module
LVL	Level
mA	Milliampere
MACCS	Marine Air Command and Control System
MACH	Machine
MAD	Magnetic anomaly detection
MAG	Magazine
MC	Microphone control
MDCS	Maintenance Data Collection System
MDS	Minimum discernable signal
MEC	Missile engagement controller
MED	Medical
MEM	Memory
MF	Medium frequency
MFC	Missile fire control
MFCC	Missile fire control computer
MFCS	Missile fire control system
MG	Motor generator
MI	Mutual interference
MIF	Missile in flight
MIL	Milliradian
MIP	Maintenance index page
MOB	Mobility
MPI	Mean point of impact

MR	Missile radar
MRC	Maintenance requirement card
MSB	Most significant bit
MSS RTF	Missile system summary—ready to fire
MT	Mechanical time
MTI	Moving target indicator
MTT	Mobile training team
MUX	Multiplexer
mW	Milliwatt
NAVMACS	Naval Modular Automated Communication System
NAVREF	Navigation reference
NAVSEA	Naval Sea System Command
NC-2	Plotting Table Mk NC-2 Mod 2A
NCO	Noncombat operations
NGFS	Naval gun fire support
NLP	Narrow-band, long pulse
NMI	Nautical miles
NNSS	Naval Navigation Satellite System
NTDS	Naval Tactical Data System
OA	Order assign
OCSOT	Overall combat system operability test
ODT	Omnidirectional transmission
OE, OFE	Order, engage
OMEGA	Navigation Set AN/SRN-12
OOD	Officer of the Deck
OPN	Operation
OSMOS	Own-Ship motion simulator

OTH	Over the horizon
OTL	Observer-target line
OTS	Over the side
PAC	Preaction calibration
PAIR	Performance and integration retrofit
PAT	Passive angle track
PD	Point detonating
PDP	Power distribution panel
PERA	Planning and engineering for repairs and alterations
PI	Position indicator
PIM	Position of intended movement
PLTHS	Pilothouse
PMA	Phased maintenance availability
PME	Performance monitor equipment
PMFL	Performance monitoring and fault location
PMS	Planned maintenance system
P/O	Part of
POFA	Programmed operational functional appraisals
PPE	Programmable processing element
PPI	Plan position indicator
PRI	Pulse repetition interval
PRO	Plotting room officer
PRR	Pulse repetition rate
PRT	Pulse repetition time
P&S	Port and starboard
PSC	Program sequence controller
PSI	Pounds per square inch

PU	Participating unit
QA	Quality assurance
QR	Quick reaction
QRN	Quick reaction number
RA	Restricted availability
RAM	Random access memory
RAP	Rocket assisted projectile
RAS	Replenishment at sea
RBCC	Radar beam control converter
RBL	Range and bearing launch
RC	Radar controller
RCVR	Receiver
RDF	Radio direction finding
RDP	Radar data processor
RDRO	Remote data readout
RDS	Radar distribution switchboard
RDT	Rotational directional transmission
RF	Radio frequency, rapid fire, range finder
RFTTG	Radio frequency test target generator
RHI	Range height indicator
RM	Room
RNG	Range
ROH	Regular overhaul
ROM	Read only memory
ROS	Remote optical sight
RPM	Revolutions per minute
RS	Recommend scheduler

RSC	Radar set console
RSR	Ready-service rings/rounds
R/T	Radiotelephone
RTF	Ready to fire
RTP	Relative threat priority (number)
RVC	Radar video converter
SAIL	Ship's Armament Inventory List
SAMIS	Ship's Alteration Management Information System
SARP	Ship's alteration repair package
SATNAV	Radio navigation (satellite)
SC	Signal converter
SCV	Sub Clutter Visibility
S/D	Synchro-to-digital conversion
SDC	Signal data converter
SDF	Surface direct fire
SDM	System data monitor
SDT	Signal data translator
SDT	Steered directional transmission
SECAS	Ship's Equipment Configuration Accounting System
SERT	Ship electronic readiness team
SFOMS	Ship's Force Overhaul Management System
SHARPS	Ships, Helicopter Acoustic Range Prediction System
SIF	Selective identification feature
SIG	Signal
SIMA	Shore intermediate maintenance activity
SIOC	Serial input/output controller

SLQ-32	Electronic countermeasures set
SLT	Search light transmission
SM	STANDARD missile
SND	Sound
SO	Surface operations
SOF	SWC order fire
SP	Sound powered
SPM	Special program material
SRA	Selected restricted availability
SRA	Slip ring assembly
SRBOC	Super Rapid Bloom Offboard Chaff Launching System, Mk 36 Mod 1
SRF	Ship repair facility
SS	Sector search
SSM	Surface-to-surface missile
STC	Sensitivity time control
STREAM	Standard tensional replenishment alongside method
STRM	Storeroom
SURF	Surface
SWBD	Switchboard
SWC	Ship weapon coordinator
SYS-1 or 2	Integrated Automatic Detection and Tracking System, AN/SYS-1 or 2
TA	Technical availability
TACAN	Tactical air navigation; naviagation set
TAO	Tactical action officer
TCD	Target-to-center display
TDD	Target detonating device

UTM	Universal transverse Mercator
UYK-7	Computer Set AN/UYK-7
UYK-20	Computer Set AN/UYK-20
VAB	Variable action button
VAC	Volts alternating current
VDC	Volts direct current
VECG	Video extractor and control group
VERTREP	Vertical replenishment
VHF	Very high frequency
VLF	Very low frequency
VNR	Variable navigation ratio
VP	Video processor
VR	Voyage repairs
VT	Variable time
WA	Weapon assignment
WCC	Weapon control console
WCIP	Weapon control indicator panel
WCS	Weapon control station
WDS	Weapon direction system
WEC	Weapon engagement coordinator
WP	White phosphorus
WSF	Weapon system file
WSN-5	Inertial Navigation Set AN/WSN-5
WSP	Wideband, short pulse
WTI	Weapon train indicator
XFR	Transfer
XMTR	Transmitter

TDS	Tactical data system
TDT	Target designation transmitter
TE	Threat evaluation
TIA	TYCOM issued alterations
TLC	Troubleshooting logic charts
TMA	Target motion analysis
TMDER	Technical Manual Deficiency Evaluation Report
TPA	Target position analyzer
TRK SUP	Track supervisor
TS	Test set
TSS	Time signal set
TTB	Target triggered burst
TT Mk 32	Torpedo Tube Mk 32
TTM	Test transmit mode
TTW	Time to wait
TTY	Teletypewriter
TV	Television
TW	Threat evaluation/weapon assignment module
TWS	Track while scan
TWS	TOMAHAWK Weapons System
UBFCS	Underwater battery fire control system
UF	Utility functions module
UFC	Underwater fire control
UFCS	Underwater fire control system
UFC SWBD	Underwater fire control switchboard
UHF	Ultrahigh frequency
UNREP	Underway replenishment

APPENDIX II

GLOSSARY

AA.—Abbreviation for AntiAircraft or Air Action.

ACCELEROMETER.—An instrument that measures one or more components of the changes in speed of a moving body in which the instrument is contained.

ACQUISITION.—The location, lock-on, and commencement of automatic tracking of a target by a fire control radar.

ACTIVE JAMMING.—International radiation or reradiation of electromagnetic energy with the intention of impairing the use of that band.

AERODYNAMICS.—The science that deals with the motion of air and other gases and with the force acting on bodies moving through these gases.

AIDED TRACKING.—A system of tracking a signal in azimuth, elevation, or range, in which a constant rate of motion of the tracking mechanism is maintained by mechanical means so that an equivalent constant rate of motion of the target can be followed.

AIRBURST.—An explosion of a projectile above the surface as distinguished from an explosion on contact with the surface or after penetration.

AIR-CONTROL PANEL.—Panel that monitors the dry-air input at each user equipment.

AIRFRAME.—The main structure of an aircraft or missile. It includes the framework and skin but not the engines or internal components.

ALIGNMENT.—Procedures that establish a prescribed angular relationship between the combat system equipment and attain accurate transmission of equipment position quantities. The prescribed angular relationship between equipments is established by leveling each equipment to an own-ship reference plane and aligning each equipment to an alignment reference.

ALIGNMENT CHECKS.—Procedures that are conducted to verify that an equipment is aligned to its reference within a specified tolerance. Alignment checks are made by comparing the indicated angular position of the nonreference equipment to that of the alignment reference when their pointing lines are parallel.

ALIGNMENT REFERENCE.—An equipment used as the reference when aligning other combat system equipment in train and elevation.

ALIGNMENT REQUIREMENTS.—Alignment requirements are based on the accuracy of the equipment and subsystems of the total combat system. Equipment and subsystem alignment requirements are dictated by the overall requirement of the operational mode that demands the most accurate alignment between equipments.

ALIGNMENT TELESCOPE.—An optical telescope mounted on a piece of equipment for alignment purposes. The optical axis of the telescope represents the mechanical angular position of the equipment.

ALPHANUMERIC.—Pertaining to a character set that contains both letters and digits.

ALTITUDE.—The vertical distance of an aircraft or object above a given reference, such as ground or sea level.

AMBIGUOUS RETURNS.—Echoes that exceed the PRT of a radar and appear at incorrect ranges.

ANALOG.—Being continuous or having a continuous range of values, as opposed to a discrete set of values.

ANGULAR VELOCITY.—A quantity related to rotational motion. Its instantaneous value is a vector whose magnitude is the rate of change of an angle θ, with respect to time t.

ANTENNA BEAMWIDTH.—Angular width of a radar beam measured between half-power points.

ANTENNA SYSTEM.—Routes rf energy from the transmitter, radiates the energy into space, receives echoes, and routes the echoes to the receiver.

ANTIJAMMING CIRCUIT.—Electronic circuit used to minimize the effects of enemy countermeasures, thereby permitting radar echoes to be visible on the indicator.

ANTITRANSMIT-RECEIVE TUBE (ATR).—Tube that isolates the transmitter from the antenna and receiver. Used in conjunction with a TR tube.

A-SCOPE.—A radar display on which slant range is shown as the distance along a horizontal trace.

ASPHYXIA.—The lack of oxygen or excess of carbon dioxide that causes unconsciousness and subsequently, death.

ASPHYXIATION.—The loss of consciousness because of a lack of oxygen or an excess of carbon dioxide in the blood.

ASYNCHRONOUS.—Not relating to any particular frequency of the system to which it is connected.

ATTENUATION.—A decrease in magnitude in transmission from one point to another.

ATTITUDE, MISSILE.—The position of a missile as determined by the inclination of its axes to its designed frame of reference.

AUTOMATIC GAIN CONTROL (AGC).—A control circuit that automatically changes receiver gain so that output signals remain relatively constant with variations in input signal strength.

AUTOPILOT.—A system that detects deviations in the flight of an aircraft and applies the required corrections to the steering controls; also called automatic pilot.

AVERAGE POWER.—Output power of a transmitter as measured from the start of one pulse to the start of the next pulse.

AXIS.—A straight line, either real or imaginary, passing through a body around which the body revolves.

AZIMUTH.—Angular measurement in the horizontal plane in a clockwise direction.

BANDWIDTH.—The range of frequencies an amplifier can amplify without causing unacceptable distortion to the input signal.

BATTERY ALIGNMENT.—The alignment of weapons and fire control equipment to a common system of reference lines and planes under specified conditions.

BEACON.—A radar signal transmitter used to establish a reference point; commonly used for shore bombardment.

BEAM-RIDER.—A missile that follows a radar or other rf energy beam directed at the target.

BEARING RESOLUTION.—Ability of a radar to distinguish between targets that are close together in bearing.

BEAT FREQUENCY.—One of the two additional frequencies produced when two different frequencies are combined. One of these beat frequencies is the sum, and one is the difference of the two original frequencies.

BENCH MARK.—A permanent reference target established by surveying. Its position, with respect to an equipment, is recorded in the smooth log, enabling the shipyard and ship force personnel to check alignment or adjust transmitting components at future dates without repeating the complete alignment procedure.

BINARY.—Having two values or states. The binary number system has two digits.

BIT.—Abbreviation for binary digit. A unit of information equal to one binary decision, or the designation of one of two possible and equally likely values or states (such as 1 or 0) of anything used to store or convey information. It may also mean "yes" or "no."

BLANKING.—The cutting off of the electronic beam in a cathode-ray tube during the time when the picture is not being formed. The beam is blanked while the spot is returning to the starting position (normally right to left).

BOOSTER.—An auxiliary or initial propulsion system that travels with a missile or aircraft and which may or may not separate from that craft when its impulse has been delivered.

BOOST PHASE.—The initial portion of a missile's flight during which it attains its flight speed.

BORESIGHT TELESCOPE.—An optical instrument mounted in a gun bore or on an equipment for alignment purposes. The optical axis of the boresight represents the pointing line of a gun mount or other equipment.

BROADSIDE ARRAY.—An antenna array in which the direction of maximum radiation is perpendicular to the plane of the array.

BURN-THROUGH RANGE.—The distance at which a specific radar can discern targets through the external interference being received. (The interference is normally associated with jamming.)

BUS.—A heavy, rigid metallic conductor used to carry a large current or to make a common connection between several circuits; also called bus bar.

BYTE.—A binary character string operated upon as a unit and usually shorter than a computer word. Frequently connotes a group of eight bits.

CANISTER (LAUNCHER).—A replaceable cylindrical shell structure that contains the launch rail and acts as a storage magazine.

CANNIBALIZE.—To remove usable parts from one piece of equipment for use in repairing another piece of equipment.

CARDIOPULMONARY RESUSCITATION (CPR).—The collective term for restoring breathing and/or the heartbeat of a person.

CENTERLINE REFERENCE PLANE (CRP).—The plane that contains the ship's centerline and is perpendicular to the master reference plane. This plane is used as the reference for establishing train zero for all equipment aboard ship.

CHAFF.—Bits of radar reflective material, such as metal foil, that are released in the air to mask the flight of an aircraft or confuse and clutter the radar picture.

CHARACTER.—A symbol, letter, or numeral.

CHIP.—Another name for an integrated circuit.

CIRCUIT.—A combination of electrical and/or electronic components connected together to perform a specified function.

CIRCULAR MIL.—A unit of area equal to the area of a circle whose diameter is 1 mil (0.001 inch). Used mainly in specifying cross-sectional areas of round conductors. Circular mil = 0.7854 square mil.

CLEAR.—To reset, as in the case of a flip-flop, counter, or register.

CLINOMETER.—A precision instrument used for measuring equipment roller path inclination. Normally in the custody of support activities. (Also called a gunner's quadrant.)

CLOCK.—The basic timing signal in a digital system. A device that generates periodic signals used for synchronization.

CLUTTER.—Confusing, unwanted echoes that interfere with the observation of desired signals on a radar indicator. Radar return from rain, clouds, land, sea, or other unwanted objects.

COLLIMATION.—The technique of bringing two optical or radio frequency (rf) axes (or a combination of optical and rf axes) into parallelism, including both the measurement and correction of errors. An example of rf-to-optical collimation is the alignment procedure for the tracking axis of a telescope mounted on the director. Collimation of two telescopes is making their optical axes parallel by sighting the projected reticle of one telescope with the other telescope when both are focused at infinity.

COMBAT SYSTEM ALIGNMENT.—Procedures necessary to establish parallelism between combat system equipment axes when the angles defined by their position transmitting components are equal. In the shipyard, combat system alignment is achieved by leveling each equipment to the weapon control reference plane and aligning each equipment to the alignment reference.

COMPUTER LANGUAGE.—The method or technique used to instruct a computer to perform various operations.

CONAR.—Acronym for Commanding Officer's Narrative Report.

CONICAL SCANNING.—Scanning in which the movement of the beam describes a cone, the axis of which coincides with that of the reflector.

CONICAL SCAN ON RECEIVE ONLY (COSRO).—A radar feature which, instead of physically scanning the antenna beam on transmission to derive target angle information, processes (or scans) the received signal to derive angle data.

CONTACT.—In radar, an object that reflects rf energy (target).

CONTINUOUS WAVE ILLUMINATOR (CWI).—Provides target illumination for semiactive homing missiles. Continuous wave refers to the continuous transmission of the illumination beam.

CORE.—A magnetic memory element.

COUNTER.—A digital circuit capable of counting electronic events, such as pulses, by progressing through a sequence of binary states.

CPU.—Abbreviation for central processing unit, a main component in computers.

CRUISE MISSILE.—A guided missile, the major portion of whose flight is at an approximately constant velocity.

D/A CONVERSION.—A process whereby information in digital form is converted into analog form.

DATA.—Information in numeric, alphabetic, or other forms.

DATA LINK.—Equipment for automatically transmitting and receiving information in digital form.

DATA TRANSMISSION.—The transfer of information from one place to another or from one part of a system to another.

DATA TRANSMISSION ALIGNMENT.—Procedures necessary to ensure that all components that transmit or receive system quantities are aligned within tolerance.

DCAP.—Acronym for Deficiency Corrective Action Program.

DECADE COUNTER.—A digital counter having 10 states.

DECODE.—To determine the meaning of coded information.

DESICCANT.—A drying agent (as silica gel or calcium chloride).

DESIGNATION.—Operational phase of a fire control or track radar during which the radar is directed to the general direction of a desired target.

DESIGNATION, TARGET.—The selection of targets that are to be engaged and transmission of the position information required for acquisition by the fire control radar or radars.

DIELECTRIC.—The insulating material between the metallic elements of an electromechanical compound or any of a wide range of thermoplastics or thermosetting plastics.

DIFFERENTIAL AMPLIFIER.—An amplifier having two similar input circuits connected so that they respond to the difference between two voltages or currents, but effectively suppress like voltages or currents.

DIGIT.—A symbol representing a given quantity in a number system.

DIGITAL.—Related to digits or discrete quantities.

DIP ANGLE.—D = 0.98 × h where h is expressed in feet above the centerline and D is given in minutes of arc.

DIRECTIONAL ANTENNA.—An antenna that radiates most effectively in only one direction.

DIRECTIVE.—An instruction (order), notice (bulletin), or change transmittal. It prescribes or establishes policy, organization, conduct, methods, or procedures essential to the effective administration or operation of activities concerned.

DIRECTIVITY.—Ability of an antenna to radiate or receive more energy in some directions than in others. The degree of sharpness of the antenna beam.

DMA.—Abbreviation for direct memory access.

DOPPLER EFFECT.—Frequency shift of a radiated signal (sound or radio) due to the relative motion between the source and the receiving point.

DOPPLER FREQUENCY.—Difference between transmitted and reflected frequencies caused by the Doppler effect.

DOWN LINK.—Radio communication from a missile to its control or launching point. It normally contains flight information.

DRY-AIR SYSTEM.—Provides dehumidified air for electronic equipment that is moisture critical.

DSOT.—Abbreviation for Daily System Operability Test.

DUCTING.—Trapping of an rf wave between two layers of the Earth's atmosphere or between an atmospheric layer and the Earth.

DUD/DUDDING.—Internal malfunctioning of a missile that prevents proper execution of all phases of missile launching and flight.

DUMMY LOAD.—A device used at the end of a transmission line or waveguide that converts the rf energy into heat and dissipates it. In this way, no rf energy is radiated out nor reflected back to its source.

DUPLEX.—Bidirectional transmission of data along a transmission line.

DUPLEXER.—A radar device that switches the antenna from the transmitter to the receiver and vice versa.

DUTY CYCLE.—Ratio of transmitted pulse width to pulse repetition period. In a transmitter, ratio of time on to time off.

ECHO.—Signal received by a radar as a result of the reflection of a transmitted pulse from objects in the field of scan.

ELECTROMAGNETIC COMPATIBILITY (EMC).—The capability of electronic equipment and systems to operate in the intended environment at designated levels of efficiency without degradation due to unintentional interference.

ELECTROMAGNETIC INTERFERENCE (EMI).—Impairment of the reception of a wanted electromagnetic signal caused by an electromagnetic disturbance, either intentional or unintentional.

ELECTRONIC COUNTER-COUNTERMEASURES (ECCM).—That division of electronic warfare involving actions taken to ensure friendly, effective use of the electromagnetic spectrum, despite the enemy's use of electronic warfare.

ELECTRONIC COUNTER-COUNTERMEASURES (ECCM) CIRCUITS.—See antijamming circuit.

ELECTRONIC COUNTERMEASURES (ECM).—That division of electronic warfare involving actions taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum.

ELECTRONIC FREQUENCY COUNTER.—An instrument that counts the number of cycles (pulses) occurring during a precise time interval.

ELECTRONIC SCANNING.—Scanning in which the axis of the beam is moved, relative to the antenna axis, in a desired pattern.

ELECTRONIC WARFARE (EW).—Action involving the use of electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum, and action that retains friendly use of the electromagnetic spectrum. There are three divisions within electronic warfare: electronic warfare support measures, electronic countermeasures, and electronic counter-countermeasures.

ELECTRONIC WARFARE SUPPORT MEASURES (ESM).—That division of electronic warfare involving actions taken to search for, intercept, locate, and identify immediately radiated electromagnetic energy for the purpose of immediate threat recognition.

ELEVATION ANGLE.—The angle between the horizontal plane and the line sight.

ELEVATION ZERO.—Elevation position at which the boresight axis and the elevation trunnion are parallel to the equipment roller path plane within prescribed tolerances.

EMERGENCY POWER.—Temporary source of limited electrical power used upon the loss of the normal power source.

EMISSION CONTROL (EMCON).—(1) The management of electromagnetic radiations to counter an enemy's capability to detect, identify, or locate friendly emitters for exploitation by hostile action. (2) Controlling the radiation of an active system, such as a radar, so that it emits energy only when absolutely necessary to perform its mission.

ENABLE.—To activate or put into an operational mode.

ENGAGEMENT, TARGET.—Collectively, all actions taken to destroy an enemy (target). This may include, but not be limited to, tracking, illumination, and weapon launching and control.

FALL TIME.—The time interval between the 90-percent point to the 10-percent point on the negative-going edge of a pulse.

FAST-TIME-CONSTANT (FTC) CIRCUIT.—Differentiator circuit in the first video amplifier that allows only the leading edges of target returns, no matter how small or large.

FEEDBACK.—In a transmission system or a section of it, the returning of a fraction of the output to the input.

FEEDHORN.—A horn-type radiator that can be directed into a parabolic reflector.

FLIP-FLOP.—A bistable device used for storing a bit of information.

FORACS.—Acronym for Fleet Operational Readiness Accuracy Check Site.

FREQUENCY.—The number of pulses in 1 second for a periodic waveform. Expressed in hertz (Hz) or pulses per second (pps).

FREQUENCY AGILITY.—This term refers to a radar's ability to change frequency within its operating band. Pulse-to-pulse frequency shift or changing the transmitter frequency radically during every interpulse is the ultimate in frequency agility.

FREQUENCY DIVERSITY.—Method of transmission and/or reception using a number of frequencies simultaneously to minimize the effects of selective fading, deliberate jamming, or interference.

FREQUENCY SCANNING.—Varying the output frequency to achieve electronic scanning.

FREQUENCY SPECTRUM.—In a radar, the entire range of frequencies contained in an rf pulse or signal.

FREQUENCY SYNTHESIZER.—A bank of oscillators in which the outputs can be mixed in various combinations to produce a wide range of frequencies.

FULL-DUPLEX.—Simultaneous bidirectional transmission of data on a transmission line.

FUZE.—A device designed to initiate a detonation of a weapon under the conditions desired, such as by impact, elapsed time, proximity, or command.

GAIN.—Any increase in the strength of a signal.

GROUND CLUTTER.—Unwanted echoes from surrounding land masses that appear on a radar indicator.

GROUND RANGE.—The distance on the surface of the Earth between a radar and its target. Equal to slant range only if both radar and target are at the same altitude.

GUIDANCE RADAR.—System that provides information that is used to guide a missile to a target.

GUN TRAIN ORDER.—A signal transmitted to the guns indicating the angle in the reference plane from own ship's bow clockwise to the perpendicular plane through the axis of the bore.

GYRO.—Abbreviation for gyroscope.

GYROSCOPE.—A mechanical device containing a spinning mass mounted so that it can assume any position in space.

HANG FIRE.—An accidental-delayed ignition of primer, igniter, or propelling charge.

HEIGHT FINDER.—A radar set that measures and indicates the height of an airborne object.

HEIGHT-FINDING RADAR.—Radar that provides target altitude, range, and bearing data.

HEMISPHERICAL SEARCH.—Another term for three-dimensional search (radar).

HITS PER SCAN.—The number of times an rf beam strikes a target per antenna revolution.

HOME ON JAM.—A missile mode of operation in which the target's jamming signal is used as the source of guidance information.

HOMING.—A guidance method by which the missile uses radiation from the target to establish a collision course.

HORIZON CHECK.—Procedures used to evaluate elevation zero alignment and roller path inclination. This procedure is normally performed while the ship is at sea.

HORIZONTAL.—A line or plane that is normal to the vertical.

HORIZONTAL PLANE.—Imaginary plane that is tangent (or parallel) to the Earth's surface at a given location.

HORN ANTENNA.—See horn radiator.

HORN (ANTENNA).—A microwave antenna produced by flaring out the end of a circular or rectangular waveguide into the shape of a horn, for radiating radio waves.

HORN RADIATOR.—A tubular or rectangular microwave antenna that is tapered and is wide at the open end.

IDENTIFICATION, FRIEND OR FOE (IFF).—A system of using electronic transmissions as a method of determining whether ships, aircraft, or ground forces are friendly or not friendly. When a signal is sent, friendly forces reply with coded pulses. Enemy forces, of course, do not know the coded pulses, so are readily identified as unfriendly.

ILLUMINATION.—The process of aiming rf energy at a target so that the reflected signal can be used by the missile for guidance information.

INDICATOR.—Equipment that provides a visual presentation of target position information.

INERTIA.—The physical tendency of a body in motion to remain in motion and a body at rest to remain at rest unless acted upon by an outside force (Newton's first law of motion).

INERTIAL GUIDANCE.—A self-contained type of guidance in which the missile senses any deviation in direction, speed, or attitude and automatically compensates for it.

INFORMATION.—In a digital system, the data as represented in binary form.

INFRARED.—Electromagnetic radiations (thermal) of wavelength between that of visible light and microwaves. Guidance system that homes in on heat radiated by the target.

INITIALIZE.—To put a logic circuit in a beginning state, such as to clear a register.

INSTANTANEOUS AUTOMATIC GAIN CONTROL (IAGC).—Circuit that can vary the gain of the radar receiver with each input pulse to maintain the output peak amplitude nearly constant.

INSTRUCTION.—In a microprocessor or digital computer system, the information that tells the machine what to do. One step in a computer program.

INTERDIRECTOR DESIGNATION (IDD).—The transmission of repeat-back information of a director to another director for the purpose of tracking the same target.

INTERFACE.—The interconnecting equipment, including wiring, data converters, switchboards, etc., that enable equipments to establish external communications with other equipments or systems.

INTERMEDIATE FREQUENCY (IF).—A lower frequency to which an rf echo is converted for ease of amplification.

INTERRUPT.—A method of stopping a process and identifying that a certain condition exists.

INTERSUBSYSTEM.—Relationship between two or more subsystems.

INTRASUBSYSTEM.—Relationship within a subsystem or between the equipments of a subsystem.

JAMMING.—The intentional disruption of the normal operation of a radar or radio system through the use of electromagnetic interference, mechanical devices, and/or deception.

JITTERED PRF.—The PRF is rapidly varied at a random rate so that false targets appear to jitter or appear fuzzy on the scope. An alternative to jittered PRF is to change the PRF momentarily. This causes the false targets to change their position on the scope.

KNOT.—A nautical mile (approx. 2,000 yd) or 1.1516 statute miles per hour. It is not a measure of distance, but of speed.

LINE OF FIRE (LOF).—An imaginary line along which a missile or other weapon is launched.

LINE OF SIGHT (LOS).—An imaginary line from radar or optical device to a target being tracked.

LIQUID-COOLING SYSTEM.—Source of cooling for high-heat producing equipments, such as microwave components, radar repeaters, and transmitters.

LOBE.—An area of greater signal strength in the transmission pattern of an antenna.

LOCK-ON.—The moment at which tracking or target seeking system begins automatic tracking of a target in one or more coordinates (e.g., range, bearing, elevation).

LOGARITHMIC RECEIVER.—Receiver that uses a linear logarithmic amplifier (lin-log) instead of a normal linear amplifier.

MAGAZINE.—The portion of a gun or missile launching system that provides for stowage.

MASTER REFERENCE PLANE (MRP).—The foundation machining reference and the roller path inclination reference during initial construction.

MECHANICAL SCANNING.—The reflector, its feed source, or the entire antenna is moved in a desired pattern.

MILLIROENTGEN.—A unit of radioactive dose equal to one-thousandth of a roentgen (see roentgen).

MINIMUM DISCERNIBLE SIGNAL (MDS).—The weakest signal that produces a usable signal at the output of a receiver. The weaker the signal, the more sensitive the receiver.

MINUTE.—A unit of angular measure equal to the 60th part of a degree and containing 60 seconds of arc.

MISFIRE.—The failure of a primer to ignite when firing action is initiated.

MIXER.—In radar, a circuit that combines the receive rf signal with a local-oscillator signal to effectively convert the received signal to a lower IF frequency signal.

MODES.—Operational phases (of a radar).

MODULATION.—The process by which some characteristic of one signal is varied in accordance with another signal.

MONOPULSE (SIMULTANEOUS) LOBING.—Radar receiving method using two or more (usually four) partially overlapping lobes. Sum and difference channels locate the target with respect to the axis of the antenna.

MOVING TARGET INDICATOR (MTI).—A device that limits the display of radar information to moving targets.

MULTIPLEX.—To put information from several sources onto a single line or transmission path.

MULTIPLEXER.—A digital circuit capable of multiplexing digital data.

NAUTICAL MILE.—The length of a minute of arc of a great circle of the earth (6,076 ft.).

NOISE.—In radar, erratic or random deflection or intensity of the indicator sweep that tends to mask small echo signals. Signals other than, and interfacing with, the signal desired.

NOISE FIGURE.—The ratio of output noise to input noise in a receiver.

NUTATE.—To oscillate through a small angle in a specific pattern.

NUTATING.—Moving an antenna feed point in a conical pattern so that the polarization of the beam does not change.

OMNIDIRECTIONAL ANTENNA.—An antenna that radiates equally in all directions (nondirectional).

ORDALT.—Acronym for ORDnance ALTeration. This may consist of minor changes (such as wiring) or major changes (such as new equipment components).

ORDNANCE.—Weapons and equipment used in their control.

ORIGIN.—The point from which measurements are made, as from the intersection of references on a graph.

OZONE.—An extremely reactive form of oxygen, normally occurring around electrical discharges and present in the atmosphere in small but active quantities.

PARALLAX.—The angular difference that results from making observations or computations to one target from two different stations; normally measured in horizontal and vertical planes.

PARAMETER.—Any of a set of physical properties whose values determine the characteristic or behavior of something.

PASSIVE ANGLE TRACK.—The boresighting of a jamming source by the radar antenna; tracking in elevation and bearing only. Also known as TRACK-ON-JAM.

PAYLOAD.—The warhead section in a military missile.

PEAK POWER.—Maximum power of the rf pulse from a radar transmitter.

PERFORMANCE ENVELOPE.—The area (range and altitude) that a missile or other weapon can effectively carry out its mission.

PERIOD.—The time required for a periodic waveform to repeat itself.

PERIODIC.—Repeating at fixed intervals.

PERIODICITY.—The rate at which an event regularly recurs.

PERIPHERAL DEVICE.—Any instrument or machine that enables a computer to communicate with the outside world or that otherwise aids the operation of the computer but does not form part of the basic installation.

PERSISTANCE.—The length of time a phosphor dot glows on a CRT before disappearing.

PIP (BLIP).—On a CRT display, a spot light or a base-line irregularity representing the radar echo.

PITCH.—Angular displacement, measured in the vertical plane, of the centerline or longitudinal axis of a ship or aircraft.

PLANNED MAINTENANCE SYSTEM (PMS).—A concept of maintenance that provides availability of equipment for mission support, reliability of equipment without compromise of schedule or quality, full service life at minimum cost, maximum utilization of skilled personnel, and control for quick reaction to changes.

PLANNED-POSITION INDICATOR (PPI).—A radar display in which range is indicated by the distance of a bright spot or pip from the center of the screen, and the bearing is indicated by the radial angle of the spot.

POINTING LINE.—The line of sight, boresight, or rf axis that defines the direction in which an equipment is pointed.

POLARIZATION.—The direction of the electrical field as radiated from a transmitting antenna, usually either vertical or horizontal.

POWER-AMPLIFIER (CHAIN) TRANSMITTER.—Transmitter that uses a series of power amplifiers to create a high level of power.

PREAMPLIFIER (PREAMP).—An amplifier that raises the output of a low-level source for further processing without appreciable degradation of the signal-to-noise ratio.

PRECESS.—To change the orientation of an axis of a gyroscope or other rotating body.

PROGRAM.—A list of instructions that are arranged in a specified order to control the operation of a digital computer.

PROGRAMMING.—The process of setting automatic equipment to perform operation in a predetermined manner.

PROPORTIONAL NAVIGATION.—A homing guidance technique in which the missile-turn rate is proportional to the turn rate of the missile-to-target line of sight.

PULSE.—A sudden change from one level to another followed by a sudden change back to the original level.

PULSE-FORMING NETWORK (PFN).—An LC network that alternately stores and releases energy in an approximately rectangular wave.

PULSE PER SECOND (pps).—A measure of the frequency of a pulse waveform.

PULSE REPETITION FREQUENCY (PRF).—The rate at which pulses are transmitted, given in hertz or pulses per second; reciprocal of pulse-repetition time.

PULSE REPETITION RATE (PRR).—The number of times per second that a pulse is transmitted; also called Pulse Repetition Frequency (PRF).

PULSE REPETITION TIME (PRT).—Interval between the start of one pulse and the start of the next pulse; reciprocal of pulse-repetition frequency.

PULSEWIDTH (Radar).—The time duration of the transmission of the pulse of energy, usually measured in microseconds or in the equivalent distance in yards, miles, etc.; also called pulse duration and pulse length.

PULSE WIDTH.—Duration of time between the leading and trailing edges of a pulse (pulsewidth for radar).

QUANTITY.—A constant, variable, function name, or expression.

RADAR.—Derived from RAdio Detecting And Ranging.

RADAR ABSORBENT MATERIAL (RAM).—Radar absorbent material used as a radar camouflage device to reduce the echo area of an object.

RADAR BEAM.—The space in front of a radar antenna where a target can be effectively detected or tracked.

RADAR DISTRIBUTION SWITCHBOARD.—An electrical switching panel used to connect inputs from any of several radars to repeaters.

RADAR HORIZON.—The point beyond which objects are not detectable by a radar due to the curvature of the Earth.

RADAR SILENCE.—The period of time during which radar transmission is stopped, usually for security reasons.

RADAR TEST SET.—Combination of several test circuits and equipment used to test various characteristics of a radar.

RADIAL VELOCITY.—The range rate of a target along the radar-beam axis regardless of target motion and direction.

RADIOACTIVITY.—A property exhibited by certain elements, the atomic nuclei of which spontaneously disintegrate and gradually transmute the original element into stable isotopes of that element or into another element with different chemical properties. The process is accompanied by the emission of alpha particles, beta particles, gamma rays, positrons, or similar radiations.

RAM.—Abbreviation for random access memory. Also, see radar absorbent material.

RANGE.—The length of a straight line between a radar and a target.

RANGE-GATE.—A movable gate used to select radar echoes from a very short-range interval.

RANGE-HEIGHT INDICATOR (RHI).—A radar display on which slant range is shown along the X axis and height along the Y axis.

RANGE MARKER.—A moveable, vertical pulse on an A-scope or ring on a PPI scope used to measure the range of an echo or to calibrate the range scale.

RANGE RATE.—The rate of change of range, usually in yards per second, caused by relative motion of own ship and target.

RANGE RESOLUTION.—Ability of a radar to distinguish between targets that are close together in range.

READ.—The process of retrieving information from a memory.

RECEIVER.—In radar, a unit that converts rf echoes to video and/or audio signals.

RECEIVER SENSITIVITY.—The degree to which a receiver can usefully detect a weak signal; the lower limit of useful signal input to the receiver.

RECIPROCAL.—Opposite or inversely related, as one of a pair of quantities whose product is one.

REFERENCE MARK.—A permanent marker installed during ship construction to identify the ship's centerline, offset centerline, or equipment bench marks.

REFERENCE PLANE.—An arbitrarily chosen plane from which quantities (usually angles) are measured.

REFLECTING OBJECT.—In radar, an air or surface contact that provides an echo.

REFRACTION.—Deflection from a straight path undergone by a light ray or energy wave in passing at an angle from one medium (as air) into another (as glass) in which its speed is different.

REFRACTIVE INDEX.—In a wave-transmission medium, the ratio between the phase velocity in free space and in the medium.

RELATIVE BEARING.—Directional coordinates referenced to the centerline of the ship with the bow designated as 000 degrees increasing in a clockwise direction through 360 degrees back to the bow.

RESOLUTION.—The minimum separation (in angle or range) between two targets at which they can be distinguished on the radar screen.

RETURN.—The rf signal reflected back from a radar target (echo).

RF RADIATION HAZARD.—Health hazard caused by exposure to electromagnetic radiation or high-energy particles (ions). Abbreviated RADHAZ.

RISE TIME.—The time required for the positive-going edge of a pulse to go from 10% of its full value to 90% of its full value.

ROENTGEN.—The unit of radioactive dose of exposure. It is the amount of gamma radiation that will produce one electrostatic unit of charge in one cubic centimeter of air, which is surrounded by an infinite mass of air at standard temperature and pressure conditions.

ROLL.—The angular rotation of the centerline or longitudinal axis of a ship or aircraft measured in an athwartship vertical plane.

SCANNING.—Systematic movement of a radar beam to cover a definite pattern or area in space.

SCINTILLATION.—Apparent change in target reflectivity. Motion of the target causes radar pulses to bounce off different parts of the target, such as fuselage and wing tip.

SCOPE.—A term often used to denote a CRT type radar indicator or a test oscilloscope.

SEA CLUTTER.—Unwanted echoes from the irregular surface of the sea that appear on a radar indicator.

SEARCH RADAR SYSTEM.—Early-warning device that searches a fixed volume of space.

SEA RETURN.—Clutter on a radar due to reflection of signals by the sea; also called sea clutter.

SEEKER.—A missile antenna or receiver that finds its target by means of heat, light, radio waves, sound or other radiation coming from the target.

SENSITIVITY TIME CONTROL (STC).—Programmed variation of the gain (sensitivity) of a radar receiver as a function of time within each pulse repetition interval or observation time. Prevents overloading of the receiver by strong echoes from targets or clutter at close ranges. The STC reduces the gain of the radar receiver for detection of close-in targets. It is particularly effective in removing close-in clutter and strong nearby signals. When adjusting STC, particular attention must be paid to close-in ranges so that small reflecting surfaces are not eliminated.

SERIAL.—An in-line arrangement where one element follows another, such as in a serial shift register. Also, the occurrence of events, such as pulses, in a time sequence rather than simultaneously.

SERVO SYSTEM.—An automatic feedback control system that compares a required condition (desired value, position, and so forth) with an actual condition and uses the difference to adjust a control device to achieve the required condition.

SIDE LOBES.—Undesirable radiation lobes of a radar antenna. A number of these exist on each side of the main beam in all directions surrounding the main beam.

SLANT RANGE.—The distance between two points that are not at the same altitude; e.g., a ship and an aircraft.

SOFTWARE.—The entire set of programs, procedures, and related documentation associated with a system, especially a computer system.

SPOOFING.—Jamming that deceives or misleads with target-like signals.

SQUIB.—A small pyrotechnic device used to fire the igniter in a rocket.

STABILIZATION.—Maintenance of a desired orientation independent of the roll and pitch of a ship or aircraft.

STABLE ELEMENT.—Gyroscopic device that maintains a reference horizontal plane.

STATIC MEMORY.—A memory composed of storage elements, such as flip-flops or magnetic cores, that are capable of retaining information indefinitely.

STATUTE MILE.—5,280 ft.

SUPERELEVATION.—An offset to the launcher's elevation order to compensate for the effect of gravity.

SUPPORT SYSTEM.—For a radar, a system that provides an auxiliary input, such as dry air, electrical power, or liquid cooling.

SUSTAINER.—A propulsion system that travels with and does not separate from the missile. The term is usually applied to solid propellant rocket motors when used as the principal propulsion system, as distinguished from an auxiliary motor or booster.

SWEEP.—The steady movement of the electron beam across the screen of a cathode-ray tube, producing a steady bright light when no signal is present.

SYNCHRO.—A small motorlike device that operates like a variable transformer and is used primarily for the rapid and accurate transmission of data among equipments and stations.

SYNCHRONIZER.—Circuit that supplies timing signals to other radar components.

SYNCHRONOUS.—In step or in phase, as applied to two devices or machines. Having a fixed time relationship.

TACHOMETER.—A small ac or dc generator, sometimes referred to as a rate generator, that converts its shaft speed into an electrical output. The tachometer is frequently used in servo systems to sense the velocity of a load.

TARGET.—In radar, a specific object of radar search or detection.

TARGET RESOLUTION.—The ability of a radar to distinguish between two or more targets that are close to each other.

TELEMETRY.—The process of measuring a quantity, transmitting the result to a distant station, and there indicating or recording the quantity measured.

TERRAIN MATCHING.—Guidance of a missile by means of a radar altimeter recording previously obtained by a reconnaissance flight over the terrain, compared with altimeter readings received during the new flight; also known as mapmatching.

THEODOLITE.—A precision, surveying instrument used for train and elevation zero alignments (more precise than a transit). Normally in the custody of support activities.

THREE-DIMENSIONAL (3-D) RADAR.—Measures the range, bearing, and altitude of a target.

TIME LAG.—The delay in a servo system between the application of the input signal and the actual movement of the load.

TIMER.—See synchronizer.

TMINS.—Abbreviation for the "Technical Manual Identification Numbering System."

TOLERANCE.—The allowable deviation from a specification.

TRACK.—Operational phase of a fire control or track radar during which the radar beam is kept on the target.

TRACKING.—The monitoring or following of a target's movement, especially by radar.

TRACK RADAR.—Radar that provides continuous range, bearing, and elevation data by keeping the rf beam on the target.

TRAILING EDGE.—The second transition of a pulse.

TRAIN ZERO.—Train position where the bearing line is normal to the ship centerline and pointing forward.

TRAJECTORY.—The flight path of a projectile or missile.

TRAM BLOCK.—A block and a pin with a cupped end (into which the ends of the tram bar fit). One tram block is permanently fastened to the rotating structure and another to the fixed structure in such a manner that when the ends of the tram bar are in each tram block, the equipment is at the tram position.

TRANSIT.—A precision surveying instrument used for train and elevation zero alignments that is normally less precise than a theodolite.

TRANSITION.—A change from one level to another.

TRANSMISSION CHECK.—In fire control system alignment, the process of verifying that the data transmission system is functioning with the required accuracy.

TRANSMITTER.—Equipment that generates, amplifies, and modulates electromagnetic energy.

TRANSMITTER FREQUENCY (CARRIER FREQUENCY).—The frequency of the unmodulated output of a transmitter.

TRAVERSE (BEARING) SIGNAL.—In a monopulse radar system, the combination of individual lobe signals that represents target offset direction and amplitude from the antenna axis.

TROUBLE TABLES.—Tables of trouble symptoms and probable causes furnished by many manufacturers, with their equipment, to help technicians isolate synchro problems.

TRUE BEARING.—A bearing given in relation to true geographic north.

TRUE NORTH.—Geographic north.

TWO-DIMENSIONAL (2-D) RADAR.—Measures the range and bearing to a target.

UPLINK.—Radio communication from a control point to a missile.

VELOCITY.—A vector quantity that includes both magnitude (speed) and direction in relation to a given frame of reference.

VERTICAL.—A line or plane passing through a point on the surface and the center of the Earth. Vertical is usually established by use of a device, such as a clinometer, that is dependent upon the force of gravity to position a bubble of air in a liquid. Such a device is actually sensing the center of the Earth's gravitational field rather than the physical center of the Earth. For all practical purposes, the ambiguities that may result from disparities between the physical center of the Earth and the center of the Earth's gravitational field are negligible when considered from the aspect of combat system alignment accuracy.

VERTICAL PLANE.—Imaginary plane that is perpendicular to the horizontal plane.

VIDEO.—Pertaining to the bandwidth and spectrum position of the signal resulting from radar or television scanning.

VOLTAGE STANDING-WAVE RATIO (VSWR).—In a waveguide, the ratio of the electric field at a maximum point to that of an adjacent minimum point.

WAVELENGTH.—The physical distance between cycles; the distance traveled by a wave in the time required for one cycle.

WAVEMETER.—An instrument for measuring the wavelength of an rf wave.

WEAPON CONTROL REFERENCE PLANE (WCRP).—The reference plane for leveling all equipment of the ship combat system.

WEAPON-RELEASE RANGE.—The maximum range at which a bomber can launch or release its weapons and strike its target.

WEIGHT.—The value of a digit in a number based on its position in the number.

WORD.—A group of bits representing a complete piece of digital information.

WRITE.—The process of storing information in a memory.

X-AXIS.—A horizontal axis in a system of rectangular coordinates; that line on which distances to the right or left (east or west) of the reference line are marked, especially on a map or chart.

X-RAYS.—Also called roentgen rays. Penetrating radiation similar to light, but having much shorter wavelengths (10^{-7} to 10^{-10} cm). They are usually generated by bombarding a metal target with a stream of high-speed electrons.

YAW.—To turn by angular motion about the vertical axis as of a ship or aircraft.

Y-AXIS.—A vertical axis in a system of rectangular coordinates; that line on which distances above or below (north or south) the reference line are marked, especially on a map, chart, or graph.

APPENDIX III

REFERENCES

FC1 Chapters Where References Were Used	REFERENCES
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INDEX

A

C

D

E

F

G

I

L

M

V

W

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